PROCEEDINGS OF

KERALA ENVIRONMENT CONGRESS 2010

FOCAL THEME

SOLID AND LIQUID WASTE MANAGEMENT

(As part of Centre of Excellence on Solid and Liquid Waste Management, Ministry of Urban Development, Government of India)

24th, 25th & 26st June 2010
Thiruvananthapuram

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FOREWORD

The significance of solid and liquid waste management has gone far beyond the traditional importance of being one of the civic amenities to be provided by the civic bodies to the residents. The contribution of municipal waste in emission of green house gases and thus to global warming has been unequivocally established and its scientific management has become one of the important components of the mitigation strategies of climate change as of now. In the National Mission on Sustainable Habitat of the National Action Plan on Climate Change for the Country, urban waste management has been recognized as a major component of the ecologically sustainable economic development.

One of the main facets of human development - health attainment equally recognises the significance of this aspect of civic management and sanitation therefore is part and parcel of public health engineering regimes of the civic systems. Special circumstances of Kerala necessitate vector population management as the main component of the strategy for combating vector borne seasonal diseases aspect of community health and therefore, it has been lately gaining increasing focus among the civic services.

Local self governments are vested with responsibility under the constitution of India to provide these civic amenities. At the same time, the practice of traditional waste management, which basically meant waste disposal to uninhabited areas, has become totally irrelevant and unacceptable in the light of the upcoming realizations regarding the impacts of such practices in global ecology and economy. This calls for reorientation of strategies and application of newer technologies and processes.

Technologies related to treatment and disposal of waste in present day scenario must be in conformity with the highest norms of conservation of material, space, energy and ecological sustainability. Environmental consequences of environment management processes itself have been considered important and therefore environmental services including hazardous waste, municipal solid waste and common effluent management activities have also been covered under the extant environmental regulations. This calls for focused work on development of technologies and processes and refinement of those available, in tune with the local circumstances including socio-cultural and environmental conditions.

One of the important facets of this domain is societal behavior. The attitude and traditional practices of handling the waste at household level have been related to availability of ample space in the homesteads wherein biodegradable waste used to be segregated and utilized for composting and recycled in the kitchen gardens/

backyards itself. With growing urbanization limiting the availability of open lands, such choices have also been limited. Consequently piling up of garbage and for handling it, centralized networking systems are taking precedence in urban areas. However, waste minimization still being the most important and initial priority of the waste management processes, awareness and capacity building of the society becomes a critical part of any strategy for attaining a societal behaviour in conformity with the changing paradigms of centralized scientific management of waste. At the same time, paucity of land also poses problem of locating sites for centralized treatment and disposal, if the piles of garbage grow bigger and bigger.

Updated information on evolving technologies, processes and societal role in attaining optimal efficiency in the waste management systems thus are critical for successful transformation of civic amenities from traditional to modern. Agencies responsible for civic environment management need to have all the options available for evaluating those in local conditions and adopting the most suitable with required modifications/ improvements. For attaining this objective, interaction among the researchers and stakeholders become imperative and can serve the managers in building their capacity of making judicious choices.

Centre for Environment and Development Thiruvananthapuram has been a trend setter in setting up such a forum for interaction on latest scientific as well as governance issues in environmental arena in the state. Like the past five events of Kerala Environment Congress, the sixth one also has the focus on the most critical concerns of environment management. Apart from providing an opportunity of availing updated information on science and technology, the event also promotes research acumen in the young researchers, which can eventually contribute to the capacity of the sector in delivery of services with most appropriate processes and technologies. No wonder that CED has been recognized as a "Centre of Excellence on SLWM" by the Union Ministry of Urban Development and has been getting support from the Ministry of Environment and Forests for holding this event every year.

I hope that the inputs of the invited experts and the scientists in the Sixth Kerala Environment Congress will be useful in strengthening the information base of the agencies involved in waste management in the state and at the same time in providing encouragement to the scientists to appreciate and focus on the relevant aspects of the concerns which can be addressed through research and technology development.

Dr S K Khanduri

KERALA ENVIRONMENT CONGRESS 2010

The Kerala Environment Congress was initiated by the Centre for Environment and Development in 2005 with the objective of enhancing the interaction between senior and junior researchers as well as policy-decision makers for sharing of expertise and experience in subjects of relevance to the sustainable development of the State.

CED established in 1993 with its Headquarters at Thiruvananthapuram is an independent Research, Training and Consultancy organization specialising on environment and sustainable development related sectors.CED tries to work in the Science and Society Interface for the country by providing scientific and technical support in the form of research inputs, capacity building and training and consultancy services and also providing implementation support to the Local Self Government Institutions especially in Kerala. The major Program Areas of the Centre are (i) Natural Resources Management (ii) Water, Environmental Sanitation and Health (iii) Climate Change and Energy Studies (iv) Coastal Systems Research (v) Information and Knowledge Management and (vi) Policy Studies and Institutional Design. CED established its Eastern Regional Centre at Bhubaneswar, Orissa to give major thrust to our activities in the eastern and north-eastern regions and has nine Project Offices spread over the state of Kerala and outside.CED is also managing two major Solid Waste Processing Plants of Thiruvananthapuram Corporation and Kochi Corporation. The Centre has at present nearly 350 staff from different disciplines and expertise. CED is the "Centre of Excellence of Ministry of Urban Development, Government of India on Solid and Liquid Waste Management" and also the Regional Resource Agency of Ministry of Environment and Forests, Government of India.

During the last 17 years, CED has completed 62 R&D, Consultancy and Training Projects supported by various International and National Agencies like the World Bank, UNDP, UNDP-GEF, JBIC, RNE, IDRC, ADB, Commonwealth Local Government Forum, Ministry of Environment & Forests. Ministry of Urban Development, Government of India, Department of Science & Technology, Ministry of New and Renewable Energy Sources, Ministry of Rural Development, Kerala State Council for Science, Technology & Environment, Local Self Government Department, Kerala, Planning & Coordination Department, Orissa, Orissa Water Resources Department, etc. The Centre is also coordinating the National Environment Awareness Campaign(NEAC) of MoEF in Kerala and Lakshadweep Islands. CED has also involved in many research and consultancy programmes in the States of Gujarat, Orissa,West Bengal and Andhra Pradesh.The Centre has involved in many projects in Orissa such as Preparation of District Plans for Jajpur and Jagatsinghpur districts,supporting the project on PAHELI survey on Human Development for all the 30 districts of Orissa, Preparation of Catchment Area Treatment Plan for Kanupur Irrigation project, Orissa and many training programmes and also taken initiatives to establish a Rural Development Academy in Orissa. The Centre is also engaged in a study for Mainstreaming the Coastal and Marine Bio Diversity Conservation into the Production Sectors of East Godavari Estuary, Andhra Pradesh.

The first Kerala Environment Congress was held at Kochi on 6th & 7th May, 2005 and was inaugurated by Dr Harsh K Gupta, the then Secretary, Department of Ocean Development, Government of India. The focal theme of the first Congress was "Coastal and Marine Environment-Issues, Problems and Potentials". The second Congress was held at Kozhikode on 15th &16th December,2006 with the focal theme" Forest Resources of Kerala", which was inaugurated by Sri.M Bhaskaran, Hon. Mayor of Kozhikode Corporation. The third Kerala Environment Congress was organized from 8th to 10th, May 2007 at Thiruvananthapuram with "Wetlands of Kerala" as the focal theme.The Congress was inaugurated by Dr T.M.Thomas Issac, the Hon. Minister for Finance, Kerala and presided over by Sri N K Premachandran, Hon. Minister for Water Resources, Kerala.The fourth Congress was organized in association with Kerala Institute of Local Administration at KILA,Trissur from 22nd to 24th April,2008 with the focal theme"Environmental Sanitation,Health and Hygiene",which was inaugurated by the former Hon. Speaker of Kerala Assembly and Member of Legislative Assembly, Sri Therambil Ramakrishnan. The fifth KEC was held from 19th to 21st August,2009 at Thiruvananthapuram, with the focal theme "Water Resources of Kerala". Hon. Minister for Water Resources, Kerala, Sri N.K.Premachandran inaugurated the Congress.

The sixth Kerala Environment Congress is being organized from 24th to 26th June, 2010 at Thiruvananthapuram with the focal theme "Solid and Liquid Waste Management". The Congress generally includes invited paper presentations, as well as paper and poster presentations for Young Scientist Award. Since one of the major objectives of the KEC is to promote young researchers (age 35 and below), we have instituted a Young Scientist Award for the best paper and poster presentation.

CED has been organizing three major streams of activities as part of the Centre of Excellence program of Ministry of Urban Development, Government of India on Solid and Liquid Waste Management-(i)Development of Strategy and Framework for Solid and Liquid Waste Management in ULBs with Thiruvananthapuram and Payyannur in Kerala as case study cities (ii) Capacity Building, Training and Awareness Programs to functionaries of ULBs and others on SLWM and (iii) Establishment of a Knowledge Centre on SLWM. CED is involved in these streams of activities during the last one year and has already initiated formulation of draft strategy and framework for SLWM; developed programs for Capacity Building and Training to ULB functionaries and also developed a "Knowledge Portal on Solid and Liquid Waste Management" which will be launched during the KEC-2010. CED is also managing two Solid Waste Processing Plants of 300 and 250 MT capacity, which gives us practical knowledge and strength in the field of Solid and Liquid Waste Management.

As part of the Capacity Building, Training and Awareness program, CED formulated a few activities such as Short Term Training Course on Solid Waste Management for ULB functionaries, which will also be launched during this Congress. The KEC-2010 is being organized with the focal theme "Solid and Liquid Waste Management" to give a major thrust to the Capacity Building Program as part of Centre of Excellence. CED expect the participation of nearly 300 researchers, ULB functionaries and policy-decision makers in the Congress, working in the field of waste management and sanitation in the country.

This Proceedings Volume contains full papers of invited and other presentations of the Congress prepared by eminent experts in the field. We hope that the deliberations in the Congress and the papers published in the Proceedings will help to evolve a strategy to formulate action plan for the Solid and Liquid Waste Management of the Local Bodies in the country. The Ministry of Environment and Forests, Government of India is kind enough to sponsor this national workshop and the support from the Ministry of Urban Development, Government of India by recognizing CED as a "Centre of Excellence on SLWM" are gratefully acknowledged. On behalf of CED, we take this opportunity to place our sincere gratitude to all the distinguished participants and other invitees who have supported us to make this Congress a success.

Dr Babu Ambat
Executive Director, CED

Contents

Foreword iii

Kerala Environment Congress 2010 v

Invited Presentations

1. Review of Strategy, Framework and Technological Options for Municipal Solid Waste Management
Damodaran V K, Geena Prasad, Joseph V T and Babu Ambat 3

2. Sustainable Small Scale Solid Waste Management for the Future
Chanakya H N, Shwetmala and Srisha Malayil 34

3. Electronic Waste Management - An Indian Outlook
Kurian Joseph 48

4. Strategy and Options for Bio-Medical Waste Management
Vijayabhas E J 61

5. Statutory Requirements, Best Practices and Status of Hazardous Waste Management
Dileep Kumar M 72

6. Management of Slaughter Houses and Abattoirs
Abraham J 80

7. Strategies and Techniques for Reuse of Grey water from Residential and Service Sector Complexes
James E J, Radhakrishnan P V and Ajithkumar P S 91

8. Wastewater Management in Urban Areas: Centralized vs. Decentralized systems
Ligy Philip 115

9. Green House Gas (GHG) Emission from Waste Sector and Clean Development Mechanism (CDM) Implementation in India: An Overview
Vinod T R and Syamala P N 121

10. Municipal Solid Waste Management: A Framework on Legal Responsibility of Local Government
Suhruth Kumar A 135

11. Waste Management: A Time Tested Public Health Tool
Biju Soman 144

General Presentations

12. Artificial Neural Network (ANN) Approach for Modeling of Resorcinol Adsorption from Aqueous Solution by Wood Charcoal
Ramhari AghavV , Pradyut Kundu, Somnath Mukherjee *153*

13. Studies on chemical and water budgets of sugar factory wastewater during land application after percolation through a soil column having crop of black gram (*Cicer arietinum* L.)
Shubhada D Bavare and Goel P K 161

14. Unmet needs of Solid waste management workers at Calicut Corporation area
Jayakrishnan T and Jeeja M C 168

15. Hazards and Management of Mercury as a hospital waste: A case study from Kerala
Jeeja M C and Thejus T J 176

16. Perceptions and Practices of Waste Handling among the Women Solid Waste Workers - A Study in Thiruvananthapuram Corporation, Kerala
Rani S S, Elezebeth Mathews and Babu Ambat 184

17. Two-stage anaerobic digestion of municipal solid waste using acid phase fermenters coupled with cst reactors with natural / synthetic biofilm support systems.
Rakesh P S, Sajithkumar K J and Ramasamy E V 192

Young Scientist's Award Presentations

18. Methylene Blue Removal from Aqueous Solution Using Zinc Oxide Nanoparticles
Anoop K, Praveena P R, George K C and Philip K C 201

19. Remediation of Heavy Metals in Waste Water Contaminated Soils using Vetiver Plants
Dhanya G and Jaya D S 207

20. Health hazards assessment among the solid waste workers of Thiruvananthapuram Corporation
Elezebeth Mathews and Rani S S 217

21. Drinking Water and Fodder Quality around Kanjikode Industrial Belt and its Impact on Cattle Health
Nisha A R, Vineetha C B, Sreelekha K P, Dhanya V R and Chandrasekharan Nair A M 225

22. Polyurethane foam as filter media in Up-flow anaerobic hybrid reactors
Sumi S and Lea Mathew 229

23. Quality Evaluation of Surface and Ground Water of Thrissur
Vineetha C B, Nisha A R, Dhanya V R, Sreelekha K P and Chandrasekharan Nair A M 234

Invited Presentations

Review of Strategy, Framework and Technological Options for Municipal Solid Waste Management

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INTRODUCTION

Efficient delivery of public services and infrastructure are pressing issues for Urban Local Bodies (ULBs) in most developing countries; and in many countries, solid waste management has become a top priority. Solid Waste Management (SWM) is a system for handling of all types of garbage. The end goal is to reduce the amount of garbage clogging the streets and polluting the environment, whether that garbage is disposed of or recycled into something useful.

Different types of interventions are essential to improve the quality of our cities and reducing the adverse health and environmental effects. Improper and unscientific SWM measures usually adopted in many countries not only has its local significance but pose much wider global implications. Climate change and effects of greenhouse gas emissions have made SWM, one of the most pressing environmental challenges globally as well as locally. It is well understood that inappropriate SWM practices, such as improper incineration and uncontrolled disposal of waste are major contributors to greenhouse gas emissions; the anaerobic degradation of waste in landfills produces methane, a gas that is 21 times more potent than carbon dioxide.

The total Indian urban population amounts to approximately 285 million (World Bank, 2008). There are 4,378 cities and towns in India. Of those cities, according to the 2001 census, 423 are considered class I, with a population exceeding 100,000(one lakh). The class I cities alone contribute to more than 72 percent of the total municipal solid waste (MSW) generated in urban areas. This includes 7 mega cities (which have a population of more than 4 million), 28 metro cities (which have a population of more than 1 million), and 388 other towns (which have a population of more than 1lakh) (NEERI, 1996).The Central Public Health and Environmental Engineering Organization (CPHEEO) estimated a per capita waste generation in Indian cities and towns in the range of 0.2 to 0.6 kilograms per day. According to Central Pollution Control Board (CPCB), average collection coverage ranges from 50 to 90 percent. Of the collected waste, 94 percent is disposed of without any scientific management practices. Hence, there is severe pollution of groundwater and surface water through leachate, as well as air through uncontrolled burning of waste.

About 40 per cent of the urban population is currently residing in 40 Metros in India (World Bank, 2008). The urban local bodies responsible for providing the basic services like water supply, sewerage and solid waste management and other amenities to the people are finding it extremely difficult to cope up with the ever increasing demand due to fast growth of urban population. Management strategies should be in such a way as to perform (i) Protection of environmental health (ii) Promotion of the quality of environment (iii) Supporting the efficiency and productivity of the economy and (iv) Generation of employment and income.

There are different types of solid waste which need to be dealt with. The first is recyclable waste, which can be recycled. Solid waste management includes the construction of facilities to recycle these goods, which include scrap metal, glass, cans, paper, plastics, wood, and similar materials. Another category is toxic waste, which could potentially contaminate the environment, meaning that it needs to be handled with care. This category includes electronic waste, a growing problem in many industrialized nations. Next is green waste which can be composted and returned to the earth.

The objective of solid waste management is to reduce the quantity of solid waste disposed off on land by recovery of materials and producing energy from solid waste. Municipal solid waste management (MSWM) involves the application of principle of Integrated Solid Waste Management (ISWM) to municipal waste. ISWM is the application of suitable techniques, technologies and management options dealing with all types of solid wastes from all sources to achieve the twin objectives of (a) waste reduction and (b) effective management of waste still produced after waste reduction (Cointreau, 2001).

LEGAL FRAMEWORK FOR SWM IN INDIA

In India, SWM is the primary responsibility and duty of the municipal authorities. State legislation and the local acts that govern municipal authorities include special provisions for collection, transport, and disposal of waste. Most state legislation does not cover the necessary technical or organizational details of SWM. Laws talk about sweeping streets, providing receptacles in various parts of the city for putting waste, and transporting waste to disposal sites in general terms, but they do not clarify how this cleaning shall or can be done. The municipal acts in many states do not specify in clear terms which responsibilities belong to the citizens. Most state legislations, with the exception of that of Kerala, does not fulfil the requirements for an efficient SWM service. A public interest litigation was filed in the Supreme Court in 1996 (Special Civil Application No. 888 of 1996) against the Government of India, state governments, and municipal authorities for their failure to perform their duty of managing MSW adequately. The Supreme Court then appointed an expert committee to look into all aspects of SWM and to make recommendations to improve the situation. After consulting around 300 municipal authorities, as well as other stakeholders, the committee submitted the report to the Supreme Court in March 1999. The report included detailed recommendations regarding the actions to be taken by class 1 cities, by the state governments, and by the central government to address all issues of MSWM effectively. On the basis of the report, the Supreme Court directed the Government of India, state governments, and municipal authorities to take necessary actions. The Ministry of Environment and Forests was directed to expeditiously issue rules regarding MSW management and handling. Thus, in September 2000, the Ministry issued the Municipal Solid Waste (Management and Handling) Rules 2000 under the Environment Protection Act, 1986.

The Municipal Solid Waste (Management and Handling) Rules lay down the steps to be taken by all municipal authorities to ensure management of solid waste according to best practices. Municipal authorities must meet the deadlines laid down in Schedule I of the rules and must follow the compliance criteria and procedure laid down in Schedule II. They are responsible for implementing provisions of the 2000 rules and also to provide the infrastructure and services with regard to collection, storage, segregation, transport, treatment and disposal of MSW. The State Pollution Control Boards are directed to process the application of municipal authorities and to issue authorization to the municipalities within 45 days of the application's submission. The CPCB is responsible for coordinating the implementation of the rules among the state boards. Even though, the municipalities were mandated to implement the rules by December 2003, with punishment for municipal authorities that failed to meet the standards prescribed; most of them did not meet the deadline.

The deadline for implementing Schedule I of the 2000 rules has already passed, and some cities and towns have not even started implementing measures that could lead to compliance with the rules (Table 1). Other cities and towns have moved somewhat forward, either of their own accord or because of pressure from the Supreme Court, their state government, or their state pollution control board.

Table 1
Four Steps of Schedule I of the 2000 Rules

No.	Compliance Criteria	Schedule
1.	Setting up of waste processing and disposal facilities	By 31.12.2003 or earlier
2.	Monitoring the performance of waste processing and disposal facilities	Once in six months
3.	Improvement of existing landfill sites as per provisions of these rules	By 31.12.2001 or earlier
4.	Identification of landfill sites for future use and making site (s) ready for operation	By 31.12.2002 or earlier

Source: CPCB, 2004-05

Under Schedule II of the rules, municipal authorities have been further directed to set up and implement improved waste management practices and services for waste processing and disposal facilities. They can do so on their own or through an operator of a facility (as described in Schedules III and IV of the rules). Standards for waste processing and disposal facilities are defined in the rules, and municipal authorities are required to meet the specifications and standards specified in Schedules III and IV.

CPCB and MoEF and other Central Ministries such as Ministry of Urban Development (MoUD) and Ministry of Renewable Energy Sources have taken initiatives to facilitate implementation of MSW rules. MoEF and CPCB have instituted a scheme for setting up of demonstration project for solid waste management in accordance with MSW Rule. Objective of the scheme is to demonstrate implementation of MSW Rule in an integrated manner. The scheme is based on cost sharing basis where concerned local body is required to contribute 50% of the total cost of the project.

CLASSIFICATION OF SOLID WASTE

Knowledge of the sources and types of solid wastes as well as the information on composition and the rate at which wastes are generated/ disposed is essential for the design and operation of the functional elements associated with the management of solid wastes. Solid wastes are generally classified in to two, based on source of generation and type.

i. Classification based on Source

Based on the source of generation, solid waste can be classified into residential, commercial, institutional, industrial, agricultural etc. (Table 2).

ii. Classification based on Type

There are mainly two categories of wastes based on the type-biodegradable and non-biodegradable wastes. This classification is based on physical, chemical and biological characteristics of wastes. Biodegradable wastes mainly refer to substances consisting of organic matter such as leftover food, vegetables and fruit peels, paper, textile, wood, etc., generated from various household and industrial activities. Because of the action of micro-organisms, these wastes are degraded from complex to simpler compounds. Non- biodegradable wastes consist of inorganic and recyclable materials such as plastic, glass, cans, metals, etc.

Management of solid waste may be defined as the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes based on

Table 2
Classification of Solid Wastes

Type	Description	Source
Garbage	Wastes from the preparation, cooking and serving of food, market refuse, waste from the handling, storage, and sale of produce and meat.	Households, institutions and commercial concerns such as hotels, stores, restaurants, market, etc
Combustible and non-combustible	Combustible (primarily organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings etc.	
Ashes	Residue from fires used for cooking and for heating building cinders	
Bulky wastes	Large auto parts, tyres, stoves, refrigerators, other large appliances, furniture, large crates, trees branches, stumps etc	Streets, sidewalks, alleys, vacant plots etc.
Street wastes	Street sweepings, dirt, leaves etc.	
Dead animals	Dogs, cats, rats, donkeys etc.	
Abandoned vehicles	Automobiles and spare parts	
Construction and demolition wastes	Roofing and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation etc	Construction and demolition sites
Industrial wastes	Solid wastes resulting from industrial processes and manufacturing operations, such as food processing wastes, boiler house cinders, wood, plastic and metal scraps, shaving etc.	Factories, power plants etc
Hazardous wastes	Pathological wastes, explosives, radioactive materials etc.	Households, hospitals, institutions, stores, industry etc.
Animals and agricultural wastes	Manure, crop residues etc.	Livestock, farms, feedlots and agriculture
Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

Source: Phelps et al., 1995

Table 3
Degeneration Time for Biodegradable and Non-biodegradable Wastes

Category	Type of waste	Approximate time taken to degenerate
Biodegradable	Organic waste such as vegetable and fruit peels, leftover foodstuff, etc	A week or two
	Paper	10-30 days
	Cotton cloth	2-5 months
	Woollen items	1 year
	Wood	10-15 years
Non-biodegradable	Tin, aluminum, and other metal items such as cans	100-500 years
	Plastic bags	One million years
	Glass bottles	Undetermined

Source: Phelps et al, 1995

scientific principles. This includes all technological, financial, institutional and legal aspects involved for solving the whole spectrum of issues related to solid wastes. The SWM processes differ depending on factors such as socio-economic status, degree of industrialization, social development (e.g., education, literacy, healthcare etc.), life style and quality of life of a location. In addition regional, seasonal and economic differences influence the SWM processes.

WASTE GENERATION AND COMPOSITION

Information on waste quantity and composition is important in evaluating alternatives in terms of equipment system, plans and management programmes. For example, if wastes generated at a commercial facility consist of only paper products, the appropriate equipments are shredders and balers. Similarly, on the basis of quantity generated, we can plan appropriate means for separation, collection and recycling programmes for wastes.

The studies carried out by the National Environmental Engineering Research Institute (NEERI) in Indian cities have revealed that quantum of MSW generation varies between 0.21-0.35 kg/capita/day in the urban centres and it goes up to 0.5 kg/capita/day in large cities (NEERI, 1996). Considering this, the waste generation in the Municipalities of Kerala can be taken as a minimum of 0.21 kg/capita/day with an increment due to the increasing trend of waste generation and that the estimate was that of 1996.

Waste composition also depends on the moisture content, density and relative distribution of municipal wastes. CPCB with the assistance of NEERI has conducted survey of solid waste management in 59 cities (35 metro cities and 24 state Capitals: 2004-05).

Characterisation of waste is necessary to know changing trends in composition of waste. Based on composition/ characterization of waste, appropriate selection of waste processing technologies could be selected.

WASTE CHARACTERISTICS

The characteristics of wastes can be divided into physical characteristics and chemical characteristics. The analysis of characteristics of waste is very important in determining the appropriate processing options and identification of technology.

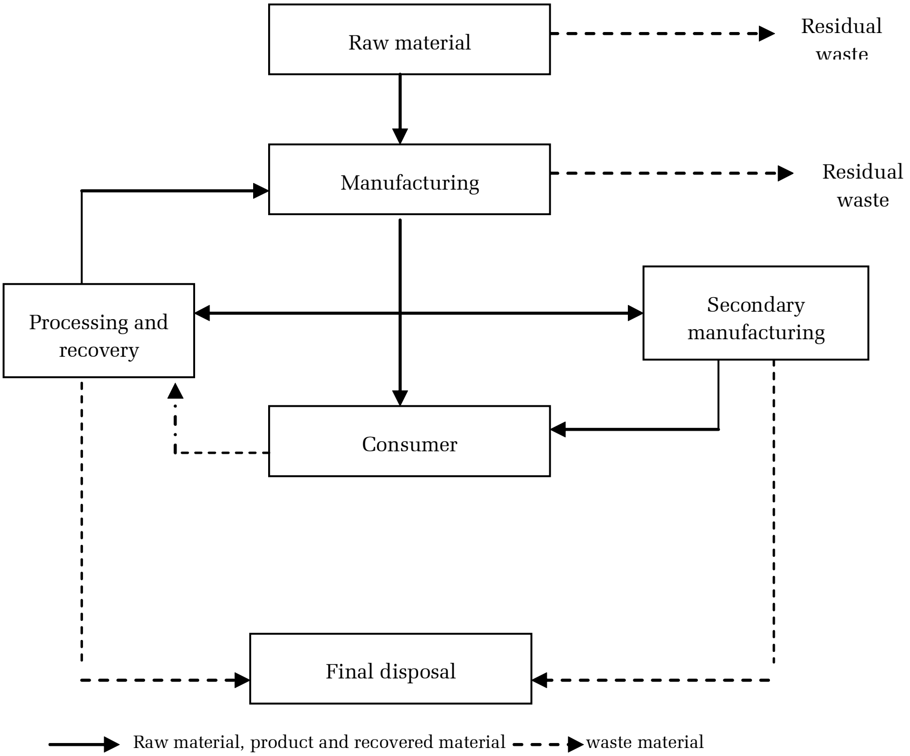


Fig 1
Chart showing Material Flow and Waste Generation
(Source: Tchobanoglous,et al.,1997)

Table 4
Typical Waste Composition

Characteristics	Low income population	High income population	Comments
Paper	1-4%	20-50%	Low paper content indicates low caloric value.
Plastics	1-6%	5-10%	Plastic is low as compared to high-income areas though the use of plastic has increased in recent years
Ash and Fines	17-62%	3-10%	Ash and fines do not contribute to combustion process
Moisture Content	30-40%	15-30%	Moisture content depends largely on the nature of the waste, climate and collection frequency. Waste can dry out while awaiting collection
Bulk Density	300-400 kg/m^3	150 kg/m^3	Heavier waste may cost more to handle and difficult to burn

Source:Ali et al.,1999

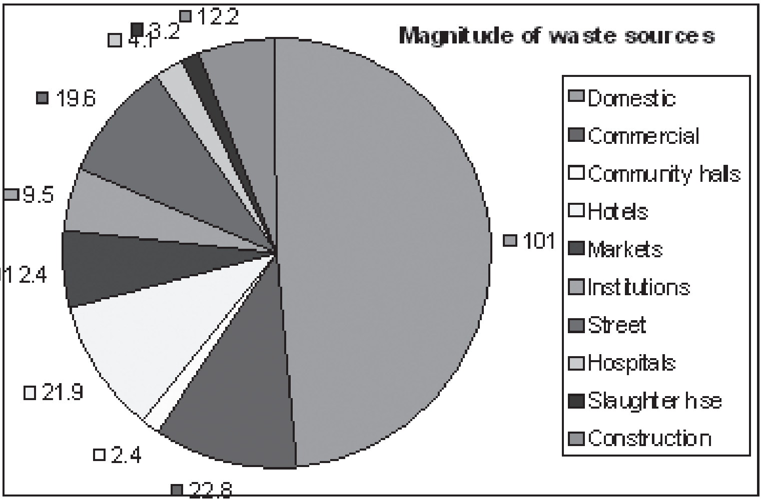


Fig 2
Magnitude of Waste Sources

Table 5
Waste characterization in Indian cities

S. No	Name of City	Compostables (%)	Recyclables (%)	C/N Ratio	HCV* (Kcal/Kg)	Moisture (%)
1	Kavarati	46.01	27.20	18.04	2242	25
2	Gangtok	46.52	16.48	25.61	1234	44
3	Itanagar	52.02	20.57	17.68	3414	50
4	Daman	29.60	22.02	22.34	2588	53
5	Silvassa	71.67	13.97	35.24	1281	42
6	Panjim	61.75	17.44	23.77	2211	47
7	Kohima	57.48	22.67	30.87	2844	65
8	Port Blair	48.25	27.66	35.88	1474	63
9	Shillong	62.54	17.27	28.86	2736	63
10	Simla	43.02	36.64	23.76	2572	60
11	Agartala	58.57	13.68	30.02	2427	60
12	Gandhinagar	34.30	13.20	36.05	698	24
13	Dhanbad	46.93	16.16	18.22	591	50
14	Pondicherry	49.96	24.29	36.86	1846	54
15	Imphal	60.00	18.51	22.34	3766	40
16	Aizwal	54.24	20.97	27.45	3766	43
17	Jammu	51.51	21.08	26.79	1782	40
18	Dehradun	51.37	19.58	25.90	2445	60

19	Asansol	50.33	14.21	14.08	1156	54
20	Kochi	57.34	19.36	18.22	591	50
21	Raipur	51.40	16.31	223.50	1273	29
22	Bhubaneswar	49.81	12.69	20.57	742	59
23	Tiruvananthapuram	72.96	14.36	35.19	2378	60
24	Chandigarh	57.18	10.91	20.52	1408	64
25	Guwahati	53.69	23.28	17.71	1519	61
26	Ranchi	51.49	9.86	20.23	1060	49
27	Vijaywada	59.43	17.40	33.90	1910	46
28	Srinagar	6177	17.76	22.46	1264	61
29	Madurai	55.32	17.25	32.69	1813	46
30	Coimbatore	50.06	15.52	45.83	2381	54
31	Jabalpur	58.07	16.61	28.22	2051	35
32	Amritsar	65.02	13.94	30.69	1836	61
33	Rajkot	41.50	11.20	52.56	687	17
34	Allahabad	35.49	19.22	19.00	1180	18
35	Visakhapatnam	45.96	24.20	41.70	1602	53
36	Faridabad	42.06	23.31	18.58	1319	34
37	Meerut	54.54	10.96	19.24	1089	32
38	Nasik	39.52	25.11	37.20	2762	62
39	Varanasi	45.18	17.23	19.40	804	44
40	Jamshedpur	43.36	15.69	19.69	1009	48
41	Agra	46.38	15.79	21.56	520	28
42	Vadodara	47.43	14.50	40.34	1781	25
43	Patna	51.96	12.57	18.62	819	36
44	Ludhiana	49.80	19.32	52.17	2559	65
45	Bhopal	52.44	22.33	21.58	1421	43
46	Indore	48.97	12.57	29.30	1437	31
47	Nagpur	47.41	15.53	26.37	2632	41
48	Lucknow	47.41	15.53	21.41	1557	60
49	Jaipur	45.50	12.10	43.29	834	21
50	Surat	56.87	11.21	42.16	990	51
51	Pune	62.44	16.66	35.54	2531	63

Source: CPCB, 2004-05

i. Physical Characteristics

Information and data on the physical characteristics of solid wastes are important for the selection and operation of equipment and for the analysis and design of processing/disposal options. The major components for determining the physical characteristics are:

Density of waste: Mass per unit volume (kg/m3) is a key factor in the design of a SWM system. Compaction of wastes to optimum density is one of the key factors in sanitary land fill operation

Moisture content: Moisture content is defined as the ratio of the weight of water (wet weight - dry weight) to the total weight of the wet waste. Moisture increases the weight of solid wastes, and thereby, the cost of collection and transport. In addition, moisture content is a critical determinant in the economic feasibility of waste treatment by incineration, because wet waste consumes energy for evaporation of water and in raising the temperature of water vapour.

A typical range of moisture content is 20 to 40%, representing the extremes of wastes in an arid climate and in the wet season of a region of high precipitation. However, values greater than 40% are also seen in states like Kerala where the state is getting around six month's rainfall in a year.

Size: Measurement of size distribution of particles in waste stream is important because of its significance in the design of mechanical separators and shredders. Generally, the results of size distribution analysis are expressed in the manner used for soil particle analysis.

ii. Chemical Characteristics

The products of decomposition and heating values are two examples of chemical characteristics. The knowledge on chemical characteristics is essential if solid wastes are to be used as fuel, or are used for any other purpose. The major components to be assessed are lipids, carbohydrates, proteins, natural fibres, synthetic organic materials (plastics), non-combustibles, heating value etc. When evaluating incineration as a means of disposal or energy recovery, we need to consider the heating values of respective constituents.

TECHNOLOGY OPTIONS FOR WASTE MANAGEMENT

The process of solid waste management has two important streams of activities such as the social engineering and technology applications. The major element of social engineering is the participation of the community in the process and their involvement in the proper management of the wastes as well as adopting the 4R concept to the maximum extent possible. The technology application deals with the use of appropriate technology for processing and disposal of solid wastes to improve the supportive capacity of the environment.

The technology options available for processing the municipal solid waste are based on either bioconversion or thermal conversion (Diaz et al., 2002; Benedict et al., 1998; Corey,1969; Tchobanoglous, 2003; UNEP, 2005; Salvato,1992).The bio-conversion method is applicable to the organic fraction of wastes, to form compost or to generate biogas such as methane (waste to energy) and residual sludge (manure). Various technologies are available for composting such as aerobic, anaerobic and vermi composting. The thermal conversion technologies are incineration with or without heat recovery, pyrolysis and gasification, plasma pyrolysis and pelletization or production of Refuse Derived Fuel (RDF)

COMPOSTING

Microorganisms such as bacteria, fungi and actinomycetes as well as larger organisms

Table 6
Typical Heating and Inert Residue Values

Component	Inert Residue %		Heating Value (kJ/kg)	
	Range	Typical	Range	Typical
Food wastes	2-8	5	3500-7000	4500
Paper	4-8	6	11500-18500	16500
Cardboard	3-6	5	14000-17500	16000
Plastics	2-20	10	28000-37000	32500
Textiles	2-4	2.5	15000-20000	17500
Rubber	8-20	10	21000-28000	18500
Leather	8-20	10	15000-20000	17500
Garden trimmings	2-6	4.5	2300-18500	6500
Wood	0.6-2	1.5	17500-20000	18500
Glass	96-99	98	120-240	140
Tin cans	96-99	96		
Nonferrous metals	90-99	96	240-1200	700
Ferrous metals	94-99	98	240-1200	700
Dirt, ash, bricks etc	60-80	70	2300-11500	7000
MSW			9500-13000	10500

Source: (Tchobanoglous et al., 1977).

such as insects and earthworms play an active role in decomposing the organic materials. As microorganisms begin to decompose the organic material, they break down organic matter and produce carbon dioxide, water, heat and humus (the relatively stable organic end product). This humus end product is compost.

Different communities of microorganisms predominate during the various composting phases. Initial decomposition is carried out by mesophilic microorganisms, which rapidly break down the soluble, readily degradable compounds. The heat they produce causes the compost temperature to rise rapidly. As the temperature rises above 40°C, the mesophilic microorganisms become less competitive and are replaced by thermophilic (heat loving) ones. At temperatures of 55°C and above, many microorganisms that are pathogenic to humans or plants are destroyed. Temperatures above 65°C kill many forms of microbes and limit the rate of decomposition. In composting process usually aeration and mixing is done to keep the temperature below this point. During the thermophilic phase, high temperatures accelerate the breakdown of proteins, fats and complex carbohydrates like cellulose and hemicellulose, the major structural molecules in plants. As the supply of these high-energy compounds become exhausted, the compost temperature gradually decreases and mesophilic microorganisms once again take over the final phase of curing or maturation of the remaining organic matter (EPA,1989 and 1995).

There are three basic steps involved in all composting practices such as preprocessing (size reduction, nutrient addition etc), decomposition and stabilization of organic materials and post-processing (grinding, screening etc). The decomposition and stabilization phase happens when the bacteria and other organisms act on organic fraction of MSW that essentially consists of proteins, aminoacids, lipids, carbohydrates, cellulose, lignin and ash in presence of oxygen. The commonly used composting technologies are windrow, aerated static pile, in-vessel composting, anaerobic composting and vermicomposting (EPA 1989 and 1995).

Windrow composting

The Windrow System is the least expensive and most common method adopted. Windrows are defined as regularly turned elongated piles, trapezoidal in cross section and upto a hundred meters or more in length. The cross-sectional dimensions vary with feedstock and turning equipment, but most municipal solid waste (MSW) windrows are 1.5 to 2 meters high and 3 to 6 meters wide.

Windrows composed of MSW are usually required to be located on an impermeable surface. The optimum size and shape of the windrow depends on particle size, moisture content, pore space and decomposition rate - all of which affect the movement of oxygen towards the centre of the pile.

Turning the pile re-introduces air into the pile and increases porosity so that efficient passive aeration from atmospheric air continues at all times. The windrow dimensions should allow conservation of the heat generated during the composting process and also allow air to diffuse to the deeper portions of the pile. They may be turned as frequently as once per week, but more frequent turning may be necessary, if high proportions of bio-solids are present in the feedstock.

Aerated Static Pile Composting

Aerated static pile composting is a non-proprietary technology that requires the composting mixture (i.e., a mixture of pre-processed materials and liquids) to be placed in piles that are mechanically aerated. The piles are placed over a network of pipes connected to a blower, which supplies the air for composting.

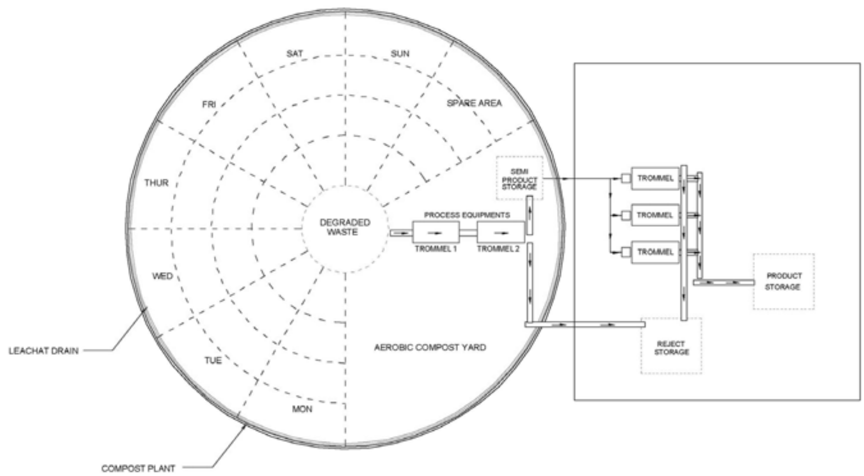


Fig 3
Layout of a Windrow composting Plant

Air circulation in the compost piles provides the needed oxygen for the composting microbes and prevents excessive heat build-up in the pile. Removing excess heat and water vapour cools the pile to maintain optimum temperature for microbial activity. A controlled air supply enables construction of large piles, which decreases the need for land. Odours from the exhaust air could be substantial, but traps or filters can be used to control them. The temperatures in the inner portion of a pile are usually adequate to destroy a significant number of the pathogens and weed seeds present. The surface of piles, however, may not reach the desired temperatures for destruction of pathogens because piles are not turned in the aerated static pile technology. This problem can be overcome by placing a layer of finished compost of 15 to 30cm thick over the compost pile. The outer layer or finished compost acts as an insulating blanket and helps maintain the desired temperature for destruction of pathogens and weed seeds throughout the entire pile. When the composting process is nearly complete, the piles are broken up for the first time since their construction. The compost is then taken through a series of post-processing steps. Producing compost using this technology usually takes about 6 to 12 weeks.

In-vessel composting system

In-vessel composting systems enclose the feedstock in a chamber or vessel that provides adequate mixing, aeration and moisture. Drums, digester bins and tunnels are some of the common in-vessel type systems. In some cases, the vessel rotates, and in others, it is stationary and a mixing/agitating mechanism moves the material around. Most in-vessel systems are continuous-feed systems, although some operate in a batch mode. A major advantage of in-vessel systems is that all environmental conditions can be carefully controlled to allow rapid composting.

Anaerobic composting

In anaerobic processes, facultative bacteria break down the organic materials in the absence of oxygen and produce methane and carbon dioxide. Anaerobic systems, if configured efficiently, will generate sufficient energy in the form of methane to operate the processes and have enough surpluses to either market as gas or convert to electricity. Conventional composting systems, on the other hand, need significant electrical or mechanical energy inputs to aerate or turn the piles. There are mainly two approaches such as Single-stage digesters and two-stage digestion.

Vermi composting

Vermi composting is a modified and specialised method of composting and it is the end product of the breakdown of organic matter by some species of earthworm. Vermi compost is a nutrient- rich, natural fertilizer and soil conditioner. The earthworm species most commonly used are Eudrillus eugineae, Eisenia foetida or Lumbricus rubellus. Small scale vermi composting is done in bins of varying sizes and style and three different types of practices, such as Non-continuous, Continuous, Continuous vertical flow and Continuous horizontal flow are adopted. The methods for large scale vermi composting are windrow and raised-bed or flow - through systems. Flow through systems is well suited to indoor facilities, making them the preferred choice for operations in colder climates. Kitchen wastes except oily and spicy items are suitable for worms. But too much kitchen waste leads to putrification

Table 7
Design and Operational conditions of Aerobic Composting Process

No	Aspects	Preferable standards and specifications
1	MSW characteristics	Sorted organic fraction of MSW, preferable with the same rate of decomposition
2	MSW Particle size	Between 25 – 75 mm for optimum results
3	C/N Ratio	Between 25 – 50 initially. Release of ammonia and impeding of biological activity at lower ratios. Nitrogen as a limiting nutrient at higher ratios
4	Blending & Seeding	Addition of partially decomposed matter (1-5% by weight) reduces composting time.
5	Moisture content	55% (optimum)
5	Windrow size	3 m length, 2 m width and 1.5 m height (optimum)
6	Mixing/turning	Every four or five days, until the temperature drops from about 66 – 60ºC to about 38ºC or less. Alternate days under typical operating conditions
7	Temperature	50-55ºC for first few days and 55-60ºC for the reminder composting period. Biological activity reduces significantly at higher temperature (>66ºC)
8	Pathogen control	Maintenance of temperature between 60-70ºC for 24 hours
9	Air requirement	Air with at least 50% of initial oxygen concentration to reach all parts of composting material
10	pH control	7 – 7.5 (optimum). Not above 8.5 to minimize nitrogen loss in the form of ammonia gas
11	Inoculums	Not desirable, except in special cases
12	Degree of decomposition	Determine by COD test or from Respiratory Quotient (RQ).
13	Area requirement	~25 m^2 for 1 ton of MSW (only for windrow formation for 21 days composting and maturity yard for 30 days stabilization). Area for machinery, packing and storage extra
14	Post treatment care	Facility for effluent (leachate) recycling and treatment and sanitary landfill of rejects (inert materials, sludge from ETP)
15	Nutrient recovery	2-4 kg N/ton; 1-2 kg P/ton; 1-2 kg K/ton
16	Product recovery	18-25% of waste input
17	Residuals for disposal	2-20% sieving overflow (plastic, metal, glass, stones, uncomposted matter

Source:Varma, 2008

before worms can process it and becomes harmful to the worms. Similarly, material sprayed with pesticides, high water content materials like water melon, woody part of garden wastes etc., are capable of preventing the process. Regular removal of composted material, adding holes to bins or using continuous-flow bin, etc., improve oxygen supply to worms. An important point to note in case of vermicomposting but widely ignored, is to carry out proper sieving of the compost before applying it in the fields. In the usual way vermicomposting is practiced now in Kerala is both labour-intensive and requires some infrastructure. As a result, most vermi compost units set up in the local bodies are not functioning now. However, at household level it is found very effective.

The following aspects have to be taken into consideration while planning a Vermi composting programme.

i. The Vermi composting plant should be protected from flies, ants etc., by providing a metal net covering.

ii. Extreme wet and dry conditions will harm the worms and care should be taken to control extreme temperature by sprinkling water or putting a wet gunny bag above the plant especially during summer.

iii. The Composting plant will not cause any smell, odour, or any unhygienic atmosphere, so it can be placed inside the house or work place.

BIOMETHANATION

In this process, methanogenic bacteria breakdown the organic material under anaerobic condition and produce methane and carbon dioxide rich biogas, suitable

Table 8
Design and Operational conditions of Vermi composting Process

No	Aspects	Preferable standards and specifications
1	MSW characteristics	Any organic waste which are not appreciably oily, spicy, salty or hard and that do not have excessive acidity and alkalinity
2	MSW Particle size	Between 25 – 50 mm for optimum results
3	Worms	*Eudrillus eugineae* (50-100 no per kg of organic waste)
4	C/N Ratio	30:1 (preferred). Brown matter (wood products, saw dust, paper etc) is rich in carbon and green matter (food scraps, leaves etc) in nitrogen. Over abundance of greens generates ammonia. Correction is by application of brown matter.
5	pH	Slightly alkaline state preferable. Correction by adding small dose of calcium carbonate.
6	Temperature	20 – 30°C
7	Moisture content	40-55% preferable; cover the tank with wet sack and sprinkle water as required
8	Base layer	Coconut husk of one or two layers with cow-dung powder (~30 kg for 4m x 1m x 0.5m size tank)
9	Placing MSW	Waste layer thickness in the tank to be < 15 cm at a time; introduce fresh waste at consecutive portion of the tank on successive days
10	Blending	Sprinkle cow-dung powder alongwith waste
11	Aeration	Regular removal of the composted material, adding holes to the bin, or using a continuous-flow bin.
12	Physical protection	Wire mesh protection from mouse, ants and other pests; avoid exposure to direct sun light or rainfall.
13	Leachate collection	500 litre leachate collection tank for 250 kg/day plant
14	Area requirement	Tank size of 4m x 1m x 0.5m for waste input of 10 kg/day of semi decomposed waste

Source:Varma, 2009

for energy production. The effluent after digestion is a rich source of nutrients and can be used as a fertilizer.

Anaerobic processing of organic material is a two-stage process, where large organic polymers are fermented into short-chain volatile fatty acids. These acids are then converted into methane and carbon dioxide. The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Further, the acidogenic bacteria convert the resultant organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, the methanogenic bacteria convert these products to methane and carbon dioxide (waste.nl, 2007). The major problem with the single stage process is that the different reactions in the process cannot be separately optimized. The acidogenic microorganisms grow fast and lower the pH of the reaction mixture, whereas the methanogens, which grow slowly, have a pH optimum around 7.0. The development of the two-stage digestion process solves this problem as hydrolysis and acidification occur in the first reactor vessel, kept at a pH of around 6.0 and methanogenesis occurs in the second vessel, operated at a pH of 7.5 - 8.2. The whole process can run with a retention time of 5 to 8 days.

The main feature of anaerobic treatment is the concurrent waste stabilization and production of methane gas, which is an energy source. The retention time for solid material in an anaerobic process can range from a few days to several weeks, depending upon the chemical characteristics of solid material and the design of the biogasification system (e.g., single stage, two-stage, multi-stage, wet or dry, temperature and pH control).

In the absence of oxygen, anaerobic bacteria decompose organic matter as follows:

$$\text{Organic matter} + \text{anaerobic bacteria} \longrightarrow CH_4 + CO_2 + H_2S + NH_3 + \text{other end products} + \text{energy}$$

The conditions for biogasification need to be anaerobic, for which a totally enclosed process vessel is required. When compared to composting it requires less area. The microbiology of anaerobic digestion and the optimum environmental considerations for the microorganisms can be achieved by selecting the proper type of digester. There are three types of digesters viz., Standard rate single-stage digester, High rate single-stage digester and High rate two-stage (called High Performance) digester.

INCINERATION

Incineration is a chemical reaction in which carbon, hydrogen and other elements in the waste mix with oxygen in the combustion zone and generates heat. The major aims of incineration of solid wastes are (i) Volume reduction (ii) Stabilization of waste (iii) Recovery of energy from waste and (iv) Sterilization of waste.

About 65 to 80 % of the energy content of the organic matter can be recovered as heat energy, which can be utilized either for direct thermal applications, or for producing power via steam turbine generators (Bhide and Sundaresan,1983). Some modern incinerators utilise higher temperatures up to 1650°C using supplementary fuel. These reduce waste volume by 97% and convert metal and glass to ash. Incinerator systems are designed to maximize waste burn out and heat output, while minimizing emissions by balancing the oxygen, time, temperature and turbulence. Complete incineration of solid wastes produces virtually an inert residue, which constitutes about 10% of the initial weight and this residue is generally land filled.

The incineration facility along with combustion of waste emits air pollutants. Other concerns relating to incineration include the disposal of the liquid wastes from floor drainage; quench water, scrubber effluents and the problem of ash disposal in landfills because of heavy metal residues.

The major incineration technologies commonly used are Mass Burning System, Modular Incineration and Fluidized Bed Incineration. The two most widely used and technically proven incineration technologies are Mass-Burning Incineration and Modular Incineration.

The operation of the combustion process plays an important role in the formation of pollutants, which are carbon monoxide, NOx (oxides of nitrogen), hydrocarbons

Table 9
Design and Operational conditions of Anaerobic Composting Process

No	Aspects	Preferable standards and specifications
1	MSW characteristics	Sorted organic fraction only; Higher the putrescibility, better is the gas yield; Fibrous organic matter is undesirable as the anaerobic micro-organisms do not break down woody molecules such as lignin
2	MSW Particle size	Shredded, minced and pulped particles increase the surface area for microbes to act and increase the speed of digestion.
3	C/N Ratio	25-30 (preferable)
4	Seeding	High gestation period is typical of anaerobic bacteria, hence seeding the digesters with sewage sludge or cattle slurry reduces reaction time and improves efficiency.
5	Moisture content	>50%; Implications on feed, gas production, system type, system efficiency.
5	Process environment	Absence of gaseous oxygen; anaerobes access oxygen from sources other than surrounding air, such as organic material.
6	Mixing/turning	Every four or five days, until the temperature drops from about 66 – 60ºC to about 38ºC or less. Alternate days under typical operating conditions.
7	Temperature	*Mesophilic* bacteria act optimally around 37°-41°C or at ambient temperatures between 20°- 45°C. *Thermophilic* bacteria act optimally around 50°- 52° and at elevated temperatures up to 70°C. Mesophiles are more tolerant to changes in environmental conditions and hence more stable, but thermophiles act faster.
8	Solids content	High-solids with a TSS concentration greater than ~20% or Low-solids with a TSS concentration less than ~15%.
9	pH control	Acidogenic bacteria through the production of acids reduce the pH of the tank. Methanogenic bacteria operates in a stable pH range and temperature.
10	Digestion system stage	Single-stage system enables all the biological reactions in a single sealed reactor, hence different species will be in direct competition with each other.
11	Residence time	For single-stage thermophilic digester, the residence time is around 14 days. For two-stage mesophilic digester, it varies between 15 and 40 days.
12	Gas cleaning	Removal of hydrogen sulphide by scrubbing of biogas or by adding ferric chloride $FeCl_3$ to the digestion tanks.
13	Dewatered digester management	Aerobic composting for materials containing lignin and maturation for breaking down the ammonia into nitrates.
14	Effluent water	Oxidation based treatment to bring down the elevated BOD and COD and curb the pollution potential.
	Degree of decomposition	Determine by COD test or from Respiratory Quotient (RQ).
13	Area requirement	~25 m^2 for 1 tonne of MSW (only for windrow formation for 21 days composting and maturity yard for 30 days stabilization). Area for machinery, packing and storage extra
14	Post treatment care	Facility for effluent (leachate) recycling and treatment and sanitary landfill of rejects (inert materials, sludge from ETP)
15	Nutrient recovery	4.0 - 4.5 kg N per ton; 0.5 - 1 kg P per ton; 2.5 - 3 kg K pr ton
16	Product recovery	Biogas; 30% fibres and 50-65% fluids

Source: Varma, 2008

and other volatile organic compounds. It also produces gaseous stream containing dust, acid gases (HCI, SOx, HF), heavy metals and traces of dioxins. The majority of modern incinerators, however, produce less particulate and gaseous pollutants than their predecessors. The various gaseous pollutants formed due to incineration processes are Carbon dioxide (CO2),Carbon monoxide (CO), Sulphur oxides (SOx), Nitrogen oxides (NOx), Particulates, Hydrochloric acid (HCI), Hydrogen fluoride (HF), Heavy metals (Hg, Cd, Pb, Zn, Cu, Ni, Cr), Dioxins and furans. There many technologies employed to carry out the necessary flue gas cleaning such as (i) Electrostatic precipitators (ESP) (ii) Fabric filters and (iii) Scrubbers. Apart from air pollution, there are other environmental concerns related to incineration like Water

Table 10
Design and Operational Conditions for MSW incineration

No	Aspects	Preferable standards and specifications
1	MSW characteristics	MSW with calorific value as high as possible; Volatile matter >40%; Fixed carbon <15%; Total inert <35%
2	Moisture content	As minimum as possible; <45%
3	Calorific value	As high as possible; >1200 kcal/kg
4	Residence time & Operating temperature	At least 1 sec for flue gas at not less than 980ºC in combustion zone
5	Stack- Particulates	Not greater that 1.8 mg/m^3
5	Stack- CO	Outlet concentration, not greater than 50 ppm (8-hr average)
6	Stack HCl_2	Less than 4.5 g/hr
7	Stack- SO_2	Not greater than 30 ppm (24-hr daily average)
8	Stack- NO_x	Not greater than 30 ppm (24-hr daily average)
9	Stack- Temperature	Flue gas temperature to be more than 150ºC
10	Dioxin or furan	0.2 ng/dry m^3 corrected to 7% oxygen
11	Opacity	No emission having average opacity of 10% or more for any consecutive 6-minute period
12	Noise	As per Pollution Control Board norms
13	Pollution control	Use of scrubber, bag house, ESP, noise screens, silencers
14	Monitoring- Emission	Online instrumentation for oxygen, plume opacity, SO_2, HCl, NO_x, CO, CO_2, Temperature and combustion index.
15	Monitoring-Operation	Online instrumentation for steam pressure and flow, auxiliary fuel, ESP, fabric filters, gaseous contaminant emission control devices.
16	Stack height	$H=14Q^{0.3}$ (Q is emission rate of SO_2 in kg/hr)
	Residue management	Bottom and fly ash to be reused to the maximum extent and the balance to be disposed of in a double-liner sanitary landfill.
17	Nutrient recovery	Nil
18	Recovery	15-25% bottom ash (including clinker, grit, glass), 3% metals
19	Residuals	3% fly ash (including flue gas residues)

Source: Varma, 2008

pollution, Land-retained pollution, Residue disposal, Noise pollution, Aesthetic impact, etc.

PELLETIZATION/REFUSE DERIVED FUEL (RDF) SYSTEM

Pelletisation of MSW involves the processes of regregating, crushing, mixing high and low heat value organic waste material and solidifying it to produce fuel pellets, also referred to as Refuse Derived Fuel (RDF). The process is essentially a method that condenses the waste or changes its physical form and enriches its organic content through removal of inorganic materials and moisture. The calorific value of RDF pellets can be around 4000 KCal/Kg depending upon the percentage of organic matter in the waste, additives and binder materials used in the process. RDF consists largely of organic components of municipal waste such as plastics and biodegradable waste compressed in to pellets, brickets or logs. RDF systems have two basic components: RDF production and RDF incineration (Chantland, 2006).

RDF production plants characteristically have an indoor tipping floor. The waste in an RDF plant is typically fed onto a conveyor, which is either below grade or hopper fed. In some plants, the loader doing the feeding will separate corrugated and bulky items like carpets. On the conveyor, the waste travels through a number of processing stages, usually beginning with magnetic separation. The processing steps are tailored to the desired products, and typically include one or more screening stages, using trommel or vibrating screens, shredding or hammer milling of waste with additional screening steps, pelletizing or baling of burnable wastes and depending on the local recycling markets and the design of the facility, a manual separation line.

Depending on the type of combustor to be used, a significant degree of separation can be achieved to produce a high-quality RDF (i.e., low ash), which typically results in the loss of a higher percentage of combustibles when compared to systems that can produce a low-quality fuel (i.e., slightly higher ash content) for firing in a specially designed combustor. These types of systems recover over 95% of the combustibles in the fuel fraction.

The RDF can be used alongside traditional sources of fuel in coal power plants, cement kiln industry, plasma arc gasification modules, pyrolysis plants etc. RDF is capable of being combusted cleanly and can provide a funding source where unused carbon credits are sold on the open market via a carbon exchange. The RDF burning technology includes spreader stroker fired boiler, suspension fired boiler, fluidized bed units and cyclone furnace units (Bjeldanes and Beard,1996)

PYROLYSIS AND GASIFICATION

'Pyrolysis and Gasification, like Incineration are optinos for recovering value from waste by thermal treatment. It is a process that converts carbonaceous materials, such as biomass into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen (Middleton, 2005; Marshall & Morris, 2006; Varma, 2008) The resulting gas mixture is called synthesis gas or syngas and is a good fuel. Gasification is a method for extracting energy from different types of organic materials. The advantage of gasification is that using the syngas is more efficient than direct combustion of the original fuel. Gasification can also be done with materials that are not otherwise useful fuel, such as biomass or organic waste. It is an important technology for renewable energy.

Plasma Pyrolysis

Plasma pyrolysis or Plasma gasification is a waste treatment technology that gasifies matter in an oxygen-starved environment to decompose waste materials in to its basic molecular structure (Williams & Nguyen, 2003; Varma, 2008). It uses high electrical energy and high temperature created by an electric arc gasifier and does not combust the waste as incinerators do. This arc breaks down waste primarily into elemental gas and solid waste (slag) in a device called plasma converter. The process has been intended to be a net generator of electricity, depending upon

Table 11
Advantages and Disadvantages of Different Technological Options

Advantages	Disadvantages
Anaerobic Digestion Energy recovery with production of high grade soil conditioner. No power requirement unlike aerobic composting, where sieving and turning of waste pile for supply of oxygen is necessary. Enclosed system enables all the gas produced to be collected for use. Controls Green House Gases emissions. Free from bad odour, rodent and fly menace, visible pollution and social resistance.	Heat released is less - resulting in lower and less effective destruction of pathogenic organisms than in aerobic composting. However, now thermophilic temperature systems are also available to take care of this. Unsuitable for wastes containing less organic matter. Requires waste generation for improving digestion efficiency.
Modular construction of plant and closed treatment needs less land area. Net positive environmental gains. Can be done at small scale.	
Landfill Gas Recovery Least cost option. The gas produced can be utilized for power generation or as domestic fuel for direct thermal applications.	Greatly polluted surface run-off during rainfall.
Highly skilled personnel not necessary. Natural resources are returned to soil and recycled. Can convert low lying marshy land to useful areas.	Soil / Groundwater aquifers may get contaminated by polluted leachate in the absence of proper leachate treatment system. Inefficient gas recovery process yielding 30-40% of the total gas generation. Balance gas escapes to the atmosphere (Significant source of two major Green House gases, carbon dioxide & methane) Large land area requirement. Significant transportation costs to far away landfill sites may upset viability. Cost of pre-treatment to upgrade the gas to pipe line quality and leachate treatment may be significant. Spontaneous ignition/ explosion due to possible build up of methane concentrations in atmosphere.
Incineration Most suitable for high Calorific Value waste, pathological wastes etc. Units with continuous feed and high through-put can be set up. Thermal Energy recovery for direct heating or power generation.	Least suitable for aqueous / high moisture content / low Calorific Value and Chlorinated waste. Excessive moisture and inert content affects net energy recovery; auxiliary fuel support may be required to sustain combustion.
Relatively noiseless and odourless. Low land area requirement.	Concern for toxic metals that may concentrate in ash, emission of particulates, Sox, Nox, chlorinated compounds, ranging from HCI to Dioxins.
Can be located within city limits, reducing the cost of waste transportation. Hygienic	High capital and O&M Costs. Skilled personnel required for O&M Overall efficiency low for small power stations.
Pyrolysis / Gasification Production of fuel gas / oil, which can be used for a variety of applications. Compared to incineration, control of atmospheric pollution can be dealt with in a superior way, in techno-economic sense.	Net energy recovery may suffer in case of wastes with excessive moisture. High viscosity of pyrolysis oil may be problematic for its transportation & burning.

Source:CPHEEO Manual, 2000

Table 12
Environmental Concerns and Control Measures

Waste Treatment technology	Environmental Concerns	Control measures
Thermo – chemical processes	Condensate from gas / steam	Recovery, recycling in process / treatment
- do -	Residual inorganic material	Inert residual materials such as broken glass, crockery and rubble to landfill.
- do -	Gasifier char (a valuable source of plant nutrients) Incinerator ash	Leachabiilty tests to determine soluble metal compounds. Contaminated char to be stabilized prior to disposal.
All power generation facilities	Noise from gasifier and engines	To be enclosed in acoustic modules with noise attenuated to 75 dB @ 1 m from source. Plant to have adequate buffer space from nearest residential areas.
All incorporating wet separation processes	Contaminated water from separation process.	Recovery, recycling in process / treatment
All	Storm water from site	If contaminated, diversion / storage for process use / treatment to specified standard before discharge.
- do -	Wind blown rubbish	Mesh fences around facility with periodic cleaning of rubbish
- do	Odour from the waste storage / processing buildings	Air from these areas to be extracted and treated to destroy odour causing compounds prior to release to atmosphere.
- do -	Exhaust gas from combustion engines or process burners.	To be within limits prescribed by CPCB for industrial air emissions.
- do -	Flies and mosquitoes	All MSW received at the WTE site to be processed and disposed off within 10 hrs of their receipt.
- do -	Rats and Birds	MSW receiving area to be cleaned daily. MSW storage area to be an enclosed / sealed building and cleaned weekly.

Source: CPHEEO Manual, 2000

composition of input wastes, and to reduce the volume of wastes being sent to landfill sites. High voltage and high current electricity is passed between two electrodes placed apart, creating an electrical arc where temperatures as high as 13,871°C are reached. At this temperature most types of waste are broken into basic elemental components in a gaseous form and complex molecules are separated into individual atoms. Depending on the input waste (plastics tend to be high in hydrogen and carbon), gas from the plasma containment can be removed as Syngas, and may be refined into various fuels at a later stage. Dioxin emissions are possible from plasma arcs when chlorine is present although the extremely high temperature at which plasma gasification operates minimizes the possibility. Process gas clean up can be necessary when gasifying waste streams such as municipal waste streams known to contain heavy metals, chlorine/fluorine, sulfur, etc.

RECYCLING PROGRAMME

Recycling is one of the fundamental parts of the waste management plan. Recycling has a lot of direct significance for the society such as (i) Economic significance

Table 13
Important Recycling Materials: Advantages and Drawbacks

Material	Advantage	Drawbacks
Aluminum	• Aluminum has a high market value. • It can be easily recycled by shredding and melting. • It can be recycled indefinitely because it does not deteriorate from reprocessing. • Aluminum recycling requires significantly less energy than producing aluminum from ore.	• Separate collection is important. • Recycling is suitable only if a processing plant is available.
Batteries	• Recycling recovers valuable metals. • Recycling protects the environment from heavy metals such as lead, cadmium and mercury.	• Large variation in type and size of batteries requires specific recycling processes. • Older batteries have high heavy metal content
Concrete and demolition waste	• Demolition waste can be crushed to gravel and reused in road construction and landscaping.	• Machinery required for crushing is maintenance intensive. • Recycled waste is valuable only if there is a lack of other construction material.
Glass	• Glass has a moderate market value • It can be sorted into colours and melted. • Use of recycled glass saves energy compared with processing raw material. • Glass can be recycled indefinitely because it does not deteriorate from reprocessing.	• Broken glass can contaminate and eliminate opportunities for recycling.
Organic waste	• Most commonly recycled by composting or anaerobic digestion.	• Though compost is very beneficial to depleted soils, it still has a low market value.
Other metal	• Scrap metal has a high market value (especially steel, copper, silver and platinum) • It can be recycled indefinitely because it does not deteriorate from reprocessing.	• High-value metals (such as copper and silver) are incorporated in electronic devices, but extraction can cause severe environmental impacts.
Paper	• Paper can be easily recycled; however, quality deteriorates with each cycle. • Paper or cardboard from recycled paper requires less energy to produce and protects forests.	• Appropriate technologies with circular processes are required to protect the environment.

Polyethylene terephthalate (PET)	• PET can be recycled if segregated from other waste. • Reprocessing into granulate is very easy. • PET has a high market value if processing plants are available.	• More 'downcyling' than recycling occurs because quality decreases with every processing cycle.
Other plastic	• Other plastic, such as polyethylene or polyvinyl chloride, can be recycled but has less value on the market than PET; the value depends on recycling and manufacturing options in the vicinity.	• Recycling requires specific machinery
Electronic waste	• Electronic waste (such as computers or mobile phones) contains high value metals. • Electronic items can be dismantled, reused or recycled.	• Metals are often covered with polyvinyl chloride or resins, which are often smelted or burned, causing toxic emissions.

Source: World Bank,2008

Table 14
Common Types of Plastics that may be recycled

Sl.No	Chemical Name	Abbreviation	Typical uses
1	Polyethylene terephthalate	PETE	Soft drink bottles
2	High-density polyethylene	HDPE	Milk cartons
3	Polyvinyl Chloride	PVC	Food packaging, wire insulation and pipe
4	Low-density polyethylene	LDPE	Plastic film used for food wrapping, trash bags, grocery bags, and baby diapers
5	Polypropylene	PP	Automobile battery casings and bottle caps
6	Polystyrene	PS	Food packaging, foam cups and plates, and eating utensils
7	Mixed plastic		Fence posts, benches and pallets

Source: Aarne vesilind, et al,2004

which includes cost reduction, employment generation, energy saving, reduced health care costs etc.(ii) Environmental and health significance such as improved environment, natural resources conservation etc., and (iii) Social significance. The recycling of waste will increase the economic value of the waste and will reduce quantum of waste to be disposed.

Source separation is an important activity in any recycling programme and it refers to the segregation of the recyclable and reusable materials at the source of generation. This requires separation of different components in different containers. In some places, a well planned programme for collection of recyclable materials is in place like Drop-off programme and Buy-back programme. A drop- off programme requires resident to separate the recyclable materials and bring them to a specified drop off or collection. Buy- back refers to a drop- off programme that provides monetary incentives to participate. In this type of programme the resident are paid back for their recyclable material directly or indirectly through the reduction in collection and disposal fees.Collection vehicles that are designed specifically for collecting recyclables have several storage bins, which can be easily loaded and often equipped with automatic container-tipping devices.

SANITARY LAND FILL

The term 'landfill' is used to describe a unit operation for final disposal of 'Municipal Solid Waste' on land, designed and constructed with the objective of minimum impact

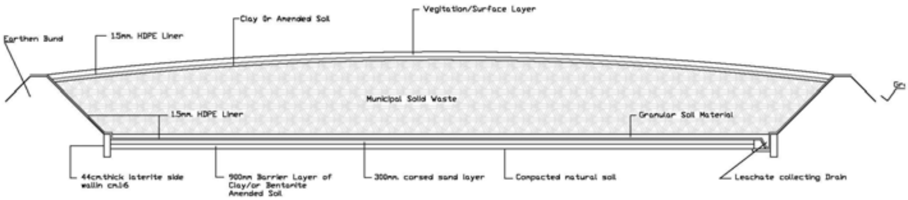


Fig 4
Cross Section of Landfill

to the environment. Sanitary land fill is a systematic disposal technique especially for the rejects after processing. This term encompasses other terms such as 'secured landfill' and 'engineered landfills' which are also sometimes applied to municipal solid waste (MSW) disposal units.

Essential Components

(a) A liner system at the base and sides of the landfill which prevents migration of leachate or gas to the surrounding soil.

(b) A leachate collection and control facility which collects and extracts leachate from within and from the base of the landfill and then treats the leachate.

(c) A gas collection and control facility (optional for small landfills) which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery.

(d) A final cover system at the top of the landfill which enhances surface drainage, prevents infiltrating water and supports surface vegetation.

(e) A surface water drainage system which collects and removes all surface runoff from the landfill site.

(f) An environmental monitoring system which periodically collects and analyses air, surface water, soil-gas and ground water samples around the landfill site.

(g) A closure and post-closure plan which lists the steps that must be taken to close and secure a landfill site once the filling operation has been completed and the activities for long-term monitoring, operation and maintenance of the completed landfill.

Landfill gas can be toxic and can lead to global warming as well as to explosion leading to human calamity. It contains a high percentage of methane due to the anaerobic decomposition of organic matter, which can be utilized as a source of energy. A typical landfill gas contains a number of components such as methane (typically making up 50-60% of the landfill gas), carbon dioxide (30-40%), oxygen and nitrogen.

SUITABLE TECHNOLOGIES FOR KERALA

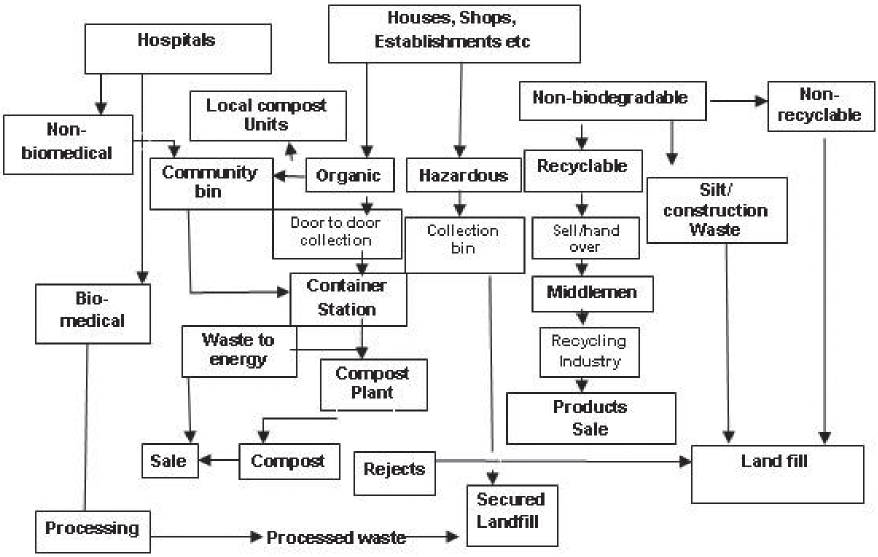
The suitability of a particular technology for the treatment of MSW depends on a number of factors that essentially include techno-economic viability, environmental safeguards, sustainability and location specificity. The important parameters that are considered generally for a suitability analysis are the quantity of waste that can be handled by a technology, physical, chemical and biological characters of waste, land and water requirement, environmental sensitivity to locations, environmental impacts/pollution potential, capital investment, O&M costs, cost-recovery, product utility, by-product usability or reject disposal, requirement of pollution control installation, etc. The suitable technologies are location specific and vary from place to place.

It is clear that the bioconversion processes have very clear edge over the thermal conversion processes in the context of Kerala. The high moisture content, low calorific value, substantially high contents of Nitrogen, Phosphorous and Potassium in MSW samples indicate that the vegetative fractions of wastes are more suitable for composting to organic manure after separating the reusable and recyclable fractions. The inert, non-biodegradable residue left after composting could be disposed off using sanitary land fills. The resource requirement for thermal methods and their environmental impacts are very high and hence, are not generally considered suitable for the State. Methods of vermi composting and biogas generation are suitable to be practiced in the outlying areas where household land extent is comparatively more (Varma, A K 2008). Energy recovery through biogas route is also suitable from the point of view of long term benefits, provided the conditions obtainable when compared against the above criteria are weighing positively.

STRATEGIES AND FRAMEWORK FOR SWM

The urban solid waste management involves two integral elements, viz, (i) the ultimate disposal of waste adopting any of the approved methods appropriate for the type of waste generated and (ii) the community action that leads to the proper handling of the waste from its source to the disposal point. In solid waste management, the primary measures are collection, segregation, storage and transportation of waste while disposal of the waste constitutes the secondary measures. The primary measures generally involve social aspects that necessitate community action whereas the secondary measures are by and large technical. It is essential that, the solid waste management system should encompass an effective and systematic mechanism for the collection, segregation, storage and transportation of the waste generated at these places. Since people's participation is vital for sustenance of the system, participatory methods should be adopted to the extent possible. A typical sequential action and strategies for implementing a solid waste management system in any urban local body is given below:

- Draw up a feasible management system which identifies and explains the sources that generate waste, the collection and transportation arrangements and the disposal mechanism.
- Collection of the Baseline Information: Information required for preparing a proper plan such as area, population, number of households, number of divisions (wards), number of zones/circles etc
- Collecting information as to the type, quantity and characteristics of waste



(Source:KSUDP,2007)

Fig5
Flow Chart Showing SWM System

generated. The activities involved are (i) waste quantification survey for all the constituents of waste to assess waste generation at houses, commercial establishments and markets; (ii) estimation of waste collected (iii) estimation of waste transported (iv) estimation of waste recycled (v) physical-chemical analysis of waste generated

- Understanding the present situation: This includes the existing mechanism for primary and secondary collection, the transportation system (availability of transfer stations and vehicles-both private and departmental vehicles), availability and adequacy of staff and the disposal methods.
- Understanding the key issues: The issues generally observed in the context of SWM are absence of segregation and storage at source and absence of organized primary collection; absence of need based schedule for sweeping; existence of exposed system of secondary storage; overflowing secondary collection points; irregular collection and multiple handling; absence of long-term, secured landfill; incompatible vehicles and equipments; low community/NGO/CBO partnership; weak institutional and financial set-up and environmental and health issues
- Preparation of solid waste treatment/disposal options and cost estimates: This can include site profile and design approach, layout plan of proposed waste treatment and disposal facility (including composting, landfill etc)
- The goals of site selection are to minimise health risk, adverse environmental impact, cost of the development, construction, operation and closure and maximize public acceptability of the project. Site selection criteria have been developed in the form of guidelines to suit Indian condition, by Central Pollution Control Board. The developed criteria encompass environmental conditions,

Table 15
Strategy for SWM

Component	Strategy	Target	Responsibility
Segregation and Storage	Segregation (biodegradable, non-biodegradable) and separate storage at source. Two separate bins will be kept for biodegradable (Green color), non-bio degradable (white color) generated in all premises	Cover all premises through a continued and organized awareness creation, motivation and subsequent enforcement	Those who generate waste
Primary Collection	Door step collection /Kerb / block of segregated and stored waste Direct collection from non domestic bulk generators.	100% door step collection	ULB, through agencies like Kudumbasree, other NGOs, residents' association
Street Sweeping	Cover all roads/streets and open spaces; and cleaning of drains (below 60 cm depth) by the sanitary workers in the afternoon.	Daily coverage of dense commercial areas; Sweeping on all days including Sundays in city centre and market area; alternate day coverage of medium density and dense housing area; and weekly coverage (twice/once) in other areas.	ULB, through CLR workers
Secondary Collection	Abolition of all open collection points by placing containers – separate for organic and inorganic; and Direct transfer of waste from primary collection vehicle to containers	100% coverage with provision for 30% additional storage capacity to prevent overflow; and Paving all container stations.	ULB, through collection vehicles
Direct Collection	Direct collection of waste from large hotels and restaurants, marriage and function halls, hospitals, construction waste, slaughterhouse, etc. by deploying exclusive vehicles for the purpose.	100% coverage; and Bi-weekly collection of bulk waste /garden waste from domestic area on pre-fixed days.	ULB, through collection vehicles
Transportation	'Container Exchange System of Transport' that transports organic and inorganic waste in dumper bins to compost plant and landfill site respectively by using dumper placer vehicles	100% removal of organic waste daily; Need based removal of inorganic/ inert waste without allowing overflow	ULB- Daily collection in transportation vehicle (covered tipping truck) of premises under direct collection system and direct transportation to disposal site.
Treatment	Treatment of organic fraction	Centralized compost plant Localized decentralized vermi compost plants Bio-gas units	ULB- Directly or through competent agencies
Landfill	Engineered landfill for inerts and compost rejects	Remediation of all ready accumulated waste; and Development of sanitary landfill	ULB- Directly or through competent agencies

Table 16
Source Segregation and Storage

Source	Storage of Segregated Waste	
	Food & Green waste (Green Color Bin)	*Non-bio-degradable(White bin)*
House Holds	10-15 litres capacity bin with lid	A bin or bag of suitable size
Hotels & Restaurants	60 litres capacity-LDPE/HDPE bins	A bin or bag of suitable size
Shops & offices	Suitable container not exceeding 60 litres	A bin or bag of suitable size
Market Stalls	40-60 litres bin-LDPE/HDPE	A bin or bag of suitable size
Marriage/town halls	Dumper Skip	A bin or bag of suitable size
Hospitals	60 litres bin for food & bio-degradable waste	Store as per Bio-medical Rules 1998

hydro geological conditions, accessibility, ecological, societal effects etc.

The ULBs can supply bins for households in first year and subsequent replacement will be by households. Non-domestic sources shall purchase bins at their own expense. The IEC plan will be designed to create the desired behavioural changes for storage and segregation of waste.

Street Sweeping and Drain Cleaning

There will be places with high concentration of people (e.g., markets) where daily sweeping/cleaning will be required even on holidays. At the same time some areas may require cleaning/sweeping on alternate days, once in three days or once in a week only. Hence beat allocation and scheduling for street sweeping and drain cleaning should be as per requirements.

Secondary Collection & Storage

- Identifying secondary collection points and setting up of container stations at all important locations of the city
- Direct Collection of waste from large and medium commercial establishments

Transportation

- Daily transportation of organic waste to processing plant
- Transportation of non bio-degradable waste at regular interval to landfill site based on waste accumulation at each containerized secondary storage facility;
- Direct transportation of construction waste to landfill site/ for land reclamation;
- Direct transportation of hotel, hospital waste(non infectious), to treatment/ disposal site;

Table17
Primary Collection-The Framework

Coverage Area	Primary Collection Vehicle	Secondary Storage
Door to Door collection (Kudumbashree, NGO, Residents' Association-RA etc)		
Residential colonies high density in gentle terrain and within a radius of 500 m from the secondary storage	Hand cart with bins - green color for Bio-degradable waste, black color bins for recyclables	Bio-degradable in dumper placer container or direct transfer to collection vehicles Non-biodegradable-Sell or dispose in black container
Peripheral area covering a radius of 2000 m from secondary storage	Auto three wheeler	
Kerb/block collection (ULB)		
Settlements of narrow access, commercial area (small shops)	Auto three wheeler	Transfer of waste to dumper containers/direct transfer to collection vehicles
Direct Collection System (ULB)		
Hotels / restaurants / Hospital- non infectious/Garden waste.	Closed vehicle (Tipper trucks) to collect biodegradable	Direct transportation to treatment yard.
Construction/demolition waste	Container /tipper truck	Direct transfer to the landfill site.
Street sweeping	Sweepers cart with litter bins	Direct transfer to container-short distance Transfer to Tipper auto-for long distance

Table 18
Operational Modalities-Roles and Responsibilities

ULB
i. Procuring hand carts and issuing to collection groups (Kudumbasree/NGO/RA etc) ii. Providing subsidy to procure auto tippers iii. Provide support to obtain loan assistance* iv. Organize and train collection groups* iv. Prescribe user fee in consultation with Community v. Monitor activities

Kudumbasree units/NGO/RA etc	
i.	Enter into agreement with ULB & community groups
ii.	Procure vehicle /equipments
iii.	Organise door step collection system
iv.	Maintain the vehicle and equipments
v.	Collect user fee as agreed

*** Where agencies like State Poverty Eradication Mission (SPEM) exist, this task may be assigned to them.**

- Direct transportation of garden waste on pre-notified days to compost plant; and
- Direct transportation of street sweeping and drain cleaning waste to landfill site.

Waste Processing and Disposal

- Development of centralized waste processing plant where there is ample space
- Development of localized decentralized waste processing plants where there is scarcity of space for waste disposal. This can be a viable option even if there is sufficient space for centralized plant since this is in line with the proximity theory of waste management.
- Setting up of bio-gas plants at the markets and slaughterhouses.
- The waste processing plants will process the organic waste through aerobic composting process and the landfill receive the inert matter and the rejects from the compost plant and decentralized plants.
- Prevention of ground water contamination, with adequate containment measures.

Capacity building and implementation

SWM is an activity in which volunteerism and public participation are the keys to success. It is not the technology but public attitude and behaviour that are going to make the difference. An IEC Plan focusing on solid waste management will therefore basically aim at the following:

- Creating behavioural change for scientific waste disposal. This will include (i) adoption of the 4R concept-reduce, reuse, recycle and recover the waste (ii) storage and segregation at source (iii) imbibing the civic responsibility of keeping the premises clean (iv) willingness to accept the civic responsibilities of citizens, and (v) willingness to part with the ad hoc approach of unscientific solid waste disposal.
- Awareness creation on the dangers of unscientific SWM. E.g., (i) health hazards (ii) aesthetic damage.
- Awareness creation on the various technical options of solid waste management.
- Exploring the possibility of converting waste as a resource.
- Proximity theory of SWM. (Scientific disposal of waste at the nearest point of

source. E.g., biogas plant at a market; composting at households etc.)

- Willingness to pay for services.
- People's participation and cooperation at all stages of waste management.
- Community adherence to rules, orders and directives
- Adoption of integrated approach. The institutional mechanism created for collection and transportation of waste could, in return, be used for sale of manure manufactured at the compost plant, etc

Role of NGOs/Residents' Associations

NGOs and Residents' Associations can play a vital role in SWM. Some areas where they can effectively work are indicated below:

- Organizing neighbourhood groups (NHGs) and imparting motivational training for storage and segregation of waste
- Organizing waste collection groups
- Propagating the 4R concept
- Propagating the proximity theory
- Organizing, training and equipping the rag pickers as door step waste collectors.
- Generating demand for household level waste management options like vermi composting and providing skilled services in setting up household units.
- Sale of manure from the compost plant by organizing the cultivators/ horticulturists
- Discouraging use of non-degradable/non-recyclable items
- Organizing awareness creation/training programmes
- Establishing community vigilance system to ensure, sustain and improve the SWM system

Apart from the positive health impact, solid waste management is a clear indicator of the effectiveness of municipal administration. It is an integral part of good governance and one of the most visible urban services influencing local perception of governance.

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Sustainable Small Scale Solid Waste Management for the Future

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INTRODUCTION

Most metros in India are producing >1000 tons per day of municipal solid waste (tpd, MSW). For example Bangalore city produces about 3600tpd of MSW. A major constituent (72%) of this is organic waste. Presently, Bangalore employs a quasi-centralized collection system coupled with generally an open-to-sky compost based processing and subsequent landfill based disposal of the non-compostable inerts. In this way it attempts to closely follow the SWM (M&H) Rules 2000. After nearly a decade of various types of grass-roots experimentation on methods for primary collection, the primary collection and transportation systems are today functioning quite satisfactory. Although a higher level of cleanliness is certainly possible - it could be a target for the future. The current mode and level of operation does not usually allow accumulation of wastes near residential areas or street corners. The waste collection system from house holds (HH) closely follows the Municipal Solid Waste (Handling and Management) Rules 2000 (MSW2000Rules), employing a variety of small powered and non-powered vehicles for direct door-to-door collection of wastes - after all this micro-systems were evolved circa 1992-94 in KSCST, Bangalore (Chanakya, 1994). The extent of wastes collected ranges from 75-90% of the total wastes generated. In order to avoid the multiple handling of wastes, the Corporation has removed most of the open bins in residential areas. Residents now hand over wastes directly to collection workers. It also restricts accumulation of waste near residential area or near street corners - although there are die-hard habits among generators to throw garbage at a location from where the bin has been removed nearly five years earlier. The informal sector for recycling is also quite active in Bangalore and is responsible for collecting the recyclables from open bins (wherever present), from the collection vehicles as they bring the collected wastes to a common location, as well as from other collection systems and from dumping and /or processing sites. A few of these recyclers also purchase the recyclables from individual households. In this way, the informal sector, in various forms, is reported to be actively recovering the recyclable wastes without too much of Governmental interference (van Buren, 1994). However, earlier, when wastes were dumped by households in street bins, it provided a good opportunity for rag-pickers to recover most of the recyclables (Chanakya and Sharatchandra, 2005). It is also important that a decentralized and economically viable processing and management system is required for fermentable components of the MSW in order to be sustainable in the long run. In Bangalore, the informal sector does not participate in collection, processing or recycling of organic waste components as reported for many other urban or peri-urban cities of Karnataka (Nunan, 2000). It has been reported that till a decade earlier, about 60% of the MSW collected was dumped at about 60 known and unknown (unrecorded) dumping sites around Bangalore. Further, among these more than 35 sites received a mixture of domestic and industrial waste (Lakshmikantha, 2006). As Bangalore is rapidly complying with the MSW2000Rules, a large fraction of the MSW is reaching designated "integrated processing and landfill sites" around Bangalore.

Citizen, resident welfare associations (RWA) and non-governmental organizations (NGO) have in the past set up many small scale processing and treatment units. These small scale collection, treatment and processing units have over two decades achieved different levels of success of motivational iec (information, education and communication.) activities. Most metros (e.g. Bangalore) have a rich experience in decentralized, resident association, NGO and other forms of small initiatives at resident locality based treatment and processing of MSW. In Bangalore the urban local body (ULB) - Bruhat Bangalore Mahanagar Palike (BBMP) has been interested and supportive or supporting these small scale efforts in many ways in the past. It supports private and NGO initiatives as a way of expanding its own waste services throughout the city. A systematic waste management requires an active approach of ULBs along with public participation. In large metropolitan area (with a population of 1 million or more), it is difficult to have meaningful public participation, a decentralized system is needed to stimulate more active people's participation (Appasamy, 1994). In some of the latest trials, attempts have been made to carry out decentralized waste treatment by rapid aerobic composting with some degree of success (Subramanya, 2009, per. comm.) coupled with recovery, processing and sale of recyclables. Several small scale efforts have been tried to reduce the pressure on transportation of wastes from localities where they have been generated. Several resident welfare based organizations have in the past attempted to process MSW within the locality of its generation and the most recent one has been the Yelahanka New Town facility. This comprises of a primary segregation system that removes a lot of the recyclables and leaves behind the fermentables that is composted in 50 kg lots. The plastics (LDPE/HDPE) are washed with hot water, dried and melted into ingots /slabs and finally sent for re-forming or recycling. Composting as the main method for rendering acceptable the fermentable fraction of USW, especially in the residential areas, does not yield high throughputs for successful enterprises. When the predominant fraction in the MSW is food wastes - these decompose to a high extent and leave behind unsightly leachate and produce very little compost - this therefore does not make economic sense. The common factor among all of these systems in the past has been the drive (and a sense of duty to fellow-men or environment) by a few of the residents to keep their locality aesthetically and environmentally clean - usually anchored by a few elderly or retired personnel. This has a low chance of sustainability under current situations in a young suburb with generally lower level of social aggregation. Another feature of these systems has been a rather ephemeral period of successful operation. Most of these systems have functioned for a specific period because of the inspiration of a few in the locality and propped up due to a sense of civic responsibility among these few. With passing age and difficulty in sustaining the initial zeal at a latter period, these initiatives have often reverted to the conventional, ULB run collection and disposal systems. Most metros today are replete with such examples. In most of the cases economic sustainability or political will have been the weak link because of which such good efforts have come to a naught. A model that could then survive not merely on society's endogenous drive but also possesses economic and political sustainability - is of great importance.

Today we know that there are several small localities willing to operate decentralized MSW processing and treatment systems. Having established this fact, we attempt to examine the various combinations of costs and income sources that can be made financially and commercially viable /sustainable. Crucial to this has been the recent introduction of small scale biomethanation as a revenue generation option that removes the menace of odour and fly nuisance associated with aerobic composting attempts (Chanakya et al, 2009; Rahman et al, 2009). We attempt to show that such a combination would not only make decentralized MSW processing and treatment sustainable, it will also greatly reduce the costs of SWM transport at the city level and will pave way for many small entrepreneurs to carry out decentralized processing facilities and be economically, environmentally and socially sustainable.

CHANGING COMPOSITION OF MSW AND ITS IMPACT

In the last 20 years the composition of the wastes generated both at the residence levels as well as the city level has changed significantly. Tables 1 and 2 show the generation rates and physical composition of Bangalore MSW collected from different types of waste generators. MSW recorded, comprises of wastes generated from residences, markets, hotels and restaurants, commercial premises, slums, street sweepings and parks. Residences contribute 55% of total of wastes, which is highest among all sources (TIDE, 2000). Waste generated from hotels and eateries form about 20%, fruit and vegetable markets contribute about 15%, trade and commerce about 6% and from street sweeping and parks about 3% . The slum areas contribute only 1% of total. This is because the slum population and area in Bangalore is low in comparison to other cities and towns. Table 2 shows the waste composition of Bangalore comprising predominantly fermentables (72%), and paper and cardboard (11.6%). Current trends show that residents generally prefer to pack all their wastes, fermentable and non-fermentables into a 'carry-bag' and throw it into the bin or other collection systems evolved in the metro and small cities. Domestic maids, who are often the largest single group involved in the daily garbage disposal also prefer this mode and often are known to refuse carrying a domestic dust bin to the primary collection or street bins. This changing attitude and 'societal stigma' needs to be addressed if MSW needs to be collected in a sensible way in future from among our citizens.

The high wet and fermentable waste content of MSW at source (e.g. >80% in Bangalore) requires its daily removal from places of generation. In a decentralized system, wastes gathered from primary collection by handcarts may be subject to

Table 1
MSW generation in Bangalore

Source	Quantity (t/d)	Composition (% by weight)
Domestic	780	55
Markets	210	15
Hotels and eatery	290	20
Trade and commercial	85	6
Slums	20	1
Street sweeping and parks	40	3

Source: Chanakya and Sharatchandra, 2005

Table 2
Physical composition of MSW in Bangalore

Waste type	Composition (% by weight)						
	Domestic	Markets	Hotels and eatery	Trade and commercial	Slums	Street sweepings and parks	All sources
Fermentable	71.50	90	76	15.6	29.9	90	72
Paper and cardboard	8.39	3	17	56.4	2.49	2	11.6
Cloth, rubber, PVC, leather	1.39		0.33	3.95	0.54	0	1.01
Glass	2.29		0.23	0.65	8.43	0	1.43
Polythene/ plastics	6.94	7	2	16.6	1.72	3	6.23
Metals	0.29		0.26	0.38	0.23	0	0.23
Dust and sweeping	8.06		4	8.17	56.7	5	6.53

Source: TIDE, 2000

immediate treatment by aerobic composting or biomethanation within the locality or ward. This will avoid transportation costs of around Rs1000-1500/t and therefore potentially more sustainable and economic. In the past a significant component of the wastes placed in open street bins were rapidly sought by rag-pickers who removed the recyclables. The impact of this is presented in Figures 1 and 2, which show that the percentage of organic waste will quickly increase in MSW from primary collection point to the time it reaches the dump site due to multilevel recovery of recyclable wastes. This also changes the extent of decomposable component of the wastes and presents various other forms of environmental implications (Chanakya and Sharatchandra, 2005). As the wastes gradually becomes enriched with easy to decompose materials, it also becomes easily amenable to anaerobic fermentation processes that convert the organic matter within to CO_2 and CH_4, the latter being a greenhouse gas. From 1988 to 2000 there is a reasonable change in waste composition: fermentables, paper and plastic has content increased by 7%, 3% and 0.2%, respectively.

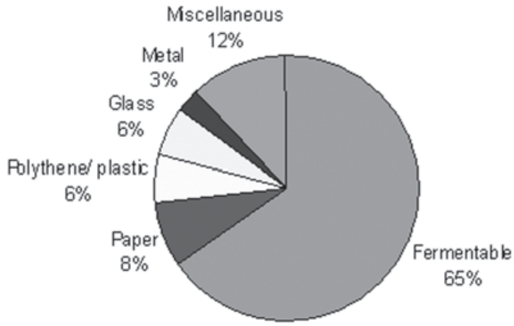

Fig 1
Composition of USW after ragpickers sort and recycled materials
(Rajabapaiah, 1988)

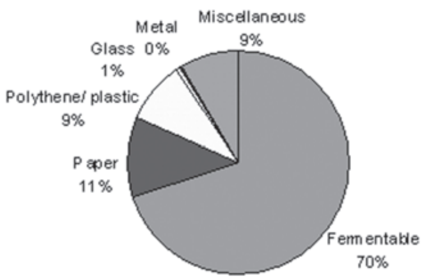

Fig 2
Composition of MSW found at the dumpsites (TIDE, 2000)

RAPIDLY INCREASING QUANTITY OF MSW

Growth of city area and increase in population (as well as population density) has increased the total quantity of MSW being generated daily (e.g. 650 tpd,1988 to 1450 tpd, 2000 and 3600 tpd, currently for Bangalore). With time there is slight change in composition of waste. The current estimates indicate that around 3600 tons of MSW is produced each day in the city of Bangalore. This has increased the per capita generation from 0.16 (1988) to 0.58 kg/d (2009). The rapid increase in the MSW generation rate has been due to the rapid changes in lifestyles of the residents brought about by the high demands for software professionals and ancillary and support professions. This trend is true for other cities and small towns in Karnataka which do not have a strong service /professional sector such as software. This change is largely cultural as well wherein older concepts of recycling, thrift and care for environment has gradually dwindled to functionally /socially acceptable norms.

Such attitudinal changes have brought about problems for safe processing and disposal of MSW around Metros. In the case of Bangalore, in addition to these problems, the city has expanded from about 200 km^2 in the 90's to about 800 km^2 of greater Bangalore. This has in the first place brought many of the traditional dumping sites close to the city or within its boundary and therefore a need to find new locations has arisen. The quantum of wastes generated is far greater than the capacity of the three permitted waste treatment and disposal sites, namely, Mavallipura, Mandur and Singehalli. As these locations are quite far-off, many of the trucks surreptitiously dump MSW at new locations on the roadsides and interior areas around Bangalore so as to reduce their transportation costs. The numbers of the shifting dumpsites has thus grown from the earlier reported 60 (Lakshmikantha, 2006) to many more.

EXTENT OF RECYCLING

Bangalore wastes have 21.27% of the recyclable materials: paper, polythene, cloth, rubber, glass and metals. Recyclable materials are one of the major sources of income. Seen below in Table 3, we indicate a hypothetical 1 tpd scale MSW based decentralized biomethanation and recyclable material recovery system. The results show that recovery of recyclable material of one ton waste will provide income of Rs.1451/t based on the known composition in 2000. A decentralized system with biomethanation and resource recovery through recyclable materials is currently running in Yelahanka New Town, North of Bangalore.

Sustainability

Sustainability of a waste management system requires satisfaction of a minimum of three bottom-line criteria of sustainability namely, economic, environmental and social sustainability. At present, city employs a door to door collection system where waste is collected directly from households and is not dumped in the street bins by generators as before. This provides little opportunities for conventional rag pickers to recover recyclables. From the primary collection activity, the collection personnel recover a few of the easily saleable recyclable materials from where it goes to dumpsite without any serious effort at segregation or treatment process. At two of the three processing sites, there are frontline segregation units that discard lighter materials and break polythene bags containing domestic wastes. This

Table 3
Proposed 1 tpd scale decentralized biomethanation and recyclable recovery system

		Quantity/ cost Rs	Recovery (%)	Rate Rs/kg or Rs/m^3	Rs
INPUT	Capital cost/d	1200 Rs/d			1200
	O, M&D/d	450 Rs/d			450
Total input					1650
OUTPUT	Gas output	60 m^3/d	100	900	900
	Paper	116 kg/d	50	15	870
	Cloth, rubber, PVC, leather	10.1 kg/d	50	12	61
	Glass	14.3 kg/d	50	3	21
	Polythene/plastics	62.3 kg/d	50	12	374
	Metals	10 kg/d	50	25	125
Total output					2351
NET GAIN					701

Source: Chanakya et al., 2009

separates out plastics, rags and fluff, wet fermentables and also heavy materials such as metals, glass, tyres and stones. With such a pre-processing stage the fermentable content rises significantly. Earlier mentioned composition of MSW shows that it has 72% of fermentable waste, with high moisture content. This situation is conducive to processing of the fermentables by composting or biomethanation. When composting of such high moisture feedstock is attempted by conventional windrow based composting process it generates excessive amount of leachates, especially in the rainy season and its fermentation results in malodors due to inadequate supply of air (Chanakya et al., 2007). It is thus important that such wastes are treated rapidly in decentralized units of 5 to 10 tpd capacities. At this scale of 500-1000 tpd there are few working technologies capable of accepting typical composition of Indian MSW for biomethanation. It is estimated that one ton of wastes requires about Rs.250 for processing by windrow composting (Basavaiah, 2008 per comm.). As a result a large quantity of wastes are found untreated at these large treatment facilities and it is therefore suggested that, when waste collection is zoned and collected zone-wise, the predominant resident and hotel wastes could be collected separately and treated nearer the site of production by biomethanation within each ward as has been done in the case of Yelahanka trial process with small scale (50 kg) composting units. This firstly avoids the need for transportation and thus saves the transportation costs. This has the capability of recovering a large extent of plastics and other recyclables making the overall process more sustainable, economically and environmentally speaking. The sustainability components of such decentralized biomethanation systems are discussed later. Small scale biomethanation plants have been in operation in three towns of Karnataka on a trial basis and that in Siraguppa town has been in operation since 2002 (Rahman et al, 2009). At this location there are three 0.5 tpd capacity 3-zone fermenters daily fed a total of 1.5-2.5 t of secondary segregated MSW of Sirguppa town. Similarly, the biomethanation plant at Koyambedu, Chennai has worked for over 3 years until it encountered various non-technical hurdles in late 2009. In Siraguppa, the digested material is then subject to vermi-composting and the recovered vermi-compost is re-used in various town gardens etc. making the overall process economically better than merely composting

Economic sustainability

The existing system of waste management requires a net input of revenue for continuous operation. Firstly, there is a collection cost and assuming a Rs1/d/kg, this translates to about Rs.1000/t. Next, there is a need to spend Rs.1000-1500/t for transporting wastes after primary collection to locations where it is to be tipped (waste treatment facilities) that are between 40-60 km outside the city. In addition the waste treatment facility charges Rs.600/t (of landfilled MSW) as tipping fee. The tipping fee provided is calculated on the basis that 30% of the wastes will be landfilled and consequently 3.3t of input MSW will lead to a cost of Rs.600 as tipping fee. This may be simplified to be Rs.200/t of MSW brought into the waste treatment facility. This indicates that there is a net input of Rs.1450/t of wastes brought in for treatment at the integrated waste treatment site. There is very little revenue streams arising out of this type of facility and therefore it is considered not economically viable in the long run.

The example of the Yelahanka New Town is used to illustrate the concept being proposed. In the proposed decentralized system containing a biomethanation plant and primary segregation and resource recovery system (as has been demonstrated in Yelahanka trials, size 5-20 tpd), one ton of MSW would result in 60 m^3 of biogas whose value is Rs.900/- as fuel gas (Table 4). A decentralized system on the other hand would not involve any transportation costs. One ton of wastes of the composition indicated earlier have the potential to recover the following at 100% recovery (although 100% recovery is difficult we indicate potential). In Table 3 we have indicated the potential costs and benefits from a 1 tpd scale decentralized biomethanation + recyclable recovery system. The results show that decentralized systems, not accounting for land costs, are more profitable and hence higher in the scale of economic sustainability than centralized large waste treatment systems currently practiced. This is obvious that at small scales, the extent of recovery of recyclables can reach nearly 100% and that at the dumpsite barely crosses 30% (visual estimate from one site in Bangalore).

Table 4
Income potential from a decentralized 1tpd system containing biomethanation plant where gas produced is converted to power or CNG.

Invested capital (M)	1	0.5	Outputs	
Capital recovery /d, 10 yr	300	150	Gas output (m^3/d)	60
Interest (SI, @ 15%)	450	225	RETURNED AS	
O,M&D@10%+5%lbr	450	225	Power (1.5 kWh/m^3)	360
Profit	450	225	As gas	900
			Compost	270
	1650	825	Case 1, power	630
			Case 2, CNG	1170

Source: Chanakya et al., 2009

Environmental sustainability

Open dumping is conducive to the generation and release of GHGs, such as methane – having 21 times more GHG potential than CO_2 (Morgenstern, 1991). Methane is released when MSW with a high content of moisture, as found in Bangalore MSW, is dumped in the open rapidly and to a greater height. However, in this case not all the part of the fermentables is converted to methane. A significant part of it suffers aerobic decomposition due to large spaces within and IPCC default values suggest that about 50% is subject to anaerobic digestion and only that fraction contributes to methane generation. Our estimates indicate that fermentable of Bangalore waste has potential for a maximum of 6.24 kgCH_4/t and using IPCC default this value is estimated to be 24.95 kgCH_4/t. As MSW in Bangalore has high moisture content, the IPCC default values need to be corrected for its moisture content to obtain sensible emission data. The key environmental sustainability gained here is by the fact that 6.24 kg of methane is not emitted from MSW and consequently a C-footprint of 6.24 kg is reduced. Second, when accountable for such a level of C-footprint per ton MSW, there is a cost avoided for methane not emitted. Third, if these fermentable wastes are used in decentralized manner to generate biogas, 70% of biochemical methane potential (BMP) can be recovered and can be a cheaper source of energy. This avoids the use of an equivalent quantity of fossil fuels in the vicinity. Fourth, the recycling of various components such as plastics, paper, glass and metal would offset various levels of GHG that are produced in the making of this primary product (not estimated in this paper). As we head into a climate conscious society, it is imperative that we plan to reduce the potential GHG emissions from waste management. Finally, the most important environmental benefit is that a significant land area is not left waste for future generations to worry about.

Social sustainability

Decentralized waste treatment will provide livelihood to 2 persons /ton in the energy unit (biomethanation plant) as well as another two persons in the waste recycling unit. When collection is included, another 8 persons may be employed. In the case of Bangalore, speaking of potential, when compared to the centralized units, the decentralized system would employ about 7000 persons daily in treatment, 7000 in processing and 28,000 in primary collection. The treatment of wastes near the point of generation returns many value added product locally such as gas for use in domestic and commercial uses in the locality, vermi-compost or compost for local uses, recycled plastics for locally useful products including road laying etc. It will greatly increase the trade and social responsibility of wastes in the locality. The exact nature and extent of social sustainability will need to be quantified in a detailed study later. A worrisome issue in social sustainability is the gradual erosion of civic values among the MSW generators as well as in their sense of duty and belonging to the local environment. This is important to ensure that citizens continue to consider wastes an environmental as well as a social responsibility /duty and act accordingly. Only then can a potential for zero waste society dreams could be achieved – a must for a land resource constrained country like India.

TOTAL RECYCLING – THE RMV-II MODEL

RMV extension stage II, of Bangalore is a high income group area with a mixture of residential building and few small shops. The BBMP has been managing the MSW at this locality. The ward councillor was greatly interested in improving waste management system as it would provide political visibility, and at least one of the waste entrepreneurs also has political ambitions. Many of the residents were concerned about waste and its environmental impacts, so they were very keen to start a good waste management system and to make their ward as the first “zero waste” ward of Bangalore. A 60 days project was started by NGO ‘Exnora Green Cross’ for 320 families of this locality. The project aimed to establish a SWM system in the whole area after this demonstration. The system would include primary collection with some gradually increasing source segregation (into organic and inorganic waste), storage and disposal of different types of solid wastes in an environment friendly manner. Waste was being collected twice daily- morning and evening to ensure an odour-free system. However, evening collection was poor as most of the families would refuse to contribute to the evening waste collection – a cultural issue hitherto not documented. The central components of the whole system were the twice collection and separation of waste into reusable /recyclables (to be sold) and the composting of organic waste. Trained waste collectors were appointed for door-to-door collection and for waste segregation. Initially only 25 houses handed over segregated household waste, however, within 10-15d this number doubled. Everyday on an average around 2.6 kg fermentable wastes were coming from each of the families – a value quite high for a typical city. The fermentables (included food waste interspersed with garden wastes) was composted on raised platforms to ensure better aeration and lower the malodour. A composting time of 60d was planned however, composting beds had to be increased. This enhanced the associated problems like smell and flies.

Meticulous documentation of materials received and their segregation has enabled accurate estimation of market values of the recyclables that were recovered (Table 5). Based on this project information, economic costs are calculated for decentralized waste management with compost plant as given in Table 5. Under the existing scenario, we calculate that with compost as the main product and in an enterprise mode and under conditions reigning in Bangalore the cost recovery period would be in the range of 4 years (Table 6, assuming 100% recycling). This is however ambitious and cannot be achieved easily. When the recycling and recovery efficiency drops to 80%, the project is unviable. An additional source of revenue needs to be identified to make the project economic. We then examine the conversion of the fermentables to biogas and expect that sale of biogas locally would offset the financial deficit projected here.

Ultimate Sustainability – Near Total Recycling with Anaerobic Digestion

The decentralized processing and recycling system based on compost and 100% recovery shows a small promise of profitability in an enterprise mode assuming this is carried out on a soft lease basis (no land costs). It is economic only at 100% recovery and this may be difficult to achieve at every location. There is clearly a need for another source of revenue generation to make the enterprise profitable. Thus instead of aerobic composting the organic fraction (leading to only one saleable product – compost), it is proposed to convert it to biogas and compost (two saleable products) by installing a biomethanation plant of the CST design – similar to the

Table 5
Decentralized Waste Management with compost plant

Categories	Rs/year	Optimum Scenario
Capital Investment	206500.00	
Cap costs Rs/yr@10.00%	20650.00	
Depreciation	38225.00	
Maintenance	30975.00	
Operation cost (Rs/yr)	493946.00	
Total expenditure per year	**583796.00**	583796.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Compost sale	229950.00	183960.00
Total net income per year	**584469.11**	**467575.29**
Surplus of income over expenditure	673.11	-116220.71
Capital Recovery Period	306.8	

Table 6
Decentralized Waste Management with biogas plant

Categories	Rs/year	Optimum Scenario
Capital Investment	586500.00	
Cap costs Rs/yr@10.00%	58650.00	
Depreciation	35425.00	
Maintenance	39975.00	
Operation cost	493946.00	
Total expenditure per year	**627996.00**	627996.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Income from biogas	325215	260172.00
Compost sale	229950.00	183960.00
Total net income per year	**909684.11**	**727747.29**
Surplus of income over expenditure	**281688.11**	**99751.29**
Capital Recovery Period (years)	2.1	5.9

one successfully operated for over 5 years in Siraguppa (Rahman et al, 2009). In this scenario, the extent of recyclables recovered and earnings accrued does not change from the previous scenario, the income from collection fees also remains the same. The various costs and returns on investment are worked out for a decentralized waste management with a biomethanation plant (Table 6). In this scenario, it is clear that under ideal situation of 100% recovery of recyclables, collection costs and biogas and compost revenues, the pay back period is only 2 years. Even under an 80% recovery situation, the viability is good.

The costs are calculated at a labour cost of Rs100/head per day (Bangalore rates) and a compost sale at Rs3000/t. In small towns these prices are lower. The labour costs are lower (Rs 60/-), the collection fee can only be about Rs 20/HH, the compost revenues are lower at Rs 2000/t and biogas value would be 20% lower. Similarly recyclables will also fetch a lower value. Thus when all the incomes from this system is lowered by 20% and compost value chosen at Rs2000/t and daily wage at Rs60/d, the biomethanation option is still viable (Table 7). This suggests that in a

Table 7
Composting and Biomethanation option for a small town scenario

A. Decentralized Waste Management with compost		
Categories	**Rs/year**	**Optimum Scenario**
Capital Investment	206500.00	
Cap costs Rs/yr@10.00%	20650.00	
Depreciation	38225.00	
Maintenance	30975.00	
Operation cost (Rs/yr)	321146.00	
Total expenditure per year	**410996.00**	410996.00
Income from collection fee@Rs.20/HH	76800.00	61440.00
Income from recyclables	167523.38	134018.70
Compost sale	153300.00	122640.00
Total net income per year	**397623.38**	**318098.70**
Surplus of income over expenditure	-13372.62	-92897.30
Capital Recovery Period	-15.4	
Assumptions of costs for a small town		
Value of compost Rs/t	2000	
Value of Biogas (Rs/m3)	12	
Cost of Labour (Rs/person/d)	60	
Collection Fee (Rs/HH/month)	20	
Value of recyclables (less by 30%)	167523.38	
B. Decentralized optimum Waste Management with biogas plant		
Categories	Rs/year	Optimum Scenario
Capital Investment	586500.00	
Cap costs Rs/yr@10.00%	58650.00	
Depreciation	35425.00	
Maintenance	39975.00	
Operation cost	321146.00	
Total expenditure per year	455196.00	455196.00
Income from collection fee@Rs.20/HH	76800.00	61440.00
Income from recyclables	167523.38	134018.70
Income from biogas	260172	208137.60
Compost sale	153300.00	122640.00
Total Gross income per year	657795.38	526236.30
Total net income per year	202599.38	71040.30
Capital Recovery Period	2.9	8.3

practical scenario biomethanation plant option is more economic and less sensitive to risks in comparison to aerobic compost plant. Along with economic sustainability, biomethanation options have many other livelihood options (Chanakya et al, 2009; not discussed here). Composting process also requires continuous use of water of around 200-300 litres per ton of waste (Patel, 2003), which has limited its use in dry areas. Daily collection of fermentables and its rapid feeding into the biomethanation plant overcomes and avoids the smell and insects, rat and dog problems. Biogas plant and composting bed give same quantity of compost, while compost beds take two to three months, biomethanation plant it requires a shorter period of 30d. The footprint would then be smaller. The enterprise could also claim C-credits (CERs) which become yet another source of revenue. Finally, it may be seen that the operation costs are high due to high involvement of labour. A major part of the labour is involved in segregation. As residents become aware the segregation needs would be low and labour deployment could be reduced by about 60% making the system a lot more profitable. In Bangalore, where demand of anaerobic compost is high, biomethanation would be a viable process with a pay back period as short as 2 years under ideal conditions and as much as 5 years under less ideal conditions. The advantage of biomethanation is even more pronounced in small towns where revenue streams from compost and recycling will be thinner. We thus show that biomethanation based decentralized system is ideal for Indian conditions for making decentralized MSW processing and treatment economically viable and sustainable in the long run.

CONCLUSION

The costs of MSW collection, transport, processing and disposal have gradually become high and less sustainable. There is a need to treat the MSW nearer the source so that segregation and recovery of recyclables are more efficient. This calls for a decentralized system within localities. Decentralized systems run so far have had aesthetic (smell and insect) and economic problems and have always been short lived. Running these sustainably in a decentralized manner requires firstly a good technology such as biomethanation (to first avoid smell and insects) that provides many more revenue streams (as from sale of biogas, C-credits, avoiding insecticides, avoiding methane emissions, compost, etc.) and secondly reasonably good recovery and sale of recyclables. In this paper we also show that the biomethanation based decentralized systems have lower business risks because of a large spread of revenue streams. This also avoids expenditure of over 1500/t for the municipalities and ULBs which becomes a big saving and can be invested in development. It is therefore important that this concept be tried with at various municipalities so that we could become zero-waste cities of the future.

Decentralized anaerobic digestion (biomethanation) of MSW in combination with decentralized resource recovery seems to have the greatest environmental, economic and social sustainability potential for our country. As we develop and begin to use more packaged products and more importantly dispose MSW in plastic packages, it will become more and more difficult to handle MSW according to current Rules in a centralized manner where greater the distance travelled, greater is the level of mix-up and difficulty in recovering the recyclables. There is a gradually eroding social and political will to take this issue seriously among the citizenry where we have lost all soft options and only hard options of people's participation and concern for the environment and future generation will need to be invoked in a variety of ways to address this issue. Moving towards a zero waste society is possible when anaerobic digestion is combined with total recycling in decentralized manner. This gives potential for a higher level of economic and environmental sustainability to a society constantly troubled by its cultural imprint on wastes.

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Electronic Waste Management - An Indian Outlook

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INTRODUCTION

The electronic industry is the world's largest and fastest growing manufacturing industry. As per MAIT (Manufacturers Association for Information Technology) estimates, the Indian PC (Personal Computer) industry itself are growing at a 25% compounded annual growth rate. This has given rise to a new environmental challenge, the growing menace of "Electronics Waste" or "E-waste". E waste is a collective name for discarded electronic devices that enter the waste stream or nearing the end of their "useful life". It consists of obsolete electronic devices such as computers, monitors and display devices, telecommunication devices such as cellular phones, calculators, audio and video devices, printers, scanners, copiers and fax machines besides household equipments such as refrigerators, air conditioners, televisions and washing machines. The key issues associated with e waste are :

- wastage of natural resources and energy that have gone into the production of each piece of equipment multiplied by the enormous numbers being discarded due to the accelerating obsolescence of technology.
- toxic materials used in the equipment manufacturing and the resultant health risks to users generally and, more particularly, to the workers involved in production and recycling processes; and
- potential environmental hazard posed by the toxic materials when disposed off in municipal landfills or dumped illegally.

Hazardous materials such as lead, mercury and hexavalent chromium in one form or the other are present in such wastes primarily consisting of :

- Cathode ray tubes (CRTs)
- Printed board assemblies
- Capacitors
- Mercury switches and relays
- Batteries, accumulators
- Electron beam generator

- Liquid crystal displays (LCDs)
- Cartridges from photocopying machines
- Selenium drums (photocopier)
- Electrolytes, PCBs bearing capacitors

The biggest concern with E-Waste is the presence of toxic materials such as lead, cadmium, mercury and arsenic, toxic flame-retardants, printer cartridge inks and toners that pose significant health risks. These materials are used in one form or the other in the production of printed circuit boards, batteries and colour cathode ray tubes. Tin-lead soldering has traditionally been the most economical and reliable part of the process technology. These components can contaminate soil, groundwater and air, as well as affect the workers of the recycling units and the community living around it. The huge range and complexity of component materials in e-products makes it difficult and expensive to dispose off or recycle them safely and at a profit. The dumping of E-waste, particularly computer waste, into India from developed countries is happening because the latter find it convenient and economical to export waste which is further complicating the problems associated with waste management.

Though, the share of E -wastes may not be alarming at this stage, it is necessary to take preventive steps to contain this, before it reaches unmanageable proportions. Given the enormous growth in electronic devices and their rapid obsolescence, it is only a matter of time before these products start flooding the waste stream, raising serious questions about the toxic substances they contain and how they will be managed. This paper highlights the issues associated with E-wastes and suggest management strategies.

SOURCES AND QUANTITY OF E-WASTES

Electronic wastes are generated from different sources (Figure 1) for most of which no authentic records exists. In addition to post-consumer E-waste, there is also a large quantity of E-waste from manufacturing in the form of defective printed wiring boards, IC chips and other components discarded in the production process.

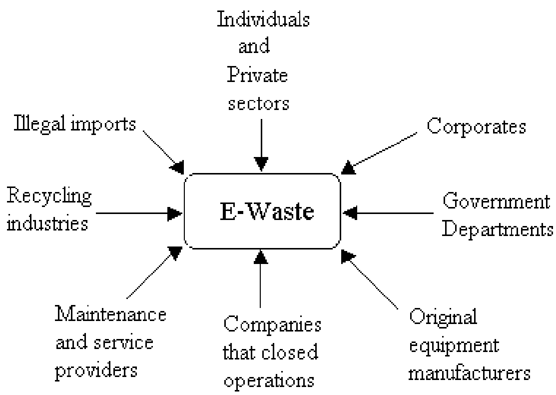


Fig 1
Sources of E-Wastes

The consumers / end users range from large volume / multiple installations (software companies and business processing organisations (BPOs)) to single installations (individual homes). Original equipment manufacturers (OEMs) generate E-wastes from products not meeting quality standards. Though the products manufactured by major units can be accounted easily, there is no system for tracking products assembled by small time vendors and the associated generation of wastes. Maintenance and service providers generate electronic scraps that are replaced by new ones. Further, E-waste from developed countries finds an easy way into developing countries in the name of free trade (Toxics Link, 2004). Most of such trade in E-waste is camouflaged and conducted under the pretext of obtaining 'reusable' equipment or 'donations' from developed nations.

Quantity of E-wastes

E-waste generation in developed countries is estimated to be about 1% of total solid waste generation and is expected to grow to 2% by 2010(Schmidt 2002). According to a 2005 estimate by United Nations Environment Program, 20 to 50 million tonnes of E-waste is generated world wide (Brigden et al. 2005). Short-life equipment such as computers and mobile phones are the most problematic. The number of personal computers worldwide, for example, "increased fivefold - from 105 million machines in 1988 to more than half a billion in 2002" (Worldwatch Institute 2005). By 2005, more than 1 billion computers were being sold each year while 100 million computers reached the end of their useful lives, 75 million of which were landfilled (Environment Australia 2005). Puckett et al. (2002) indicate that the volume of E-waste is mainly due to planned obsolescence and the throw away ethics, which are partly driven by the potential for "... massive increase(s) in corporate profits, particularly when the electronics industry does not have to bear the financial burden of downstream costs".

The volume of E-waste will likely to increase in the near future, especially with the increasing number of people in developing countries coming 'online' with communication technologies.In developing countries, it ranges 0.01% to 1% of the total municipal solid waste generation. The increasing "market penetration" in developing countries, "replacement market" in developed countries and "high obsolescence rate" make E-waste as one of the fastest waste stream. In China and India, though annual generation per capita is less than 1 kg, it is growing at an exponential pace.

As there is no separate collection of E-waste in India, there is no clear data on the quantity disposed of each year. At the most rudimentary level, the potential supply of E-wastes is equal to those products sold, but even this data is highly fragmented and incomplete. The uncertainty in the total number and profile of the sales of these products is complicated by the profile of their use, obsolescence, and failure. According to a recent study (Shobana and Kurian, 2006) in Chennai, the usage of three key electronic products (Computers, Television and Mobile Phones) varies with the income of households as depicted in Fig 2. The obsolescence rate of these electronic products depicted in Fig 3 can be used to make an estimate of E-waste generation from the city as depicted in Fig 4. Personal computers, televisions and mobile phones weighing about 20000 tonnes is estimated to become obsolete in

Fig. 2
Usage of Electronic Products by house holds in Chennai
(Shobana and Kurian, 2006)

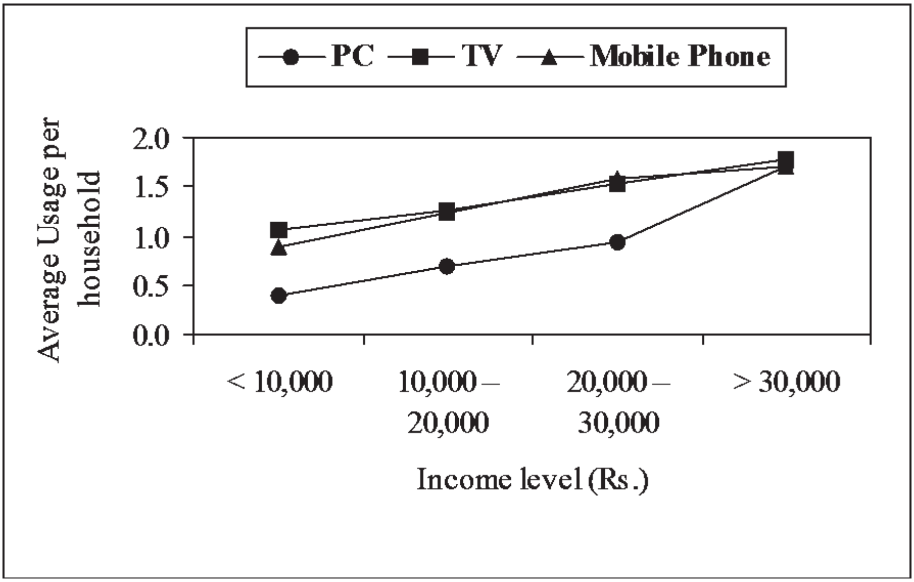


Fig. 3
Average life of Electronic Products in Chennai (Shobana and Kurian, 2006)

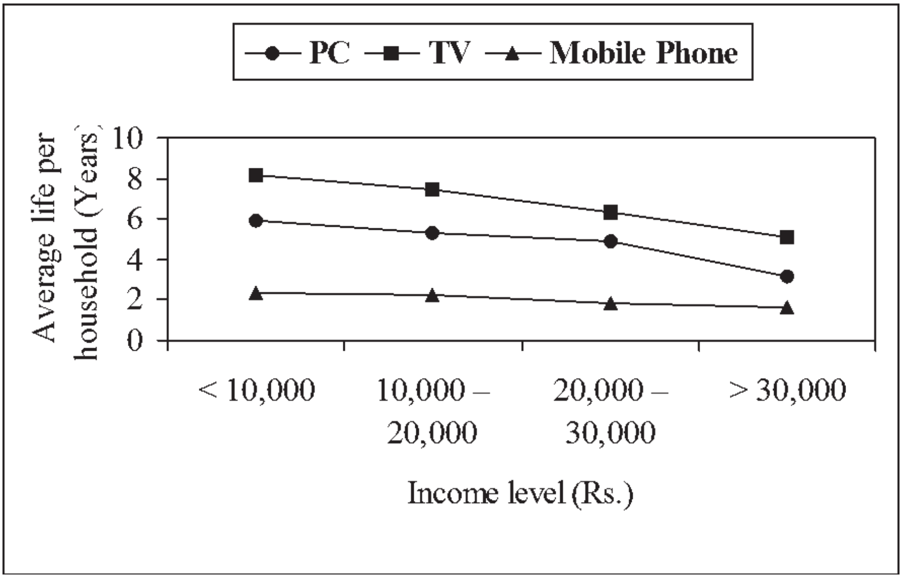
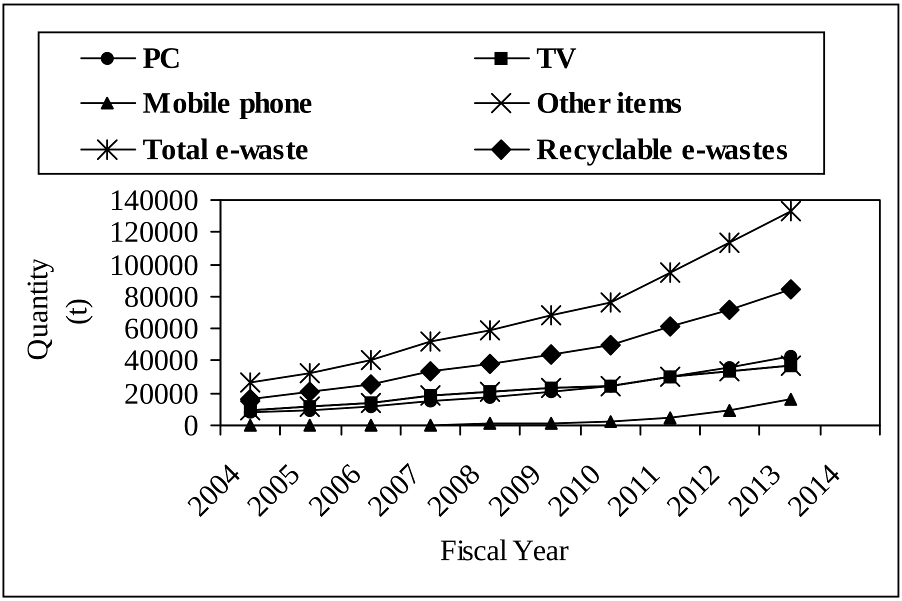


Fig. 4
E-waste generation and recycling potential in Chennai
(Shobana and Kurian, 2006)



Chennai during 2005-2006 and the same is projected to increase by five times in the year 2014 - 2015.

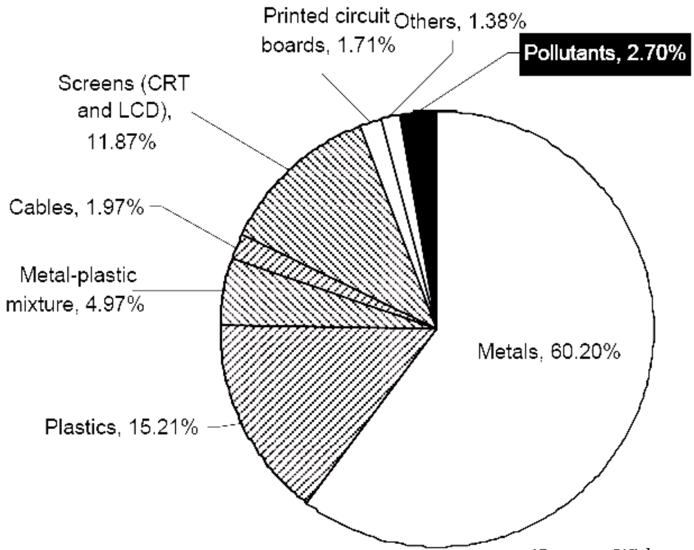
According to a survey by IRG Systems, the total waste generated by obsolete or broken down electronic and electrical equipment in India has been estimated to be 1,46,180 tonncs per year. This is expected to exceed 8,00,000 tonnes by 2012. Ten states (Maharashtra, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab) generate 70% of the total E-waste generated in India. As per a study by Bangalore-based NGO, the Bangalore city with 1,322 software companies, 38 hardware units and business process outsourcing units with a workforce of 60,000, disposed 8,000 tonnes of the wastes per year. The small size of cell phones has both positive and negative implications for waste. Because they are so small and lightweight, cell phones generate only a negligible quantity of waste per unit. However, their small size also makes them more likely to be thrown out in the trash, and ultimately to pose threats to the environment and public health.

Composition of E-Wastes

Typical fractions of E-wastes at a waste processing facility presented in Figure 5 are indicative of typical composition of E-wastes. E-waste contains more than 1000 different substances, including considerable quantities of valuable materials such as precious metals as listed below.

Precious metals – Au (gold), Ag (Silver), Pd (Palladium), and to a lesser extent Pt (platinum)

Fig. 5
Material fractions of e wastes at a Recycling Facility in Switzerland



(Source: Widmer et al, 2005).

Base metals	–	Cu (copper), Al (aluminium), Ni (nickel), Sn (tin), Zn (zinc), Fe (iron), etc.
Special metals	–	In (indium), Bi (bismuth), Sb (antimony), Se (Selenium), etc.
Hazardous Metals	–	Hg (mercury), Be (Beryllium), Pb (lead), Cd (cadmium), As (arsenic), etc.

Iron and steel are the most common materials found and account for almost half of the total weight of E-wastes. Plastics are the second largest component by weight representing approximately 21% and Non-ferrous metals, including precious metals, represent approximately 13% of the total weight of E-wastes(with copper accounting for 7%). Toxic substances and other harmful substances are usually concentrated in printed circuit boards.

POLICY AND REGULATION

Clear regulatory instruments, adequate control to both legal and illegal exports and imports of e-wastes and ensuring their environmentally sound management, are essential. Several countries such as Belgium, Denmark, Italy, Netherlands, Norway, Sweden, Switzerland, Portugal, Japan, Taiwan and South Korea have 'mandatory' electronics recovery laws. The Ministry of Environment and Forests (MoEF), Government of India has brought out the 'Guidelines for Environmentally Sound Management of E-Waste' and is in the process of bringing out the "E-Waste (Management& Handling) Rules. Since E-waste or its residues fall under the category of 'hazardous" and "non-hazardous waste", they shall be covered under the purview of "The Hazardous Waste Management Rules" and "The Municipal Solid Wastes (Management and Handling) Rules". An E-waste Policy must have the objectives of:

- Minimizing the E-Waste generation.
- Utilizing the E-Waste for beneficial purposes through environmentally sound recycling.
- Ensuring the environmentally sound disposal of residual waste.

Key elements of the E -waste management regulations to ensure these shall include:

- Responsibility of each element in the E-waste Value Chain namely the Producers - (Extended/Individual Producer Responsibility), Dealers, Collection agencies/ collection Centres, Dismantlers, Recyclers, Consumers and bulk consumers
- Procedure for Authorization of producers, collection agencies, dismantlers, recyclers and enforcement agencies
- Procedure for registration/renewal of registration of recyclers
- Regulations for import of E-waste
- Liability of producers, collection agencies, transporter, dismantlers and recyclers
- Information & Tracking
- Elimination of hazardous substances used in electronic equipments
- Setting up of Designated Authority to ensure transparency, audit and inspect facilities, examine authorization/ registration etc.
- Specific product take-back obligations for industry;
- Greater attention to the role of new product design;
- Requirements for green product design by restricting the use of hazardous substances (lead, mercury, chromium IV, cadmium, PBBs and PBDE) in electrical and electronic products
- Requirement for producers to provide information on the components and hazardous substances present in their products, as well as on safe use and recycling.
- Greater scrutiny of cross-border movements of Electrical and Electronic Products and E-waste
- Increasing public awareness by labeling products as 'environmental hazard'
- Promoting eco-friendly practices, such as upgrading or repairing electronic products instead of buying new ones.
- Implementation of extended producer responsibility (EPR), obliging producers to cover the costs of collection, recycling and disposal.
- The establishment of standards and a certification system for second hand appliances, and recycling and disposal enterprises, to ensure safety and the environmentally-sound processing of E-wastes.

WASTE MANAGEMENT HIERARCHY AND STRATEGIES

Eco-designing of products, source reduction, close-loop recycling etc, are potential options to reduce the E-waste stream. Designers could ensure the product is built for re-use, repair and/or upgradeability. Stress should be laid on use of less toxic, easily recoverable and recyclable materials which can be taken back for refurbishment, remanufacturing, disassembly and reuse.

Recycling and reuse of materials are potential options to reduce E-waste. Recovery of metals, plastic, glass and other materials reduces the magnitude of E-waste. These options have a potential to conserve the energy and keep the environment free of toxic material that would otherwise have been released.

Extended producer responsibility (EPR) principle has been one of the main driving forces while regulatory frameworks for the environmental and economic management of E-wastes. EPR is the principle in which all the actors along the product chain share responsibility for the lifecycle environmental impacts of the whole product system. The greater the ability of the actor to influence the environmental impacts of the product system, the greater the share of responsibility for addressing those impacts should be. These actors are the consumers, the suppliers, and the product manufacturers. Consumers can affect the environmental impacts of products in a number of ways: via purchase choices (choosing environment friendly products), via maintenance and the environmentally conscious operation of products, and via careful disposal (e.g., separated disposal of appliances for recycling). Suppliers may have a significant influence by providing manufacturers with environment friendly materials and components. Design for Environment (DfE) and Life Cycle Assessment (LCA) are two concepts that support low materials intensity, low toxicity and high recyclability. The use of these concepts in the E-product manufacturing, information technology and communications industries continues to grow significantly, which leads to the development of easily recyclable E-products. Manufacturers can reduce the life-cycle environmental impacts of their products through their influence on product design, material choices, manufacturing processes, product delivery, and product system support.

E-Waste Recycling

E-waste is a rich source of metals which can be recovered and brought back into the production cycle. This particular characteristic of E-waste has made E-waste recycling a lucrative business in both developed as well as developing countries. Managing the increasing volumes of E-waste effectively and efficiently requires special logistics for collecting the E-waste as well as waste processing techniques to prevent the leakage and dissipation of toxics into the environment (Deepali et.al, 2005).

The informal recycling techniques currently used in recycling of E-waste are very primitive, without the appropriate facilities to safeguard environmental and human health. These include several steps such as:

- stripping of metals in open-pit acid baths to recover gold and other metals
- removing electronic components from printed circuit boards by heating over a grill using honeycombed coal blocks (coal mixed with river sediment which is contaminated) as fuel
- chipping and melting plastics without proper ventilation
- burning cables for recovering metals, and also burning unwanted materials in open air
- disposing unsalvageable materials in the fields and riverbanks
- toner sweeping
- dismantling electronic equipment and
- selling computer monitor yokes to copper recovery operations (Wong et. al, 2007).

Recovery of copper wires through the burning of polyvinyl chloride (PVC) and PBDE protected cables can release toxic chlorinated and brominated dioxins (PCDD/PBDD) and furans (PCDF/PBDF). Open burning of computer casings and circuit boards stripped of metal parts can produce toxic fumes and ashes containing polycyclic aromatic hydrocarbons (PAHs).

For electronic product recycling, there are a number of problems that have to be faced at the strategic level, none of which is more challenging than waste collection. An option is to have collection centers at which obsolete products can be dropped off, and nonprofit organizations have can take back products that can be reused in other channels. An appropriate collection site can be selected by taking into consideration the geographic location, the ease and convenience to consumers, and the population distribution. Another mechanism that is growing in popularity in developed countries is the 'special event', organized at a public venue such as an electronics retailer to which the general public is invited to come and drop off their E-waste, often with a fee associated for each item. This option working well in the developed countries is likely to be much more difficult to implement in India as the price charged to the public may deter participation and lower the volume collected. Furthermore, waste recycling is a market-driven and growing industry in India, albeit one driven by economic necessity associated with poverty.

Indian E-waste recycling system has been developed very organically, as a natural branching of the scrap industry which accepts scrap from many sources. In contrast to Developed countries, where consumers pay a recycling fee, in India it is the waste collectors who pay consumers a positive price for their obsolete appliances. The small collectors in turn sell their collections to traders who aggregate and sort different kinds of waste and then sell it to recyclers, who recover the metals. The entire E-waste recycling industry in India is based on a network existing among scrap collectors, traders and recyclers, each adding value, and creating jobs, at every point in the chain. The main incentive for the players is financial profit, not environmental or social awareness. Nevertheless, these trade and recycling alliances provide employment to many groups of people.

Collection, dismantling, sorting and segregation and even metal recovery are done manually in India. Therefore, the E-waste recycling sector employs many unskilled or semi-skilled workers (estimated to be about 10,000 people in Delhi itself). Rag pickers and waste dealers easily adapted to the new waste stream and a large number of new businesses were created in re-using components or extracting secondary raw materials.The lack of formal guidelines, a lax enforcement of existing environmental laws combined with low level of awareness among workers regarding the hazards of the chemicals and process result in exposure to hazardous conditions.

To maximize economic value, the disassembly process starts with high-end parts, which are more valuable, and finishes with low-end parts. Employees responsible for component recovery must know (i) how to disassemble the system, (ii) which components are valuable, and (iii) which components, such as a hard drive, require special care in handlings. Another purpose for the demanufacturing step is to remove hazardous materials. For instance, printer ink cartridges must be removed before the printer can be recycled, because ink is a hazardous substance. Laminated metals are also removed and disposed of because of the difficulty in removing the laminated film from the metal. Proper selection of the order for demanufacturing steps is key to output efficiency. After working systems, valuable components, and hazardous materials are removed from the E-waste, the materials recovery process begins. The primary goal of this process is to separate different types of materials that can be recovered and sold.

Cathode ray tubes are a major item in electronic recycling due to their volume, recycling costs, and disposal restrictions. A CRT consists of two major parts. One is the glass components (funnel glass, panel glass, solder glass, neck) and the other is the non-glass components (plastics, steel, copper, electron gun, phosphor coating). Because CRTs contain lead (Pb), proper handling is necessary to avoid contamination of air, soil, and ground water. There are two technologies currently available for CRT recycling: glass-to-glass and glass-to-lead recycling. To date, the preferred process for the disposal of CRT glass is to recycle it into new CRT glass. Collected CRTs are sent to the recycler and whole glass is ground into cullet without separation of panel and funnel glass.The recycler sends the cullet to the CRT manufacturers for use in making new CRTs. CRT glass compositions differ depending on the manufacturer and when it was made, especially for panel glass. This is one reason why glass manufacturers are reluctant to take recycled CRT glass. Glass companies do not want to mix different types of glass. Using recycled CRT glass can create some risk to the glass manufacturing company due to the difficulty in determining the exact composition of recycled glass. The risk involved with using glass with an unknown composition is that a small addition of the wrong composition can contaminate the contents of an entire glass furnace and lead to changes in glass properties.

The material flow in and out of the system is totally unmonitored at present. The precious metal flow is one of the key economic drivers of the system. The glass fraction creates little economic incentive, as the material is extremely cheap and cannot be used for high quality products without better separation techniques. In terms of volume, however, the glass fraction outweighs all other flows. The metal flows split into ferrous metals (the second largest group of the whole system), aluminium, copper and mixed and precious metal flows.

CONCLUSION

Although awareness and readiness for implementing improvements is increasing rapidly, there are many obstacles to manage end-of-life electronic products (E wastes) safely and effectively. The lack of reliable data poses a challenge to policy makers wishing to design an E-waste management strategy and to an industry wishing to make rational investment decisions. Reliance on the capacities of the informal sector for E-waste recycling pose severe risks to the environment and human health, though, collection and pre-processing are handled efficiently by the informal sector offering numerous job opportunities.

Presently there are about 10 formal recycling units in India. With the changing legislative framework in India, it is foreseen that the big players in e-waste recycling might compete with the informal sector for raw material. The formal sector is now willing to network and channelize value added components from the informal sector. The informal sector has also recognized the damage caused to the environment and health by the unsustainable practices adopted by them for extraction of precious metals.

A solution to the E-waste problem rests on the following set of key principles.

- All parties that handle E-Wastes must be subject to the reporting, registration and treatment requirements.
- Obligated parties must accept to receive all E -Wastes that is returned to them.
- Municipalities must focus on separate collection of E-wastes
- Authorities must provide for effective inspection and control, spot free riders, punish illegal practices
- ban on the export of E-wastes

It may be inappropriate that the E-Waste management requirements addresses only one actor in society, namely, producers or parties that act on producers' behalf, for meeting the collection target without providing them the means to fulfil their responsibility. First of all, they are not in a position to oblige consumers to return end-of-life appliances to the producers. Secondly, they cannot possibly prevent other parties in society -scrap merchants- from selling electronic waste to make a profit. Five broad parameters need to be considered when designing an E-waste management system. These include:

- Legal Regulation: how elaborate is the legislation, i.e. how much detail does it specify for the operational management of system?
- System Coverage: whether it is collective (all inclusive for any brand) or brand-specific (each brand owner is individually accountable).
- System Financing: who pays?, how much? and for what?.
- Producer Responsibility: how much responsibility the producer shoulders, at which points, and how the responsibility is shouldered in practice.
- Ensuring Compliance: Checks and balances, especially to prevent free riders. Penalties for non-compliance and targets for collection or recycling are often used to ensure compliance.

Manufacturer / Producer should reduce the life-cycle environmental impact of their products through influence on product design, choice of material, manufacturing processes and product support system including product take-back at the end of life of the product. The dealers should ensure that the E-Waste thus collected are safely transported back to the producer or to authorized collection center as the case may be. They may also promote buy-back or exchange schemes offered by the producers. Consumers using electrical and electronic equipment should ensure that used equipments which are not fit for the intended use are deposited with the dealer or authorized collection Centres in order to be sent to the authorized dismantler or registered recycler.

The E-Waste Collection Centres are the intermediaries between the E-Waste generators and the dismantlers /recyclers. These centres may be set up individually or jointly by E-producers, importers, refurbishers and recyclers in pursuance of their responsibilities to collect E-Waste and to channelize the same for reuse or refurbishment or recycling. Such Collection Centres are responsible to transfer E-Waste collected by them only to authorized recyclers/ refurbishers/ dismantlers. Dismantles may be authorized to dismantle used electrical and electronic equipments (E-Waste) into their components in an environmentally sound manner and to hand over these to authorized recyclers . Authorised Recyclers shall process E-Waste or components thereof for recovering various constituents for reuse.

To make any system sustainable and viable for operation there is a need to provide economic and fiscal instruments that support the system. Structured package of incentives may be provided to authorized Collection agencies / Dismantlers / recyclers for effective implementation of E-Waste Management. Special Incentives may be given to authorized Collection agencies/ Dismantlers/recyclers to set up their plants in designated non-residential areas.

Electronic equipment Manufacturers may give incentives to their customers for product return through a "buy back approach" whereby old electronic goods are collected. All vendors of electronic devices shall provide take-back management services for their products at the end of life of those products. The old electronic product should then be sent back for its parts to be either recycled or re-used, either in a separate recycling division at the manufacturing unit or in an authorized facility. Informal SMEs and larger smelting industries (processing metal, glass and plastic wastes) may be supported through specific training in cleaner technologies and process handling to improve current E-waste processes by introducing best affordable technologies (BAT) and by upgrading and qualifying low and medium-skilled labor.

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Strategy and Options for Bio-Medical Waste Management

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INTRODUCTION

All developmental activities lead to the generation of wastes. These wastes cause environmental degradation and consequent health effects to human. These matters brought to the attention of the United Nations. The first UN Conference on Human Development held in Stockholm in 1972 helped in a big way to create higher awareness among all member countries. In India also, the people began to think about the dangers of pollution after the UN declaration. Until then, there were only isolated regulations to prevent and control pollution. These thoughts at home gave birth to the first comprehensive legislation in the country at national level to control water pollution and thereby to protect the environment. Thereafter, over the years, there was a series of legislations in this direction. One such major piece of notification under the Environment (Protection) Act of 1986 is the Biomedical Waste (Management and Handling) Rules, 1998.

Kerala is having the highest number of health care institutions as per the 2001 census. About 26% of the health care establishments in India are located in Kerala. The number of hospital beds in all these institutions is about 120000. It is roughly estimated that about 2 kg per bed of solid wastes are generated in these hospitals. The biomedical waste is about 20% of the solid waste generated. This gives a picture of the quantity of biomedical waste to be managed by the hospitals in Kerala.

Biomedical Waste Rules

The Government India as contemplated under sections 6, 8, and 25 of the Environment (Protection) Act, 1986, has made the Biomedical Wastes (Management & Handling) Rules, 1998. The rules are applicable to every institution generating biomedical waste which includes hospitals, nursing homes, clinics, dispensaries, veterinary institutions, animal houses, pathological laboratories, blood banks by whatever name called. The rules are applicable to even handlers.

What is Biomedical Waste?

The biomedical waste is generated during the diagnosis, treatment or immunization of human beings or animals, or in research activities pertaining thereto, or in the production or testing of biologicals. The different locations or points of waste generation in a health care establishment are: the operation theaters/wards/labour rooms, the dressing rooms, the injection rooms, the intensive care units, the dialysis rooms, the laboratories, the corridors and the premises of hospitals.

Responsibilities of hospitals

It is mandatory for such health care institutions to:

- Set up requisite biomedical waste treatment facilities like incinerators, autoclaves and microwave systems for treatment of the biomedical wastes, or ensure requisite treatment of the waste at a common waste treatment facility.
- Make an application to the concerned State Pollution Control Board for grant of authorization. A fee as prescribed shall accompany each application for grant of authorization.
- Submit a report to the prescribed authority by 31 January every year. The report should include information about the categories and quantities of biomedical handled during the preceding year.
- Maintain records about the generation, collection, reception, storage, transportation, treatment, disposal and/or any form of handling biomedical waste.
- Report any accident to the State Pollution Control Board.

Authorization from Pollution Control Board

Every occupier of hospitals, nursing homes, veterinary hospitals, animal houses, pathological laboratories and blood banks, generating biomedical wastes are required to obtain the authorisation of the State Pollution Control Board. *However clinics, dispensaries, pathological laboratories, blood banks providing treatment/service to less than 1000 (one thousand) patients per month is exempted from obtaining authorisation.*

After setting up required waste management facilities, the occupier needs to make an application in Form-I to the State Pollution Control Board for grant of Authorization. The State Pollution Control Board on receipt of the application will make such inquiry as it deems fit, and if it is satisfied that the applicant possesses the necessary capacity to handle biomedical waste in accordance with the Rules, it will grant or renew an Authorization as the case may be. An Authorization will be granted for a period of 3 years.

CATEGORIES OF WASTE

The biomedical wastes are categorized into ten according to its characteristics taking into account treatment and disposal. The different categories of waste as per the rule are given in Table 1.

Segregation of biomedical waste

Creating a system for segregation of waste is the first step. Segregation at source of different types of biomedical wastes and their appropriate storage and/or disinfections sterilization, etc. would ensure that infectious wastes do not get mixed with non-infectious wastes as this would infect the entire waste. Only a small fraction of

Table 1
Categories of Biomedical Waste

Waste Category	Type Of Waste	Treatment And Disposal Option
Category No. 1	Human Anatomical Waste (Human tissues, organs, body parts)	Incineration@/deep burial*
Category No. 2	Animal Waste (Animal tissues, organs, body parts, carcasses, bleeding parts, fluid, blood and experimental animals used in research, waste generated by veterinary hospitals and colleges, discharge from hospitals, animal houses)	Incineration@/ deep burial*
Category No. 3	Microbiology & Biotechnology Waste (Wastes from laboratory cultures, stocks or specimen of live micro organisms or attenuated vaccines, human and animal cell cultures used in research and infectious agents from research and industrial laboratories, wastes from production of biologicals, toxins and devices used for transfer of cultures)	Local autoclaving/ microwaving / incineration@
Category No. 4	Waste Sharps (Needles, syringes, scalpels, blades, glass, etc. that may cause puncture and cuts. This includes both used and unused sharps)	Disinfecting (chemical treatment@@ / autoclaving / microwaving and mutilation / shredding##
Category No. 5	Discarded Medicine and Cytotoxic drugs (Wastes comprising of outdated, contaminated and discarded medicines)	Incineration@ / destruction and drugs disposal in secured landfills
Category No. 6	Soiled Waste (Items contaminated with body fluids including cotton, dressings, soiled plaster casts, lines, bedding and other materials contaminated with blood.)	Incineration@ / autoclaving / microwaving
Category No. 7	Solid Waste (Waste generated from disposable items other than the waste sharps such as tubing, catheters, intravenous sets, etc.)	Disinfecting by chemical treatment@@ / autoclaving / microwaving and mutilation / shredding# #
Category No. 8	Liquid Waste (Waste generated from the laboratory and washing, cleaning, house keeping and disinfecting activities)	Disinfecting by chemical treatment@@ and discharge into drains
Category No. 9	Incineration Ash (Ash from incineration of any biomedical waste)	Disposal in municipal landfill
Category No.10	Chemical Waste (Chemicals used in production of biologicals, chemicals used in disinfecting, as insecticides, etc.)	Chemical treatment @@ and discharge into drains for liquids and secured landfill for solids.

* Deep burial shall be an option available only in towns with population less than five lakh & in rural areas.
** Mutilations / Shredding must be such as to prevent unauthorised reuse.
@ There will be no chemical pre-treatment before incineration. Chlorinated plastics shall not be incinerated.
@@ Chemical treatment using at least 1% hypochlorite solution or any other equivalent chemical reagent. It must be ensured that chemical treatment ensures disinfection.

waste generated by health care institutions is actually infectious or hazardous. It is estimated that 80-85 per cent is non-infectious, 10 per cent is infectious and 5 per cent is hazardous.

Segregation of waste into infected or contaminated waste and non-infected waste is mandatory and is a prerequisite for safe and hygienic waste management. Segregation at source makes it easier to prevent spread of infection, help it easier to choose among the options of disposal, and can reduce the load on the waste treatment system and prevent injuries.

The Schedule 1 of the Rules have laid down certain directions regarding segregation and storage to ensure safe and hygienic handling of infectious and non-infectious waste. The segregation of biomedical waste into various categories and storage in four different coloured containers (Table 2) are taking into account the treatment

Table 2
Colour Coding and Type of Container

Colour Coding	Type of Container	Waste Category	Treatment options as per Schedule I
Yellow	Plastic bag	Cat.1,Cat.2, Cat.3 and Cat.6	Incineration/ deep burial
Red	Disinfected container/plastic bag	Cat.3, Cat.6, and Cat.7	Autoclaving/Micro waving/ Chemical treatment
Blue/ White Translucent	Plastic bag/ puncture proof container	Cat.4 and Cat.7	Autoclaving/Micro waving/ Chemical treatment and destruction/ shredding
Black	Plastic bag	Cat.5, Cat.9, and Cat.10 (solid)	Disposal in secured landfill

and disposal facilities available. The Biomedical waste shall be segregated into containers/bags at the point of generation in accordance with Schedule **II** prior to its storage, transportation, treatment and disposal. The containers shall be labeled according to Schedule **III** of the rule. Apart from the biomedical waste the general waste or the garbage generated in health care establishments such as office waste, food waste and garden waste is advisable to be stored in green coloured containers. The local bodies are duty bound to collect such general waste stored in green coloured containers.

Advantages of segregation

- Segregation reduces the amount of waste needs special handling and treatment.
- Effective segregation process prevents the mixing up of medical waste like sharps with the general municipal waste.
- Prevents illegal reuse of certain components of medical waste like used syringes, needles and other plastics.
- Provides an opportunity for recycling certain components of medical waste like plastics after proper and thorough disinfection.
- Recycled plastic material can be used for non-food grade applications.
- Of the general waste, the biodegradable waste can be composted within the hospital premises and can be used for gardening purposes.
- Recycling is a good environmental practice, which can also double as a revenue generating activity.
- Reduces the cost of treatment and disposal.

Proper labelling of bins

The bins and bags should carry the biohazard symbol indicating the nature of waste to the patients and public. Schedule III of the Rule specifies the label for biomedical waste containers / bags. Label shall be non-washable and prominently visible

Collection of Biomedical Wastes

The collection of biomedical waste involves use of different type of containers for wastes from different sources like operation theatre, laboratory, wards, kitchen, corridor etc. The containers/bins should be placed in such a way that 100 % collection is achieved. Sharps must always be kept in puncture-proof containers with hypochlorite solution to avoid injuries and infection to the workers handling them

Storage of biomedical wastes

The Rules recommend different colour codes for waste containers in which different types of wastes needs to be stored. Clinical and general wastes should be segregated at source and placed in colour coded plastic bags and containers of definite specifications prior to collection and disposal.The container should comprise of an inner plastic bag of varied colour depending on the type of waste. It should be of a minimum gauge of 55 micron (if of low density) or 25 micron (if of high density), leak proof and puncture proof, and should match the chosen outer container. The outer container is a plastic bin with handles, and of a size which will depend on the amount of waste generated. The inner polythene bag should fit into the container with one-fourth of the polythene bag turned over the rim.Labeling has been recommended to indicate the type of waste, site of generation, name of generating hospital or facility. This will allow the waste to be traced from the point of generation to the disposal area.The containers are then to be transported in closed trolleys or wheeled containers that should be designed for easy cleaning and draining.

If for any reasons, it becomes necessary to store the waste beyond such period, permission from the prescribed authority (established by the government of every State and Union Territory) must be taken, and it must be ensured that it does not adversely affect human health and the environment. Once collection occurs, then biomedical waste is stored in a proper place. No untreated biomedical waste shall be stored beyond a period of 48 hours. Segregated wastes of different categories need to be collected in identifiable containers. The duration of storage should not exceed for 8-10 hours in big hospitals and 24 hours in other health care institutions. Each container may be clearly labelled to show the ward or room where it is kept. The reason for this labelling is that it may be necessary to trace the waste back to its source. Besides this, storage area should be marked with a caution sign.

Transportation

Untreated biomedical waste shall be transported only in specially designed vehicles. The waste should be transported for treatment either in trolleys or in covered wheelbarrows. Manual loading should be avoided as far as possible. The bags / container containing biomedical wastes should be tied/ lidded before transportation. Before transporting the bag containing biomedical wastes, it should be accompanied with a signed document by Nurse/ Doctor mentioning date, shift, quantity and destination. Special vehicles must be used so as to prevent access to, and direct contact with, the waste by the transportation operators, the scavengers and the public. The transport containers should be properly enclosed. The effects of traffic accidents should be considered in the design, and the driver must be trained in the procedures he must follow in case of an accidental spillage. It should also be possible to wash the interior of the containers thoroughly

PERSONNEL SAFETY DEVICES

The use of protective gears should be made mandatory for all the personnel handling waste.

***Gloves*:** Heavy-duty rubber gloves should be used for waste handling by the waste retrievers. This should be bright yellow in colour. After handling the waste, the gloves should be washed twice. The gloves should be washed after every use with carbolic soap and a disinfectant. The size should fit the operator.

***Aprons, gowns, suits or other apparels*:** Apparel is worn to prevent contamination of clothing and protect skin. It could be made of cloth or impermeable material such as plastic. People working in incinerator chambers should have gowns or suits made of non-inflammable material.

***Masks*:** Various types of masks, goggles, and face shields are worn alone or in combination, to provide a protective barrier. It is mandatory for personnel working in the incinerator chamber to wear a mask covering both nose and mouth, preferably a gas mask with filters.

***Boots*:** Leg coverings, boots or shoe-covers provide greater protection to the skin when splashes or large quantities of infected waste have to be handled. The boots should be rubber-soled and anti-skid type. They should cover the leg up to the ankle.

BIOMEDICAL WASTE TREATMENT SYSTEM

The Biomedical waste treatment and disposal are to be done very carefully, as it is infectious in nature. Considering the then level of information and knowledge, the Government of India has specifically laid down the treatment and disposal options. All health care institutions are required to follow this without fail. As per the Rule, the biomedical waste has to be treated and disposed of in accordance with options suggested under Schedule **I**, and in compliance with the standards prescribed in Schedule **V** of the Rule.

Any biomedical waste treatment system should comprise of segregation at source, storage in colour-coded containers, systematic collection, transportation to treatment site, treatment considering the type of waste and disposal considering the type of waste. Segregation of biomedical waste is based on the category of waste. Storage and collection of waste in colour-coded containers is based on the treatment adopted.

The treatment options for biomedical waste as per the schedule I of the Rules are incineration, deep burial, autoclave, microwave, chemical treatment, destruction and shredding, and disposal in secured land fills. Disinfection refers to procedures, which reduce the number of microorganisms on an object or surface but not the complete destruction of all microorganism or spores. Sterilisation on the other hand, refers to procedures, which would remove all microorganisms, including spores, from an object. Sterilisation is undertaken either by dry heat (for 2 hours at 170^{o}C in an electric oven – method of choice for glass ware and sharps) or by various forms of moist heat (i.e. boiling in water for an effective contact time of 20 minutes or steam sterilization in an autoclave at 15 lb/sq inch at 121^{o}C for 20 minute)

Specifications of equipments

Incinerator: The biomedical waste incinerator shall meet the following operating and emission standards:

(i) Operating standards

1. Combustion efficiency (CE) shall be at least 99.00 %.
2. The combustion efficiency is computed as follows:

$$CE = \frac{\%CO_2}{\%\ CO_2 + \%\ CO} \times 100$$

3. The temperature of the primary chamber shall be 800 +/-50°C
4. The secondary chamber gas residence time shall be at least 1 (one) second at 1050 +/- 50°C

(ii) Emission standards

Table 3

Parameters	Concentration, mg/Nm³ (At 12 % CO² correction)
1. Particulate matter	150
2. Nitrogen oxides	450
3. HCl	50
4. Minimum stack height	30 m above ground level
5. Volatile organic compounds in ash	shall not be more than 0.01%

Waste to be incinerated not to be disinfected with chlorine containing substances.Chlorinated plastics should not be incinerated. Toxic metals in incineration ash should be limited to within regulatory quantities.Only low sulphur fuels like LDO/LSHS to be used as fuel

Deep Burial

- A pit or trench should be dug about 2 m deep. It should be half filled with waste, then covered with lime within 50 cm of the surface, before filling the rest of the pit with soil.
- It must be ensured that animals do not have access to burial sites. Covers of galvanized iron/wire meshes may be used.
- On each occasion, when wastes are added to the pit, a layer of 10cm of soil be added to cover the wastes.
- Burial must be performed under close and dedicated supervision.
- The deep burial site should be relatively impermeable and no shallow well should be close to the site.
- The pits should be distant from habitation, and sited so as to ensure that no contamination occurs of any surface water or ground water. The area should not be prone to flooding or erosion.
- The location of the deep burial site will be authorised by the prescribed authority.
- The institution shall maintain a record of all pits for deep burial.

Autoclaving

The basic objective of autoclaving is to disinfection and treating biomedical waste.

1. When operating a gravity flow autoclave, medical waste shall be subjected to:
   i. A temperature of not less than 121°C and pressure of 15 pounds per square inch (psi) for an autoclave residence time of not less than 60 minutes; or
   ii. A temperature of not less than 135°C and a pressure of 31 psi for an autoclave residence time of not less than 45 minutes; or
   iii. A temperature of not less than 149°C and a pressure of 52 psi for an autoclave residence time of not less than 30 minutes.
2. When operating a vacuum autoclave, medical waste shall be subjected to a minimum of one prevacuum pulse to purge the autoclave of all air. The waste shall be subjected to the following
   i. A temperature of not less than 121°C and a pressure of 15 psi for an autoclave residence time of not less than 45 minutes; or
   ii. A temperature of not less than 135°C and a pressure of 31 psi for an autoclave residence time of not less than 30 minutes.
3. Medical waste shall not be considered properly treated unless the time, temperature and pressure indicators indicate that the required time, temperature and pressure are reached during the autoclave process. If for any reason, time, temperature or pressure indicator indicates that the required temperature, pressure or residence time was not reached, the entire load of medical waste must be autoclaved again until the proper temperature, pressure and residence time were achieved.
4. Recording of operational parameters: Each autoclave shall have graphic or computer recording devices which will automatically and continuously monitor and record dates, time of day, load identification number and operating parameters through out the entire length of the autoclave cycle.
5. Validation test:

   Spore testing: The autoclave should completely and consistently kill the approved biological indicator at the maximum design capacity of each autoclave unit. Biological indicator for autoclave shall be Bacillus stearothermophilus spores using vials or spore strips, with at least $1_{*}10^{4}$ spores per million. Under no circumstances will an autoclave have minimum operating parameters less than a residence time of 30 minutes, regardless of temperature and pressure, a temperature less than 121°C or a pressure less than 15 psi.
6. Routine tests: A chemical indicator strip/tape that changes colour when a certain temperature is reached can be used to verify that a specific temperature has been achieved. It may be necessary to use more than one strip over the waste package at different location to ensure that the inner content of the package has been adequately autoclaved.

Microwave Treatment

1. Microwave treatment shall not be used for cytotoxic, hazardous or radioactive wastes, contaminated animal carcasses, body parts and large metal items.

2. The microwave system shall comply with the efficacy tests/routine tests and a performance guarantee, may be provided by the supplier before operation of the unit.
3. The microwave should completely and consistently kill bacteria and other pathogenic organism that is ensured by the approved biological indicator at the maximum design capacity of each microwave unit. Biological indicators for microwave shall be Bacillus subtilis spores using vials or spore strips with a least $1_{*}10^{4}$ spores per ml.

Chemical Treatment

Using 1 % hypochlorite solution does chemical disinfection.

Destruction and Shredding

The discarded medicine shall be destructed before disposal. It is advisable that the discarded medicines are returned to the manufacturer for destruction.The solid materials, particularly plastic shall be shredded before sending to the recyclers. These materials are to be disinfected before shredding.

Disposal in Secured Land fills

This is an arrangement for disposal of discarded medicine and chemical waste.

HEALTH HAZARDS ASSOCIATED WITH BIOMEDICAL WASTES MANAGEMENT

According to the WHO, the global life expectancy is increasing year after year. However, deaths due to infectious disease are also increasing. A study conducted by the WHO reveals that more than 50,000 people die everyday from infectious diseases. One of the causes for the increase in infectious diseases is improper waste management. Blood, body fluids and body secretions which are constituents of biomedical waste harbor most of the viruses, bacteria and parasites that cause infection.

This passes via a number of human contacts, all of whom are potential ‘recipients’ of the infection. Human Immunodeficiency Virus (HIV) and hepatitis Viruses spearhead an extensive list of infections and diseases documented to have spread through biomedical waste. Tuberculosis, Pneumonia, Diarrhea diseases, Tetanus, Whooping cough etc., are other common diseases spread due to improper waste management.

Occupational health hazards

The health hazards due to improper waste management can affect

- The occupants in institutions and spread in the vicinity of the institutions
- People happened to be in contact with the institution like laundry workers, nurses, emergency medical personnel, and refuse workers.
- Risks of infections outside hospital for waste handlers, scavengers and (eventually) the general public
- Risks associated with hazardous chemicals, drugs, being handled by persons handling wastes at all levels
- Injuries from sharps and exposure to harmful chemical waste and radioactive

waste also cause health hazards to employees.

Hazards to the general public

The general public's health can also be adversely affected by bio-medical waste.

- Improper practices such as dumping of biomedical waste in municipal dustbins, open spaces, water bodies etc., leads to the spread of diseases.
- Emissions from incinerators and open burning also lead to exposure to harmful gases which can cause cancer and respiratory diseases.
- Exposure to radioactive waste in waste stream can cause serious health hazards.

An often-ignored area is the increase of in-home healthcare activities. An increase in the number of diabetics who inject themselves with insulin, home nurses taking care of terminally ill patients etc., all generate biomedical waste, which can cause health hazards.

Health hazards to animals and birds from Biomedical Wastes

- Plastic waste can choke animals, which scavenge on open dumps.
- Injuries from sharps are common feature affecting animals.
- Harmful chemicals such as dioxins and furans can cause serious health hazards to animals and birds.
- Heavy metals can even affect the reproductive health of the animals
- Change in microbial ecology, spread of antibiotic resistance

ACTIVITIES CARRIED OUT IN BIOMEDICAL WASTE MANAGEMENT BY IMAGE

The management of biomedical wastes in individual health care institutions is economically not feasible. IMAGE was conceived and launched to support healthcare providers to face the challenges and responsibilities of the Biomedical Waste (Management and Handling) Rules 1998. The project was launched on 21st October 2001 by Dr. S. Arulraj the then National President of IMA. In spite of the challenges Indian Medical Association Kerala State Branch went ahead and established a Common Biomedical Waste Treatment and Disposal Facility at Palakkad. The Facility was dedicated to the nation on 14th December 2003 by Dr. V.C. Velayudhan Pillai,the former National President of IMA.

From the outset, IMAGE (*Indian Medical Association Goes Eco-friendly*) the biomedical waste treatment and disposal scheme of Indian Medical Association has been a different cup of tea altogether, unique in conception and execution. The scheme is a testimony to what IMA is capable of. The brand IMA has withstood the difficulties in dealing with an issue concerned with waste. The story of IMAGE is the story of public trust in IMA. It is the unshakable faith in IMA's credentials that has sustained IMAGE.

The relevance of IMAGE

IMA has invested in IMAGE around Rs 3 crore for the project. This liability is being shared on a cooperative basis by the affiliated institutions. However, this expenditure will amount to only one tenth of the cost the institutions would incur if they choose an individual facility. Health care institutions can affiliate with IMAGE by paying a non-refundable one time affiliation fee along with the duly filled up prescribed application form. The affiliation fee is Rs. 1000/- per bed. The minimum affiliation fee for clinics, laboratory, diagnosis centre, dental clinics with two chairs, etc will be Rs. 5000/- only. Government hospitals have been exempted from paying affiliation fee. The affiliation applications are available from IMAGE. IMAGE provides comprehensive service to health care institutions by training hospital staff, advice and assistance in procuring materials for installing a waste management system, collection of biomedical waste from hospitals in colour coded bags, transportation in specially designed vehicles, treatment and final disposal in the common facility. Thus infectious waste generated from hospitals is disposed off most scientifically within 48 hours. The expenditure for service is by collecting daily charges.

As of today IMAGE serves in all the 14 districts of the state. More than 2500 health care establishments are affiliated to IMAGE. This amounts to total bed strength of about 65000. Today IMAGE handles more than half of the biomedical waste generated in Kerala. IMAGE consists of a common treatment and disposal facility and a fleet of 28 specially designed vehicles which collect and transport biomedical waste from all the affiliated hospitals everyday conforming to all the legal regulations. The treatment facilities consist of three incinerators, two autoclaves, a plastic shredder, sharp pits, facility for storage of incineration ash, waste water treatment plant, etc. The IMAGE has made an agreement with the KEIL (Kerala Environmental Infrastructure Limited) Ernakulam for collecting and transporting to their common facility all incineration ash and waste water treatment plant sludge. This is an institution of excellence. This model is unique to Kerala and has propelled the state ahead of other states.

Training the staff of the institutions for scientific segregation of biomedical waste; provision to make available colour coded bags and containers with emblem; daily collection of segregated and contained biomedical waste from institutions; safe disposal of the biomedical waste in the plant as per the rules; to make available monthly statement regarding the quantity of biomedical waste collected and disposed on behalf of the institutions and facilitate to obtain Authorization from the State Pollution Control Board; these are some of the services extended to health care facilities in the state by the IMAGE.

CONCLUSION

We need innovative and radical measures to clean up the distressing picture of lack of civic concern on the part of hospitals and slackness in government implementation of bare minimum of Rules, as waste generation particularly biomedical waste imposes increasing direct and indirect costs on society. The challenge before us, therefore, is to scientifically manage growing quantities of biomedical waste that go beyond past practices. If we want to protect our environment and health of community we must sensitize our selves to this important issue not only in the interest of health care managers but also in the interest of community.

Statutory Requirements, Best Practices and Status of Hazardous Waste Management

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INTRODUCTION

Waste, that can pose a substantial danger, immediately or over a period of time to human, plants, and animals and to environment are classified as hazardous waste. A waste is classified as hazardous, if it exhibits characteristics of ignitability, corrosivity, reactivity and toxicity. Waste is considered ignitable, if the flash point of the waste is less than 60^{o}C. If pH of the waste is less than 2 and greater than or equal to 12.5, it is considered as corrosive. A reactive waste has a tendency to become chemically unstable under normal condition or react violently, when exposed to air or mixed with water or can generate toxic gases. If the waste contains heavy metals like arsenic, barium, cadmium, chromium, lead, mercury, selenium etc., it is considered as toxic. Toxicity of solid waste is determined by testing of leachate from solid waste mixed with an acidified leaching medium for a period of 24 hours.

The management of hazardous waste at all stages of production, handling, storage, transport, processing, treatment and ultimate disposal is a real concern. In India, it was not gained attention until the major industrial accident at the Union Carbide Factory at Bhopal took place in 1984. The accident took place due to leakage of methylisocynate in to the air and its disasters. Consequences on the community, exposed the lacunae on environmental legislations regarding the management of hazardous chemicals/ wastes in India. No agency was made responsible, for the lapse, in the absence of legislations applicable to chemical storage outside the factory building. For rectifying this gap, an umbrella Act, namely the Environmental (Protection) Act, 1986 was come into being and it deals with all spheres of environmental protection activities.

The development of environmental programs in developing countries lags behind that of developed countries by a decade or two. Developed countries, initiated Comprehensive Hazardous Waste Management Program in the late 1970s, and early 1980's. Whereas, in the developing countries it did not began to turn their attention to the environmental programs, until the 1990's.

In India, individual industries are responsible for management of hazardous wastes generated in their industrial units. Companies competing in the global market are aware that ISO 14000 standards may become a non-tariff trade barrier. Many companies have therefore registered, their Environmental Management System (EMS) to ISO 14001 Standards. This has resulted in companies seeking better solution to their waste disposal problems and a greater consciousness to minimize and manage hazardous waste.

The management of hazardous waste at all stages of its production, handling, storage, transport, processing and ultimate disposal, is a concern to community, industry and regulatory authorities. Thus the hazardous wastes require special attention and suitable disposal options in order to prevent water, air and land pollution.

LEGISLATIONS

The Environmental (Protection) Act, 1986 is the most important legislation enacted by the Parliament, intended for preserving and protecting all spheres of environment. It is known as the Umbrella Act for environmental protection. It lays down safeguards for prevention of chemical accidents, taking remedial measures and for laying down procedures and safeguards for hazardous substances. Under the E (P) Act, a number of Rules have been notified by the Ministry of Environment and Forests, Government of India. The following legislations, are having focus mainly on hazardous waste:

i. The Hazardous Waste (Management & Handling) Rules, 1989 (amended in 2000, 2003 & 2008)

ii. The Manufacture, Storage and Import of Hazardous Chemical Rules, 1989

iii. The Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996

iv. Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Micro-organisms/Genetically Engineered Organisms or Cells, 1989

v. The Public Liability Insurance Act, 1991

vi. The National Environment Tribunal Act, 1995

Among these legislations, the Hazardous Waste (Management & Handling) Rules, is primarily intended for ensuring safe handling of hazardous wastes, specifying guidelines for generators, importers and exporters of hazardous wastes. Other legislations are dealing with the storage of chemicals, preparedness to handle chemical accidents, manufacture, usage including import and export of genetically modified hazardous micro- organisms or cells, payment of compensation to victims of chemical accidents and courts for dealing with hazardous chemical accidents. The Hazardous Wastes (Management & Handling) Rules 1989 was further amended in 2000, 2003 and 2008. The primary objective of this Rule is to ensure appropriate collection, reception, treatment, storage and disposal of hazardous wastes listed in Schedule 1, 2, 3 of the amended Rules. From this one can find that, there is a good legal backing at present for effectively dealing with management of hazardous wastes.

There are some international regulations and restrictions which are applicable for Transboundary movement of hazardous wastes. The Basel Convention on 'Control of Transboundary Movement of Hazardous Waste and Disposal', 1989 to which India is a party and it come into being in May 1992. Another one regulation is related to transportation of dangerous goods evolved by UN Expert Committee and it came into force in 2001. India signed the regulation under the Stockholm Convention on Persistent Organic Pollutants (POPs) on 14th May, 2002. The Persistent Organic

Pollutants include pesticides known as the dirty nine (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex and toxaphene), industrial POPs(PCBs and hexachlorobenzene) and unintended by- products (dioxins and furans). It is evident from the above that the Government of India has made significant efforts to put in place the legal and regulatory frame work for controlling pollution from hazardous wastes.

ENFORCEMENT PROGRAMS

Various stakeholders of hazardous waste management as per the HW Rules are government authorities, occupier, operator of a facility, importer, exporter and transporter. The authorities include the Ministry of Environment and Forests, Government of India, State Government, Central and State Pollution Control Boards. Occupier here is a person who has control over the affairs of the facility or premises. Operator is a person who owns or operates a facility for collection, reception, treatment, storage and disposal of hazardous waste. Importer is an occupier or any person who imports hazardous waste. Exporter here is any person under the jurisdiction of the exporting country who exports hazardous wastes. Duties and responsibilities of all stakeholders are specified in the HW Rules. State pollution Control Boards are responsible for inventorisation of hazardous wastes, grant and renewal of authorization, monitoring of provisions and conditions specified in the authorization issued, examination of application for import submitted by the importer for recommending it to the Central Government, implementation of programs for prevention and reduction of hazardous wastes and to take punitive actions against violations.

In the amended Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008 contains 8 schedules specifying various hazardous waste categories and list of authorities and their duties. The Schedules specified under the HW Rules is given in Table1.

Table 1
Schedule Specified under the Hazardous Waste Rules, 2008

Sl.No	Schedule	Category
1	Schedule – I	List of processes generating hazardous wastes(36 processes)
2	Schedule – II	List of waste constituents with concentration limits
3	Schedule – III	List of wastes applicable for imports and exports (Part A, B, & C)
4	Schedule – IV	List of hazardous wastes requiring registration for recycling/reprocessing
5	Schedule – V	Specifications of used oil suitable for reprocessing/recycling (Part A) and fuel derived from waste oil (Part B)
6	Schedule – VI	Hazardous wastes prohibited for import & export
7	Schedule – VII	List of authorities and corresponding duties

There are 36 processes which generate hazardous wastes listed in Schedule I. and five broad categories of wastes classified based on their toxic concentration levels are given under Schedule II. From these two schedules, major share of hazardous wastes can be identified. Classification of hazardous waste, based on toxic concentration levels of hazardous chemicals coming under schedule 2 of the HW Rules is summarized and given as Table 2.

Table 2
Waste Categories based on Toxic Concentration Levels in Schedule 2 of HW Rules

Risk class	Number of categories of waste type	Upper limit of waste Concentration to be considered as hazardous waste
A	20	≥ 50 mg/kg
B	30	≥ 5000 mg/kg
C	17	≥ 20000 mg/kg
D	9	≥ 50000 mg/kg
E	E1 - E5	No limit

QUANTITY OF WASTE

Growth of industries has resulted in extensive use of chemicals and release of huge quantities of hazardous wastes into the environment in the form of solids, liquid and gases. In India, about 44 lakh TPA of hazardous wastes is generated (CPCB, 2006). State wise status of hazardous waste generation, quantities of each type waste and possible disposal options are given in Table 3. The information on Hazardous Waste as reported by the SPCBs/PCCs and subsequently submitted by the Supreme Court Monitoring Committee to the Hon'ble Supreme Court on November 29, 2006 is given in the following Table 3.

Table 3
State-wise Inventory of Hazardous Waste Generating Units with Quantity

Sl. No	State	Number of district	Number of Units generating hazardous waste		Quantity of waste generated according to waste type (TPA)			
			Authorized	**Total**	**Recycled**	**Incinerable**	**Disposal**	**Total**
1	Andhra Pradesh	23	478	501	61820	5425	43853	111098
2	Assam	23	18	18	-	-	166008	166008
3	Bihar	55	31	42	2151	75	24351	26578
4	Chandigarh	1	37	47	-	-	305	305
5	Delhi	9	-	403	-	-	-	1000
6	Goa	2	25	25	873	2000	5869	8742
7	Gujarat	24	2984	2984	235840	34790	159400	430030
8	Hariyana	17	42	309	-	-	31046	32559
9	Himachal Pradesh	12	71	116	-	63	2096	2159
10	Karnataka	27	413	454	47330	3328	52585	103243
11	Kerala	14	65	133	93912	272	60538	154722
12	Maharashtra	33	3953	3953	847436	5012	1155398	2007846
13	Madhya Pradesh	61	183	183	89593	1309	107767	198669
14	Orissa	30	78	163	2841	-	338303	341144
15	J&K	14	-	57	-	-	-	1221
16	Pondichery	1	15	15	8730	120	43	8893
17	Punjab	17	619	700	9348	1128	12233	22745
18	Rajastan	32	90	344	52578	6747	95000	140610
19	Tamil nadu	29	1088	1100	193507	11564	196002	401073
20	Uttar pradesh	83	768	1036	36819	61395	47572	145786
21	West Bengal	17	234	440	45233	50894	33699	129826
	Total	**524**	**11138**	**13011**	**-**	**-**	**-**	**4434257**

(after, CPCB, 2006)

Fig 1 shows the State wise status of hazardous waste generation

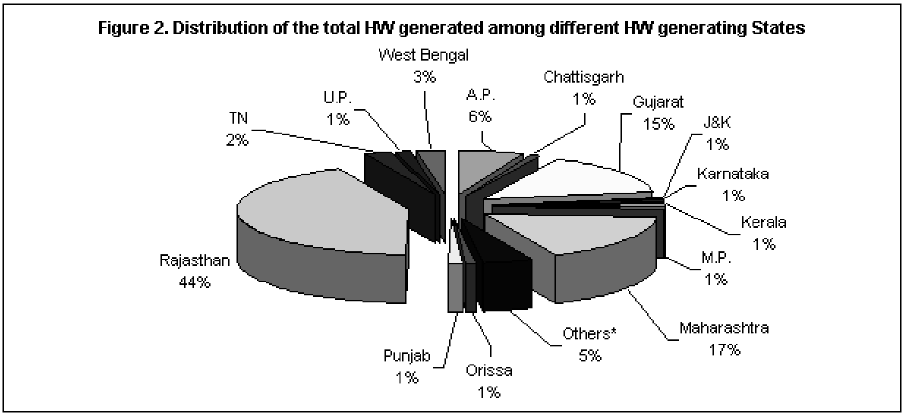

Fig 1
Distribution of the total HW gerenated among different HW generating states

HAZARDOUS WASTE MANGEMENT

Important elements of hazardous waste management are generation and onsite storage, transportation, processing, recovery of resources and final disposal. Care should be taken for on-site storage, moving hazardous waste from point of generation to treatment and disposal facility, tracking of movement of hazardous waste, treatment for recovery of resources and final disposal. It should ensure that it is done in accordance with the guidelines given by CPCB and in accordance with the Hazardous Waste Rules.

On-site Storage

Special care and precaution should be taken for storing of hazardous waste. These wastes often lie unidentified along with the non-hazardous waste .Proper containment with rain protection is to be done for reducing leachate formation and for avoiding pollution of surface and ground water. If the waste is in slurry form it should be stored in lined ponds or tanks. Containers or liner used must be compatible with the waste to be stored. Certain waste materials such as acids and caustics require plastic drums with liner, and or drums made of stainless steel. Containers holding hazardous waste should always be closed during storage, is the most important aspect.

Transportation of Hazardous Waste

HW disposal facilities are functioning in major industries in their premises. Whereas, for others, they have to transport the waste to disposal facility situated away from point of generation. Wastes are usually enclosed in containers and transport in vehicles like trucks, tanker, tractor and trailer etc. to the disposal sites. The transporter who transports hazardous waste from source of generation to the off-site facility should ensure that proper labeling and marking on the container is done before loading on the vehicle. The driver should also be provided with necessary equipments like fire extinguishers, gas masks, safety goggles, first aid kit etc. He should be trained to handle the equipments and capable of tackling emergency situations like leaks and accidents. A Transport Emergency Card (TREM Card) carrying instructions to be followed in the case of spillage or accidents should be supplied to the driver.

A manifest system should be adopted in order to keep the track with the movement of hazardous wastes from source of generation to the disposal site and to entrust responsibilities to the concerned persons. The information include the details of waste to be transported like nature, quantity, composition, mode of transportation and special precautionary measures to be taken up .The manifest should be duly signed by the generator, transporter, and the owner of the disposal site. An off-hand emergency plan should be prepared by the owner for tracking emergency situations like spillage and accidents. A manifest system to be followed specified in the Hazardous Waste Rules is given in Table 4.

Table 4
Manifest system to be followed as specified in the Hazardous Waste Rules

Sl No	Copy of Manifest	Colour of Manifest	Receiving Agent
1	Copy - 1	White	Occupier to PCB
2	Copy - 2	Yellow	Transporter to Occupier as receipt of waste
3	Copy -3	Pink	Transporter to Operator as proof of waste receipt
4	Copy - 4	Orange	Operator to Transporter
5	Copy - 5	Green	Operator to PCB
6	Copy - 6	Blue	Operator to occupier

Spillages and Accidents

The transporter is responsible for taking appropriate steps to clean up the waste spillages which may occur during transport. In the case of any accidents or spillages of hazardous waste during transit, the clean up measures taken up by the transporter should be reported immediately to the nearest Police Station. The transporter should also report to the regulatory authorities about the event.

Processing and disposal of Hazardous waste

Processing and disposal of hazardous waste is done for recovering useful materials from the waste. Hazardous waste can be finally disposed of in secured Landfills prepared in accordance with the HW Rules. Selection of a particular technology for treatment of hazardous waste depends on characteristics, quantity, techno-economic consideration and environmental requirements. The commonly adopted methods of treatment of hazardous waste are physical, chemical, thermal and in some cases biological. But the widely adopted methods are physical, chemical and thermal technologies of treatments. Prior to disposal, hazardous wastes are treated for recovering resources and useful materials as it enable to reduce its hazardous nature and make it convenient for disposal. The commonly adopted physical and chemical treatment technologies are dewatering, chemical precipitation, chemical oxidation, reduction, solidification and stabilization, evaporation and ozonation. Incineration and Pyrolysis are the thermal treatment technologies generally adopted for hazardous waste.

Disposal of Hazardous Waste

Secured landfill having two composite liner systems is the commonly adopted disposal system for hazardous wastes. Treatment, Storage and Disposal Facility (TSDF) is the integrated facility used for final disposal of hazardous waste. The Central Pollution Control Board (CPCB) has brought out specific guidelines for establishment, operation and post closure of TSDF. The operator and user of the facility have to follow the guidelines and to seek approval from the State Pollution Control Board. State wise distribution of TSDF in India is given in Table 5.

Table 5
Status on Sites Identified, Notified, TSDFs under Construction and TSDFs in Operation

S. No.	Name of the State/UT	Number of sites identified	Number of sites notified	Number of TSDF under construction	Number of Common TSDFs in operation
1.	Andhra Pradesh	02	02	01	01
2.	Arunachal Pradesh	Nil	Nil	Nil	Nil
3.	Assam	Nil	Nil	Nil	Nil
4.	Bihar	01	01	Nil	Nil
5.	Chhattisgarh	02	-	-	-
6.	Delhi	03	-	-	-
7.	Goa	02	-	-	-
8.	Gujarat	-	-	-	07
9.	Haryana	01	01	-	-
10.	Himachal Pradesh	01	-	-	-
11.	Jammu & Kashmir	Nil	Nil	Nil	Nil
12.	Jharkhand	Nil	Nil	Nil	Nil
13.	Karnataka	02	01	01	Nil
14.	Kerala	01	01	01	-
15.	Madhya Pradesh	09	03	01	-
16.	Maharashtra	06	04	02	02
17.	Manipur	Nil	Nil	Nil	Nil
18.	Meghalaya	01	-	-	-
19.	Mizoram	Nil	Nil	Nil	Nil
20	Nagaland	Nil	Nil	Nil	Nil
21.	Orissa	01	01	-	-
22.	Punjab	01	01	01	-
23.	Rajasthan	08	01	01	-
24 .	Sikkim	Nil	Nil	Nil	Nil
25.	Tamil Nadu	08	03	-	-
26.	Tripura	Nil	Nil	Nil	Nil
27.	Uttar Pradesh	07	02	03	-
28.	Uttaranchal	02	Nil	Nil	Nil
29.	West Bengal	01	01	01	-
30.	Andaman & Nicobar Islands	Nil	Nil	Nil	Nil
31.	Chandigarh	Nil	Nil	Nil	Nil
32.	Daman & Diu,	01	Nil	Nil	Nil
33.	Lakshadweep	Nil	Nil	Nil	Nil
34.	Pondicherry	01	-	-	-
Total		**61**	**22**	**12**	**10**

(After CPCB 2009)

TSDF IN KERALA

In Kerala, large scale industrial units are having their own hazardous waste treatment and disposal facility. Secured Landfills (SLF) are constructed and operated by them for the purpose. They have to comply with the specification, standards, operation and maintenance protocol as specified in the Hazardous Waste (Management and Handling) Rules and the conditions stipulated by the State Pollution Control Board in the Authorization issued and guidelines issued by the Central Pollution Control Board.

In Kerala, one TSDF was established in 2006 in a 50 acre land spared by the FACT, Cochin Division at Ambalamedu in Ernakulam district. The Kerala Enviro Infrastructure Limited (KEIL) is a joint venture company of the Kerala State Industrial Development Corporation (KSIDC) and participating industries, established with a capital investment of about Rs. 24 crores. The Central and State Governments have issued a subsidy amount of Rs. 2 crores each for establishing the facility. It has a design period or active life period of about 20 years. It is having a landfill capacity of 50,000 TPA and treatment and stabilization capacity of 25,000 TPA.

CONCLUSION

Quantity of hazardous waste generation is increasing year after year; hence adequate importance should be given by all stake holders for the safe management of hazardous waste. Comparing with quantity of hazardous waste generated in the national level, very negligible quantity (about 1 %) of hazardous waste is generated in Kerala. However, utmost care is to be taken in Kerala for management of hazardous waste, considering its special characteristics such as land constraints, possibility of generation of more leachate due to prolonged period of rainy season, possibilities on surface water contamination due to presence of more number of surface water bodies and mixed land use for industries and residential purpose. Sludge generated from various industrial wastewater treatment plants, if it is coming under the hazardous waste category, it should be handled carefully, otherwise, once separated sludge from wastewater treatment plant may again got mixed up with run off water. Therefore the TSDF facility available at Ernakulam should be utilized by all hazardous waste generators, for ensuring eco-friendly hazardous waste management in Kerala.

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Management of Slaughter Houses and Abattoirs

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INTRODUCTION

The Indian Meat sector is endowed with enormous potential for development both in domestic and international arenas. Over 65% of the Indian population is non-vegetarians providing one of the biggest domestic markets in the world for meat and meat products. During the past five years, there had been an unprecedented growth of 21% in meat production, proving that it is the fastest growing segment in the livestock sector in India. Over 60 countries are now importing meat from India and the demand is steadily growing. We have several advantages for the meat sector, with the largest population of livestock in the world. We rank first in the case of cattle and buffaloes, second in the case of goats, third in the case of sheep and sixth in the case of poultry. The Indian meat is lean with less than 4% fat in our beef and buffalo beef. Our meat is chemically clean since we do not use growth promoters, anabolics, and antibiotics in the feed for livestock. It is also safe from radio-active substances as it is not irradiated. Generally, the livestock are fed with fodder and as such the nutritional quality is better. The international price structure is also favorable for the Indian meat sector.

In spite of the several advantages, we are sitting on a volcano as far as the quality and hygienic standards are concerned. Meat production in India has never attracted the attention of food quality parameters in the past. In fact, it is the most neglected sector. All over the world, meat is produced in modern scientific abattoirs under strict hygienic standards with Veterinary ante-mortem and post-mortem inspection and certification. Our infrastructure facilities are very poor with traditional, unscientific and obsolete practices. Slaughterhouses have become the most contaminated and polluting environment. Byproducts are either underutilized or wasted causing a huge loss to the revenue of the farmer.

Livestock production including meat animal rearing is a livelihood activity for majority of the rural population in India. Large number of male calves of cattle and buffaloes are subjected to early mortality for want of care, nutrition and good management. Low carcass weight due to slaughter at early age or at lower live weights is also contributing to poor meat yield. Emphasis on animal production is the best method for insulating the farmers against revenue loss on account of agricultural farming. A pragmatic approach would be to help the farmers to look after the male calves of cattle and buffaloes and raise them efficiently to proper slaughter weight. Such animals should be procured directly by pocessing group avoiding the middle men so that the farmers get better benefits. A backward and forward integration in animal production, processing and marketing is necessary.

Kerala, with more than 95% of its population being meat eaters, is the most ideal state in India for the development of the meat sector. Though, our animal resources are meager, we have plentiful supply of unproductive and male population of livestock of the neighboring states for our meat production. With highest literacy rate, absence of taboos and sentiments, highest per capita meat consumption, nutritional and hygienic awareness, good roads, sea port and air ports, the state is endowed with best opportunities for development of its meat sector. No efforts have been done in the past for reorganizing and modernizing the sector to face the challenges and opportunities. It is high time that, we wake up and develop the meat sector which would provide tens of thousands of employment both direct and indirect, development of several meat based industries, better returns to the farmers, better utilization of byproducts, safe pollution free environment and protection and promotion of human health. With increasing population and decreasing landholdings, it is imperative to increase the productivity and efficiency of the meat sector by adopting modern technology, provision of improved germplasm, scientific modern practices in production and processing and to adhere to food safety principles. A comprehensive plan of action is necessary to address the problems and to utilize the opportunities in this sector.

ISSUES AND PRIORITIES

- Large majority of the animals used for meat production are brought from neighboring states. As such the monitory benefit goes to the farmers of other states and the middle men who are animal traders.
- Most of these animals are unhealthy, diseased or aged. This adversely affect the quality of the meat
- Several diseases are spread to our animals endangering the livestock population and the health of the consumers.
- Infrastructural facilities in existing slaughterhouses are extremely inadequate and obsolete.
- Transportation of animals on hoof or trucks causes traffic jams, injuries and bruises.
- Absence of veterinary ante and post mortem meat inspection results in release of diseased, contaminated, adulterated, poor quality meat to the consumers. This endangers the health of the consumers.
- Underutilization or wastage of slaughterhouse byproducts resulting in revenue loss and poor returns to the farmers.
- Absence of effluent treatment and solid waste treatment results in severe pollution to the environment.
- Lower carcass weight of goats and sheep, causing lower productivity.

- Unscientific, traditional slaughter procedures results in unhygienic practices and poor quality and productivity.
- While the demand for meat and products is great, the production and supply is less.
- Employment generation potential in this sector is not exploited.
- Industrial development is at rock bottom level.
- No efforts taken for meat animal production, supply of fodder, and feed.
- There is no quality control in this sector.
- No agency to help entrepreneurs and to guide them in the right direction.
- No government support is provided for establishment of meat based industries.
- Dearth of supply of piglets and other improved varieties of small animals for the farmers.
- No efforts done in the past for value addition in meat sector.

The priority for solving the problems faced by the meat sector in Kerala and to improve the living conditions of the farmers and meat processors is to establish modern abattoirs and meat processing plants with a Farm to Fork approach. It is also essential to scientifically reorganize the sector for value addition, byproducts utilization; solid and liquid waste treatments with Food Safety Approach (HACCP).

FACILITIES PROPOSED FOR THE MODERN MULTI-SPECIES ABATTOIR AND MEAT PROCESSING PLANT

Capacity of the Plants can be as follows:

- 100 cattle/ buffalo in one shift. (300 large animals per day)
- 50 Pigs per shift.
- 200 goats/sheep per shift.
- 1000 birds per hour.
- 100 Rabbits per shift.

FACILITIES REQUIRED FOR THE ABATTOIR COMPLEX

Large Animal Slaughter Hall

- Unloading platform with ramp
- Animal Lairage
- Weigh bridge
- Stunning box/ Halal restrainer with tilting facility.
- Captive bolt stunner
- Bleeding rail with electric hoist, blood collection facility,
- Electric conveyor to the dressing rail.
- Overhead track system with beef roller trolleys, differential platforms, flaying facility(optional hide pullers), carcass splitters, evisceration facility, working platforms, conveyor switches/change over, pressure washers, meat inspection

platforms, knife set, knife rack, knife sterilizers, meat trolleys, offal barrows, meat trucks, chutes, offal conveyors.

Sheep and Goat Slaughter Hall

- Stunning trap with electric stunners, bleeding rail, blood collection facility, conveyors, overhead track system with roller trolleys, switches, working platforms, splitters, knife set, knife sterilizers, pressure washers, meat trucks, offal barrows etc.

Pig Slaughter Hall

- Pig lairage, ramp, stunning trap with electric stunner, electric conveyor. scalding tank, hoist, de-hairing machine, conveyor to the dressing track, singing blow lamps, scrapers, pressure washers, knife set, knife rack, knife sterilizers, carcass splitters, evisceration facility, meat inspection platform,

Poultry Dressing Hall

- Fully automatic dressing system with automatic moving racks, stunner, bleeding tray, scalding tank, de-feathering machine, dressing line, viscera puller, pressure washers, screw chiller, portioning facility.

Rabbit Slaughter Hall

- Stunner, restrainer, bleeding facility, blood collection facility, pelt removal facility, dressing track, evisceration facility, pressure washer, meat trucks, offal trolleys, knife set, knife sterilizers, meat inspection facility, offal inspection facility.

Common Facilities: Deboning halls, Meat Processing halls, Store, Packing halls,

Workers: Change rooms, toilets, lockers, foot operated hand wash facility, hand driers, protective gadgets, and canteen.

Value addition processing equipments: Meat and bone cutters, meat mincer, bowl Chopper, Meat Tenderiser, Hydraulic sausage filler, Meat slicer, Meat Mixer, Cutlet molding machine, vacuum packing machine, sealers, Store room, packing rooms. retort processing machinery.

General purpose machines: Boilers, steam line, air compressor, air line, Generators, change over switches, control panels, plant room, Water treatment plant, Water source,

Refrigeration facilities: Chillers, air-conditioned de-boning halls, AC Meat processing hall, tunnel freezer, plate freezer, Freezer store,

R&D Laboratory with all facilities

Solid and Liquid waste Treatment: Effluent Treatment Plant, Bio-gas plant,

Dry Rendering Plant: with pre-breaker, conveyors, dry rendering cooker, percolating tank, conveyor, Decanter/Centrifuge, belt conveyor, milling plant & bagging facility.

Others: Packing hall, store room, administrative building, Lairages, processing hall, engineering workshop, vehicle service station, Internal roads, compound wall, Fire fighting equipments, training Centre with all facilities, land development, external electrification, Internal fly-proofing, special epoxy coated flooring(joint free), and all civil works.

The estimated expenditure for a Model Slaughter House is given in Table 1. Table 2 shows different types of Slaughter Houses and treatment.

Table 1

Estimated Expenditure for Model Slaughter House

Components	Rs. In Lakhs
Land	100
Land development	20
Civil Works	150
Overhead track system (Cattle, goats, pigs and rabbit)	100
Automated line for poultry	60
Machinery & Equipment	200
Dry Rendering Plant	125
Effluent Treatment Plant	30
Biogas plant	8
Electricals & Generator	100
Refrigeration Plant & accessories	100
Water Treatment Plant	15
Refrigerated Van	20
Animal Carrier	10
Laboratory	15
Unforseen	25
TOTAL	**1078**

Table 2

Different types of Slaughter house and treatment

Sl.No	Category of Slaughter House	Essential Treatment
1	Large	Self cleaning type screening, anaerobic treatment, aerobic treatment and filter press for dewatering of sludge.
2	Medium	Two stage screening (bar type), anaerobic pond and polishing pond.
3	Small	Two stage screening (bar type), anaerobic pond and polishing pond.

LIQUID WASTE/EFFLUENT TREATMENT FACILITIES

During the above mentioned operations the waste generated is of liquid and solid nature. The liquid waste should be washed away by safe potable and constant supply of fresh water at adequate pressure throughout the premises of slaughtering. The wastewater from slaughter house is heavy in pollution and, therefore, it should not be allowed to mix with the municipal drain system without pre-treatment meeting sewage standards.

The wastewater treatment system should essentially comprise of:

i. Self cleaning type screening or two stage screening (Bar type);

ii. Oil and grease trap;

iii. Anaerobic treatment;

iv. Aerobic treatment; and

v. Filter press for dewatering of the sludge

Screening

Screening is a pre-treatment that consists of separation of floating and suspended organic and inorganic materials by physical process. It is used as the first step in all treatment works. A screen is a device with openings generally of uniform size for removing bigger suspended or floating matter in the sewage. Generally they are circular or rectangular in shape. Mainly three types - coarse, medium or fine screens are used.

Bar screen is composed of vertical or inclined spaced at equal intervals across a channel through which sewage flows. In the wastewater treatment of slaughter house bar type two stage screening are used (Coarse and medium screen).

Coarse screens have larger openings of 75 to 150 mm are often termed as coarse rack or trash rack. Their principal function is to prevent the entry of floating matter like logs, rags, carcasses etc. that is brought in by the flowing sewage. Medium bar screens have clear openings of 20 to 50 mm. Bars are usually 10mm thick.

Oil and Grease Trap

It should be placed before anaerobic pond. If not provided oil and grease forms odorous scums on the surface of the main treatment system. It blocks the main pipe line and also inhibits biological growth. It is rectangular tank with a difference of 0.3 m from inlet to outlet, so that the floating oil and grease will not come to the following treatment module.

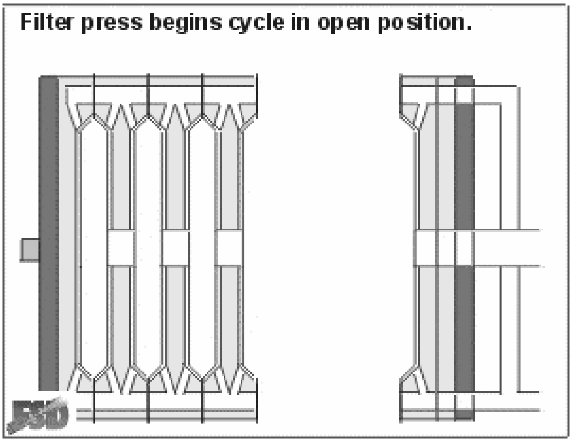
Anaerobic pond

Anaerobic ponds are used for digestion of sludge mainly municipal sludge. Depending on temperature and waste characteristics, BOD load of 400- 3000kg/ha.day and 5-50 day retention period would result in 50 - 85 percentage BOD reduction. Such ponds are constructed with a depth of 2.5 - 5m to conserve heat and minimize land area requirement. Usually they have odour problem.

Filter Press -Dewatering Operation

A filter press is a liquid-solid separation device used to reduce the volume and weight of a slurry waste or process stream by separating liquid filtrate and solid filter cake. This process is often referred to as dewatering.

The operation of a filter press is a batch process. Depending on the particular application, the filter press may be used to recover the solid particulate, the liquid stream, or both.



The filter press accomplishes dewatering within a series of chambers into which process slurry is pumped. Filtered liquid (filtrate) passes through filter cloths and exits the press leaving behind filtered solids (filter cake). The filter press is then opened and the filter cake is discharged by gravity as each plate is shifted.

Duckweed Pond Technology

It is an earthen basin, preferably lined, where duckweed plant grows and covers the entire water surface. This system can be used in secondary or tertiary treatment. It requires nitrogen, phosphorous and potassium for growth. A uniform cover of duckweed cuts off penetration of sunlight into the water thereby eliminating the growth of algae and aquatic plants which could have consumed the nutrients. The excess duckweed biomass should be harvested and the fresh one can be introduced into separate fish pond to grow fish.

The above given information is with regard to a modern multi-species abattoir with meat processing facilities. However, in a State like Kerala. we have more than 900 slaughter facilities covering almost all the Panchayats, Municipalities and Corporations. All the above mentioned slaughter facilities are Service Type slaughter houses and they are owned by Local Self Governments. Many of them are just Slaughter Slabs having only primitive facilities for slaughter of animals. Majority of such slaughter slabs do not posses any facilities for hygienic slaughter or for solid and liquid waste treatment. As such, the facilities pose a threat to the health of the consumers and to the environment. There are very few slaughter houses owned by the Local Self Government, which have so called modern facilities like lairages, slaughter facilities like overhead track system and effluent treatment plant. None of the above mentioned slaughter houses have refrigeration facilities or meat processing facilities. Efforts are being taken to modernize the slaughter houses in Kerala but a proper perspective is yet to be evolved in this regard.

A second type of slaughter facility is the slaughter house with lairage, slaughter facilities, overhead dressing rails, worker's platforms, carcass cleaning facility, meat inspection facility and of course, slaughter house waste management facilities. Such slaughter houses could also be managed by the Local Self Governments. Refrigeration facilities are optional in this case.

Abattoirs are integrated facility for hygienic slaughter, processing, refrigeration, meat processing, deboning, packing and freezing. There shall be refrigerated trucks to transport the products to the desired markets. Such facilities are either owned by private entrepreneurs or owned by private-public participation. In all the above establishments, it is essential to provide facilities for hygienic slaughter of animals and processing of meat with facilities for ensuring safety and certification of meat(Veterinary inspection of meat). Solid and liquid waste treatment are also mandatory. It would be ideal to provide trained man-power for slaughter and dressing and for processing of meat. HACCP principles have to be implemented effectively in order to ensure safety of the products. Wherever possible, resource recovery and utilization are recommended. In case, treatment of slaughter house by-products are not possible, it is essential to remove/sell such products on a daily basis and under no circumstances, such by-products should be stored without treatment.

Utilisation of Livestock/Abattoir byproducts

The dynamic scope of by-products utilization from abattoirs/livestock and its multifarious benefits are generally not realized by industries, governmental agencies, farmers and the public. A major part of such byproducts are considered as waste which, cause environmental pollution, and it's potential to enhance the financial viability of such projects are neglected. By-products from livestock should therefore be considered as wealth. The scope and potential of by-products utilization comprises of newer industries, employment generation, increased revenue generation, better returns to the farmer and environmental protection and safety. The yield of byproducts from cattle and buffaloes range from 65 - 75% of live weight compared to 50 to 60% of live weight in other animals. Yield of by-products from poultry ranges from 30 to 40% depending on the type of dressing. The value of unprocessed raw byproducts ranges from 10 to 20 % of the total value of the animal while the revenue returns from processed by-products would be equal to the value of meat derived from the animal. It is unfortunate that such a valuable wealth is either wasted or under-utilised in our country. While considering the various types of byproducts utilization, we have to be realistic and be aware that there are several inherent handicaps in the collection and utilization of byproducts from slaughter houses. Establishing industrial units based on by-products generally requires huge investments. As such, it is essential to evaluate the availability of raw materials and compare the cost involved before jumping into new projects. It may be worth to establish bio-gas plants in small slaughter houses and plan to utilize blood by drying it under sun light or mix the same with bran, cook it and dry for utilizing it as feed for poultry or pigs. It would be ideal to know more about the various by-products and its end products (Table 3).

Table 3

Livestock/Abattoir By-Products and End Products

By-product	End Product
Blood	Pharmaceutical products, leather finishing agent, plywood adhesive, feed, fertilizer
Bone Gelatine	Photographic, pharmaceutical, explosives, printing, food
Tallow	Soap, cosmetics, food, feed
Bone ash	Ceramics
Glue	Adhesives
Hide/Skin	Leather, Collagen: Cosmetics, Glue, Gelatin.
Intestine	Casings: food, surgical sutures, musical strings, sports guts, Prosthetic materials-collagen sheets, burn dressing, Heparin, feed.
Horn & Hoof	Horn meal, manure, Neats foot oil, Fire extinguishers, protein hydrolysate
Hair/Wool	Carpets, felt, upholstery, amino acid, brushes
Stomach	Rennin for dairy industry
Lungs	Heparin, lung meal
Brain	Cholesterol
Bile	Bile paste in detergents, cholic acid, deoxy cholic acid, chenedoxy cholic acid used in pharmaceuticals
Fat	Fatty acids, Tallow, pharmaceuticals, feed, food, cosmetics,greese, lubricants, soaps
Pancreas	Trypsin, Insulin
Liver	Liver extract, liver meal
Adrenal	Adrenaline
Pituitary	Pituitary hormones
Testes	Sex hormones
Thymus	Deoxyribonucleic acid
Vitreous humour	Hyaluronic acid
Intestinal content & Stomach Contents	Bio-gas production, manure, Power generation.

In medium to large slaughter houses, it is essential to have a Rendering Plant which, would serve effectively to utilize the byproducts like bones, feathers, stomach, internal organs, fat, horns, hooves, intestine etc. The capacity of the plant should be selected based on the availability of raw materials. The machinery selection depends on the type of rendering preferred. Four different systems of rendering are in practice.

- Batch Wet Rendering
- Dry Batch Rendering
- Dry Continuous Rendering
- Continuous Low Temperature Rendering

The Wet Rendering System is being slowly replaced by the Dry Rendering Systems because of the international requirements on sterilization of the end product. The Wet Rendering System is preferred for production of edible fats since it retains the colour of rendered fat. In this process, the cooker is filled with preground raw materials and then steam is injected into the cooker at 3 bar pressure, and cooking process continued for 4 to 5 hours. Free flowing fat is drained and the cracklings are pressed to remove the fat. Wet Rendering can be done in a continuous process also. In this case screw presses are used to extract the fat from the cracklings.

The Continuous Low Temperature System is similar to the Batch Wet Rendering process except that it is continuous. The raw materials are ground and it is cooked in preheater at 90 oC for about 30 minutes. Liquid tallow is decanted and the cooked materials are sent to a screw press, then the solids are dried and ground. Centrifugal method is used for separation of fat from the solids. The evaporator works at low pressure, at 100 oC.

Dry Batch Rendering System is the one that is generally preferred in medium to large slaughter houses. The machinery comprises of (1) a Pre-breaker (2) Screw conveyor or a Traveling Electric Hoist (3)Steam Jacketed Cooker (4) Percolating Tank (5) Fat Balance Tank and a Fat Pump (6) Screw Conveyor to Screw Press or (7) Centrifuge or Screw Press (8) Conveyor to the Milling Unit (9) Milling Unit and (10) Packing Unit.

Dry Rendering of slaughter house byproducts comprises basically of cooking, moisture reduction, separation of fat, and protein meal. Animals and raw materials intended for rendering should be inspected by a Veterinarian to determine the type of risk involved in processing the material. If animals condemned are involved, it has to be flayed before size reduction. Carcasses and other byproducts are fed into a pre-breaker for size reduction of the materials. Care should be taken to remove metal objects in the raw materials. The Dry Rendering Process comprises of charging the materials into the cooker, air release from the cooker, closing of the valves, cooking under dry heat, hydrolysis/sterilization, moisture reduction , and further processing to remove fat and dry matter. Care should be taken to permit only the permitted quantities of raw materials into the cooker. In a 1500 litre capacity cooker, the quantity of raw materials permitted comprises of any one of the following item:

1.	Mixed byproducts of slaughter house	: 750 - 900 Kg
2.	Blood alone	: 500 - 650 Kg
3.	Feather & water	: 600 - 650 Kg
4.	Mixed poultry offal	: 650 - 750 Kg

While charging the bones, take care to add soft tissue at least 40% of the capacity.

Initially the blow valve should be fully opened during preheating and charging. During the first part of heating, the air valves are kept opened to release the non-condensable gases which may be obnoxious. After about 45 to 60 minutes the air relief/vapour valves are closed completely in the case of slaughter house byproducts including bones. The valves can be closed after about 20 minutes in the case of feathers or mixed poultry waste. After closing the valves, the temperature and the pressure will rise slowly. The pressure required for sterilization is only 2 bar and if the pressure rises above that the blow off valve may be opened slowly to reduce the pressure. The sterilization time required in the case of large animal by-product is 20 minutes while that for blood and poultry raw materials will be 30 minutes. After sterilization the pressure has to be slowly reduced to atmospheric pressure in about 15 to 20 minutes. Drying time varies depending on the type of materials. In modern cookers, the moisture content of the end product can be set automatically. Before discharging the materials from the cooker, the steam inlet valve has to be closed. Then stop the agitator and release the product into the percolator. Melted fat will get drained into the fat balance tank, the bottom of which is steam heated. The greaves are conveyed to the centrifuge for further removal of fat. The greaves then are conveyed to the milling plant and the end product is packed according to the requirement. The continuous dry rendering system is adopted when the raw materials to be treated is huge quantity. However, it works almost like extruders at high temperature. Steam pressure cannot be applied in this system and as such sterilization of the product is difficult. Gelatine is prepared from Bone processing. Approximately 50 Kg tallow could be extracted from one tonne of bones. Edible, pharmaceutical and photographic gelatine are made from Ossein and Dicalcium phosphate is a byproduct in Ossein manufacture.

A major handicap in production of hygienic meat is the dearth of trained man-power. It is ideal to establish Training Institutes attached to modern abattoirs in order to develop trained manpower in various specialized field of activities. Such Institutes could provide training for butchers, skilled workers, supervisors, managers and Veterinary Officers . A research laboratory would also be necessary to ensure the quality of all the products manufactured in the abattoir. All the products should be ideally packed, labeled, and stored at the appropriate temperature regimen. Regular training should be imparted to all the workers and supervisory staff to make them aware of the HACCP principles. Management's support in ensuring commitment quality and safety of all the products manufactured in their establishment is essential.

Strategies and Techniques for Reuse of Grey water from Residential and Service Sector Complexes

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INTRODUCTION

One of the targets of the Millennium Development Goals is to halve the proportion of people without sustainable access to safe drinking water and sanitation by 2015. Water scarcity today afflicts 250 million people in 26 countries, and over the next 20 years, the world's population will increase from six billion to an estimated 7.2 billion, while the average supply of water per person is expected to drop by one-third (Saravanan et al., 2002). By 2015, 88% of the one billion-person growth in the global population will occur in cities; the vast majority of this growth will occur in developing countries (UNDP 1998). An increase in urban water supply ensures an increased wastewater generation, as the depleted fraction of domestic and residential water use is only in the order of 15 to 25% (Scott et al. 2004). Addressing water scarcity requires a multidisciplinary approach for managing the water resources which will maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. The lessons learned from the social, economic and environmental impacts of earlier water resources development and inevitable prospects of water scarcity call for a paradigm shift in the way we approach water resources management. The well grounded rationales for water recycling and reuse are the principles of sustainability, environmental ethics and public participation

In the last two decades, in India, although there has been significant increase in the coverage of drinking water as compared to other regions in the world, regional disparities still exist. India's urban water sector domain is characterised by increasing competing uses, allocation issues, declining sources and inconsistent supplies, service delivery gaps, insufficient models for sustainable urban water management, multiple institutional players, low sensitivity levels towards environmental safeguards, etc. With the cities promoting water-intensive developments, the need today is to treat urban water management on a wider canvas in contrast to conventional approaches. Urban areas in India generated about 5 billion liters a day (bld) of wastewater in 1947 which increased to about 30 bld in 1997 (Winrock International India 2007). According to the Central Pollution Control Board (CPCB), 16 bld of wastewater is generated from Class-1 cities (population >100,000), and 1.6 bld from Class-2 cities (population 50,000-100,000). Of the 45,000 km length of Indian rivers, 6,000 km have a bio-oxygen demand above 3 mg/l, making the water unfit for drinking (CPCB 1998).

The commercial and residential structures that compose most urban development use in excess of 80% of their potable flow for non-potable, or "non-drinking" quality consumption, resulting in a costly, inefficient use of a limited resource. In select commercial applications, 75% or more of the domestic supply serves toiletry fixtures alone. Conservatively, 70% of the current urban water demand could be supplemented by reclaimed or reuse water technology. Urban reuse of wastewater has proven the most effective way to reduce water resource consumption and the environmental dangers posed by the disposal of large quantities of insufficiently treated wastewater. Water reuse is mainly for non-potable such as (i) agricultural (ii) urban (iii) industrial or (iv) indirect potable reuse as infiltrated aquifer recharge.

An estimated 80% of wastewater generated by developing countries, especially China and India, is used for irrigation (Winrock International India 2007). Hussain et al. (2001) reports that at least 20 million hectares (ha) in 50 countries are irrigated with raw or partially treated wastewater. Strauss and Blumenthal (1990) estimated that 73,000 ha were irrigated with wastewater in India. As per the estimate of Buechler and Mekala (2003) even just along the Musi River, that runs through Hyderabad city in Andhra Pradesh State, and the canals and tanks off this river, approximately 40,000 ha of land are irrigated with urban and industrial wastewater diluted with fresh river water especially during the monsoon season. More than 80% (only 4,000 MLD of 17,600 MLD wastewater generated in India is treated) of wastewater generated is discharged into natural water bodies without any treatment due to lack of infrastructure and resources for treatment (Winrock International India 2007). The Water Act covers industrial effluent standards, but ignores the domestic and municipal effluents even though they constitute 90% of India's wastewater volumes (Sawhney 2004).

SEWAGE TREATMENT STATUS IN URBAN AREAS OF INDIA

In India, cities having more than hundred thousand population are classified as Class I cities and towns having fifty to hundred thousand population as Class II towns. According to the Census figure of 2001, the number of class I cities is 414 and class II towns is around 489. There are 211 sewage treatment plants (STPs) in 112 of the 414 Class I cities and 31 STPs in 22 of the 489 Class II towns. Besides, 27 STPs are in 26 other smaller towns. Of these, 186, 24 and 21 STPs are operational and 25, 7 and 6 are under construction in Class I cities, Class II towns and other smaller towns, respectively. Thus, in all there are 269 STPs, including 231 operational and 38 under construction. All Class I cities and Class II towns together generate an estimated 29129 MLD sewage. Against this, installed sewage treatment capacity is only 6190 MLD (Table 1). There remains a gap of 22939 MLD between sewage generation and installed capacity. In percentage, this gap is 78.7% of the sewage generation. Another 1743 MLD (equal to 6%) capacity is under planning or construction stage. If this is also added to existing capacity, we are left with a 21196 MLD (equal to 72.7% of the sewage generation) gap in sewage treatment capacity that has not even planned yet (CPCB 2005).

Table 1
Sewage generation and treatment capacity in Class I cities and Class II towns

City category & Population	Number of cities	Sewage generation, MLD	Installed sewage treatment capacity, MLD	Capacity gap in cities having STPs, MLD (A)	Sewage generation in cities having no STPs, MLD (B)	Total capacity gap, MLD (A+B)	Planned treatment capacity, MLD
Class I cities having more than 10 lac population	39	13503	4472 (In 29 cities)	6135	2896	9031	1549
Class I cities having 5 to 10 lac population	32	3836	485 (In 13 cities)	1293	2058	3351	123
Class I cities having 2 to 5 lac population	119	4807	768 (In 34 cities)	804	3235	4039	4
Class I cities having 1 to 2 lac population	224	4018	322 (In 36 cities)	373	3323	3696	32.5
All the above Class I cities together	414	26164 (100%)	6047(23.1%) (In 112 cities)	8605 (32.9%)	11512 (44%)	20117 (76.9%)	1708.5 (6.5%)
Class II towns having 0.5 to 1 lac population	489	2965 (100%)	200 (>143*) (4.8%) (In 22 towns)	Nil	2822 (95.2%)	2822 (95.2%)	34.1 (1.15%)
All Class I cities and Class II towns	893	29129 (100%)	6190 (21.3%)	8605 (29.5%)	14334 (49.2%)	22939 (78.7%)	1742.6 (6.0%)

(Source: CPCB, 2005)

As discussed above only a portion of the sewage generated in Indian cities is treated. The untreated sewage finds their way into water bodies and thus pollutes ground and surface water. Centralized treatment facilities, though common in developed countries, seems to be a non-viable option in Indian urban context due to the unplanned urban conglomeration of buildings, unavailability of land, complicated sewer networks required and high cost involved in infrastructure development. Again many of the techniques available today for sewage treatment are also high energy consuming. Today combined wastewater-blackwater (heavily polluted wastewater generated from the toilet and contains large concentrations of faecal matter and urine) and grey water (non-industrial wastewater generated from domestic usages including showers, bathroom sinks, kitchen sinks, dishwashers and washing machines comprise 50-80% of residential "waste" water) is discharged into sewer lines requiring handling of enormous volumes at treatment plants. Separating these two streams and treating them individually is a viable option, a trend gradually receiving world wide acceptance. Since the grey water is less polluted, it can be used for non- potable purpose like garden irrigation even without treatment (except kitchen water) or with light treatment compared to conventional high cost wastewater treatment. The substitution of drinking water with treated grey water can be used for purposes other than potable water, e.g., toilet flushing and garden irrigation; support the sustainability of valuable water resources (Nolde 2000). Furthermore, considerable amounts of added chemicals, in addition to sludge which arises during drinking water treatment, can be minimized.

In water scarce environments, wastewater reuse and reclamation are often considered as a viable option for increased water resources availability. From a process technology point of view, separate treatment of black water, possibly together with kitchen waste, and grey water is most logical. Faecal matter and urine contain not only half of the COD and the major fraction of the nutrients in domestic wastewater, but also most of the pathogens and micro- pollutants, like pharmaceuticals and hormones, while produced in a small volume. Concentrating risks in a very small volume enables their better control and limits the negative environmental effects.

In developing countries where water is scarce, grey water reuse in schools, hospitals and government institutions is proving to be an essential alternate water resource to fresh ground, surface or rainwater supplies (Godfrey et al., 2007). Studies from the Middle-East and India for example indicate that grey water systems have water saving of 3.4% to 33.4% per annum (Al-Jayyousie, 2003). In 1993-94 Victoria University of Technology in conjunction with Melbourne Water designed, installed, monitored and assessed grey water reuse system on four home sites (Christov a-boal et al., 1995). Specifically, grey water recycle augments existing water use efficiency. In a recent global study of grey water reuse by the Canadian Water and Wastewater Association (CWWA), sanitary uses of grey water (i.e. toilet flushing and cleaning) were the primary use (CWWA 2005).

Composition of Grey water

It is estimated that grey water constitutes around 55 to 80% of domestic wastewater (Karma El-Fadl 2007). In terms of basic water quality parameters (TSS, BOD, turbidity), it is considered to be comparable to a low-or medium grade wastewater. Jefferson et al. (2004) found that, though similar in organics content to full domestic wastewater, grey water tends to contain fewer solids and is less turbid than full domestic wastewater, suggesting that more of its contaminants are dissolved. The same study also suggested that the COD/BOD ratio in grey water can approach 4:1, much higher than that of domestic wastewater, which is typically around 2:1.

The composition of grey water depends on each household's activities and varies according to socio-economic status, cultural practices, cooking habits, cleaning agents used, as well as demography. In general, grey water in low and middle-income countries may contain the following parameters:

Table 2
Physical composition of Grey water

Soaps Detergents Fibres from clothes Hair	Suspended solids Dissolved solids Food particles Grease Oil

(Source: Karma El-Fadl 2007)

Typical chemical characteristics of grey water are presented in Table 3. Treatment requirements vary based on chemical characteristics and intended use of treated grey water.

Table 3
Chemical characteristics of Grey water

	NEERI, 2007		Ruiz *et al.*, 1998	
Item	**Range**	**Average**	**Range**	**Average**
pH	6.4 – 8.1	7.7	6.95 – 8.3	7.8
TSS (Mg/L)	40 – 340	190	116 – 424	226
Turbidity (NTU)	15 – 270	161	NA	NA
COD_t (Mg/L)	NA	NA	220 – 985	693
COD_s (Mg/L)	NA	NA	63 – 523	322
BOD_5 (Mg/L)	45 – 330	170	250 – 640	360
Nitrite (Mg/L)	0.1 – 1.0	0.55	NA	NA
Ammonia (Mg/L)	1.0 – 26	13	2 – 34	20
Fats (Mg/L)	NA	NA	57 – 199	100
TKN (Mg/L)	2- 23	12	9.5 – 65	38
Total P (Mg/L)	0.1-0.8	0.62	0.58 – 9.6	5.5
Sulphate (Mg/L)	<0.3 – 12.9	5.6	2.1 – 145	38.5
Conductivity (mS/cm)	325-1140	732	NA	NA
Hardness (Mg $CaCO_3$/L)	15-50	35	NA	NA
Sodium (Mg/L)	60-250	140	NA	NA
Alkalinity (Mg $CaCO_3$/L)	NA	NA	54 – 902	281

The microbiological quality in terms of number of thermo-tolerant coliforms of grey water from various sources by different researchers is presented in Table 3. Thermo-tolerant coliforms are also known as faecal coliforms (expressed as colony forming units per 100 ml) and are a type of micro-organism which typically grow in the intestine of warm blooded animals (including humans) and are shed in millions to billions per gram of their faeces. A high faecal coliform count is undesirable and indicates a greater chance of human illness and infections developing through contact with the wastewater. Typical levels of thermo-tolerant coliforms found in raw sewage are in the order of 10^6 to 10^8 cfu/100ml.

Grey water characteristics also vary according to source; each fixture contributing to the grey water collection system will carry its own particular contaminant load. Friedler (2004) recommends excluding fixtures like the kitchen sink and dishwasher from a grey water system, because they constitute only 25-30% of grey water volume but contribute nearly half of its COD content. For this reason, the least contaminated streams of household grey water are usually prioritized for reuse.

Table 4
Microbiological Quality of Grey water

Source	Thermo tolerant coliforms (cfu)/100 ml			
	Rose *et al.*, 1991	Kapisak *at al.*, 1992	California DHS 1990	Brandes 1978
Bathing	$6x10^3$ cfu	$4x10^5$ MPN	<10 to $2x10^8$	$6x10^3$ cfu
Laundry wash water	126 cfu	$2x10^3$ – 10^7 MPN	--	--
Laundry rinse water	25 cfu	--	--	--
Kitchen	--	--	<10 to $4x10^6$	$2x10^9$
Combined greywater	6 to 80 cfu[A] $1.5x10^3$ cfu[B] $1.8x10^5$ to $8x10^6$ cfu[C] $13x10^{6D}$		$8.8x10^{5CD}$ $1.73x10^5$	

Source: Jepperson et al., 1994

A- Family without children
B- Families with children
C- Other study Quoted cfu-colony forming units/100 ml
D- Kitchen and bath only MPN-most probable number
Note: cfu can be considered similar or of the same magnitude order as MPN

RATIONALE AND BENEFITS OF WASTE WATER RECYCLE AND REUSE

Water reclamation and reuse allow for more efficient use of energy and resources by tailoring treatment requirements to serve the end-users of water and reduces pollution. Increasing water demands, water scarcity and droughts, environmental protection and enhancement, socio-economic factors, public health protection, etc., are the major factors driving the need for wastewater reuse. Water recycling can decrease diversion of freshwater from sensitive ecosystems thereby enhancing conservation of fresh water supplies significantly. Recycled water could be used to create or enhance wetlands and riparian (stream) habitats. Nutrients in reclaimed water may offset the need for supplemental fertilizers, thereby conserving resources. If this water is used to irrigate agricultural land, less fertilizer is required for crop, thus by reducing nutrient (and resulting pollution) flows into waterways, auxiliary activities such as tourism and fisheries could be enhanced.

Identification of appropriate treatment technology for water reuse is very important and some of the crucial challenges to be addressed are: (i) water recycling and treatment techniques to be employed can be quite complex and site specific (ii) technical feasibility, cost and public policy acceptance remains a major challenge (iii) the broad spectrum of pathogenic micro-organisms present in high concentrations in wastewater may pose potential health risks to the workers or adjacent residents who may be exposed to wastewater recycling activities and to the public who may consume wastewater irrigated crops or recreate on wastewater irrigated lawns or lakes and (iv) in the case of recycling for potential domestic use, the organic and inorganic toxic chemicals and micro pollutants from industrial and domestic sources are a cause for concern.

Types of Waste Water Re-Use and Treatment

Wastewater is reused in many ways: direct reuse, indirect reuse, intentional direct reuse for non-potable purposes, unintentional indirect reuse, intentional indirect reuse for potable purposes etc. Direct reuse consists of treated waste water delivered to the user directly by pipe or through a reservoir. It is restricted to non- potable uses like industrial processes, recreational facilities, and irrigation in some countries. If untreated grey water is used for irrigation, toilet flushing, etc., it is unintentional direct use for non-potable purposes. When treated and untreated waste water is returned to a water body and is inadvertently taken for use, then it is indirect reuse and it commonly occurs in rivers. Unintentional indirect reuse happens when a source of drinking water receives the wastewater resulting in an uncontrolled and unplanned reuse. Intentional indirect reuse of reclaimed waste water for potable purposes include planned ground water recharge with extensively treated effluents from treatment plants after advanced treatment. Broadly, wastewater is treated in centralized facilities which has mainly three levels,– primary, secondary and tertiary levels.

Primary treatment: Treatment involving sedimentation (sometimes preceded by screening and grit removal) to remove gross and settleable solids. The remaining settled solids, referred to as sludge, are removed and treated separately.

Secondary treatment: Generally, a level of treatment that removes 85% of Biological Oxygen Demand [BOD] and suspended solids via biological or chemical treatment processes.

Secondary treated reclaimed water usually has a BOD of <20 milligrams per liter (mg/L) and suspended solids of <30 mg/L, but this may increase to >100 mg/L due to algal solids in lagoon systems.

Tertiary treatment: The treatment of reclaimed water beyond the secondary biological stage. This normally implies the removal of a high percentage of suspended solids and/or nutrients, followed by disinfection. It may include processes such as coagulation, flocculation and filtration

CENTRALIZED AND DECENTRALIZED APPROACHES TO WASTEWATER MANAGEMENT

The environmental problems associated with urban areas are a consequence of the number of people producing wastes, and their high concentration. On the other hand, the large concentrations of people would appear to offer greater opportunities for centralized approaches to the provision of infrastructure and services, which may actually reduce the per capita cost of service provision. However, the population density in peri-urban areas, and the latter's distances from existing centralized wastewater disposal systems, often mean that economies of scale do not exist, so that centralized systems for wastewater collection and disposal require disproportionately large investments which are unaffordable to the majority of the peri-urban poor.

In the past, the conventional wisdom has been that centralized systems are easier to plan and manage than decentralized systems. There is some truth in this argument when municipal administrative systems are centralized. However, experience shows that centralized systems have been particularly poor at reaching peri-urban areas, especially those that fall outside municipal boundaries and have not been responsive to local needs and resources. It has also been argued that they express power relationships within which service to the urban poor is always given a low priority.

In response to the deficiencies of centralized approaches to service delivery, in recent years there has been increasing emphasis on the potential benefits of adopting decentralized approaches to wastewater management, which are considered to be particularly appropriate for peri-urban areas. Decentralized wastewater systems may provide a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas. Broadly speaking, the implications of decentralization on wastewater management systems relate to planning and decision-making, design of physical infrastructure, and management arrangements for operation and maintenance. More generally, decentralization is also seen as a way of strengthening the role of local government and democracy in general, and as an effective means of addressing environmental and health concerns. The basic tenet is that local control, as opposed to centralized control, will result in more accountable service providers and better services. It is arguable that decentralized systems are more compatible with decentralized approaches to urban management than centralized systems. There has also been an increased emphasis on a more holistic approach to waste disposal that stresses the benefits of reducing the strength or quantity of waste at source and, where possible, recycling or re-using it close to the point where it is produced. One conceptual model which incorporates these different aspects is the household-centred environmental sanitation approach, which starts from the assumption that sanitation problems, including wastewater disposal, should be solved as close to their source as possible, with decisions and the responsibility for implementing them flowing from the household to the community to the city and, finally, to higher levels of government. Although decentralized systems have yet to be widely accepted and implemented in practice, they do appear to offer a number of potential advantages. These relate to opportunities for greater stakeholder involvement in decision-making and planning, to financial advantages, and to the benefits of segregation of wastewater at source and compatibility with local demands for wastewater re-use.

GREY WATER TREATMENT TECHNOLOGIES

Domestic wastewater management in urban and semi-urban areas is based on the conventional approach of collecting the wastewater, both grey and black water in sewerage systems and treated in a conventional sewerage treatment plant. Alternatively the grey water, consisting of 70 to 80 % of the per capita water requirement can be collected, treated and re-used on-site, thereby promoting more efficient water use. There are many methods for reusing grey water, from simple bucketing to complex treatment and recycling systems. However, on-site reuse of domestic wastewater is subject to various restrictions due to concerns about effluent quality, maintenance and health issues.

International status

Diversion systems: Grey water diversion systems are used in New South Wales, Australia for grey water reuse. It denotes typically direct grey water from the laundry or bathroom to the garden for immediate use, without making changes to its quality. The water is not stored for more than a few hours, if at all. Diversion devices can be installed to divert grey water from bathroom or laundry (not kitchen) to sub-surface irrigation systems. Kitchen wastewater must not be reused in diversion device systems due to a high content of oils, grease and bacteria in wastewater generated from kitchens. There are two types of diversion devices- gravity diversion and pump diversion. In the case of former, gravity provides pressure to move the water from the house to the irrigation system.

Treatment systems: This improves the quality of the wastewater by filtering, disinfecting and otherwise treating it. Treated water can be stored for longer periods without the risk of it going septic. Its higher quality and ability to be stored means that it can be used for more purposes, including garden watering, toilet flushing and even clothes washing.

A wide variety of treatment technologies are used worldwide for treatment of grey water. It includes compact packaged unit of different companies and one or more secondary wastewater treatment system along with required primary treatment of grey water, with or without disinfection depending on the characteristics of grey water and the required quality and use of treated water.

At Klosterenga, in the capital of Norway, Oslo, the grey water is treated in an advanced nature based grey water treatment system in the courtyard of the building. The system consists of a septic tank, pumping to a vertical down-flow single pass aerobic biofilter followed by a subsurface horizontal-flow porous media filter. The Klosterenga system was built in 2000 and has consistently produced an effluent quality averaging to: COD 19 mg/l, Total nitrogen 2.5 mg/l, Total phosphorus 0.03 mg/l and Faecal coliforms – nil.

The total area requirement is $1m^2$/ person and the effluent meets European swimming water standards with respect to indicator bacteria and WHO drinking water standards with respect to nitrogen. The low area requirement of the system and the high effluent quality facilitates use in urban settings, discharge to small streams, open waterways or irrigation or groundwater recharge (Jenssen 2003)

Membrane Bio-Reactor: Lesjean and Gnirss (2006) investigated grey water treatment with a membrane bioreactor operated at low SRT and low HRT. On the site of the

Berlin- Stahnsdorf WWTP, ten private apartments and one office building are connected to the Sanitation Concept for Separate Treatment (SCST) scheme whereby urine, faecal matter and grey water are collected and stored separately. The MBR unit was constantly fed over 8 months with fresh grey water coming from bathrooms and kitchens, after a buffer tank of maximum of 8 h, and was successively operated with 20 d, 9 d, 6 d and 4 d sludge age. Due to the very short HRT, the sludge concentration was maintained in the approximate range of 10 g MLSS/L down to 2 g MLSS/L. The COD was well eliminated (>85% COD-removal), and ammonification and nitrification remained complete (>80% TKN-removal), even with the lower sludge age. However, the nitrification rates were relatively low (<0.7 mgNNH 3/ gVSS.h), and nitrogen removal was inconstant and ranged from 20 to 80%, due to the presence of nitrate in the permeate. Indeed, the main elimination mechanism was bioassimilation for cell growth, and therefore the removal rate depended strongly on the grey water characteristics (both COD and TN).

A modular MBR plant was installed at CanTho University to treat the heavily loaded grey water from a dormitory of the Can Tho University (grey water from kitchens, showers, wash hand basins). All effluent values met the standards specified in the fbr sheet H201 (2005) for the reuse of treated water for toilet flushing and laundry washing. Also the microbial quality requirements according to Vietnamese standards for irrigation are easily met.

The 4-Barrel System: Between 2001 and 2003, INWRDAM conducted a grey water treatment and reuse research project in Tafila, Jordan with financial support from the International Development Research Centre in Ottawa, Canada (IDRC). The Tafila project resulted in developing practical and low-cost grey water treatment methods and these were outfitted in twenty-three households, the main Mosque and the girls' secondary school.

Four plastic barrels constitute the treatment kit. The four barrels are lined up next to one another and are interconnected with 50 mm PVC pipes. The first barrel is a grease, oil and solids separator and thus acts as a pre-treatment or primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease and soap foam, float. This barrel has 160 litre capacity and a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. The second and the third barrels have 220 litre capacities and are filled with gravel 2-3 cm in size.

Once solids and floating material settle in the first barrel, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next, the water from the top of the second barrel enters into the bottom of the third barrel. This water passes through the gravel lumps and from the top of the third barrel is taken into the fourth. Anaerobic treatment is accomplished in the two middle barrels. Anaerobic bacteria gets established on the stone surface so that when the grey water passes through the stones, the bacteria works on breaking down components of the organic material found in the grey water. The last barrel acts as a storage tank for treated grey water. Within one to two days of resident time in the treatment kit, the influent greywater is expected to undergo a treatment level equivalent to between primary and secondary treatment. Fig:1 shows an installed 4-barrel system

The Confined Trench (CT) System: Two plastic barrels and a dug trench filled with gravel media constitute the confined trench (CT) unit. The first barrel functions as

Source: Al-Beiruti and Najib, 2003

Fig 1

Installed 4-barrel system in houses at Jordan

a grease, oil and solids separator and thus acts as a pretreatment or primary treatment chamber, where the solid matter from the influent grey water settles and the floating components, such as grease and soap foam floats and can be removed regularly. The first barrel has 160 litre capacity and a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. A trench is dug close to the first barrel with dimensions of approximately 3 meters long, 1 meter wide and 1 meter deep and it is filled with 2-3 cm sized graded gravel. Pre-treated wastewater from the first barrel enters the bottom part of the trench from one side and follows slowly to the other end. The trench is lined with a 400-500 micron thick polyethylene sheet. The sides of the side trench are plastered with a mud layer, so that the polyethylene liner sheet is not punctured by sharp stones. A 120 litre capacity plastic barrel is perforated and burred in the gravel at the exit end of the trench so that wastewater flows throughout the trench and upwards to fill this barrel. Residence time of grey water in the trench is two to four days under anaerobic conditions. The confined trench unit can serve more than one nearby family sharing the same garden plot and it can deliver more water quantity between pumping cycles.

National Status

Sullage Treatment System

Ion Exchange India is operating a sullage recycle system at its training centre in Panchgani, at a capacity of 1,800 litres per day. In the recycling process, sullage from the kitchens and bathrooms is collected in an underground RCC tank where the water is treated by coagulation, filtration and disinfection, and then pumped to the overhead tank from which it is supplied for low-end uses. The treated water is used for toilet flushing and gardening. Simple construction and affordable capital costs make it easy for both new and existing buildings to go in for the system and the payback can be in as little as 15 to 18 months. The company has also installed a sullage recycle plant, capacity 5 cu.m. per hour, for a large residential complex at Vasai, near Mumbai; beautiful gardens are now maintained in an otherwise water-stressed area (Ramachandran, 2002).

Greywater for Irrigation in Chennai

Finding water for gardening in Chennai has been a difficult proposition in recent years with dipping groundwater levels and the increasing demand for drinking water. Chennai Corporation recently launched a drive to source recycled grey water for watering avenue trees and plants in parks and for other gardening purposes. Several residents in the city have started turning to grey water to meet their gardening needs. The local body recommends a simple two stage recycling technique which includes creating a primary treatment pit consisting of charcoal and blue metal (which is used for construction) and a secondary pit that will just hold the water and help settle some of the smaller impurities. The outlet of water from kitchen and bathroom needs to be diverted to the primary pit. It would of course be best if a separate pipeline is created for grey water from kitchen and bathrooms to the treatment pits at the time of construction itself.

Greywater Treatment Plants in Ashram Schools, Madhya Pradesh

Dhar and Jhabua are two districts of Madhya Pradesh in Central Province of India which suffer recurrent water quantity and quality problems. Lack of water is major reason for low sanitation coverage in schools. In many residential schools in Dhar and Jhabua Districts, limited availability of freshwater has prompted UNICEF, in collaboration with NEERI and other governmental and non-governmental partners, to explore the use of grey water for appropriate purposes such as flushing of toilets. A holistic water management is adopted in these schools by integrating different water usages and corresponding quality requirements. It has been found out in Ashram schools that water requirement is about 60-70 litre per student per day as against drinking/cooking water requirement of 5 litre per day. The grey water treatment plants have been constructed by providing treatment techniques such as screening, equalization, settling, filtration and aeration. This simple treatment has resulted in use of treated grey water in flushing the toilets.

UNICEF and NEERI along with government and non-government partners have constructed six grey water treatment plants at tribal schools in Dhar and Jhabua districts. The purpose of the plants was to make water available to flush toilets, to improve sanitation, to use treated grey water for gardening and for floor washing. The operation and maintenance of these grey water treatment plants are looked after by students and Parent Teachers Association (PTA). Performance evaluation of grey water treatment plant was undertaken by NEERI by collecting samples from seven treatment plants. The turbidity removal efficiency of 50% (<200 NTU) is observed in all the grey water treatment plants. Considering direct correlation between turbidity and microorganism, it can be stated that microbial removal efficiency of these grey water treatment plants is also approximately 50%.

The Cost Benefit Analysis study conducted by NEERI concluded that the cost of the system may be recovered in two years. Additionally, the system provides secondary benefit such as improved education, clean environment and time available for other activities. Indirect economical benefits are also there.This case study is a classic example of how a simple application of grey water reuse system can be of tremendous economic benefit and viability on such a micro level. This study is definitely a leading light while formulating future policies and implementation strategies in Indian scenario of wastewater recycling and reuse models.

Greywater Recycling System in Hotels in Kerala

The grey water is let through a multi stage low maintenance system to treat it and recycle it for flushing, gardening and other non potable end uses.

Greywater' Grease traps (for removal of fat and grease)' Anaerobic filters (for partial BOD removal)' Submersible pump chamber' Constructed wetlands (for BOD reduction to 30 mg/l)' Polishing pond (for BOD removal to 0 mg/l)' online chlorination (for disinfection)' Overhead tank for flushing /gardening

The wastewater from the bathrooms, kitchen and wash areas of the hotels is first led to grease traps for removing grease and fat. After the grease trap, the grey water is directed to upflow filters for removal of solid particles and also for partial BOD reduction due to anaerobic action. The effluent from the filter is pumped to multi-stage constructed wetlands /reed beds at the top of the mount. The treated effluent is collected in a polishing pond, where the final polishing and BOD removal is effected mainly by water plants like duck weed. This water is chlorinated and pumped to the overhead tank for flushing, gardening and other non-potable end uses.

In addition to the above explained proven technologies in grey water treatment and reuse, some of the conventional wastewater water treatment units either individually or in combination can be used for grey water treatment, which is described below.

Septic Tank

A septic tank consists minimum of 2, sometimes 3 compartments. The compartment walls extend 15 cm above liquid level. The anaerobic bacteria present in the tanks decompose the solid wastes that have settled to the bottom of the tank thereby transforming most of the wastes in solids and gases. The outflow, through a series of subsurface pipes is distributed throughout the drain field. Here effluents undergo final treatment as the soil absorbs and filters the liquid whereas rest of the materials is broke down by the microbes. It is not possible for the septic tanks to dispose all the materials which enter the system. The solid that is left behind and which is not decomposed need to be removed on a regular basis; otherwise the system will fail.

Grease and light particles which form a layer of scum on the top are prevented by the use of baffles installed at the inlet and outlet of the tank. The scum formed is to be removed periodically. The Suspended Solids removal rate drops drastically when accumulated sludge fills more than 2/3 of the tank. This must be avoided; especially in cases where the effluent is treated further in a sand or gravel filter. The inlet may dive down inside the tank, below the assumed lowest level of the scum or may be above the water level when the inlet pipe is used to evacuate gas. The vent pipe for digester gases should end outside buildings, at a minimum of 2 m above the ground.

The treatment quality of a septic tank is in the range of 25% - 50% COD removal. Post treatment may be provided depending on the type of reuse.

Imhoff Tank

Imhoff or Emscher tanks are typically used for domestic or mixed wastewater flows above 3 m^3/d. The tank consists of a settling compartment above the digestion chamber. Funnel-like baffle walls prevent up-flowing foul sludge particles from getting mixed with the effluent and from causing turbulence. The effluent remains fresh and odourless because the suspended and dissolved solids do not have an opportunity to get in contact with the active sludge to become sour and foul. Retention times of much longer than 2 h during peak hours in the flow portion of the tank would jeopardize this effect.

The sludge and scum must be removed regularly, at the intervals the sludge storage had been designed for. Only part of the sludge should be removed so as to always keep some active sludge present. Sludge should be removed right from the bottom to be sure that only fully digested substrate is discharged. When sludge is removed, it should be immediately treated further in drying beds or compost pits for pathogen control. Pipe ventilation must be provided, as biogas is also produced in the Imhoff tank.

Anaerobic Filter

The anaerobic filter, also known as fixed bed or fixed film reactor is the treatment of non-settleable and dissolved solids by bringing them in close contact with a surplus of active bacterial mass. This surplus together with "hungry" bacteria digests the dispersed or dissolved organic matter within short retention times. Anaerobic filters are reactors consisting of supporting material layer. On the surface of these material layers or bed fixation of microorganism and the development of biofilm takes place. Anaerobic filters can be applied not only for treating concentrated wastewater but also for those wastewaters that have low organic load (grey water). If they are preceded by a reactor that retains settled solids, they will work better.

It is suitable for domestic wastewater and all industrial wastewater which have a lower content of suspended solids. The bacteria in the filter are immobile and generally attach themselves to solid particles or to the reactor walls. Filter materials like rocks, cinder, plastic, or gravel provide additional surface area for bacteria to settle. Thus, the fresh wastewater is forced to come into contact with active bacteria intensively. The larger surface area for the bacterial growth helps in the quick digestion of the wastes. A good filter material provides a surface area of 90 to 300 m^2 per meter cube reactor volume. Biological oxygen demand up to 70% to 90 % is removed in a well operated anaerobic filter.

Pre-treatment in settlers or septic tanks may be necessary to eliminate solids of larger size before they are allowed to enter the filter. When the bacterial film becomes too thick it has to be removed. This may be done by back-flush of wastewater or by removing the filter mass for cleaning outside the reactor. Nonetheless, the anaerobic filter is very reliable and robust. Anaerobic filters may be operated as down flow or up flow systems. A combination of up-flow and down-flow chambers is also possible.

Baffled Septic Tank

Baffled septic tank or anaerobic baffled reactor in fact is a combination of several anaerobic process principles - the septic tank, the fluidized bed reactor and the UASB. The up-flow velocity of the baffled septic tank, which should never be more than 2 m/h, limits its design. The limited upstream velocity results in large but shallow tanks. It is for this reason that the baffled reactor is not economical for larger plants. However, the baffled septic tank is ideal for grey water treatment because it is simple to build and simple to operate. Hydraulic and organic shock loads have little effect on treatment efficiency. Treatment performance is the range of 65% - 90% COD (70% - 95% BOD) removal.

Since the tanks are put in series, a part of the active sludge that is washed out from one chamber is trapped in the next. It also helps to digest difficult degradable substances, predominantly in the rear part, after easily degradable matters have been digested in the front part, already. The baffled septic tank consists of at least four chambers in series. The last chamber could have a filter in its upper part in order to retain eventual solid particles. A settler for post-treatment could also be placed after the baffled septic tank.

Equal distribution of inflow, and wide spread contact between new and old substrate are important process features. The fresh influent is mixed as soon as possible with the active sludge present in the reactor in order to get quickly inoculated for digestion. The wastewater flows from bottom to top with the effect that sludge particle settle against the up-stream of the liquid. This provides the possibility of intensive contact between resident sludge and newly incoming liquid. The water stream between chambers is directed by baffle walls that form a down-shaft or by down-pipes that are placed on partition walls for better distribution of flow.

Relatively short compartments (length < 50% to 60% of the height) are provided in order to distribute the wastewater over the entire floor area. The final outlet as well as the outlets of each tank should be placed slightly below surface in order to retain any possible scum.

CONSTRUCTED WETLANDS

Constructed wetlands are created artificially to improve the quality of water. These wetlands are designed on the lines of natural wetlands which are considered as the earth's kidney as they filter the pollutants from the flowing water. These wetlands utilize all the natural processes including wetland vegetation, soils, and associated microbes for improving water quality.These wetlands are generally constructed for wastewater with low suspended solid content whereas the COD concentration should be below 500 mg/l. These are considered as an excellent and most effective technology to upgrade septic tank effluent to high quality. There are three basic treatment systems of constructed wetlands:

- The overland treatment system
- Vertical flow filter
- Horizontal flow filter

The water is distributed on carefully contoured land by channels and sprinkles for overland treatment. Horizontal filter on the other hand is simply operated and can be maintained easily. In vertical filter, water is distributed by distribution device to two or three filter beds.

Types of Constructed Wetlands

Surface Flow Wetlands

The important components of surface wetlands are shallow basin, soil or other medium to support the roots of vegetation, and a water control structure for maintaining the shallow depth of water. Wetlands that are constructed for treating mine drainage or agricultural runoff are surface flow wetlands. In these types of wetlands, layer which is near surface is aerobic whereas substrate and deeper layers are anaerobic

Subsurface Flow Wetlands

The main constituents of the subsurface flow wetland are sealed basin with a porous substrate of rock or gravel. The water level in this type of wetland remains below the top of the substrate. Subsurface wetlands are suitable for those wastewater that have low solid concentration and whose flow system is uniform.

Hybrid System

In Hybrid system or multistage system different cells are fabricated for different types of reactions. They are suitable for mine drainage.

Waste Stabilization Ponds

Ponds (lagoons) or waste stabilization pond system are artificial lakes which consists of sedimentation ponds (pre-treatment ponds with anaerobic sludge stabilization), anaerobic ponds (anaerobic stabilization ponds), oxidation ponds (aerobic cum facultative stabilization ponds), polishing ponds (post-treatment ponds, placed after stabilization ponds). But all ponds are not ideal for grey water treatment due to large land area requirement and in case of facultative or anaerobic ponds, there will be nuisance by mosquito breading, or bad odour. Polishing ponds can be used as a post treatment pond after gravel filter or constructed wetland, in which use of the fish to control mosquitoes is possible and more over it will give a good aesthetic appearance if it is constructed in garden.

Aerobic ponds receive most of their oxygen via the water surface. For loading rates below 4 g BOD/m^2/d, surface oxygen can meet the full oxygen demand. Oxygen intake increases at lower temperatures and with surface turbulence caused by wind and rain. Oxygen intake depends further on the actual oxygen deficit up to saturation point and thus may vary at 20°C between 40 g O_2 /m^2/d for fully anaerobic conditions and 10 g O_2 /m^2/d in case of 75% oxygen saturation. (Mudrak & Kunst, after Ottmann 1977).

The secondary source of oxygen comes from algae via photosynthesis. However, in general, too intensive growth of algae and highly turbid water prevents sunlight from reaching the lower strata of the pond. Oxygen production is then reduced because photosynthesis cannot take place. The result is a foul smell because anaerobic facultative conditions prevail. Algae are important and positive for the treatment process, but are a negative factor when it comes to effluent quality. Consequently, algae growth is allowed and wanted in the beginning of treatment, but not desired when it comes to the point of discharge, because algae increase the BOD of the effluent. Algae in the effluent can be reduced by a small last pond with maximum 1 day retention time. Baffles or rock bedding before the outlet of each of the ponds have remarkable effect on retaining of algae.

Membrane Bio-Reactor

Membrane bioreactor (MBR) technology has gained popularity in wastewater treatment and especially for decentralized and reuse applications. The technology consists of a compact unit which combines activated sludge treatment for the removal of biodegradable pollutants and a membrane for solid/liquid separation. MBRs have a small footprint making them attractive where space is limited and water treatment for internal recycling is desirable, e.g. for buildings (equipments being generally located in the cellar) or on ships. Further advantages of the system are the high quality of its effluent. However, investment and operational costs are high. Such high-tech solutions are normally too expensive for developing countries so that potential benefits have to be precisely evaluated.

CHOICE OF TECHNOLOGY

The choice of a technological scheme depends on local circumstances and requirements. In a new location to be built or in a situation when there is no treatment infrastructure at all, a maximum recovery and reuse of resources can be achieved when wastewater streams of a different degree of pollution are separately collected and affinitively treated. Black water is then separately collected from grey water. The treatment can be house-on-site, community-on-site or combination of both. When reuse is an objective, a minimal amount of transport of water should be used for black water. This will make its treatment and reuse less complex and cost-effective. When concentrated black water is treated anaerobically, addition of kitchen waste can be considered for maximization of methane recovery.

For existing infrastructure, several options are available for providing a more sustainable wastewater treatment. Conventional septic tanks to treat black water or all domestic wastewaters can be upgraded to Decentralized Wastewater Treatment System (DEWATS). Construction of small bore sewer system and transport of the effluent to a post-treatment step is a relatively cheap way to reduce hygienic risks, reduce pollution of ground water or make the wastewater applicable for irrigation and/or fertilisation. When stabilization pond systems are used as a main treatment, an anaerobic reactor can be introduced as pre-treatment leading to a substantial reduction of space requirement, water evaporation, methane emission and odour nuisance.

The scale of the treatment system being implemented, house-onsite or community-onsite, determines choice of the optimal treatment scheme. An important aspect of the current sanitation infrastructure is its high comfort and majority of users do not really feel the necessity to change it. Introduction of source separated treatment on the local scale means for the inhabitants installation of new pipeline and location of the facilities for the treatment of black and/or greywater in their close neighborhood. However, when well informed and when change is not associated with their own financial contributions people stand not against new developments.

CENTRE OF EXCELLENCE AND PILOT STUDY IN THIRUVANANTHAPURAM MUNICIPAL CORPORATION

The Ministry of Urban Development, Government of India has initiated many programmes in order to promote excellence in specific areas of urban management, project implementation and urban governance. One of the activities proposed under the Capacity Building Scheme for Urban Local Bodies (CBULB) is to set up Centres of Excellence in reputed institutions in the country to create the necessary knowledge base for improving municipal service delivery and management. The basic objective of these Centres will be to foster cutting-edge and crosscutting research, capacity building and technical knowledge base in the area of urban development. The CoEs will address urban development issues at national, state and local levels and will provide support to state and local governments. The Ministry has established one 'Centre of Excellence on Solid and Liquid Waste Management' at CED.

One of the specific objectives of the Centre of Excellence is to develop Strategy and Methodology for Urban Waste Water Management, through adopting a practical approach for Waste Water Recycling and Reuse to the maximum extent in the urban areas. The water use for human life can be considered in three lines such as (i) uses which require treated water like drinking, cooking or similar purposes, (ii) uses which requires partially treated water and (iii) use for which untreated water can be utilized. The present trend of water use shows that treated water is used by people for purposes where untreated or partially treated water can be utilized. Another issue to be addressed is how the waste water after use such as bathing water, waste water from kitchen, washing, etc., can be utilized for purposes other than drinking through simple treatment (recycle and reuse).There is no mechanism to enforce differential use of water for different purposes and necessary legal and institutional framework has to be developed.

As part of Centre of Excellence on Solid and Liquid Waste Management of the Ministry of Urban Development,Government of India,CED conducted a pilot study on water consumption and wastewater discharge methods adopted in Thiruvananthapuram Municipal Corporation(TMC). The study was focussed on major water consumers, in order to investigate their water consumption rate, discharge/treatment methods adopted etc. The characteristics of the grey water generated from these consumers have also analysed.

The characteristics study was carried out to ascertain the nature of the grey water generated from different types of users with a view to selecting proper treatment technology and to know what extent the treatment required. Characteristics study also helps to understand the need for separation of grey water source based on concentration of pollutants and to explore the possibilities of diversion of grey water for irrigation.

The study covered 62 apartment complexes(flats), 44 hotels and 19 hospitals . The main sources of water for these major consumers are mostly Kerala Water Authority(KWA), open well, bore well or dual supply of KWA and open well and/or bore well. From the study, it is observed that the per capita water consumption is more than 200 lpcd and some flats have even more than 500 lpcd which is very much higher side than national average per capita water consumption of 135 lpcd (IS 1172: 1983). The wastewater from these consumers is disposed directly to central sewer system. Very few flats, hotels and hospitals have septic tank facility to discharge their liquid waste. The study also revealed that only 3 flats and 2 hospitals have their own wastewater treatment facility. The water harvesting structures are available only in 7 flats and 6 hotels out of the total number covered.

Characteristics of Grey water of different sources

Grey water samples are collected from representative generating sources and the results of the analysis are presented in the following table. Samples are taken from flats and hotels 4 each, 3 hospitals, 1 public office and 1 hostel. As representatives of specific water consumers, samples are taken from 2 automobile service stations and1 fish market. All chemical analyses were carried out at CED Environmental Laboratory according to the standard methods for the examination of water and wastewater (APHA, 1995).A total of 19 parameters were analyzed and some of the major parameters which are having a bearing on grey water treatment are discussed below.

Suspended solids and organic compounds

The Total Suspended Solids varied from 193.3 mg/l to 1300 mg/l for different types of users. The composition of grey water varies greatly and reflects the lifestyle of the residents and the choice of household chemicals for washing-up, laundry etc. In the case of hotels for example the suspended solid varied from 640 mg/l to 1340 mg/l. This underlines the difficulty in selecting treatment options for different type of grey water. Characteristic of grey water is that it contained high concentrations of organic materials from cooking, residues from soap and detergents. The kitchen waste water portion in the grey water seems to be responsible for increasing BOD and COD. The varying constituents of the kitchen waste may also be contributing to these higher values. In the case of hospital waste water, the values ranged from 360-650 mg/l. The average BOD and COD of the waste water from different sources was comparatively higher than those of domestic sewage (Henze and Ledin 2000). The major reason may be the concentrated nature of the waste water due to less dilution. High concentrated, less volume kitchen waste water has to be separated from grey water for economic treatment. Although considered as a relatively clean, simple wastewater, polluted with mainly COD, the concentration and composition of COD can vary considerably from one to another location (Jefferson 2001). Some of the sub-streams of grey water are lightly polluted - bath and wash water, others especially kitchen wastewater carry a significant pollution load. The oil and grease content also deserve special mention as it has to be removed before subjecting the waste water to any kind of treatment.

Nutrients

Grey water normally contains low levels of nutrients compared with normal wastewater. Levels of nitrogen and other plant nutrients are always low, but in some grey water, high concentrations of phosphorous can be found (Swedish EPA, 1995). The most important source of nitrogen in wastewater is human waste. Nitrate content varied from 0.099 mg/L to 5.4 mg/L for different sources. Amount of various forms of nitrogen depends on several physical, chemical and biological processes in wastewater. Phosphorous content varied from 1.84 mg/L in the service station wastewater to 5.66 mg/L in the hospital wastewater. Over all there was not much variation for phosphorous content of different sources. Phosphorous originates from washing and dish-washing powder. If people use only P-free detergents, the phosphorus content of the grey water should be reduced to levels lower than normally found in an advanced treated wastewater.

The nutrients in grey water are mainly inorganic. Potassium and phosphorus are

Table 5
Characteristics of Grey water Analysed

Factors analysed	Fish market	Public office	Hotel		Hospital		Hostel	Flat		Service station	
			Range	Average	Range	Average		Range	Average	Range	Average
TSS (mg/L)	1300	480	640-1340	925	70-360	193.3	1350	60-630	307.25	220-420	320
ACIDITY as $CaCO_3$ (mg/L)	145	82.5	10-130	68.75	10-135	72.5	225	80-215	126.25	10-15	12.5
ALKALINITY as $CaCO_3$ (mg/L)	125	120	25-97.5	88.75	35-110	73.3	140	10-55	23.75	210-260	235
CHLORIDE (mg/L)	849.73	35.98	10.5-22.4	32.84	10-15.9	13.47	17.494	32.5-50.5	44.35	45	45
HARDNESS as $CaCO_3$ (mg/L)	300	19	17.5-85	42.25	53-158	91. 67	212	24-89	59	80-96	88
BOD (mg/L)	353	430	690-730	721.7	360-650	543.6	740	627-850	765.6	456.8-470	463.4
COD (mg/L)	820	456.7	1106-1456	1375.55	718-982	893.57	1115	1030-1620.5	1420.4	834-856.6	845.3
OIL & GREASE (mg/L)	960	78	225-456	546.5	55-870	451.67	180	90-210	144	240-830	535
SULPHATE (mg/L)	690	45	33.3-118.5	81.37	32.4-87.5	53.5	129.9	40.77-129.9	55.29	712-760	736
TEMPERATURE (^{0}C)	36.5	31.2	31.3-31.6	31.75	31.6-32.6	32.1	32	27.2-29.7	28.55	30.2-30.6	30.4
pH	7.36	7.28	5.49-6.87	6.38	6.43-6.71	6.57	5.74	5.74-7.24	6.85	7.5	7.5
CONDUCTIVITY (μs/cm)	3.41 ms	258	133.6-1399	773.4	207-296	261.67	555	194-339	284	1095-1134	1114.5
TDS (ppm)	1.71 ppt	128	66.8-696	385.7	103-149	130.67	280	97-169	141.75	545-559	552
TURBIDITY (NTU)	1110	264	247-1050	674	22-187	112.67	1109	167-1050	434.25	652-1058	870
NITRATE-N (mg/L)	1.535	0.0997	0.23-1.44	0.71	0.31-1.4	0.73	5.4	0.074-0.41	0.22	1.038-1.835	1.43
NITRITE-N (mg/L)	0.4673	0.026	0.033-0.467	0.22	0.065-0.12	0.088	0.967	0.026-0.233	0.10	0.167-0.360	0.26
AMMONIA-N (mg/L)	12.35	1.354	0.177-5.8	2.455	2.34-7.89	5.4067	4.432	3.627-15.687	7.66	0.150-0.168	0.16
PHOSPHATE (mg/L)	5.5	0.12	0.256-4.58	2.064	0.46-5.66	2.23	3.57	1.38-3.46	2.2	1.843-1.854	1.84
MPN (MPN/100 ml)	>1100	Nil	3->1100	925	28-150	84.3	Nil	460->1100	780	28-58	43

used in detergents and their concentrations will mainly reflect the usage rate of these products. The other sources of nutrients are (solid) kitchen residues (food leftovers) ending up in a kitchen water.

The variation in concentration and composition is due to personal and cultural habits with respect to water use and waste handling and the quality and quantity of products used for kitchen, laundry and personal care. Handling of food wastes in the kitchen may have an important impact on composition of kitchen refuse water.

Pathogens

The proportion of pathogens in grey water is generally low. In the case of public office and hostel no indicator organisms are detected. The maximum numbers of indicator organisms (>1100 MPN/100 ml) was present in the hotel, flats and fish markets. Pathogens are primarily added to wastewater with the faeces. The risk of infection is a function of the faecal contamination of the water. As grey water does not contain faeces, it is normally regarded as rather harmless. Still, many public authorities around the world regard grey water as a health hazard. One explanation for this is that high numbers of indicator bacteria are usually found in grey water. Recent research has proved that growth of enteric bacteria such as the faecal indicators is favoured in grey water due to its content of easily degradable organic compounds. Thus a focus on bacterial indicator numbers leads to an overestimation of faecal loads and, thereby, the hygienic risk.

A well-functioning wastewater treatment plant including mechanical, chemical and biological steps should not be expected to remove more than 90-99% of incoming pathogens. Untreated grey water can be expected to contain far lower densities of pathogens than effluent water from an advanced wastewater treatment plant. Treated greywater can thus be expected to have a much better hygiene quality than any kind of mixed wastewater.

The MPN values also warrant disinfection of the waste water before discharge. The characteristics of greywater show that it can be treated conveniently to acceptable levels. In certain cases like the fish market waste water, the chloride content is high, hence advanced treatments like reverse osmosis may be necessary.

Experiments on Grey water Treatment at CED

The Centre for Environment and Development installed the four - barrel system for purposes of demonstration and gaining expertise in grey water treatment at office premises. The source of wastewater is mainly utensil wash water from kitchen sink and lunch box wash water by the staff. It is estimated the wastewater generated at CED is 100 litres per day. The wastewater is allowed to pass through 4 barrels, the first one for sedimentation and skimming, next two barrels for attached growth biological treatment with shredded plastic media and the last one for final collection, from where the treated water can be used for non-potable purposes.

The values of Turbidity, TSS, BOD and COD in the outflow water were less by 33.72, 65, 55.43 and 53.33 percent respectively in comparison to the inflow water, after one month of installation (Table 6). The removal rate of parameters under study is less, since the system is at its initial stages of performance. Continuous monitoring will be carried out until the system gets stabilized. Once the process get stabilized the effluent parameters is expected to be in the safe discharge level. Further

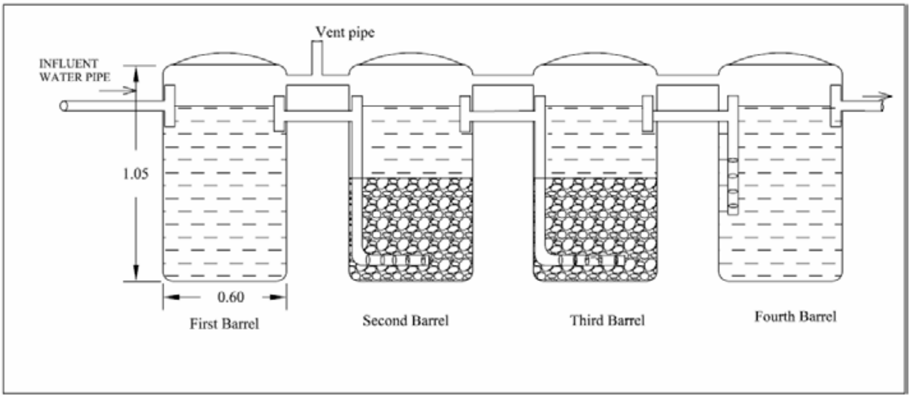

Fig 2
Design of 4-barrel system installed at CED

Table 6
Concentration of different constituents in inflow and outflow

Parameter	Inflow	Outflow	% Removal
Turbidity, NTU	102.6	68	33.72 %
TSS, mg/L	120	42	65 %
BOD, mg/L	875.5	390.2	55.43 %
COD, mg/L	946.6	441.7	53.33 %

modifications like filtration unit and disinfection can be incorporated depending on the end use.

Suggested Measures

Based on the survey made in TMC area, the following measures are suggested for grey water management in the residential and service sector complexes in urban areas.

- The use of domestic water supplied should be restricted to drinking, cooking, bathing and washing clothes and other similar uses. As far as possible recycled water should be used for other purposes dealing with parks, gardens, landscapes, golf courses, construction, industries, flushing etc.
- Use of recycled water should be made compulsory in all large building complexes to the extent possible.
- All new building plans and land development plans shall compulsorily indicate the onsite wastewater treatment and disposal arrangements and water reuse infrastructure including the plumbing plans etc.

- All apartments or group housing complexes as well as commercial, institutional and industrial complexes should make plumbing and infrastructure provision for separate treatment of blackwater and greywater and also for use of recycled water for flushing, washing and for watering gardens.
- Separate conveying system should be provided for blackwater and greywater to facilitate reuse of greywater for gardening and washing purposes when new facilities and services are planned. This may require suitable storage facilities that are to be indicated in the building plans.
- Location of treatment and disposal facilities for treating wastewater should be indicated in the plans for all new constructions.
- Regulatory organisations like Planning Authorities, Pollution Control Boards, and Transport Authorities should ensure water reuse at the time of licensing or permitting new developments.
- Massive IEC programs for awareness generation about the actual water availability status and sustainability of water resources in the state and also the importance of waste water recycle and reuse,water conservation and water harvesting etc., have to be formulated

CONCLUSION

This paper made an attempt to consolidate the information on potential of greywater reuse, the technology used in many situations with respect to the reuse and brief description of technologies adopted in the international and national scenario. It is definitely more rational to develop and incorporate a cost effective, energy efficient and technically simple greywater treatment system while adhering to the needs of discharge regulations. The studies initiated as part of the Centre of Excellence program is to develop a strategy and framework for waste water recycle and reuse in the Urban Local Bodies in the country with Thiruvananthapuram City Corporation and Payyannur Municipality as case study cities.Activities will be formulated with these objective at other ULBs, once the pilot study is completed.

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Wastewater Management in Urban Areas: Centralized vs. Decentralized systems

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INTRODUCTION

The rapid increase in the urban population (eleven fold increase in the last century) and the number of urban centers in India, has created a major challenge to ULBs entrusted with the task of waste management. These challenges can be met only when there is a full and undivided attention of our planners and decision makers. We must protect our environment and aquatic resources in order to achieve better management of health aspects. The wastewater generation has increased from 7,000 MLD in 1978-79 to 17,000 MLD in 1994-95 in cities with a population of more than one lakh. (Class I cities). However, the increase in treatment capacity has been only 46%. In fact, only 39% of wastewater was treated in the year 1978-79. In the year 2003, only 26% of wastewater generated in cities was treated before it was let out. Twenty-seven cities have only primary treatment facilities and forty-nine have primary and secondary treatment facilities. Treated or partly treated or untreated wastewater is either disposed into surface water bodies such as natural channels, rivers, lakes, ocean etc. or used on land for irrigation/ fodder cultivation. The mode of disposal is: (i) indirectly into the rivers/ lakes/ ponds/ creeks in 118 cities; (ii) on to the agriculture land in 63 cities, and (iii) directly into rivers in 41 cities. In 44 cities, it is discharged both into rivers and on agriculture land. The coastal area in India accommodates about 25% of its population. In many of the coastal cities, the wastewater finds its way into estuaries, creeks, bays etc. Therefore, there is an urgent need of addressing the wastewater management problem in urban areas of our country.

On the other hand, In India, water scarcity is a major problem. General population growth and urbanization will tremendously increase the number of people living in urban cities. It is predicted that the urban population of 280 million in 2000 will be reaching 400 million in 2015. In such a situation, providing access to safe drinking water and adequate sanitation facilities will remain as a challenge for India. At present, 89% of the urban population has access to safe drinking water and 30% has access to sewerage. A continuous supply of water for 24 hours in all the days of a week is available only for less than 5% population even in Delhi.

Water use has increased ten-fold between 1900 and 2000. This increase in demand on water resources was taken its toll. The world is already facing water shortages in Africa, the Middle East and parts of North America, Asia and Europe. Eighty-eight developing countries, containing close to one-half of the world's population, already experience water deficits, with resulting constraints on human and ecosystem health, as well as economic development.

According to World Health Organization, 1.1 billion people around the world lacked access to improved water supply and more than 2.4 billion (40% of worlds population) lacked access to improved sanitation in 2000. It is reported that the greatest development failure of the twentieth century is the failure to provide safe drinking water and adequate sanitation services to all the people. The provision of clean drinking water in adequate quantity and proper sanitation is necessary to protect human health and environment. Even in the twenty-first century, water related diseases are common in developing and undeveloped countries though it is eradicated in wealthier countries. Water related diseases can be divided into four categories: waterborne, water washed, water based and water related insect vector. Almost all these diseases are associated with lack of proper water supply and inadequate sanitation.

According to Central Public Health Engineering Organization (CPHEEO) estimates, as on 31 March 2000, 88% of urban population has access to a potable water supply. However, this supply is highly erratic and unreliable, due to the poorly maintained old transmission and distribution networks. Most of the time, the quality of supplied water is also inadequate. Consequently, physical losses are typically high, ranging from 25 to over 50 per cent. Low pressures and intermittent supplies allow back siphoning, which results in contamination of water in the distribution network. Water is typically available for only 2-8 hours a day in most of the Indian cities. The situation is even worse in summer when water is available only for a few minutes, sometimes not at all. According to a World Bank study, of the 27 Asian cities with populations of over 1,000,000, Chennai and Delhi are ranked as the worst performing metropolitan cities in terms of hours of water availability per day, while Mumbai is ranked as second worst performer and Calcutta fourth worst (Source: Background Paper - International Conference on New Perspectives on Water for Urban & Rural India - 18-19 September, 2001, New Delhi.). In most cities, centralized water supply systems depend on surface water sources like rivers and lakes. Chennai, for instance, has to bring water from a distance of 200 km whereas Bangalore gets its water from the Cauvery River, which is 95 km away. Where surface water sources fail to meet the rising demand, groundwater reserves are being tapped, often to unsustainable levels.

Water and wastewater treatments have been viewed as separate issues until recently. However, there has been a paradigm shift in recent years due to the scarcity of fresh water and the stress created by partially treated wastewater on the existing sources. Instead of viewing wastewater as a "problem" if it is viewed as a "resource", many of the water supply and wastewater management problems can be handled in a sustainable manner. There have been many efforts all over the world in recycling and reuse of wastewater. For example, the "newater" scheme in Singapore has adopted recycling and reuse in a big way, and this has proven very successful. In Chennai, a few industries buy the "secondary treated" domestic wastewater and then treat it further to use it as "process water". Enforcing agencies such as Central and State Pollution Control Boards are insisting on "zero discharge" from major industries in order to protect the sources and reduce the consumption. Although "recycling and reuse" is a great concept, if it is not practiced properly, it can lead to more problems, as it happened in many cases of grey water recycling.

To face the alarming situation, the most preferable solution is to reduce the use of water (water conservation), recycle the wastewater and the proper management of available water sources.

WASTEWATER MANAGEMENT SYSTEMS

Wastewater treatment systems can be either the conventional centralized systems or the entirely onsite decentralized systems. The centralized systems are usually planned, designed and operated by government agencies which collect and treat large volumes of wastewater for the entire communities, thus making use of large sewer net works, major excavations and manholes for access (Fisher, 1995; USEPA, 2004). On the other hand, decentralized systems treat wastewater of individual houses, apartment blocks or small communities (Tchobanoglous et al., 2004; USEPA, 2004). Moreover, decentralized systems , treat and reuse/dispose treated wastewater at or near the generation point. In case of centralized systems the treated wastewater is reused/disposed off in places far from the generation point. Fig1 represents the general objectives of wastewater management ststems vs decentralized systems characteristics

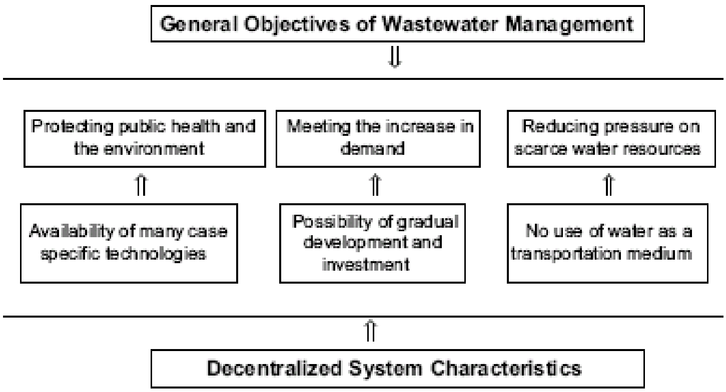

Fig1
General Objectives of Wastewater Management Vs Decentralized system Characterestics
(Adopted from Massoud et al, 2009)

CENTRALIZED VS. DECENTRALIZED WASTEWATER TREATMENT

As conventional or centralized wastewater treatment systems collect, treat and discharge large quantities of wastewater, constructing a centralized wastewater treatment system for small rural or semi-urban areas requires huge capital investments. Usually such a system results in burden of debts in the local government bodies of developing nations. Decentralized or cluster wastewater treatment systems are designed to operate at small scale (USEPA, 2004). They reduce the adverse impact of wastewater on the environment and public health. By providing decentralized wastewater management systems, one can increase the ultimate reuse of wastewater depending on the socio-economic aspects of the community, technical options topography and hydro-geological conditions and the socioeconomics. When used effectively, decentralized systems promote the return of treated wastewater within the watershed of its origin. Moreover, decentralized systems can be designed and installed based on the requirement of the locality. Decentralized systems are more preferable for communities with improper zoning, such as scattered low-density populated rural areas (USEPA, 2005). Centralized systems are situated faraway from the habitats. Hence most of the time, such systems does not require public participation. However, in case of decentralized systems, public participation is essential.

Decentralized systems often can yield better environmental benefits, with respect to sewage treatment. By treating the water upstream, neighboring areas requiring irrigation can receive the treated discharge, which indirectly can refill aquifers. Large-scale sewage treatment plants are often unable to make use of the treated water in the locality where it is generated. Decentralized wastewater management has the potential to be the catalyst for the re-creation of local institutions. The new emerging civic agenda of smart growth, community preservation, open space planning, ecologically sound economic development, resource conservation, and watershed management demands can be easily managed with decentralized wastewater management systems. Thus the economic, environmental and quality of life can be improved significantly.

Looking beyond the traditional assumption that wastewater is simply a matter of safe disposal and the public health; the real contemporary wastewater issues are the economic and environmental issues in which the public has a primary interest: i) Drinking water quality ii) Deterioration of recreational water resources and other natural systems services, iii) Property Values, iv) Economic development in small and rural communities and v)Urban sprawl

Decentralized wastewater management is not just about the disposal of wastewater and the public health. It has the potential to contribute to the formation of an infrastructure to sustain watershed integrity. Decentralized wastewater treatment is about the "watershed agenda" and the principles of "community preservation" and "sustainable development". When approaches to the real wastewater issues are successfully accomplished everyone benefits, ie i) Local communities win open space zoning, water quality and supply protection, increased development capacity and an expanding tax base, ii) Natural systems are sustained through prudent zoning and reduction of non-point pollution, iii) Developers win additional lots for development and higher margins typically associated with conservation subdivision design and municipal infrastructure, iv) Regulation wins because it gains partners in compliance management such as the municipality and perhaps a watershed authority and v) Citizens and homeowners win because property values are enhanced with municipal infrastructure, water quality and supply management is improved, and economic development and quality of life issues are not restricted by infrastructure limitations.

The problem associated with decentralized systems are that, if not managed properly they can contaminate the entire water resources in that area and cause public health issues. It is reported that more than 80% of the Open and bore well waters in Kerala are bacteriologically contaminated. Improper design and management of individual septic tanks may be a reason for this. The speciality of Kerala state is that it has high density of wells and septic tanks.

SELECTION OF APPROPRIATE SYSTEMS AND TECHNOLOGIES

Selection of appropriate systems will be based on the topography, hydro-gelogical conditions, land availability, existing wastewater management facilities and recycle and reuse facilities. On the other hand, the process of evaluating and selecting appropriate wastewater treatment technology should consider the life cycle cost of such a system including design, construction, operation, maintenance, repair and replacement. Over the operational lifetime of the system the operation and maintenance costs are equally important to construction costs. Cost estimates on a national basis for wastewater treatment systems are difficult to develop, primarily due to varying conditions of each community such as population density, land costs, and local performance requirements.

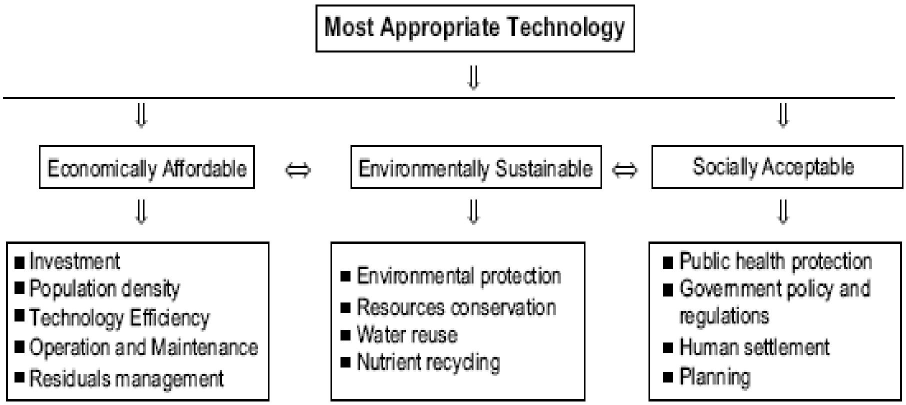

Fig 2.
Characteristics of most Appropriate Technology (Adopted from Massoud et al, 2009)

MANAGEMENT OF DECENTRALIZED WASTEWATER TREATMENT SYSTEMS

In general, operation and maintenance of decentralized systems are left to homeowners leading to system failure in many places due to improper maintenance. Usually decentralized systems like septic tanks are considered as temporary solutions awaiting centralized treatment; many systems are not properly designed and maintained. Hence, it is essential to develop policies, programs, guidelines, and institutions to ensure the proper design, construction as well as operation and maintenance of decentralized wastewater treatment systems. While preparing building codel, scientific knowledge need to be incorporated based on the localities to decide the distance between decentralized wastewater management systems and drinking water sources. With rapidly increasing population and decreasing water resources, wastewater is becoming a significant resource. Accordingly, there is a substantial need for more integrated management of decentralized wastewater treatment systems. An integrated management approach include economical, social, technical and environmental dimensions which need to be taken into consideration. Need and system requirement for wastewater management vary from country to country and locality to locality. Proper management of waste management systems are essential for protecting public health and local water sources, increasing the property value and avoiding expensive repairs. The major problems associated with the management of decentralized wastewater treatment systems include

- Funding
- Public involvement and awareness
- Inappropriate system design and selection processes
- Inadequate inspection, monitoring and program evaluation

As mentioned earlier, from the inception stage to planning, design, execution, operation and maintenance, participation of local people are essential for the successful management of decentralized wastewater management systems. An effective management program can reduce the potential risks to public health and the receiving environment during the installation, operation and maintenance phases of the decentralized wastewater treatment system. Rigorous management strategies are essential for high-risk areas. However, simple awareness and education programs for the local people may be sufficient for non sensitive areas. It is essential to carry out integrated risk assessment regularly to manage and mitigate any emerging problem. Environmental policies should be integrated with development planning and regarded as a part of the overall framework of economic and social planning. Even when laws are well drafted and jurisdictional mandates are clear, implementation problems arise primarily when environmental requirements target economically important activities particularly those owned by the government. Thus, institutional arrangements would be needed to implement these environmental control policies.

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Green House Gas (GHG) Emission from Waste Sector and Clean Development Mechanism (CDM) Implementation in India: An Overview

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INTRODUCTION

The increase in concentration of Greenhouse gases (GHGs) in the atmosphere in the last 100 years, mainly due to anthropogenic activities contribute to global warming and climate change. Important GHGs are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6). Although water vapor is also an important GHG, since water vapor concentrations in the atmosphere do not have any harmful effect on humans, it is not generally considered. GHGs are transparent to incoming solar radiation, but opaque to outgoing long wave radiation, an increase in the levels of GHGs could lead to greater warming. GHGs differ in their warming influence (radioactive forcing) on the global climate system due to their different radioactive properties and lifetimes in the atmosphere. These warming influences may be expressed through a common metric, Global Warming Potential (GWP), based on the radioactive forcing of CO_2. The global warming potentials of major GHGs are given in Table 1. Studies have observed that over the 20th century, the mean global surface temperature increased by 0.6°C (IPCC, 2001). The precipitation has become spatially variable and the intensity and frequency of extreme events like flood and drought has increased. The sea level also has risen at an average annual rate of 1–2 mm during this period. The continued increase in concentration of GHGs in the atmosphere is likely to result in large changes in ecosystems, leading to possible catastrophic disruptions of livelihoods, economic activity, living conditions and human health.

The international debate on climate change is highly influenced by studies that estimate the GHG emissions trajectories of the developed nations. These studies were based on detailed energy-economy models that project global and region or country-wise GHG emissions and have often applied assumptions and techniques that do not reflect the ground realities of the developing countries. In order to formulate a fact-based perspective on climate change in India, the Government of India through the Ministry of Environment and Forests (MoEF), has supported a set of independent studies by leading economic institutions under the initiative 'Climate

Table 1

The global warming potential of major GHGs

Greenhouse gas	*Global warming potential	Atmospheric life (years)
CO_2	1	5 to 200
CH_4	21	12
N_2O	310	114
HFC	140 to 11,700	1.4 to 260
PFC	6,500 to 9,200	10,000 to 50,000+
SF_6	23,900	3200

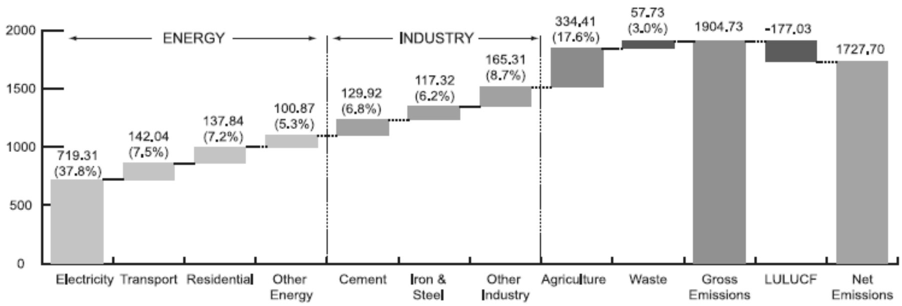
*Based on the heat trapping abilities and the time the gas stays in the atmosphere (IPCC, 2001)

Modeling Forum, India (MoEF, 2009). This initiative is aimed at better reflecting of the policy and regulatory structure in India, and its specific climate change vulnerabilities. These studies used distinct methodologies, based on the development of energy-economic and impact models that enable an integrated assessment of India's GHG emissions profile, mitigation options and costs, as well as the economic and food security implications.

India's GHG Emissions Profile

India ranked fifth in aggregate GHG emissions in the world, behind USA, China, European Union and Russia in 2007. The GHG emission of India is nearly one fourth of that of USA and China and the emissions intensity of India's GDP declined by more than 30% during the period 1994-2007. GHG emissions from Energy, Industry, Agriculture, and Waste sectors constituted 58%, 22%, 17% and 3% of the net CO_2e emissions respectively (Fig. 1). Between 1994 and 2007, India's GHG emissions without Land Use Land Use Change and Forestry (LULUCF) have grown from 1251.95 million tons of CO_2e to 1904.73 million tons of CO_2e at a compounded annual growth rate (CGAR) of 3.3% (MoEF, 2010). A comparative analysis of GHG emissions by various sectors is shown in Table 2. However, per capita emissions are very much lower than those of either developed countries or other major developing economies. For example, in 2006 India's per capita CO_2 emissions from fuel combustion (not total emissions) was estimated at 1.13 tonnes, compared to 4.28 for China, 8.07 for European Union, 19.0 for USA and 4.28 for the world average (IEA, 2008). The preliminary findings of the initiative 'Climate Modeling Forum, India' (MoEF, 2009) shows that India's GHG emissions in 2031 may vary from 4.0 billion tonnes to 7.3 billion tonnes of CO_2e.

But as India continues its rapid industrialisation, it is clear that the country's emissions will play an even larger role in the future. Long-term scenarios for India vary but all show a sustained increase in carbon dioxide emissions over the next century (Sukhla, 2006). This highlights urgent need for significant endogenous technological change in all scenarios, including improvements in current technologies and introduction of new and clean energy technologies and resources.



(Source: MoEF, 2010)

Fig. 1

GHG emissions by sector in 2007 (million tons of CO_2e)

Table 2

A Comparison of GHG emissions in India between 1994 and 2007

Sector	GHG emissions (in million tons of CO_2e)		
	1994	**2007**	**CAGR (%)**
Electricity	355.03 (28.4%)*	719.30 (37.8%)*	5.6
Transport	80.28 (6.4%)	142.04 (7.5%)	4.5
Residential	78.89 (6.3%)	137.84 (7.2%)	4.4
Other Energy	78.93 (6.3%)	100.87 (5.3%)	1.9
Cement	60.87 (4.9%)	129.92 (6.8%)	6.0
Iron & Steel	90.53 (7.2%)	117.32 (6.2%)	2.0
Other Industry	125.41 (10.0%)	165.31 (8.7%)	2.2
Agriculture	344.48 (27.6%)	334.41 (17.6%)	-0.2
Waste	23.23 (1.9%)	57.73 (3.0%)	7.3
Total without LULUCF	**1251.95**	**1904.73**	**3.3**
LULUCF	14.29	-177.03	
Total with LULUCF	**1228.54**	**1727.71**	**2.9**

*Percentage emission from each sector with respect to total GHG emissions without LULUCF

(Source: MoEF, 2010)

National Action Plan on Climate Change

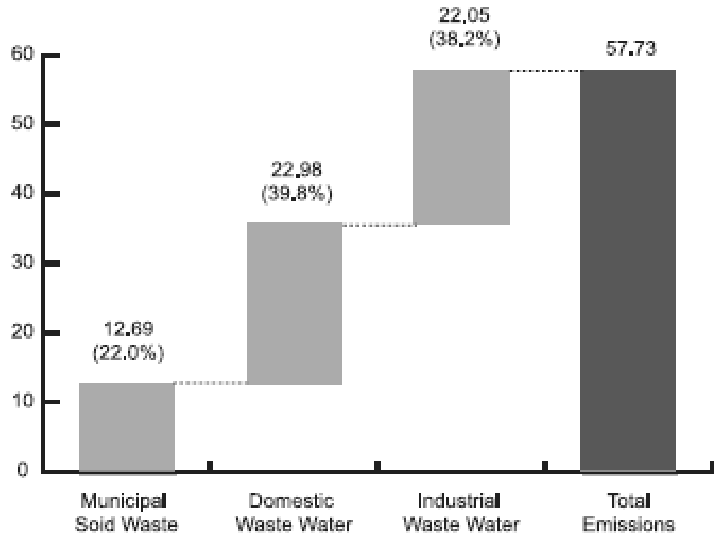
The emission intensity of India's economy in 2006, estimated at 0.34 kgCO_2 per US$ GDP (at 'Purchasing Power Parity', 2000 prices), was roughly equal to the emission intensity for European Union (0.33 kgCO_2) and below the world average (0.49 kgCO_2) (IEA, 2008). In July 2007, Prime Minister Manmohan Singh publicly committed to ensure that "India's per capita emissions never exceed the per capita emissions of the industrialized countries" (GOI, 2008). While an important statement of intent, without a legal basis either domestically or internationally to motivate compliance it is at this stage largely symbolic. India's strategy for tackling climate change while pursuing development is set out in its National Action Plan on Climate Change (NAPCC), released in 2008. It includes a target to reduce the emissions intensity of India's economy (per unit of GDP) by 20% between 2007/08 and 2016/17, also articulated in the Eleventh Five Year Plan (2007-2012). The NAPCC has the following eight National Missions at its core:

- National Solar Mission
- National Mission on Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Eco-system
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change

GHG Emissions from Waste Sector

Municipal and industrial wastewater having higher BOD values emits more methane under the similar climatic conditions. Organic fractions present in the municipal wastewater are degraded to produce methane. Municipal Solid Waste (MSW) management contributes 14% of total global methane emissions and methane is produced through the natural process of the bacterial decomposition of organic waste under anaerobic conditions in sanitary landfills and open dumps. Landfill gas, a mix of primarily CH_4 and CO_2, is emitted as a result of the restricted availability of oxygen during the decomposition of organic fraction of waste in landfills. Methane makes up nearly 50% of landfill gas, the balance being mostly CO_2 mixed with small quantities of other gases. Methane is the second largest contributor to global warming among anthropogenic greenhouse gases, after carbon dioxide. If the current waste management policies are followed, the methane emission is projected to reach 254 Giga gram (Gg)/year by the year 2025.

In India, the waste sector emissions were 57.73 million tons of CO_2e from municipal solid waste management, domestic waste water and industrial waste water management (Fig. 2; Table 3). It is estimated that the MSW generation and disposal resulted in the emissions of 12.69 million tons of CO_2e in 2007. Waste water management (domestic and industrial waste water) emitted 45.03 million tons of CO_2e (MoEF, 2010).



(Source: MoEF, 2010)

Fig. 2

GHG emissions from waste (million tons of CO_2e)

India, Pakistan and China turn out to be the lowest contributors in terms of per-capita methane emission. Although per capita methane contributions in the developing countries are found to be lower, their gross contributions are still important in view of the larger population size. In US, methane emission has increased from 24.85 million MT (CO_2e) in 1990 to 35.21 million MT (CO_2e) in 2005. During the same time in India, this increase was from 56.90 million MT (CO_2e) to 73.25 million MT (CO_2e). Therefore, methane mitigation strategies are important in the developed as well as the developing countries.

Table 3

GHG emissions from waste sector (thousand tons)

	CH4	N2O	CO2e
Municipal Solid Waste	604.51	-	12694.71
Domestic Waste Water	861.07	15.8	22980.47
Industrial Waste Water	1050.00	-	22050.00
Total	**2515.58**	**15.8**	**57725.18**

(Source: MoEF, 2010)

In India, most of the solid wastes are disposed of by land filling in low-lying areas located in and around the urban centres resulting in generation of large quantities of biogas containing a sizeable proportion of methane. India generates nearly 40 million tons of MSW every year and is expected to cross over 125 million tons by 2030. In order to manage such a huge waste generation, a national policy and legislation for MSW management, titled the Municipal Solid Waste (Management and Handling) Rules, was notified in 2000 (MoEF, 2000) and it came into effect from January 2004. As per these rules, the Urban Local Body (ULB) is responsible for the management of MSW including collection, transportation, treatment and disposal of MSW. However, most ULBs are yet to take initiatives to comply with the Rules due to lack of financial resources, institutional weaknesses, and improper choice of technology. ULBs are spending most of their funds on collection and transportation with minimum focus on treatment and disposal of MSW. As a result, the current practices of the uncontrolled dumping of waste on the outskirts of towns/cities have created serious environmental problems including unabated emission of methane. The reduction of CH_4 emissions from landfills would make a significant contribution to the curtailment of greenhouse gas stock.

CLEAN DEVELOPMENT MECHANISM (CDM)

The Kyoto Protocol

In 1992 famous Rio Earth Summit, United Nation Framework Convention on Climate Change (UNFCCC) was adopted with an objective to stabilize atmospheric concentration of GHG at levels that would prevent dangerous humane interference with climate system. The UNFCCC came into effect on 21st March, 1994 according to which industrialized countries shall have the main responsibility to mitigate climate change. A protocol to the UNFCCC, known as Kyoto Protocol, was adopted during COP-3, in December 1997, which enjoins upon the developed country parties to reduce their GHG emissions by a global average of 5.2% below the 1990 levels during 2008-12; which India acceded in August, 2002 and come into force from 16th February, 2005. Developed countries are categorized under Annex 1 countries and are legally bound by the Protocol while the developing nations, categorized as Non Annex 1 countries, which ratify the Protocol, are not legally bound by it.

The Kyoto Protocol has identified Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HPC), Perfluorocarbons (PFC) and Sulphur Hexafluoride (SF_6) as the six main GHGs for setting the targets. Among the six gases identified in the Protocol, CO_2 is the most important one since it accounted for more than four fifths of total GHG emissions from developed countries in 1995. Besides, reductions of CO_2 emissions from fuel combustion, activities in the Landuse Landuse Change and Forestry (LULUCF) Sector such as afforestation and reforestation which help absorption of Carbon dioxide are also included in the Protocol.

The Kyoto Protocol has brought out three flexibility mechanisms for GHG emission abatement namely (i) Joint Implementation (JI), which allows countries to claim credit for emission reduction that arise from investment in other industrialized countries, which result in a transfer of 'emission reduction units' between countries; (ii) Clean Development Mechanism (CDM), through which industrialized countries can finance mitigation projects in developing countries contributing to their sustainable development; and (iii) International Emissions Trading (ET), which permits countries to transfer parts of their 'allowed emissions' - assigned amount units. All these mechanisms are market-based ones; the first two are project based, where as the third one allows the developed countries to sell surplus emission of one country to another developed country.

Clean Development Mechanism (CDM)

CDM is a mechanism for promoting technology transfer and investment from developed countries to the developing countries for projects to reduce the emissions of GHGs. The mechanism allows the governments or private parties of developed countries to make investment for emission reduction projects in developing countries and, in turn, get the benefit in terms of "Certified Emission Reduction (CER)" which could be credited against their national emission reduction targets. A CER or Carbon Credit is defined as the unit related to reduction of 1 ton of CO_2 emission from the baseline of the project activity. Thus, CDM is intended to serve the dual purpose of assisting the developing countries in their pursuits for sustainable development as well as providing an opportunity to the developed countries for contributing towards reduction of global concentrations of greenhouse gases at lesser cost.

In the international agreements, no definition of sustainable development in the CDM-context was determined and no general standard was settled. It is up to the host countries' Designated National Authority (DNA) to control whether a proposed project complies with the national criteria of sustainable development. Only a short section of the Project Design Documents (PDD) that is written for project evaluation of the UNFCCC Executive Board (EB) contains information about the expected contribution of the projects to sustainable development. It comprises aspects related to environmental, social and economic impacts. This information however will not be evaluated by the Executive Board since the EB is only responsible for the compliance of the GHG reduction targets. A typical CDM project would have to go through the process cycle shown in Table 3.

The objective of any CDM project should be to provide environmental and social benefits, as well as to reduce GHG emissions. A host country, upon review of a preliminary project proposal, may require an environmental impact assessment (EIA), which will have to be completed before the project can proceed. If an EIA is required by the host country, or if stakeholder input shows that there are local environmental or social concerns about the initiative, the CDM project should be evaluated using the highest international environmental and social assessment procedures and standards, such as the criteria for hydroelectric facilities prepared by the World Commission on Dams. The host country may also define the types of environmental impacts that would require a full EIA, but, to reduce the risk of delay and negative input from stakeholders, it is recommended that only CDM projects that can meet internationally agreed upon environmental and social standards be considered by project developers and users.

The methodology approval process consists of a desk review by a roster of experts, UNFCCC web site posting for public input, and a recommendation back to the Executive Board from its Methodology (Meth) Panel. The methodology is assessed against the basic requirements for a CDM project in the Marrakech Accords, focusing particularly on baseline definition, additionality, and monitoring protocol. Each baseline methodology must use one of three approaches:

Table 3

Sequence of the CDM project cycle

Activity	Definition	Responsible Entity
Project Development	Developing a CDM project	Project Proponent
Project Design Document	Developing a CDM – PDD	Project Proponent
Project Approval	Approval from Host government	Host Country Designated National Authority (DNA)
Validation of the project design document	Independent evaluation of PDD, including calculations of baseline emissions and estimated project emissions	Designated Operational Entity (DOE)
Registration of the Project	Formal acceptance of a validated PDD	CDM Executive Board (EB)
Project Implementation and Monitoring	Commissioning & operation of the CDM project and measuring & recording project performance related indicators/parameters	Project Proponent
Verification	Periodical independent review of monitored GHG reductions	Designated Operational Entity (DOE)
Certification	Written assurance on the actual GHG reductions verified	Designated Operational Entity (DOE)
Issuance of CERs	Issuance of Certified Emission Reductions (CER), based on DOE's certification	CDM Executive Board (EB)

a) Existing actual or historical emissions;

b) Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or

c) The average emissions of similar project activities undertaken in the previous five years in similar economic, environmental and technological circumstances, and whose performance is among the top 20% of their category.

CDM Eligibility

The eligibility criteria for the CDM projects include the following:

- The projects must be approved by all parties involved
- The project contributes to the Sustainable Development of the host country
- The project results in real, measurable and long term benefits in terms of climate change mitigation
- The reductions must be additional to any that would have occurred without the project

To qualify for credits, GHG emissions from a project activity must be reduced below those that would have occurred in the absence of the project. Without this "additionality" requirement, there is no guarantee that CDM projects will create incremental environmental benefits, contribute toward sustainable development in the host country, or play a role in the ultimate objective of stabilizing atmospheric GHG concentrations. Any CDM project therefore requires the estimation of 'baseline' emissions - "those without the project, less the actual emissions" that will occur after a project has been implemented. Each CDM project must follow a prescribed process to earn certified emissions reductions. For participation in CDM, all countries are required to meet the following prerequisites viz. (i) Ratification of the Kyoto Protocol; (ii) Establishment of a National CDM Authority; and (iii) Willingness for voluntary participation in CDM. In addition to the aforesaid pre-requisites, the developed countries should also comply with the following requirements as stipulated in the Protocol:

- National System for the estimation of GHG emissions;
- National registry and annual inventory;
- Accounting system for sale and purchase of emission reductions; and
- Establishment of assigned amount as per emission limitation and reduction commitment to reduce their overall GHG emission by at least 5 per cent below 1990 levels in the first commitment period of 2008-2012.

India's National CDM Authority

The Ministry of Environment and Forests (MoEF) is the nodal ministry dealing with climate change and CDM issues in India. It established the Designated National Authority (DNA) in December 2003 as the National CDM Authority (NCDMA). The NCDMA is chaired by the Secretary of MoEF. The other members are the Secretary, Ministry of External Affairs, the Secretary, Ministry of Finance, the Secretary, Department of Industrial Policy and Promotion, the Secretary, Ministry of New and Renewable Energy Sources, the Secretary, Ministry of Power, the Secretary, Planning Commission and the Joint Secretary of Climate Change, MoEF. The Member-Secretary of the NCDMA is the Climate Change Director of MoEF.

Status of CDM projects in India

India is generally positive of the CDM concept, though is somewhat critical of its application so far. CDM has generated an additional revenue stream for some private companies, and has also generated interest and awareness about climate change in different strata of Indian society. Industry, in general, is upbeat about CDM and has taken measures to ensure that projects that earn them carbon credits are made known to the public. Amongst the developing nations, India is the second largest beneficiary after China of the carbon trade through the CDM. India was one of the early movers into the CDM market with its first registered project coming within a month of the Kyoto Protocol being ratified. Currently 22.8 per cent of the 2237 projects registered worldwide have occurred in India (Table 4) accounting for 18.8 per cent of Certified Emission Reductions (CERs) issued worldwide (Table 5).

CDM and Waste Management Sector

Among the various sectors, waste management is sector no. 13. There are many large scale and small scale approved methodologies in this sector covering CDM benefits for projects of bio mass, waste water, MSW processing and landfill gas capture. The potential CDM mechanisms that are being applied or can be applied in the MSW management sector in developing countries could be wastes-to-energy such as capturing landfill gas and generate electricity, anaerobic digestion of organic fraction of wastes and production of biofuel or biogas, composting, incineration, and cogeneration as well as minimization of waste volume that would be sent to landfill. This sector is one of the most under-utilized sectors.

There have been waste projects under the CDM since the beginning of the mechanism; many of them are landfill gas projects. Several large scale projects involving advanced

Table 4

Region wise CDM Project Registration

Region	KP parties	Parties with DNA	Parties with project experience	Parties with registered projects	Number of projects**
Annex 1 parties (AI)	40	32	*na	19	na
NAI-Africa (NAI-AFR)	52	46	26	16	45
NAI-Asia and the Pacific (NAI-ASP)	52	39	31	27	1710
NAI-Latin America and the Caribbean (NAI-LAC)	33	28	20	20	469
NAI-Eastern Europe	9	9	7	5	13
				Total Registered Projects	2237
				Total Registered Projects in India	509

* Not available ** as on 09.06.2010 (Source: http://cdm.unfccc.int)

Table 5

Certified Emission Reductions (CERs) issued worldwide

Country	*CER issued	Percentage of total
China	206,761,467	49.24
India	78,894,794	18.79
Republic of Korea	55,156,766	13.13
Brazil	41,398,774	9.86
Mexico	6,606,353	1.57
Others	31,117,456	7.41

* As on 03.06.2010 (Source: http://cdm.unfccc.int)

municipal solid waste treatment technologies including incineration, gasification, and anaerobic digestion and composting have been registered under the CDM. However, these large scale projects have been limited in number as the technologies used are capital-intensive, have high operating costs, are more complicated than land filling and small-scale composting, and are often not sustainable in the developing world. Currently, there are 2237 registered projects of worldwide of which nearly 21 % registered CDM projects are in Waste Management Sector. Out of the 509 registered projects in India, Waste Management Sector constitutes only 4.9 % of the total registered projects (Table 6). In addition to the CDM, there are voluntary carbon market opportunities for landfill gas and other waste sector projects. Table 7 shows the list of registered CDM projects in Waste Management Sector in India.

Table 6

Registered CDM Projects in different sectors

Sectoral Scope	*Projects Registered (World)	*Projects Registered (India)	Percentage of Projects Registered (India)
(01) Energy industries (renewable/ non-renewable sources)	1662	403	24.3
(02) Energy distribution	0	0	-
(03) Energy demand	26	17	65.4
(04) Manufacturing industries	128	65	50.8
(05) Chemical industries	67	6	8.9
(06) Construction	0	0	-
(07) Transport	3	1	33.3
(08) Mining/mineral production	26	0	0.0
(09) Metal production	7	1	14.3
(10) Fugitive emissions from fuels (solid, oil and gas)	136	6	4.4
(11) Fugitive emissions from production and consumption of halocarbons and sulphur hexafluoride	22	5	22.7
(12) Solvent use	0	0	-
(13) Waste handling and disposal	469	25	5.3
(14) Afforestation and reforestation	15	3	20.0
(15) Agriculture	124	10	8.1

* Note that a project activity can be linked to more than one sectoral scope; as on 31.05.2010

(Source: http://cdm.unfccc.int)

Table 7
List of Registered CDM Projects in Waste Management sector in India

Sl. No	Project Title	Reductions *	Registered Date	Ref
1	Methane Extraction and Fuel Conservation Project at Tamil Nadu Newsprint and Paper Limited (TNPL), Kagithapuram, Karur District, Tamil Nadu	35860	14 Jan 06	0124
2	Off gases utilisation from C – 03 washing tower in Primary Reformer as fuel	7226	04 Jun 06	0382
3	3 MW Poultry Litter Based Power Generation Project, Hyderabad	65794	30 Jun 06	0399
4	SIDPL Methane extraction and Power generation project	31966	03 Sep 06	0498
5	"Methane Avoidance by Municipal Solid Waste Processing in the city of Chandigarh, India"	40308	04 Sep 06	0510
6	Avoidance of Wastewater and On-site Energy Use Emissions and Renewable Energy Generation in IFB Agro Distillery unit	70760	08 Sep 06	0496
7	Methane recovery and power generation in a distillery plant	44729	29 Sep 06	0505
8	Avoidance of methane gas emission to atmosphere from C-03 washing tower by effictively utilizing the C-O3 off gas as fuel in primary reformer at Indo Gulf Fertilisers, (a unit of Aditya Birla Nuvo Limited) Jagdishpur	9829	29 Oct 06	0613
9	Methane recovery from waste water generated from wheat straw wash at Paper manufacturing unit of Shreyans Industries Limited (SIL)	12578	02 Apr 07	0935
10	SESL 6 MW Municipal Solid Waste Based Power Project at Vijayawada & Guntur, Andhra Pradesh	64599	15 Apr 07	0959
11	Methane Capture and use as fuel at Rajaram Maize Products, Chattisgarh	4609	05 Jun 07	0945
12	"Forced Methane extraction from Organic wastewater", at Mandya District, Karnataka by M/s Sri Chamundeswari Sugars Ltd.	34424	27 Jul 07	1088
13	The TIMARPUR-OKHLA Waste Management Company Pvt Ltd's (TOWMCL) intergrated waste to energy project in Delhi	262791	10 Nov 07	1254
14	3.66 MW poultry litter based power generation project by Raus Power in India	51353	27 Mar 09	2348
15	Municipal Solid Waste based Composting at Kolhapur, Maharashtra	30430	01 Apr 09	2217
16	Methane extraction and energy generation project activity at Shirala, Maharasthra	16093	02 Apr 09	2399
17	Avoidance of methane emissions from Municipal Solid Waste and Food Waste through Composting	23431	05 May 09	1904
18	Integrated Municipal Waste Processing Complex at Ghazipur, Delhi	111949	23 May 09	2378
19	Upgradation, Operation and Maintenance of 200 TPD Composting facility at Okhla, Delhi	33461	22 Jun 09	2470
20	Establishment of Compost Production Unit of 100 TPD at Lalganj	42050	04 Jul 09	2505
21	Upgradation and expansion of A.P.M.C compost plant at Tikri, Delhi	35329	18 Jul 09	2502
22	Methane recovery from wastewater generated at Paper manufacturing unit of Sree Sakthi Paper Mills Ltd., Kerala	3923	01 Oct 09	2434
23	Installation of Bundled Composting Project in the state of Tamil Nadu	115162	17 Jan 10	2867
24	Gorai Landfill closure and Gas Capture Project, Mumbai, India	124028	07 Feb 10	2944
25	Methane recovery from wastewater treatment at Dwarikesh Sugar Industries Limited (DSIL)	9408	25 Apr 10	3191

* Estimated emission reductions in metric tonnes of CO2 equivalent per annum (as stated by the project participants) As on 31.05.2010 (Source: http://cdm.unfccc.int)

CDM: POST 2012 ISSUES

The parties to both the Kyoto Protocol and the UNFCCC are now considering what to do to accomplish the goal of the UNFCCC after the first compliance period ends in 2012. The CDM set three goals: to produce sustainable development, to help developing countries accomplish the objective of the UNFCCC, and to reduce costs of compliance for parties with quantitative targets. The evidence presented above points to the possibility that the CDM is accomplishing these goals, but only to a limited extent. It also shows that to the extent that developed world resources are to be transferred to the developing world to accomplish climate change mitigation, there may be more efficient ways of doing so than through the CDM as currently implemented. The CDM market as it has developed has failed to encourage, in substantial measure, the addition of low carbon intensity energy infrastructure in the developing world. Analysts have begun to revise downward the number of emission reductions now expected from the CDM due to regulatory delays, unavailability of finance for projects and the fact that some carbon contracts are being canceled as prices have fallen and demand has slackened.

In December 2007, the parties to the Kyoto Protocol and the US, which is not a signatory to the Protocol but is a signatory to the UNFCCC, signed onto The Bali Roadmap which called for worldwide agreement on an extension or a successor to the Kyoto Protocol. The Bali Roadmap calls for this goal to be reached by the annual meeting of the parties to the UN Framework Convention on Climate Change in Copenhagen in December 2009. But COP 15 failed to get a legally binding agreement or certify specific targets to reduce GHG emissions and participants proposed limiting global warming to 2^{o}C. In the meantime, negotiations are ongoing and parties are working hard to address the many issues involved. These include whether developing countries that are large emitters (especially China, India, Brazil) should have targets, what can be done to scale up reductions under the CDM, and new mechanisms to create emission reductions that can be linked to new national regulatory programs in the US, Australia and elsewhere.

CONCLUSION

Despite the uncertainty post 2012 and the economic decline across the world, the carbon market has continued to stimulate sustainable development in the developing world. The carbon compliance market totaled $126 billion dollars in 2008 and the historical data indicate that European buyers remain the dominant buyers in the compliance market with most of the buyers coming from the private sector (90%) and the balance (10%) from governments (Capoor and Ambrosi, 2009). The US, which produces 25% of the global GHG emissions, appears to be finally accepting responsibility to join the rest of the world in regulating GHGs. Despite a current downturn in the GHG markets due to the economic slump, all indications are that the compliance and voluntary carbon markets will grow significantly in the years to come. There will be significant opportunities for additional offset projects including projects in the waste sector.

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Municipal Solid Waste Management: A Framework on Legal Responsibility of Local Government

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INTRODUCTION

Management of solid waste is the most important component in the public health and environment sanitation concern of a modern society. It is the responsibility of the Local Government Institutions to Conceive, Constitute, Implement, Monitor and Manage Solid Waste Management Programme and it is an obligatory function of the Local Government Institutions according to the existing laws and corresponding rules.

Different initiatives, decisions and programmes have already initiated in many of the Urban Local Bodies in India for the said purpose, especially for collection, storage, transportation and disposal of solid waste. But there was no attempts made with comprehensive conceptual and practical perspective. There was no public support or participation towards those measures in waste disposal. Lack of scientific, technological and environmental planning and implementation of such activities, created much criticism also. Different environmental issues, health problems, chances for epidemics, economic crisis and managerial problems are involved in Municipal Solid Waste Management Programmes. Hence, it necessitates a number of measures including reduction of waste through regulating consumption, segregation of waste at the source itself, collection, storage and transportation with strict adherence to the corresponding rules, bio-degradable waste can be converted in bio-fertilizers or manure and non-degradable waste materials shall be subjected to effective recycling or disposal measures which are less harmful both to the human environment and natural environment at large.

A Legal perspective and policy shall be formulated to achieve the goal of scientific solid waste management. These aspects are briefly dealt here from the experience of implementing a perspective planning for SWM in Thiruvananthapuram City Corporation.This can be taken as a basic experience for other ULBs with similar nature. A deliberate attempt was made here to evolve a strategic policy framework proposal with respect to the responsibility of ULB in Solid Waste Management.

Policy Approach

Even though solid waste management and liquid waste disposal are the obligatory functions of LSGI, waste management can not be administered only by the LSGI without the assistance, support and co-operation of the Local Public Officials, Elected Representatives, Voluntary Workers, Technical Experts and Media persons. LSGI shall take an initiative to evolve locally adaptable, acceptable and enforceable methodology for waste management with public partnership and participation (a kind of Public-Public Partnership-PPP) with leadership of elected representatives and effective co-ordination and co-operation of experts in the concerned fields and ownership of the concerned Local Government Institutions. Implementation of the scheme shall be useful to generate employment opportunity and income generation source for the weaker sections of the society in order to integrate it with poverty alleviation and employment assurance schemes. It shall be made a genuine effort to built up an indigenous, dynamic,sustainable, operational system as an 'alternative and self depended programme with reasonable, rationale and efficient measures for Municipal Solid Waste Management (MSW).

Analysis of Scenario

Thriuvananthapuram City Corporation, though it had established the first MSW Management Plant at Vilappilsala in 2000, was failed to administer its responsibility due to different reasons like proper management of infrastructure for segregation of wastes, collection,transportation and processing,sanitary landfilling of the left out after processing,etc. It also had problems due to the attitudinal constraints of both the local community as well as functionaries of the ULB and the grama panchayat, where the Ptocessing Plant is located. The Environment Impact Audit of the existing system of MSW Management shows that the following are the issues which seek urgent interventions from concerned authorities in the Thiruvananthapuram City Corporation.

- Absence of appropriate segregation and direct collection mechanism of the sources themselves.
- General public attitude towards waste materials and the general trend to dispose off them in public places or streets.
- Drainage blocks due to restraint of channels by plastics and such other waste materials.
- Unscientific disposal of waste collected and stored by certain groups mainly engaged by Residents Association or Kudumbasree groups in particular localities.
- Constraints to treat the waste materials due to unscientific measures of collection and transportation.
- Impossibility to differentiate degradable and non-degradable materials and incapability to subject the waste materials for bio-degradation process.
- Environmental hazards and health problems including causing of contagious diseases due to interim dumping and reloading of waste materials in open yards and transporting them in open careers.
- Inadequacy and ineffective administration of waste management in Hospitals, Slaughter Houses, Markets, Flats and Hostels, Community Hall etc.

- The unhealthy practices and conditions generated due to transportation problems.
- Lapses in the proper administration and conduct of functions in the treatment plant, and the after effect of such lapses suffered by the local people in their day to day life.
- Leaching and logging of waste water in the nearby locality of the treatment plant.
- Continuous socio-political resistance against the existing waste management mechanism in the city.

Hence a framework with remedial measures, to evolve a participatory, self dependent, scientific, environmentally sound and pollution free process for MSW management system for the City has been formulated through the involvement of the experts, policy-decision makers and people's representatives in the Corporation. Essentially it is a framework based on the Reduction, Reuse, Recover, Replace, Recycle policy.

The said programme with the major elements may distinguish the present project from all other efforts in this regard in the history of the capital city. It is evident from the higher rate of public support, considerable co-operation and effort of the officials and employees, voluntary activities, elected representatives and technical experts with a common vision and mission. Leadership and ownership of the elected representatives, valuable contributions made by voluntary experts and technical personnels in planning, environment creation, implementation, monitoring and feed back analysis of the process are unique features. Public support from the residents associations, print and electronic media, socio-political organizations, community based organizations and academic institutions are also to be cited in this regard.

One of the most important factor for the solid and liquid waste management programme in any urban local body is the formulation of suitable policies and legal framework for implementation. Enforcement from the part of the ULBs is important alongside the implementation of different activities and components of SWM. Thiruvananthapuram City Corporation also faced problems due to the lack of clear vision on the legal responsibility and framework especially in the context of Municipal Solid Waste(Management and Handling Rules)2000 and the 74th Amendments and the policy and legal framework formulated based on these.This paper briefly analyses the policy and legal aspects related to solid waste management in ULBs with the special experience from Thiruvananthapuram Corporation.

LEGAL RESPONSIBILITY OF LSG IN MSW MANAGEMENT

Right to clean and healthy environment is one among the basic rights provided to a citizen by the Constitution itself[1]. Right to Environment is an inevitable, indivisible part of the right to life and livelihood of human being. Right to clean drinking water, safe and healthy environment, clean air and light, shelter, healthy workplace etc., are incorporated as new generation rights, into the core of the Constitution[2]. The efforts made by Green Lawyers, Green Judges and Green Legislations have considerably contributed in this regard.

Responsibility of the state to protect secured status and opportunity to its citizens

[1] Part III Article 21 of the Constitution of India 1950.

[2] Judgments pronounced by the Supreme Court of India and other Higher Courts during the period form 1985 – 2000.

was also established in the Constitution. Duty and obligation of the state to protect and maintain the social security measures to establish a healthy and empowered society with man and women and youth is also evident there[3]. In addition to this, the state has higher rate of obligation to constitute, establish and manage programmes for the betterment of public health, social security and living status of people. State also has the responsibility to mobilize resources for the same[4].

According to the corresponding provisions of the Constitution, it is stated that every citizen has a responsibility and duty to maintain the natural environment, clean atmosphere and protect forest and wildlife etc[5]. Hence, it is evident that individual human being is also responsible for supporting the waste management programmes through complying with its rules and regulations. Their violations may create public nuisance as well as result in other forms of offences. Laws imposes penalty to those who cause such negligent act or omission, or commit such offences resulting annoyance or inconvenience to the general public at large or who are residing in the vicinity.

The Corporation has intended to enforce above said rights , duties and obligations of the individual, and the state which is officiated through the Corporation. Steps taken by the Corporation is an innovative attempt to utilize the powers and responsibilities vested with the LSGI in order to perform the function entrusted to it in MSW management through a scientifically planned, socially supported and locally adaptable process developed by an action research and voluntary consultancy which is owned by and accountable to the general public.

MSW Management is an essential function of LSG according to the existing laws and rules[6]. By those provisions, the ownership of all kinds of solid waste produced within the territorial limits of the ULBs (Corporations/Municipalities) is vested with them itself. Hence, the primary responsibility to dispose of such waste is also vested with the ULB. The ULB has an ultimate responsibility not only to manage but also to the final disposal of the MSW[7] and has the power to seek reasonable and appropriate method to perform those responsibilities and it can even sell out the liquid-solid wastes generated or accumulated within its jurisdiction in order to dispose off such materials. ULB is also empowered to reform or revise any of such waste management system as part of its responsibilities and has the power to introduce adequate measures for the collection, storage, transportation, and final disposal or management of solid-liquid waste generated, produced in or discharged into any public place or private premises with in its local jurisdiction. The ULB is also empowered to issue directions or orders to the owner or occupier of any private land or building to install and maintain such measures to ensure proper waste disposals from such premises[8]. It can also make an effort to regulate and control solid– liquid waste disposal to any unoccupied land or premises and for proper

[3] Part II Article 39 of the Constitution of India 1950

[4] Rothlam Municipal Corporation V. Vasdhichand 1980 SC.

[5] Article 51 A (f), (g) of the Constitution of India (42nd Amendment Act 1976)

[6] Corresponding provisions of Kerala Municipalities Act (1994) and Municipal Solid Waste Management (Management and Handling) Rules (1995)

[7] Sections 209, 330 and 333 of the Kerala Municipalities Act 1994

[8] Sections 326, 327 of the Kerala Municipalities Act 1994

management of the same with scientific measures. They may impose any charges or fees so as to meet any such expenses incurred due to the performance of the said responsibilities from the owner or occupier such land or premises[9].

It is also relevant that the Corporation/Municipality has a power to prevent solid waste disposal in private premises, and storage or discharge of liquid– solid waste materials or effluents in to any private land in any illegal or unlawful method or disposal of animal waste inclusive of leather , flesh and blood, and usage of unfit vehicles without proper coverage for transportation of any such waste materials[10].They have a power to prohibit discharge of waste into public canals or path ways or public places which may cause annoyance or nuisance to the people at large. It is also empowered to prevent its servants from disposal of waste materials in places which are not permitted for the same purposes[11].

ULB has power to delegate and authorize its officials to enter in to or inspect or investigate the said violation of laws, rules and prescriptions if any caused or apprehended and also to impose penalty against whom the responsibility is fixed in this regard[12].

The ULB can impose regulation on and implement remedial measures to manage or to control disposal of solid waste in unoccupied premised also[13]. It can also impose control on using non- permitted, unscientifically designed and uncovered vehicles for transportation of waste materials including waste from slaughter houses[14].

The ULB has power to prohibit and prevent causing annoyance and inconvenience to the people and committing public nuisance through open disposal or discharge of solid waste or collection, storage and disposal of waste materials in unauthorized places and in unauthorized manner. It can impose such orders even against their servants[15].

Judicial Direction on Municipal Solid Waste Management

Certain other powers are also vested with the Corporations/Municipalities under the directive issued by the Supreme Court[16] contains those provisions such as:

i. Notify any place within in or outside the territorial jurisdiction of the ULB as dumping yard or disposal yard for MSW produced from the ULB area and utilize such place for the said purpose.

ii. Install measures for treatment of the bio -degradable waste materials to aerobic

[9] Sections 334 of the Kerala Municipalities Act 1994
[10] Sections 335 – 339 of the Kerala Municipalities Act 1994
[11] Section 340 – 343 of the Kerala Municipalities Act 1994
[12] Sections 343 – 345 of the Kerala Municipalities Act 1994
[13] Section 334 ibid
[14] Sections 335 – 339 ibid
[15] Sections 340 – 343 ibid
[16] Almitra H. Patel v Union of India (1996 SC)

or anaerobic process so as to convert it in to organic manure and sell out the bio-fertilizer under feasible prices.

iii. Dispose off hazardous bio-medical waste materials from hospitals and medical institutions through any appropriate technology including incineration method.

iv. The ULB can entrust or engage any agency within public, private or corporate sector in order to deal with responsibilities and delegate functions related to MSW management in commercial basis under direct or indirect agreement.

v. The ULB has power to issue appropriate notices, directions and orders to owner, occupier or manager of any industry, workshop, manufacturers, commercial or shopping centres, market places, godown, hotels, slaughter houses, hospitals and nursing homes, community halls, flats etc. in order to obey and enforce the corresponding measures in this regard. If it is not so performed ULB itself can carry out the function and collect the cost incurred due to the function, and fine from the concerned persons through revenue recovery procedure.

vi. Penalty at the rate of Rs. 10,000/- is to be imposed on any person acts against or not complying or causing violation of any such orders and who may be imposed with an additional fine of Rs. 100/ day for continuation of the offence.

vii. The ULBs have power to establish appropriate facilities for segregation, collection, storage, treatment and management of MSW, and for cleaning of public streets and public places, including domestic waste, ashes, solid waste, dust, debris, building waste, industrial and hospital wastes etc. without causing public nuisance or inconvenience.

viii. It can also prohibit any act or omission contravening the said orders and directions.

ix. In case of violation, it can impose spot fine of Rs. 250/- and if there is a failure to obey such orders with in 15 days, it can initiate prosecution against the concerned person. In the absence of actual culprits, the owner or occupier of the land can be apprehended responsible for the said offences.

Citizen's Responsibility

In order to perform the functions and responsibilities vested with the LSG under the existing laws, regulations and judicial decisions, higher rate of social commitment and public co-operation are essential. Hence it is relevant to fix the legal responsibility of individual or collective responsibility of citizens in this regard, such as;

- Obey the orders, directions and guidelines, bye-laws issued by the LSG.
- Not to dispose off solid waste in those places which are not mentioned for that purpose including public street or public places.
- Use segregation process in collection and storage of domestic waste.
- Dispose waste materials in places mentioned for the same only in the prescribed manner.
- Building wastes and debris, garden waste, etc., shall be disposed off with prior permission and only in the permitted manner.
- Participate and support MSW management programmes.

The Supreme Court has issued orders on mandatory and directory guidelines so as to establish the responsibilities of the State, the LSG and the citizens according to the recommendations given by the national level expert committee constituted by the Supreme Court.

FUTURISTIC APPROACH

There can be an important finding from the scenario analysis that there is no authoritative guideline or byelaws prescribed, resolved or published by the ULBs for the MSW Management functions. Such a prescription shall be enforceable under the existing law[17] and only the LSG or its official authorities can perform their duties with legal support and mandate. The guideline shall incorporate adequate provisions to deal with management and handling of industrial or commercial waste, building material debris, and bio-medical waste[18].

Following elements shall be incorporated with in the primary objective of such a guideline.

- Emphasis on the approach of Recover, Reduction, Reuse, Recycling, Replacement of waste at the source itself.
- Relevance to segregation, collection, transportation and treatment in scientific, adaptable, participatory and lawful process.
- Policy guidelines for permitting public, private and voluntary agencies to perform associated functions.
- Policy guidelines in contractual agreements and responsibilities there under to each parties involving in waste management process.
- Establishment of dumping yards, waste process units, sanitary landfill, capping and closure of such yards etc. including any collaboration in this regard.
- Constitution of expert consultation committee and public participation committee for monitoring and evaluation of the schemes.
- Assure openness, transparency, performance of citizen's charter, and public accountability in MSW Management process.

Legal Frame Work

The concerned LSG shall prepare a P3 guideline, with partnership and participation of public in this respect with following components. It shall be drafted with the assistance of experts in different fields, recognized by the elected local body, and implemented through the official functionaries of the LSGI with effective support of the local society.

Structure of the Guideline:

- Objective Clause – Legal Frame Work, Applicability and Enforcement.
- Definition Clause – Comprehensive and inclusive with multiple orientation.
- Segregation, Collection, Storage and Transportation Mechanism.

[17] Municipal Solid Waste (Management and Handling) Rules 2000 under Environment (Protection) Act 1986

[18] EP Act 1986

- Obligatory functions of the LSG, Committees, Officials, Contractors, Agencies, Employees and Citizen as well as Institutions.
- Implementation and Enforcement Network.
- Penalty and Corrective measures
- Grievances -Disputes Redressel Mechanism
- Schedule on Fees, Charges and Functional expenses.
- Annexure if any
- Responsibilities, Duties and functions shall be prescribed in a legally enforceable and practically viable manner in respect of;
    - The Elected Representatives and the Municipal Council
    - The Steering Committee
    - The Health and Education Standing Committee
    - The Ward Committee and Ward Sabha
    - The Functional Committee
    - The Officials including the Secretary, the Health Officer, Health Supervisor Health Inspectors and the Employees
    - The SHG volunteers who are incorporated as Voluntary Environment Guard (VEG)
    - The Waste Management Agency enters into a contract with the LSG
    - The Individual Citizen
    - The owners and occupancies of different premises and institutions

MoU between LSGI and Independent Contractor

There shall be adequate legal preparation and frame work for the establishment, management and maintenance of the institutionalized mechanism for MSW management measures. Stipulate the basic structure and provisions of MoU which can be derived in between the LSG and independent contractors in MSW management activities. The responsibility, rights, powers and liability of the contracting parties shall be specified there under.

- Monitoring, feed back and correctional measures and the provisions for the same shall be incorporated with;
    - Continuous Performance Audit and Technical Environment Impact Audit
    - Time bound Social audit with the participation of the different stakeholders
    - Financial Audit by the authorized agencies under the law for the time being

Good Governance Measures

- Right to Information,Transparency provisions with adequate functional responsibility shall be incorporated
- IEC component shall be incorporated as an essential function of the LSG, Ward Sabha, Neighbourhood Groups (NHG).

- Grievance Redressal Services, Dispute Redressal Mechanism, structures, powers, functions and procedures for the GR_DR system shall also be incorporated.
- Penal Provisions corresponding to the law for the time being shall be incorporated along with reformative, restrictive, preventive and retributive measures as part of the penalties and their imposition. Procedural formalities, along with summary procedures and Natural Justice Prescriptions shall also be incorporated therewith.
- A Citizen's Charter in this regard shall be prepared, published, and shall be revised for every year and disseminated among the people, as a part of the mandatory function of the LSG.
- Research, creative technology adaptations, local level technology utilization priorities and funding shall also be incorporated within the framework of the guideline.

BYE-LAWS ON MSW MANAGEMENT

The existing legislation, under Environment Protection Act and Rules, Local Government Enactments adequate provisions are there to empower the LSGI in order to prepare, pass, publish, and enforce bye-laws on MSW Management according to the prior concurrence and approval of the State Government. Such a bye-law may include details regarding the said MSW management process, powers, functions and responsibilities of different authorities and agencies in this respect, duties and responsibilities of the functionaries, rights and liabilities of individual citizens and their collectives, accountability, grievance redressal and social audit on the effective implementation of the said bye-laws. As part of the present initiatives, Thiruvananthapuram City Corporation has evolved detailed bye-law through a number of technical and social deliberations, informal and formal consultations, opinion creation among general public and experts, formal presentment and recognition of the corporation council and legal ratification of the State Government.

Waste Management: A Time Tested Public Health Tool

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INTRODUCTION

The rise and fall of public health is closely related with our understanding and approaches to the hygienic and sustainable means of dealing with the filth and rubbish that naturally gets accumulated around human dwellings. In a wider sense our ability to deal with wastes can be considered the most deciding factor in human survival and progress. In early eighteenth century industrial upheavals have resulted in urbanization in most of the western nations of the world. The enormous progress in industrial, social and political developments in the mid-eighteenth century Europe has brought in urbanization. Along with its many advantages, congregation of people in the crowded cities brought forth many challenges to the system, especially in providing of basic amenities like water, shelter and sanitation to all. The problem was not limited to the poor folk as evident from the "great stink in Paris" in the 1880's. The practice of manual removal of human excreta from the rudimentary toilets in the affluent houses, and the unscrupulous practice of throwing them into the sewerage channels meant for storm water passage and the resultant havoc had paved way to sanitary awakening in Italy(Barnes, 2006). Similar initiatives occurred in most other leading nations of that period propelled by earnest efforts from farsighted personalities like Johann Peter Frank in Germany, Jeremy Bentham and his disciple Edwin Chadwick in United Kingdom and Louis Pasteur in France(Barnes, 2006). The emergence of bacteriology under the crusade of Louis Pasteur in France and Robert Koch in Germany during the nineteenth century gave the much needed empirical bases to public health, especially the germ theory, which was the leading philosophy of public health in its formative years.

Identification of the mosquito vector of malaria by Ronald Ross in India in 1897 and the vector of yellow fever by Walter Reed in Cuba has resulted in successful control initiatives of these tropical menaces giving way to much economic and developmental progress, as in the completion of the Panama canal. Most of the newly formed or freed nations, like India, had acquired the public health infrastructure and legacy from their colonial rulers and introduced much restrictive legislation in tune with the public health philosophy of that period.

In contrast to the state patronage of public health initiatives in Europe, it was Non-Governmental Organizations (NGOs) and the academic institutes that took up the task in United States in the early twentieth century. The impetus given by the Rockefeller Foundation, the Harvard and the Michigan Universities and the establishment of London School of Public Health and Tropical Hygiene and schools of public health at John Hopkins, Harvard, etc., brought in more diversity and scientific acumen to the discipline in the US; late starters always have the advantages of learning from their predecessors. However the basic premise of focus on sanitation and environmental modification has not changed, although more emphasis is given nowadays to the macro-environment than to the immediate/domestic environment in earlier times.

So, waste management (basic sanitation) had been the immediate felt need for the establishment of the ancient public health initiatives and ironically that continues to be one of the most pressing concerns to public health till date. Archeological studies reveal that ancient civilizations in Asia, Europe, Africa and South America had built good and functioning sewerage systems for their townships. Urbanization has undoubtedly helped humanity a lot by bringing together more talents and expertise and providing a congenial atmosphere for innovation and entrepreneurship(Brockerhoff, 2000). Even hardcore green romanticists cannot deny the fact that urban cities are the economic engines of our countries, including the developing nations, contributing to 60-80 percent of their Gross Domestic Production. But if we want to reap the full advantages of urbanization, we ought to build suitable mechanisms for the scientific and safe management of the enormous amounts of waste generated by the crowded populations.

DEFINITION OF WASTE

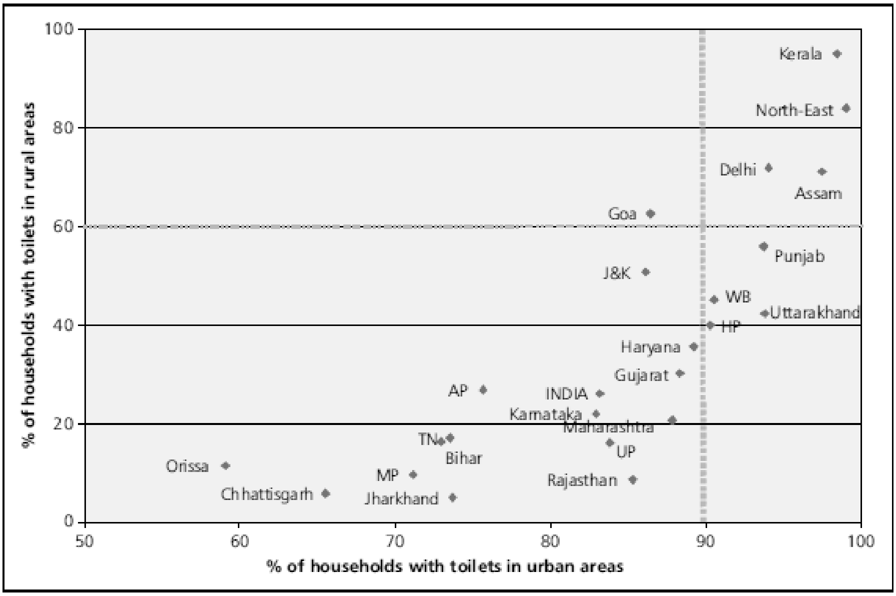
Present day human civilizations flourish on what they produce. Urban settings help us to produce so many things, which would have been impossible in a distributed society. The facilities and possibilities brought together by urbanization, of multiple skills, talents, ethnicities and cultural diversities and the requisite infrastructure and resultant leisure time helps in innovation. Quite naturally in the process many unwanted things would also be produced which needs to be cleared off. Waste can be defined as anything discarded by an individual, a household or an organization(Rushton, 2003). Naturally only a few among the complex mix of waste is hazardous to us, wherein lays the importance of segregation of waste at its origin itself. Segregation at source will substantially reduce the amount of hazardous waste, making it easier to handle. With proper planning of all aspects of waste management, like generation, collection, processing, transportation and disposal, we should be able to tackle the ill effects of the waste.

Domestic wastes are best segregated into biodegradable and non-biodegradable for the ease of management. It is mainly the biodegradable part of the wastes that demands daily evacuation and management. Segregation of wastes from its generation onwards shall reduce the degradable part of domestic wastes, which need to be removed on a daily basis, by half to one third the quantity which would be a great relief to the overburdened municipal waste management system. Moreover segregation shall improve the quality of the waste products, be it manure, recycled products like plastic pellets etc. Another useful categorization, especially in the context of industrial or bio-medical wastes is segregation into hazardous and non-hazardous wastes. Naturally hazardous wastes demands careful, specialized, thorough and costlier management compared to non-hazardous ones. Segregation at origin shall reduce the quantity of hazardous wastes substantially (one eighth to one tenth). One high power committee that studied the situation in United Kingdom calls for further sub classification of industrial wastes into hazardous, with high hazardous potential, moderate hazardous potential, and low hazardous potential and non-hazardous wastes(Henderson et al., 1999).

HEALTH HAZARDS

Hazards associated with waste depend upon the content and the means of management. Waste is a mixture of different materials, mostly in small and insignificant quantities except for a few items, depending on the site or means of production. Wastes are broadly classified by their physical, chemical and biological characteristics. Municipal wastes, domestic wastes, industrial wastes, mining field wastes, etc., that contain less than 70% water are considered solid wastes whereas industrial or municipal waste waters containing less than 1% of suspended contents are considered liquid wastes. American regulatory body classifies wastes into nonhazardous, hazardous and special. Nonhazardous wastes are those that pose no immediate threat to human health and/or to environment like municipal wastes, household garbage, high volume industrial and agricultural wastes(Suk, 2008). Hazardous wastes are those that pose toxicity to living organisms either because of its contents, or because it is generated by treatment of hazardous substances or because it got into contact with another hazardous element. Bio-medical wastes, the wastes generated from healthcare settings that contain infectious, radioactive or other toxic materials are considered a special category of hazardous wastes requiring special attention in its disposal. Till recently the third category of industrial waste in the West has been Special wastes, including mine spills, oil field wastes and other radioactive wastes that require special and individualized attention in their disposal. Recently they are being subcategorized into three based on their hazardous probabilities like ignitability, corrosiveness, reactivity and toxicity(Suk, 2008). Mismanagement of wastes results in waterborne diseases, airborne diseases, vector-borne diseases, zoonoses, radio-active hazards and difficulties with pests and stray animals. The methods adopted should suit the composition of the waste and the context of the situation. Over enthusiasm in disposing the entire wastes through the final, ultimate waste disposal means can turn to be counter productive, as there is not a final and ultimate way of disposal of wastes. One should weigh out the options based on ecologic sustainability as well as economic pragmatism(Lomborg, 2001).

The health hazards related to mismanagement of wastes could be immediate and direct ones like food borne or waterborne infections which are caused by cross contamination of the wastes with human excreta. It has been noted that, areas which lack proper waste management systems lack basic sanitation also. This fact is exemplified by Fig.1 which shows that only four states in India has achieved the goal of basic sanitation coverage(60% for rural areas and 80% for urban areas) as per the NFHS-3 report (Banu and Kim, 2009). Decomposition of organic wastes result in fly breeding which will aid in the mechanical transmission of pathogens into our food materials, causing diarrheal diseases, typhoid, poliomyelitis, worm



AP = Andhra Pradesh, HP = Himachal Pradesh, J&K = Jammu and Kashmir, MP = Madhya Pradesh, TN = Tamil Nadu, UP = Uttar Pradesh, WB = West Bengal.

Source: National Family Health Surveys of India, 2005–2006.

Fig.1

Status of Availability of Toilets

infestations, etc. Also humped up wastes will attract vermin, rodents, stray animals, etc., resulting in unexpected rise of zoonoses like Weil's disease (rat fever), rabies, etc. The unscrupulous lodging of wastes into storm water drains and other sewerage systems can cause clogging of the system resulting in waste water retention, helping in mosquito breeding, resulting in many mosquito borne diseases like dengue, chikungunya, etc. Discarded plastic containers and other packing materials, thrown here and there can also act as potential breeding ground for mosquitoes. Construction wastes, although looks innocuous in health terms at the first look, can pose serious health impacts when it obstructs the natural flow of storm water, resulting in mosquito breeding. In addition, many often contain radio-active materials like radon which can results in long term health hazards. However, studies on people living near landfill sites, including the infamous Love Canal Landfill in New York City from 1930s to 1970s are not giving any definite conclusion on decrease in birth weights or any congenital anomalies expect for an increase in respiratory ailments to the local residents due to proximity of their residence to landfill sites(Rushton, 2003, Prota et al., 2009).

More literature is available on health hazards of people involved in the waste management; especially from an occupational health angle. There are definite risks inherent in almost all sorts of waste management schemes like incineration, pyrolysis, composting, land-filling, etc; but these should be seen as any other occupational risk. The new and innovative adaptations of technological options have really brought down the occupational hazards associated with waste management(Mattison et al., 2000). Lomborg argues that the risk associated with living near landfill sites are negligible compared to the risk posed by many other industrial activities.6 However, workers involved in the waste handling should use all possible safety precautions as the chance for certain types of cancers (non-Hodgkin's lymphoma and soft tissue sarcoma) are slightly higher among them compared to general population(Prota et al., 2009).

HEALTHY WAYS OF WASTE MANAGEMENT

The motto of healthy waste management principles could be abbreviated as "**Segregate at source & 11 R's.**" We have already discussed the importance of segregation at source. Degradable and non-degradable wastes should be segregated at all levels from households to agricultural to industrial settings. Segregation to hazardous and non-hazardous types is essential in industrial settings including healthcare settings, which requires much more specialized segregation at source itself(Henderson et al., 1999). Recent trends is to sub-segregate these into different items, even for municipal wastes, but we should not adopt that without careful analysis of the practical aspects of implementation, as adherence to complicated schema might not work well with all communities. The R's represent the following eleven important activities.

1. Reduce
2. Reuse
3. Replace
4. Recycle
5. Redesign
6. Resell
7. Rectify
8. Relocate
9. Realize
10. Report
11. Reprimand

Reducing waste requires special attention. It was generally believed that waste generation is an unavoidable consequence of affluence; which is proven to be a wrong concept. Many of the developed nations, with higher per capita waste production like US (2 kg/person/day) and Germany (1.2 kg/person/day) have progressively decreased their per capita waste production by 15-30% of their production during 1980's in response to well conceived ecologic policies. Many others like Japan (1.1 kg/person/day) and France (1.3 kg/person/day) could substantially reduce their waste production to maintain those at the levels in 1980's curbing the increase over the last 2 decades(Lomborg, 2001). The success story of Singapore in reducing their per capita water consumption by 10 liters (165L/person/day in 2003 to 155L/person/day in 2010) over a period of just seven years shall definitely motivate many others to follow sue(Report, 2010). Reuse as a potential means of waste management should be done with caution, ensuring hygiene, but is definitely a progressive step that can be practiced easily. There are many innovative ways of value addition to the discarded products that are being pioneered in various cities and towns of the world which ought to be adapted to our settings. Replacing hazardous substances by eco-friendly options as in using paper cups instead of plastic ones has proved to be very effective alternatives, although its overall carbon footprint needs to be evaluated. Vegetarianism is an example of replacing our foodstuffs with less energy intensive products than meat production, which might give in more dividends in terms of reduction of non-communicable diseases. Recycling is very much an option to address water scarcity, as Singapore presently meets 25-30% of their water demand through recycled water(Report, 2010). Recycling need not be the best option for all sorts of materials but its feasibility can be checked out wherever possible. Redesigning is definitely an option especially in the construction industry. For example, the overuse of cement by the construction industry, which is very energy intensive in its production, by locally available alternatives like clay needs to be explored.The habit of reselling, which is a common practice in many western countries needs to be promoted elsewhere, especially of children's toys, toy cycles and other household utensils, which gets laid idle in many households after a short stink of time, as the children grow up. Hygiene aspects need to be taken care of in the transaction. Proper maintenance, or rectification of leakages, defects or inadequacies, especially that of machineries is also very important in the waste management initiatives, as more often defective machines let out more pollutants, or partially burned fuels into the environment. This is very important as we use quite a lot of machines nowadays. Relocation of potential polluting enterprise or industry over to less populated places, geographically locating various enterprises in a complementary way so that byproducts and rejects of one enterprise could be utilized by others in an economically viable way, etc., needs to be explored. The advantages of Geographic Information System (GIS) could be used in planning and in optimizing the transportation pathways.

Let us realize that the success of healthy waste management initiative lies in building the awareness of people regarding the consequences of improper waste disposal and the various options of good waste management. High voltage campaign should be launched to reach out to all sections and age groups of people posing this as a healthy habit if not a social obligation. Information Communication Technology (ICT) do offer several effective ways of passing the messages to the public in a cost effective way. Care should be taken to widen the meaning of sanitation to a way of life rather than restricting only to the management of night-soil and waste water. Emphasis should be given to impart modesty in one's needs, frugality in one's food, carefulness in the use of water and energy and promotion of sleep hygiene, work hygiene etc. The ongoing realize campaign should involve people from various fronts of life and disciplines, not only to ensure involvement, but to bring in ideas and resources that could be complementary.Reporting is a proof of successful awareness (realize) campaign. We should encourage people to report any potential problems with wastes and its management. Of course, this can results in many false allegations and the rhetoric of litany, but the overall advantage of reporting and transparency shall have an overarching positive outcome. Again, the advantages and maneuverability of modern media could be utilized to build an omnipotent and democratic reporting framework. Many misdoings could be avoided just by reporting, making it to the knowledge of the public; and the Not In My Back Yard (NIMBY) mentality of people could be successfully utilized for this. This should also be seen for its continuing education potential especially to the argumentative and litigation-prone people like that of Kerala. Reporting on mismanagement of wastes should be made a part of the public health surveillance system.

Last but not the least; strict legislative measures should be part and parcel of the waste management initiative, in order to reprimand offenders in a constructive way. At present, we have enough technical know-how to handle the wastes that we generate, provided everyone obliges by the principles of segregate at source and the 11 R's. Waste management is more of a societal activity which needs support from each and every citizen. Strict laws and legislative measures are needed to ensure proper adherence to good sanitation practices, which is a political decision.

CONCLUSION

The issues with waste and its management have resulted in the origin of the discipline of public health in the past and it continues to be a major public health intervention till date which can bring down much morbidity, mortality and improve the quality of people's lives. However, the present day practice of considering waste management as the sole prerogative of municipal officials and health department should be done away with. All departments and sections of public should share the responsibility. For example, the Information Technology (IT) department should have a policy on how to deal with the increasing electronic wastes. They should ensure that the industry buys back the discarded items and dispose them off in a healthy way. Similarly the agricultural department should keep a log of the chemical fertilizers, insecticides, herbicides, etc., that they distributes through their outlets and should keep a geo-referenced map of the various items usage pattern. They also need to ensure that chemicals are used within the permissible limits and should have documented reports for the same which can be verified by the authorities if necessary. Similarly education department should have clear strategy to inculcate sanitation as a lifestyle to the young generation.

Because of the advances in scientific innovations, present day waste management is not a technical prerogative, but a political prerogative as in many other issues of pubic health.

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General Presentations

Artificial Neural Network (ANN) Approach for Modeling of Resorcinol Adsorption from Aqueous Solution by Wood Charcoal

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INTRODUCTION

The phenolic compounds are discharged in to the environment by industrial wastewater from coal conversion, coke preparation, petroleum refineries, and pesticide, insecticide, pulp and paper, plastic, textile, dye, polymeric resin, and pharmaceutical industries(Gonen and Aksu, 2003). The content of phenolic compounds in industrial wastewater (about 200-2000 mg/L) is usually higher than the standard limits (mostly less than 0.5 mg/L) established for their release into aquatic environment(Ahmaru Zzaman and Sharma, 2005). It gives undesirable test to the drinking water even at low concentrations. Phenolic compounds are very harmful to organisms even at low concentrations due to its toxicity and carcinogenicity properties(Din et al., 2009). According to IS 2490 (Part III) - 1974, the concentration of phenols in the industrial effluents should not exceed 1.0 mg/ l before safe discharge into the surface water. Resorcinol is fatal if swallowed, is a skin and lung irritant, and may cause methanoglobinemia. The consumption of resorcinol affects adversely on the cardiovascular system, central nervous system, blood; liver, and kidneys(Arinjay Kumar, 2003).Various treatment methods are available for removal of non biodegradable and volatile organic compound such as adsorption, ion exchange, reverse osmosis, chemical oxidation, precipitation, distillation, gas stripping, solvent extraction, complexation and bio-remediation(Mukherjee et al., 2007). Among these methods, adsorption is a well-established and powerful technique for treating domestic and industrial effluents.

Modeling of batch adsorption process is important for optimization of the operating parameters. When circumstances or processes are not understood well enough or parameter determination is unpractical, there is distinctive advantage for black-box modeling(Strik et at., 2005). Artificial neural network are capable to capture complex and non linear relationship between input and output patterns. Annadurai and Lee (2007) used artificial neural network for the modeling of adsorption of Phenol using Pseudomonas Pictorum (NICM-2074). The input parameters of ANN model were Maltose dose (g/l), Phosphate (g/l), pH and Temperature. The predictive results of the ANN model and Multiple Regression Analysis (MRA) were also compared. The values of coefficient of correlation for ANN model and MRA model were 0.97 and 0.90. This indicates that the results of ANN model are better than that of MRA model. Singh et al., (2006) explored the possibility of using Neuro-Fuzzy Technique for the modeling of cadmium removal using hematite as adsorbent. The percentage error in the forecasting of adsorption of cadmium by ANFIS is less than that of ANN. They also found that ANFIS captures irregularities and uncertainties better than that of ANN. Yetilmezsoy and Demirel (2008) used backpropogation neural network for the modeling of Pb (II) adsorption from aqueous solution using Antep Pistachio Shells by using MATLAB software. They had done modeling with ten types of backpropogation training algorithms available in MATLAB software. They found that results of Levenberg Marquadart backpropogation algorithm (Coefficient of Correlation = 0.93) are better than other training algorithms. The efficiency of adsorption of Pb (II) using Pistachio Shells is @ 99%. The maximum adsorption capacity of Pistachio Shell for Pb (II) was observed 27.1mg/g. A very limited work has been carried for modeling of the batch adsorption study of phenol using low cost carbonaceous adsorbent such as rice husk ash from aqueous solution. The objective of the present study is to develop ANN model for prediction of phenol removal efficiency of batch adsorption study using rice husk ash as adsorbent using neural network tool box of MATLAB (Annadurai and Lee, 2007).

MATERIALS AND METHODS

Preparation of adsorbent and synthetic wastewater

The wood charcoal was purchased from local market and pulverized to different sizes (425-600?). Then the wood charcoal was washed several times with distilled water and then pretreated with 1(N) HNO3 solution. After soaking for 24 hrs, wood charcoal was separated from HNO3 solution and again thoroughly washed several times with distilled water. Then it was dried in hot air oven at 105-110 0C for 24 hrs. and stored in a desiccators.

To prepare stock solution of resorcinol, 1 gm of resorcinol (Merck Chemical Corporation) was diluted to 100 mL of double distilled water (i.e. 10000 mg/L concentration). Then 10 mL of stock resorcinol solution was diluted to 100 mL of double distilled water (i.e. 1000 mg/L concentration). This solution is called as intermediate stock resorcinol solution. The synthetic wastewater samples were prepared by diluting 2 mL of intermediate stock resorcinol solution to 100 mL with double distilled water (i.e. 20 mg/L concentration).The pH of the synthetic wastewater was adjusted by using 1N NaOH and 1 N HCl solution using a digital pH meter (Electronic Model 101E).

All the experiments were conducted at room temperature. The test samples were agitated with a reciprocating type horizontal shaker (Remi, India) at 140 rpm speed. The pH, adsorbent dose and initial phenol concentration were studied for their effects on phenol removal.

Batch adsorption studies

Batch studies were conducted for evaluating adsorption potential of resorcinol on wood charcoal. Total 29 sets of batch adsorption test were conducted by varying adsorption dose, initial concentration of phenol, pH and time of contact. For each set of experiment, resorcinol spiked synthetic wastewater (100 mL) with predetermined conditions including initial resorcinol concentration, pH, and adsorbent dose were loaded into a 250 mL polythene vial. Then vial was shaken on a reciprocating type horizontal shaking machine. Then vial were removed from shaker at appropriate interval of time. The sample solution was then filtered with filter paper (Whatman no. 42) and analyzed using UV spectrophotometer (Varian make) at 500 nm wavelength as per the Standard Methods(APHA, 1989). The percentage of Resorcinol Removal Efficiency (RRE) in each experiment was calculated as:

$$RRE = \frac{Co - Ce}{Co} \times 100 \quad .... \quad ..(1)$$

Where $C0$ = initial resorcinol concentration (mg/L)

Ce = Concentration of resorcinol at time t (mg/L)

Artificial Neural Network

The working principle of Artificial Neural Network is based on the working of the human brain which consists of interconnected biological neurons. The architecture of ANN consists of input layer, one or more hidden layers and output layer. Each layer of the network consists of a number of interconnected processing elements, called as neurons. These neurons interact with each other with the help of the weight. Each neuron is connected to all the neurons in the next layer. In the input layer, data are presented to the neural network. The output layer gives the response of the network to the input given i.e. input data. The hidden layers enable these networks to represent and compute complicated associations between inputs and outputs. The architecture of feed forward neural network is shown in Fig 1.

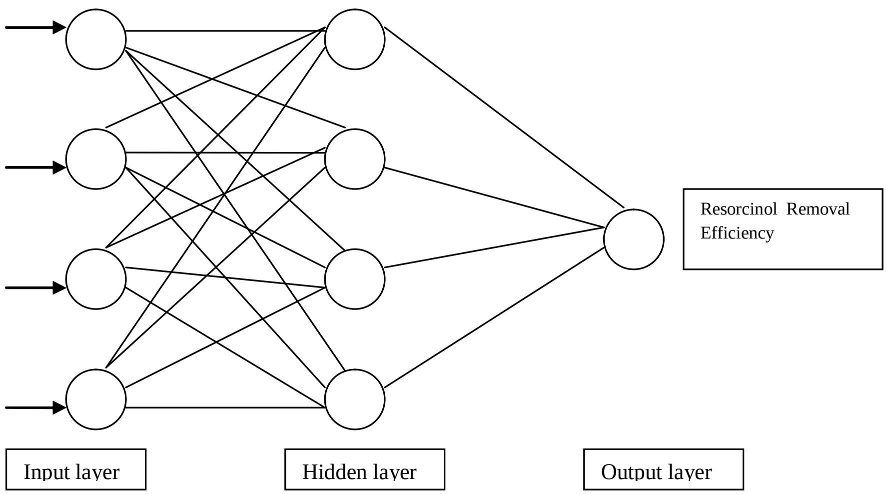

Fig1

Architecture of the ANN Model

The number of hidden layers is selected depending on the complexity of problem. Generally one hidden layer is sufficient for investigation of most of the problems. The number of neurons in the hidden layer is selected by trail and error method starting from minimum and then increasing depending on the nature of problem. The training of neural network is carried out by presenting a series of data of input and target output values. The parameters which affect the output should be selected as input parameters. The backpropogation training algorithm has been widely used to model the various problems in the environmental engineering. In the backpropagation training algorithm, the neurons in the hidden layer and output layer processes its inputs by multiplying each input by its weight, summing the product, and then processing the sum using a nonlinear transfer function, also called activation function, to produce a result. The most common transfer function used is the sigmoid function. The learning in the neural network takes place by modifying the weights of the neurons according to the error between the actual output values and the target output values. The changes in the weights are proportional to the negative of the derivative of the error.

The backpropagation is a gradient decent method to minimize the network error function:

$$E = \sum_{j=1}^{k} \sum_{i=1}^{n} (e_i(j) - t_i(j)) \text{------------------------------} (2)$$

Where ei (j) and ti (j) are the estimated and targeted value, respectively. N is the number of output nodes and K is the number of training simples.

Before starting the training of an ANN, the weights are initially randomized. Based on the error propagation, the weights are adjusted based on equation:

$$\Delta W_{ij}(n) = \alpha \frac{\partial E}{\partial W_{ij}} + \eta \Delta W_{ij}(n-1) ------------------- (3)$$

Where Wij (n) and Wij (n-1) are the weights increment between node i and j during the adjacent iteration α and are learning rate and momentum factor. Careful selection and appropriate adjustments of the learning rate are necessary for successful training of back propagation neural network.

The training of the ANN model is carried out by presenting the entire data set of input values to the network and it is continued till the average mean square error is minimized. After the training is over, the trained neural network should correctly reproduce the target output values for the training data provided. The weights of the trained neurons are then stored in the neural network memory. The testing of the trained network is carried out by presenting the set of test data and then comparing the out put of the network with the actual values of the output. The performance analysis of ANN mode can be done by several statistical parameters such as coefficient of determination (R), mean square error, root mean square error etc. A well-trained model should have R value close to 1 and values of error terms should be minimum.

ANN Software

In this work, neural network tool box of MATLAB 7 software was used to predict the phenol removal efficiency. Total 28 data sets of experimental work carried out were used for training, validation and testing of the model. The range of the variables used is shown in Table 1.

Table 1

Model Variables and their range

Sr.No.	Variable	Range
1.	Amount of wood charcoal (g/L)	10 - 100
2.	Initial concentration of resorcinol (mg/L)	10 - 100
3.	pH	3 - 9
4.	Contact time (min)	30 - 300
5.	Resorcinol Removal Efficiency (%)	0 - 100

A three layer neural network with tansig transfer function in the hidden layer and linear transfer function in the output layer was used. The experimental data obtained from batch adsorption study is classified as input matrix and target matrix. Out of the total 28 data sets, 15, 7, 6 samples were used for training, validation and testing. The data sets obtained were scaled in the range of 0.2 to 0.8 by following equation no.(2)

$$Nj = 0.2 + \frac{0.6(Oj - O\min)}{(O\max - O\min)} \text{-------------------------} (2)$$

Where Nj, Oj Omin, Omax are normalized, observed, minimum and maximum values of data series. The output of the network was again denormalized before comparison using equation no. (3).

$$Oj = O\min + \frac{(O\max - O\min)(Nj - 0.2)}{0.6} \text{-------------------------} (3)$$

The Levenberg - Marquardt (LM) training algorithm was used for the training of the ANN model.

RESULTS AND DISCUSSION

The training of the ANN model was started by taking 2 neurons in the hidden layer and was continued up to 20 neurons. It was observed that the mean square error was minimum for 12 neurons in the hidden layer. The training of the ANN model is shown in Fig. 2. The training was stopped after 7 epochs. The performance analysis of formulated ANN model was carried out by using statistical parameter such as Mean Square Error (MSE= 9.55). The error value of testing of ANN model is small. The experimental values and ANN predicted values of resorcinol removal efficiency (RRE) are shown in Table 2. The results of the linear regression analysis carried out between experimental values and ANN predicted values for test data set are shown in Fig 3.

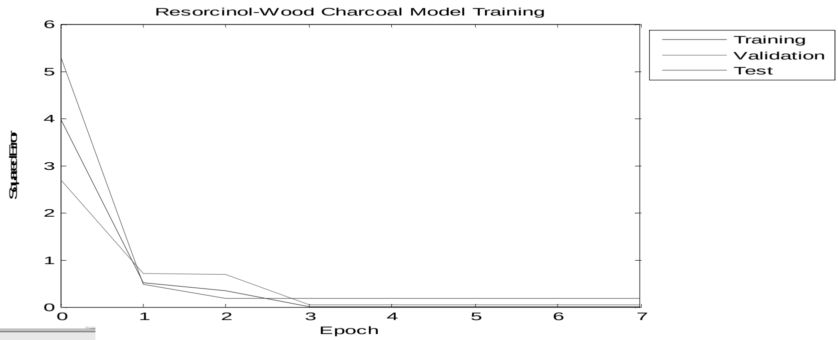

Fig. 2

ANN Model training for prediction of Resorcinol Removal Efficiency

Table 2

Comparative Results on experimental and model values

Sr. No.	Experimental Values of Resorcinol Removal Efficiency (%)	ANN Predicted Values of Resorcinol Removal Efficiency (Test data) (%)
1	62.25	61.44
2	75.71	77.00
3	71.28	70.44
4	83.87	83.70
5	79.37	82.74
6	69.04	69.49
7	70.78	78.01

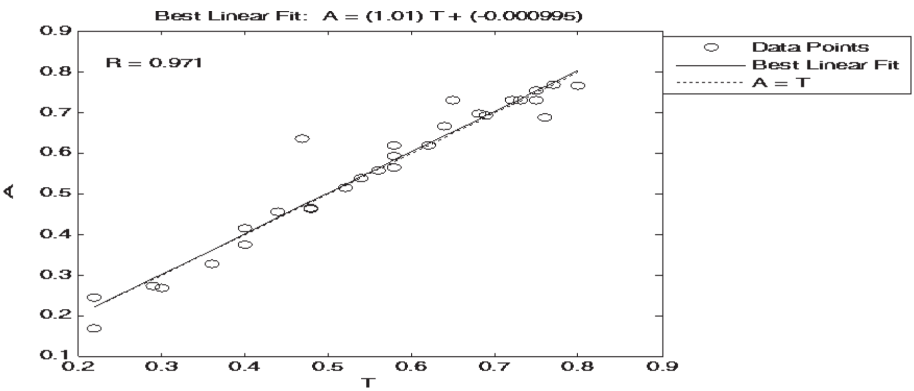

Fig 3

Linear regression for prediction of Resorcinol Removal Efficiency

(Note: A represents network response; T represents observed data.)

The two lines are used to show the success of the prediction. The one is the perfect fit (predicted data equal to experimental data), on which all the data of an ideal model should lay. The other line is the line that best fits on the data of the scatter plot with equation Y = mx + c and it is obtained with regression analysis based on the minimization of the squared errors. The coefficient of determination of this line is also presented (R). The closer to 1 this factor is and the closer the coefficients of the line to 1 and 0, respectively, are the better the model is. The value of coefficient of determination (R) = 0.971 which is closer to 1. The results of the test data of ANN model are shown in fig.4. It was found that the predicted values of resorcinol removal efficiency by ANN model are very close to the experimental values for all data sets in test series.

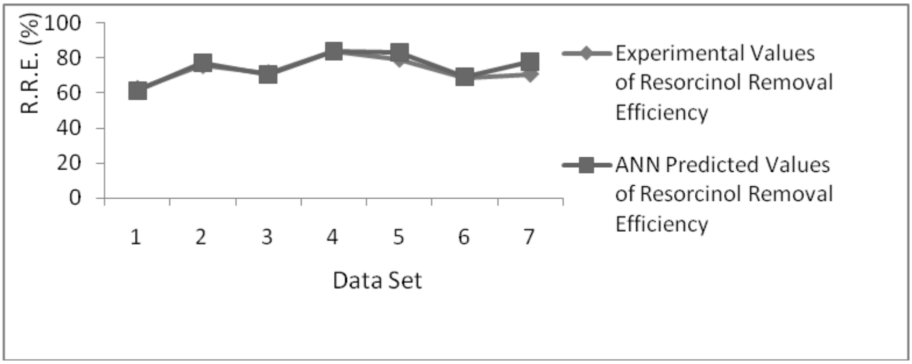

Fig.4
Experimental and ANN predicted Values of Resorcinol Removal Efficiency

CONCLUSION

In this work, the forecasting of resorcinol removal efficiency of batch study using wood charcoal as adsorbent has been carried out by using feed-forward back-propagation neural network. The network modeling and analysis was done using MATLAB software. The formulated ANN model had four inputs i.e. initial concentration of resorcinol, dose of adsorbent, pH, and contact time. The architecture of modeled network was a 4-12-1 network trained with Levenberg-Marquardt algorithm. The results of ANN model were compared with the experimental values. The ANN model forecasted values of resorcinol removal efficiency (%) were found to be reasonably close to test values. Therefore, it is concluded that ANN had good potential for prediction of resorcinol removal efficiency in the batch adsorption study. A large database in the training set would further improve the predictions.

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Studies on Chemical and Water Budgets of Sugar Factory Wastewater during Land Application after Percolation through a Soil Column having Crop of Black Gram (*Cicer arietinum* L.)

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INTRODUCTION

There is growing concern for the environmental pollution caused by municipal sewage and industrial effluents, especially in developing countries. These liquid wastes are generally discharged either into water bodies or on lands. The indiscriminate disposal of wastewaters into water bodies creates damage to aquatic life. At many places wastewaters are also treated by land application with some suitable crops under cover. The practice of applying wastewaters in the land may be called as land treatment, land application of soil. The land works as a filter retaining organic matter, salts and nutrients while excess water percolates in to the soil. Improper wastewater irrigation, however, may affect microbial flora, and change the soil characteristics and its texture. But a good secondarily treated effluent can be considered sufficiently safe for unrestricted irrigation for almost all the crops. The sugar factory waste is highly rich in organic matter and contains dissolved salts and sugars. Chemically, it may be acidic or alkaline in nature; and BOD values may exceed 10,000 mg/L. Biological degradation of organic matter leads to rapid consumption of oxygen.

The present study has been made on land application of undiluted (100 %) sugar factory waste with plant cover of Cicer arietinumto work out potential of the soil for waste treatment by percolating the waste through a long column of soil. Emphasis has been made in the study to check that at which depth of the soil, various constituents of the waste are retained, and what is leached out along with the percolating water. Budgets for the water and the chemical constituents present in the waste have also been made.

MATERIALS AND METHODS

The soil columns for the study were prepared with acrylic sheets having a length of 77 cm and an area of 20 × 20 cm. The upper end of the column was kept open while the base was sealed leaving a small hole which is connected with a tube to collect the percolating water. The column was filled with 67 cm of soil leaving 10 cm open space for growing plants and applying the wastewater. The seeds of black gram

(Cicer arietinum) were sown in the column. The soil used for the experiment was black cotton garden soil. The soil was added with cattle compost in the ratio of 1:5 (20% compost) before filling the columns.

The experiment was carried out for 15 days. The column was added with a calculated quantity of wastewater and the percolated water recovered was measured every day. Chemical analysis of the percolated wastewater for various parameters was made every day using standard methods (APHA-AWWA-WPCF, 1981), and the data were used later to make budgets of the various wastewater constituents. After termination of the experiment, the soils from upper, middle and bottom layers of the column were collected and used for the chemical analysis following the methods of Trivedy and Goel (1984).

RESULTS AND DISCUSSION

After applying wastewaters to soils, the excess free water drains out due to gravity, which usually occurs after ½ to 2 days (Arceivala, 1981). The drained out water is called as leachate. In the present study the formation of leachate started after 4 days of the experiment. The moisture retained by the soil is called field capacity. The field capacity is made-up of capillary water, which is retained in the pore spaces against the force of gravity, and the hygroscopic water, which is held onto the soil particles and not moved by either gravity or capillary force. Fine textured soils such as black cotton soils, taken in the present experiment, are usually able to hold more capillary water than the coarse textured soils. It is only the capillary water which is available to plants, as the hygroscopic water is unable to move by any force.

The water budget can be made from data on quantities of the sugar factory waste added daily and waste recovered after percolation through the soil column as given in Table 1. During 15 days of the experiment, total quantity of the wastewater added was 37 litres, out of which 16.25 litres was recovered after percolation and the remaining 20.75 litres was retained by soil of the column, which was partly absorbed by the plants and partly evaporated. On percentage basis, the data show that about

Table 1
Water budget indicating the daily quantities of the sugar factory waste added, recovered after percolation and retained by the soil column.

Days	Waste added (L)	Waste recovered (L)	Waste retained / Evaporated (L)
1	5	-	5
2	2	-	2
3	1	-	1
4	3	-	3
5	3	2	1
6	3	2	1
7	-	0.05	-0.05
8	3	0	3
9	3	2.5	0.5
10	2	1.5	0.5
11	3	2	1
12	3	2.2	0.8
13	3	2	1
14	3	2	1
Total	37	16.25	20.75

56% of the waste was retained by the soil column while 44% could be percolated and came out of the column. The recovery of the percolating water was started from the fifth day while during first four days, 11 litres of the waste added was retained by the soil column. It was observed that out of the daily added waste only one-third was retained and two-thirds came out of the column, once the whole column was wet.

The chemical budget of the constituents was made from the results of chemical analysis of the waste added and recovered after percolation. To find out the total quantities of the chemicals added, the quantity in each parameter in mg/L was multiplied by the total quantity of the waste added. For evaluating the total quantities recovered, the quantity of each parameter every day was multiplied by the respective volume of the percolated waste recovered, and finally summing up all the quantities for the number of days of the experiment. The quantities of various chemicals retained by the column were calculated as the difference between the total quantities added and recovered. The data obtained are presented in Table 2 and Fig. 1.

Table 2
Chemical budget of the sugar factory waste added to the soil column.

Pollutants	Quantities added in g	Quantities recovered		Quantities retained	
		Absolute quantity in g	%	Absolute quantity in g	%
T.S.	75.81	34.72	45.8	41.09	54.2
T.D.S.	73.67	32.01	43.5	41.66	56.5
T.S.S.	2.15	2.71	126.3	-0.56	-26.3
B.O.D.	8.14	1.15	14.2	6.99	85.9
C.O.D.	68.08	28.62	42.0	39.46	58.0
Chlorides	32.63	13.44	41.2	19.20	58.8
Ca	4.45	3.61	81.10	0.84	18.9
Mg	0.18	0.08	45.3	0.10	54.7
Na	5.96	1.31	22.0	4.65	78.1
K	11.11	1.37	12.3	9.74	87.7

The results indicate that, during the 15 days period, total quantity of total solids (TS) added was 75.81 g out of which only 34.7 g could be recovered, while the rest was retained. This indicates that on a percentage basis, 54.2 % total solids were retained while 45.8 % were recovered. However, for total dissolved solids (TDS), 43.5 % were recovered and 56.5 % retained by the soil column. The total BOD added to the column was 8.14 g, out of which 1.15 g could be recovered while 6.99 g was retained by the soil indicating that the soil is quite efficient in removal of BOD. For chlorides, it was noted that only 3.44 g came out of the total quantity (32.63 g) added, while the rest were retained by the soil. The results indicate that the soil does not have much capacity to retain chloride. Sodium (78.1 %) and potassium (87.7 %) also showed higher retention by the soil during percolation of the waste.

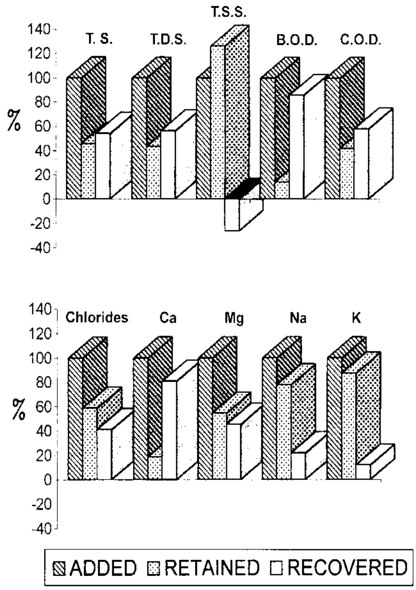

Fig. 1
Budget of various substances present in sugar factory waste after their land application in the soil column

The data on the chemical analysis of the original soil and soil at various depths in the column after the waste has percolated through it are given in Fig. 2. The concentration of nitrogen was increased in the deeper layers of the soil column after percolation of the waste. The concentration of phosphorus was 15.9 mg/100g in the original soil, which varied from 11.54 mg/100g to 14.93mg/100g in the soil column after percolation of the waste indicating that it has not been increased in the soil. The maximum value of phosphorus in the soil column was found in the middle layer, whereas the minimum value in the lower layer.

The organic matter in soil column increased considerably in the upper layer after percolation of the waste. Chloride concentration in the whole column fell after the percolation. The highest value was in the lower layer (19.9 mg/100g). Concentration of calcium and magnesium increased in the upper layer, but decreased in rest of the column. In the upper layer, the concentration of calcium and magnesium was 721.4 mg/100g and 414.2 mg/100g as compared to the original values of 641.3 mg/100g and 243.6 mg/100g respectively. In most of the soils amended with spent-wash, large accumulation of ions like chloride and sulphate was reported by Singh et al. (1980), Rajukannus & Manickam (1996), Valliappan (1998) and Malathi (2002), which can result in their leaching with subsequent irrigations, thus polluting the groundwaters.

The maximum accumulation of sodium occurs in the middle layer where its concentration reaches to 140.3 mg/100g, almost double to that of the original

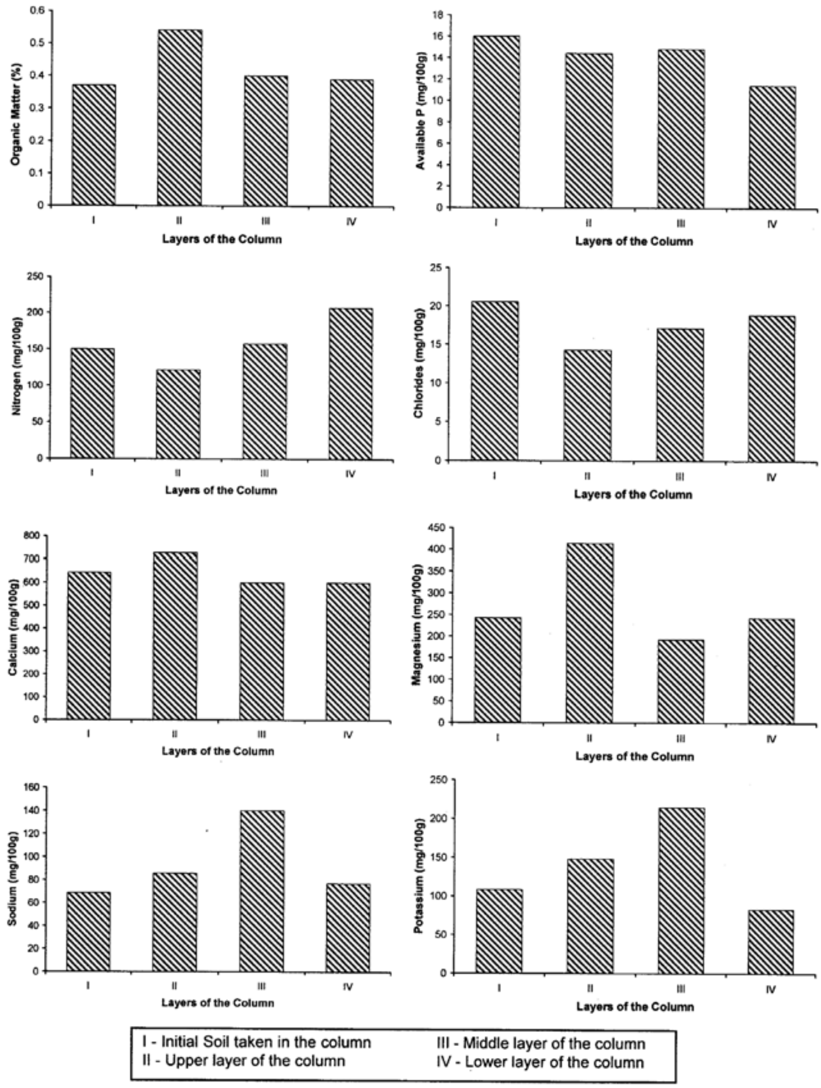

Fig 2

Quantities of various substances present in the original soil and their retention at various depths in the soil after land application of sugar factory waste in the soil column.

concentration of 69.0 mg/100g. The maximum accumulation of potassium was in the middle layer (214.5 mg/100g) followed by 148.2 mg/100g in the upper layer as against the original concentration of 109.2 mg/100g. The lower layer showed a decline in the potassium concentration with a fall of almost 20%. Shenbagavalli et al. (2009) found that potassium, which remained higher (9097 mg/L) in the biomethanated spent-wash, accumulates in soil during land application in larger amounts resulting in its greater leaching afterwards.

The wastewater, as it percolates through the soil, gets renovated or treated by physical, chemical and biological means. However, the treatment of waste in this way usually leads to the build-up of salts in the soil. The build-up of salts in soils depends on the leaching properties of the soil as it is inversely proportional to the leaching fraction, which can be calculated by the following formula.

$$\text{Leaching fraction} = \frac{L}{(I + P)}$$

Where,

L = Volume of leachate

I = Volume of irrigation water

P = Volume of precipitation

In the present study, 'P' was zero because no rain during the period of the experiment has occurred. The leaching fraction calculated for the present experiment comes out to be 0.44, which is usually the value obtained for well drained soils (Arceivala, 1981) and may not lead to much build-up of excessive quantities of salts in short periods.

The results of the study indicate that the greater quantities of dissolved solids, chlorides, magnesium, potassium and organic matter are retained by the soil. It is reported that the maximum retention of the substances by the soil usually takes place for phosphorus, calcium and magnesium (Arceivala, 1981). While potassium and magnesium are greatly removed by clayey soils, the removal of phosphorus and calcium is more in coarse textured soils. In the present study, the results were obtained almost on this pattern as there was maximum removal for potassium and magnesium due to the clayey nature of the soil, while calcium showed only a little removal by the soil. In an experiment by Shenbagavalli et al. (2009) on salt leaching after application of spent-wash in a soil column, it was found that there is greater leaching of salts from the soil later. There seems to be development of an equilibrium after which most of the salts present in the waste are leached out of the soil rather than their accumulation.

It can be concluded that indiscriminate use of sugar factory effluents can damage the soil condition and pollute groundwaters due to leaching. Soil column study can evaluate the capacity of soil to treat wastewaters during land application and indicate its potential to pollute groundwaters.

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Unmet needs of solid waste management workers at Calicut Corporation area

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Introduction

Solid waste management is one of the important seven accepted components of sanitation (Anon, 2007). Now with the under standing of the kick backs experienced by "Kerala Model of Health" as emerging and reemerging diseases which were attributed to environmental problems like poor waste management . The problem got worsened by high consumption pattern of Keralites and low per capita availability of land (Anon, 2008). Due to the peculiar consumption pattern in the state the per capita solid waste generation is high. Segregation of waste at the source is poor and the practice of house hold level composting which was very common earlier has now fallen in to disuse (Anon, 2007). The increase in the quantity of waste and the increased non biodegradable components has become a challenge. Plastic and E waste are now on increase (Kumar D, 2010).With the rapid urbanization, the solid waste management in most of the cities in Kerala is posing a major environmental problem. Rough estimates reveal that the quantity of waste generated from the Urban towns in the State comes to 2,800-3,000 tonnes per day. It is estimated that only 50% of the waste generated is collected for disposal. Every day a quantity of about 1,500 tonnes of waste is left to decompose on road margins, drains, canals, water bodies and open space (Anon, 2008). The per capita waste generated in urban areas was 400 grams/day and in rural area was 250 grams/day. Thus a five member family per day produce 1.5 to 2.5kg solid waste (Kumar D, 2010).

Table 1

Sources of solid waste and rate of generation (Anon, 2007).

Sl No	Source	Percentage of Total
1	House hold waste	49
2	Hotels ,Marriage halls	17
3	Shops& Markets	16
4	Street sweepings	09
5	Construction	06
6	Slaughter house, Hospitals	03

Table 2

Composition of Solid waste (Anon, 2007).

Sl No	Component	Percentage of Total Kerala
1	Biodegradable	71-83
2	Paper	3.5-5
3	Plastic ,Rubber, Metal, Glass	5-9
4	Inert,earth	4.9-11.5

Municipal solid waste (Management and Handling) Rules 2002 assign local self government institutions the primary responsibility for implementing the waste management (Reghunandanan, 2008). Thus solid waste management is one of the most important mandatory functions of the Urban Local Bodies(ULBs). Many ULBs in Kerala are aware of the problems of health, sanitation and environmental degradation and there has been lot of developments in this sector during the last decade (Reghunandanan, 2008**).** Attempts have been made in this area and more concerted efforts were made to improve SWM system to ensure a better urban environment (Reghunandanan, 2008). Though there are technological and organizational hindrances, many of the urban and rural areas have realized the importance and initiated action towards improved management of solid waste (Anon, 2007). Out of the 53 municipalities 17 have land and treatment facilities and 33 have only land and no facilities. Out of the 999 grama panchayats , facilities are available in 112 only 126 had land for waste management.

About 10-15% of the solid waste generated are collected by rag pickers for recycling and reuse (Varma, 2008). *Problems faced by the local bodies are non availability of suitable land for final disposal of the waste, resistance offered by the local people around the dumping ground, and inadequate infrastructure facilities(Ambat, 2000).*

The reason for poor waste management is due to the absence of segregation and primary collection from the its origin. To fill up this lacuna **Kudumbasree** – the State Poverty Allevation Mission has initiated an innovative enterprise namely, '**Clean Kerala Business**'. Under this enterprise, women from the financially backward families who are the members of the Community Based Organisations (CBOs) of Kudumbashree are engaged in door to door household waste collection and transport to the transit points fixed by the Urban Local Bodies(Anon, 2008). Now 155 Kudumbashree solid waste management groups are in operation in 18 urban local bodies in the State. The advantage of Kudumbashree model of solid waste collection group is that it can fill the existing gap of solid waste collection and segregation without any additional financial burden to the urban local bodies. Calicut is one of the ULB who have pioneered the programme(Anon, 2008).

Table 3

Profile of Kozhikode Corporation Area (Reghunandanan, 2008).

•	Total Population	: 436527 (2001 census)
•	Total Area	: 82.67 Sq km
•	Electoral Wards	: 55 (Previously 51)
•	Revenue Wards	: 39
•	Total house holds	: 82,369
•	Commercial Establishments	: 12,853

Table 4
Solid Waste generation points at Kozhikode corporation area (Reghunandanan, 2008).

•	Households	: 82639 Nos
•	Hotels and Restaurants	: 1012 Nos
•	Commercial Establishments	: 12, 853 Nos
•	Markets Large	: 2 Nos
•	Markets - Medium	: 4 Nos
•	Markets - Small	: 13 Nos
•	Offices and Institutions	: 300 approx
•	Hospitals - 58	: Nos - 5530 beds
•	Marriage community hall	: 21 Nos

Sources and Quantity of Solid Waste Generated

About 250 tonnes of muncipal solid waste is generated in Kozhikode Corporation every day. The per capita waste generation is estimated to be 477 gms / day Out of this about 120-150 tonnes is collected by the Corporation every day. In terms of percentage contribution, domestic waste generated from the house hold account for 47 percentage of total waste generated. Waste from commercial establishments and hotels account for 24 percent of the waste.

Table 5
Types of waste generated

•	Bio - Degradable wastes	: 70 %
•	Recyclable wastes	: 15 % .(Paper, plastic, metal, rubber, glass)
•	Inert	: 10 %
•	Others	: 5 %
•	Per Capita generation of wastes 500 gm / day	

Solid Waste Management System

The solid waste management was initiated on Aug 15th 2004- in 7 wards and then scaled up to all wards in two stages. Before the implementation of the project a feasibility study was conducted by collecting opinion from the households in the Corporation area and was found to be acceptable and viable. Awareness was created by conducting awareness programmes as well as distributing printed materials. Two units of kudumbashree have been formed in each of the selected wards.

Primary Collection: Corporation distributed separate 15L bins (Green and White) to each and every households , Green bins for biodegradable and white bins for non biodegradable wastes. The wastes are being segregated at source and being stored in the bins provided by the Corporation. Commercial establishments have to provide two bins at their institution for source segregation.

The Kudumbashree volunteers organize door to door collection of the waste during 6am to 9 am and moved to secondary collection points. They collect them in the 50L bins in segregated way and placed in the Auto rickshaw and then moved to secondary collection points. For the transport of the collected waste to secondary collection point each units procured 2 Auto Rickshaws through Bank finance. The Corporation have arranged subsidy from the Plan fund for purchasing Auto Rickshaw. In the beginning the primary collection was done on daily basis later changed to alternate day due to non feasibility.

Secondary collection: From the Secondary collection points the waste collected are shifted directly to the Corporation vehicles. There are about 32 secondary collection points identified by the Corporation. These wastes in its segregated form transferred to the secondary collection vehicles are directly transported to the solid waste treatment plant at Nheliyanparamba in the Cheruvannur Nallalam Panchayat 10 KM away from the city and then being processed and converted into manure. The transportation facilities have been strengthened by purchasing adequate vehicles for waste transportation. 8 Covered type of LCV's , with internal separation for bio and non bio - degradable wastes, have been purchased as part of the project implementation and open tractor trailers are modified into covered type.

Processing: There are 18.98 acres of land for this purpose. The waste processing plant has been set up in the processing plant site in the year 2000 by Excel Industries, Bombay. The waste is heaped into windrows and treated with adequate inoculums and then subjected to aerobic composting.

Supportive Action against littering: Along with the waste collection system the Corporation organized squad works against littering. Spot fine was imposed against littering or dumping wastes in public places. A debris service was started by which public can hire the service of the Corporation for removing construction wastes, garden wastes etc with a nominal fee. The system of sweeping, drain cleaning, and waste collection by the contingent workers were strengthened in the Corporation and the working time was changed to 5am to 11am (Reghunandanan, 2008).

Advantages: The littering in public places were reduced and the city remains clean. The waste depots and waste bins are not seen in public places and the city became bin less city. The project is being studied by other local self government institutions to implement the same in their institutions. Kozhikode won 'Green City Award' of

Plastic India Foundation on October 1st ,2005. KILA Identified Kozhikode Corporation's MSWM Project as one of the best practices (Reghunandanan, 2008).

Now the waste management system implemented in all 55 wards. There are 68 women groups involved with 424 members. The compost treatment plant was planned for 300 MT of waste every day. There has been a drastic increase in the quantity of waste collected and reaching the compost facility during the last few years increasing from 111 MT in 2002 to an average of 210 MT in (2006). The necessity of decentralization of treatment and disposal of waste is a crucial challenge to the Municipal Corporation. Hence a concerted effort to reduce the waste at source should be planned. Decentralized treatment of waste should be given priority so as to save on cost and to mitigate the ill effects of big plants. In this back ground to know the operational issues and unmet needs of workers a study was conducted.

RESULT AND DISCUSSIONS

Data from 313 persons were collected by direct interview using a questionnaire during the medical check up arranged at four places conducted in a week interval.

The average age was 43 years showing that most of the women were in the peri menopausal age groups. 88.5% were married and living together and 5.8% were either widows or separated. 5.4% were unmarried. Together 11.2% of the women are living without spouse which indicate the support needed for them. All of them were from BPL families and the average monthly income from this job was rupees 1889.

Before joining the job 44% were employed in some places and left it. 26% were not able to attend their job regularly. The major causes were their own illnesses (22.7%) and very few due to some family problems or problem with co workers.

About 22% have opined that the present system of waste management is ideal and 59% complained about it's defects. 80.8% perceived that family members have got good opinion about the work done by them .

Even though 80.8% of the clients have very good opinion about the workers 21.4% of them opined that they were not cooperating with their work.

Working environment and human relations: 56% complained that coworkers are leaving the job and choosing other avenues. 11% complained about the bad human relation with their co workers. This is a challenge for the sustainability of the project.

Problem with clients: The problem faced by the workers at the collecting house holds are given in Table.6

The unnecessary waiting in front of the closed doors can be reduced by using whistles or horns as alarm or by fixing the timings of collection.. The house holds are asked to keep their bins out side the house for collection (9).The caging of pets should be made mandatory. Most of them are not segregating waste and mixing, so the strategy should be changed from creating awareness to behavior change communication (8). As a part of "malinya muktha" Kerala Campaign and based on High court direction the Government decided to ban plastics up to 30 microns in thickness .Even then

Table 6.
Problems faced by workers.

No	Issues with clients	Percentage
1	Non corporation	21.4%
2	Delay in payment	24%
3	Un necessary waiting	33.5%
4	Pets problems	25%
5	Mixing of wastes	78.3%
6	Putting sharps	29.7%
7	Mixing plastics	83%

the carry bags are widely used and disposed with garbages. The sharps like broken glasses and metal pieces are causing injuries to workers. That can be stored separately and used for recycling (Anon, 2008).

The main operational issues they found were problems with vehicles. They can be listed as follows.(a)Difficulty in paying loan installment (b) Condition of the vehicles is poor (c) No workshop facility. (d) Can not afford repair Cost (e) Non availability of vehicle washing facilities (f) Delay and Timings of secondary collection vehicles. The problem with the transportation was similarly reported from other parts of Kerala. The fleet of transportation available are not sufficient, >70% of vehicles have served for more than 10 years and 25% vehicles were of the road. Most of the vehicles are open spreading bad odour. All the temporary storage points are not cleared daily(Anon, 2007).The vehicle for waste transportation should have the following features. There must be a transportation schedule in each areas with timings and routes. The size and quality of the containers should match the space available in the vehicles for transport (Reghunandanan, 2008). 18 of the 50L trays can be kept in one auto (Menon et al, 2006). The compartment of the vehicle should be made of stainless steel and should have an in built provision to drain out the leach out in to tanks fixed at the bottom. In the treatment yard there must be facility to wash the vehicles and containers daily wastes and the washed water should be collected in septic tanks to reduce BOD and recycling (Reghunandanan, 2008; Menon et al, 2006).

Problems regarding the narrowness of the paths which leads to inaccessibility by the autos and difficulty in carrying the waste loads can be overcome by providing them wheel barrows. Bicycle with special carriages is a cost effective option. (Author). A wheel barrow /handcart with 4 plastic trays cost 7500 rupees. A handcart With 6 trays cost 9000 rupees (Anon, 2008).

Use of personnel protective equipments and hygiene: In order to get protection from health hazards every body engaged in waste management should take personnel protective measures. Every body handling waste has to be provided with personal protective wears and equipments and ensure the consistent use. Gloves, masks brooms, trays, gumboot, rain coat etc (Anon, 2008)

One pair of good surgical gloves cost rupees 40 only (Anon, 2008). The causes of not using the gloves were allergy, tearing, difficulty to working. The hygiene practices are neglected due to tiredness or heavy house hold works.

Table 7
Use of Personal Protective Measures

Use	Always	Occasionally	Never
Gloves during work	92.3%	6.4%	1%
Foot wear during work	99%	1%	0
Washing hands after work	99.4%	0.6%	0
Bathing after work	93%	3.5%	3.5

The morbidities mainly attributed due to their occupation were as follows.

After entry in to the job of waste management 13% were hospitalized at least once which was higher than general population.

Table 8
Reported Illness of Workers.

Morbidity	< last 1 year	Before 1year	Nil
Falling with waste	33.5	20.8	36.5
Vehicle accidents	5	16	78
Injury with sharps	50.2	20.5	26.9
Animal attacks /bite	6	2.6	90.4
Chemical Injury	2.3	0.6	97.5
Chikungunya	44.6	3.2	49.2
Skin disease	36.7	NAD	NAD

Other major infectious disease reported among them were jaundice, typhoid and lepto spirosis.

Joint pain due to ergonomic problems

The mean experience in the present job was 4.75+ 7 years and the working hours/ day were 6.15+1.7 hours. Since they have to carry and lift load while collecting ,loading and unloading the joint problems are very common. This was worsened by the non availability of worker friendly and women friendly tools and equipments(Reghunandanan, 2008).The ideal capacity for the waste bins having capacity of 11L is 450 grams- Bin 350+ lid 100grams (Menon et at, 2006).

Table 9
Joint problems

Joint affected	Low back	Neck	Shoulder	Elbow	Knee	Ankle
Prevalence	37.8%	18.5%	33.9%	27.7%	42%	25%

The mean height of workers were 150+8 cm and 14.4% were malnourished with BMI < 18.5. Without considering the appropriateness the LSG often purchase unsuitable vehicles which are over height or inappropriate bins which are difficult to lift (Reghunandanan, 2008).

CONCLUSION

Waste segregation at the source should be strengthened with the help of Residents Associations.The ergonomical issues should be solved by providing user friendly equipments like appropriate light weight bins and barrows. Some projects should be implemented for the health and welfare of workers.

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Hazards and Management of Mercury as a Hospital Waste: A Case Study from Kerala

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INTRODUCTION

Mercury is the only metal which is liquid at ordinary temperature. It is a heavy, odorless, lustrous liquid metal that sinks in water. Its unique properties are suited to numerous technological and manufacturing products and processes. After the understanding of Mercury toxicity in human beings and environment many developed countries have abandoned mercury instruments and substituted with alternative instruments (Thejus, 2008). Many have developed protocol for management of mercury containing hospital wastes to prevent human hazards. In developing countries like India most of the hospitals are still using mercury containing instruments. Hence the health care workers are exposed to mercury poisoning and the environment is contaminated with mercury wastes.

Hospitals are one of the major contributors of mercury in the waste streams. If these wastes are disposed of with our regular trash then the mercury can contaminate our environment. Breakage, waste disposal, and spills from these products release mercury to the atmosphere or to drains, where it can persist for many years. Waste water streams emanating from hospitals often show a higher than expected level of mercury. Medical care facilities may also emit mercury through accidental spills and releases, which discharges to wastewater and landfills (Agarwal et al., 2009). Any release is costly and may add to mercury's build-up in the environment. Another significant source of mercury emissions are Incinerators. This mercury can travel anywhere from a few hundred feet to thousands of miles away from its original source. With this background a case study was conducted in Kerala to study the mercury usage in healthcare establishments , the handling and disposal procedures of mercury waste by the healthcare workers.

REVIEW OF LITERATURE

Mercury in the environment in its organic form can lead to disastrous health consequences. The crippling nervous disease developed by a few thousand people who consumed fish and shellfish harvested from mercury contaminated waters in Minamata Bay and Agano river basin in Japan decades ago is perhaps the most telling example of its toxic effects. So mercury poisoning is sometimes referred to as "Minamata disease."

Over the years, water pollution with mercury has increased in Indian waters. A 1999 study tested and analyzed ground water samples from eight places in three states — Gujarat, Andhra Pradesh and Haryana — where mercury contamination has been reported dangerously high(Agarwal et al., 2009).The solid wastes from dumping sites in municipal areas of Kerala contain heavy metals including Mercury.

HEALTH IMPACTS

The two properties that make mercury extremely unmanageable are bio-accumulation and bio-magnification. **Bio-accumulation** is the retention of the toxic substance in the tissues, especially muscles. The bioaccumulation factor from water to edible fish tissue exceeds 10 million for certain species of fresh and ocean water fish, thus increasing the potential for mercury poisoning. **Bio-magnification** is the process by which the toxic metal increases in concentration as it moves up the food chain (up to 10,000 times the original levels, in some cases). Nursing infants are the highest in the food chain and can be exposed to dangerously high levels of this element (2).

Mercury may be fatal if inhaled and harmful if absorbed through the skin. It may cause harmful effects on the nervous, digestive and respiratory systems, and the kidneys. Mercury may also cause lung injury – effects may be delayed. Mercury is corrosive to some metals. It is a skin sensitizer – it may cause allergic skin reaction, and it is a reproductive hazard. The most likely routes of exposure are inhalation of inorganic mercury vapour after a spill or during a manufacturing process, or ingestion of methyl mercury from contaminated fish, absorption through skin. Mercury can pass the skin barrier, blood-brain and the placental barrier and thus cause devastating effects on the functioning and growth of the brain and the growing foetus. It is a potent renal and neuro toxic substance. The nervous system effects of mercury toxicity are sometimes referred to as "Mad Hatter's Disease" (Agarwal, 2009).

Mercury continually released into the environment will increase its levels since it does not break down. It then circulates in the atmosphere and is redistributed throughout the environment.

MAJOR FORMS OF MERCURY INTOXICATION

Mercury interacts with sulfhydryl group's in vivo, inhibiting enzymes and altering cell membranes. The pattern of clinical intoxication from Mercury depends to a great extent on the chemical form of the metal and the route and severity of exposure.

- Acute inhalation may cause chemical pneumonitis, non cardiogenic pulmonary oedema. Acute gingivo stomatitis, and neurologic sequelae. Acute ingestion can result in a corrosive potentially dangerous hemorrhagic gastroenteritis followed within hours to days by acute tubular necrosis and oliguric renal failure
- Chronic poisoning results in a classic triad of tremor, neuropsychiatric disturbance, and gingivostomatitis. Acrodynia is an uncommon idiosyncratic reaction to a sub acute or chronic exposure and occurs mainly in children. It is characterized by painful erythema of the extremities and may be associated with hypertension, diaphoresis, anorexia, insomnia, irritability, or apathy and a

military rash. Methyl mercury is a reproductive toxin (Agarwal et al., 2009).

The Environmental Protection Agency (EPA) estimates that for an adult of average weight, exposure to 0.021 milligrams of inorganic or organic mercury per day in food or water will probably not result in any harm to health.

USES OF MERCURY IN HOSPITAL

- Mercury thermometer
- Sphygmomanometers
- Dental amalgam
- Dilation and feeding tubes

Other uses

- Batteries,
- Fluorescent lamps
- Thermostats
- Bleach
- Laboratory chemicals

Mercury thermometer

Thermometers are the most frequently used mercury containing equipments in hospital set up. A thermometer is a device used to measure temperature or temperature changes. The most common method of measuring body temperatures is with a mercury-in glass. There are different methods by which we can take body temperature with a thermometer. When its tip is inserted into the mouth (oral temperature), under the armpit (axilliary temperature) or into the rectum via the anus (rectal temperature). The mercury thermometer, right from production to its usage and final disposal, poses a health hazard to the workers/consumers. There is approximately 1 gram of mercury in a typical fever thermometer. This is enough mercury to contaminate a lake with a surface area of about 20 acres, to the degree that fish would be unsafe to eat. The breakage rate of mercury thermometers is quite high – about 4-5 every month in each ward (Agarwal et al., 2009; Agarwal, 2009).

Mercury thermometers are an issue because when these or any other product containing mercury breaks, the mercury can evaporate, creating a risk of dangerous exposures to mercury vapours in indoor air. This volatilized and liquid mercury enters the environment through air, water effluent or solid waste system, and can be deposited in lakes and rivers, where it can be transformed into highly toxic methyl mercury.

In fact, mercury based thermometers are being phased out internationally. Even then most of the hospitals in India are using mercury- containing instruments and there are no immediate plans to phase them out. An average sized hospital in Delhi may record a breakage rate of 70 thermometers in a month and thus contribute around 840 gms mercury per year through thermometers alone (Agarwal et al., 2009).

Sphygmomanometers

Blood pressure is generated by the activity of the heart and blood vessel system and is widely accepted as a measure of cardiovascular performance. Therefore blood pressure levels and variations are considered to be an indicator of cardiovascular function and overall health. Sphygmomanometers are the commonest form of blood pressure measuring apparatus used in every clinic and every ward of the hospital which contain mercury manometers. Blood pressure equipment has approximately 60 grams of mercury. Taking into account BP apparatus and assuming a leakage of only around 1/3rd of the total amount of mercury in it (60 gms), and assuming two spills a month, around 480 gms of mercury may be wasted in an year . Considering mercury wastage of a hospital only due to thermometers and sphygmomanometers and ignoring all other sources, a hospital is accountable for an environmental mercury burden of 1,320 gms/ year (Agarwal et al., 2009; agarwal, 2009).

Most hospitals calibrate the BP apparatus by themselves. The Maintenance Department does this in most cases, and generally, the person doing it has adopted methods used by his/her predecessor. It is without any formal training on the methods of calibration or the hazards of mercury. According to some experts the mercury vapour level in such calibration rooms is much higher than the permissible limits. If one fails to clean up a mercury spill, then the mercury will eventually volatilize and might reach dangerous levels in indoor air. The risks increase if one attempts to clean up a mercury spill with a vacuum cleaner, or if the mercury is heated for some reason. The danger of significant mercury exposure is greatest in a small, poorly ventilated room.

Dental Uses

Dental fillings are done by using amalgams. Mercury vapour from amalgam is the most dangerous form of mercury, ensuring adverse developmental effects at lower levels than other forms. Although all the dentists are aware of the hazards of mercury, there is a general belief that a mercury Amalgam lasts longer(Agarwal et al., 2009). Going with a very conservative estimate (considering only mercury fever thermometers, BP apparatus and amalgams and ignoring all other uses of mercury in a hospital), an average sized hospital, with a dental wing would generate around 2.8 kg/annually of elemental mercury as hazardous waste, which is disposed into drains, or yellow bags or the general waste bins indiscriminately (Agarwal et al., 2009).

CFL Lightings

All the hospitals are fitted with CFL lightings which often get broken or fused. Compact fluorescent lamps have emerged as a viable option to sharply reduce the energy demand for lighting. Besides saving power, these lamps also hold the potential to earn carbon credits. Welcome as it is, this shift to energy efficiency has brought with it the problem of disposing waste fluorescent lamps that contain the toxic chemical mercury. As a country that consumed an estimated 140 million-plus CFL units during 2007, and given the robust growth in sales, India cannot afford to ignore the dangers of releasing mercury into the environment (Anon, 2009).

Laboratory chemicals

The mercury compound in a chemical formulation may be an active ingredient, a preservative, or a contaminant introduced during manufacturing. On an average India produces 10 to 12 million instruments a year including clinical and laboratory thermometers as well as blood pressure measuring instruments, consuming about 15 tones of mercury annually. Most of the mercury from this broken equipment either goes down the drain or is collected and put in black bags. As far as the hospitals are concerned, none of them check for mercury release, either in the incinerators or in the effluent released.

MERCURY WASTE MANAGEMENT GUIDE LINES

Mercury is not extracted in India; it is totally imported. Mercury and Mercury containing wastes are included in the waste streams of the Basel Convention on trans-boundary movements of hazardous waste and their disposal.

Mercury bearing wastes has been banned under Schedule 8 of the Hazardous Waste (Management and Handling) Amendment Rules 2003.

Workers working around mercury should wear protective clothing and gloves along with mercury respirators that prevent them from breathing in mercury vapour. People, who are constantly exposed to mercury, should be regularly tested to make sure they are not suffering any health effects due to the exposure (Anon, 2009).

In Delhi Health Care Facilities have been directed to put up / display a template at the prominent locations for the commitment to minimize mercury waste(Thejas, 2008).

Handling and disposal

Immediately after a spill keep all people and pets away from the spill area. To minimize the mercury that vaporizes, turn off any heaters and turn up any air conditioners. Ventilate the area by opening windows .

Never use a vacuum to clean up a mercury spill. Not only will the mercury contaminate your vacuum; the heat from the vacuum will evaporate the mercury, further distributing it throughout the house. Similarly, never use a broom to clean up mercury. It will only distribute the mercury into smaller beads, and will contaminate the broom (Thejas, 2008).

Assemble the necessary supplies before attempting a clean up. These include gloves, eye protection, an eyedropper or a syringe, and two stiff pieces of paper or cardboard, two plastic bags, a large tray or box, duct tape or packing tape, a flashlight and a wide mouth container. Remember that any tools used for clean up should be considered contaminated and disposed of with the mercury(Jayakrishnan, 2003).

Do not touch the mercury. Remove all jewelry and watches from your hands, as mercury will bond with the metal. Put on gloves, preferably rubber gloves to minimize contact with mercury. Use the flashlight to locate the mercury. The light will reflect off the mercury beads and make them easier to find (Jayakrishnan, 2003).

On a hard surface or tightly woven fabric, use stiff paper to push beads of mercury together. Use the eyedropper to suction the beads of mercury, or working over the tray to catch any spills, lift the beads of mercury with the stiff paper. Carefully place the mercury in a wide mouth container. Pick up any remaining beads of mercury with sticky tape and place contaminated tape in a plastic bag along with the eyedropper, stiff paper, and gloves. Label the bag as mercury waste. Place this bag and sealed container in the second bag.

ALTERNATIVES

Now majority of products that use mercury purposefully have acceptable alternatives that are currently available for use in health care facilities.

Alternatives for mercury-containing Thermometers are **e**lectronic (digital), Infrared, chemical Strip, glass filled with alcohol, gallium, indium or tin (Thejas, 2008; Thejas, 2009).

Alternatives for mercury-containing Sphygmomanometers are Aneroid and electronic BP apparatus.

Alternatives for Dental amalgams are Composite fillings, metal ceramic crown, glass inomer, synthetic polymer, gold alloy etc.

The use of mercury-free products is a cost effective choice when the direct and indirect costs are considered. Even after the availability of much safer alternatives for all mercury uses in medical sector, the government policies are silent on eliminating these toxic products. The healthcare sector has not started looking at issues of emissions from waste incinerators or the effluents discharged into sewage seriously(Agarwal et al., 2009; Agarwal, 2009).

CASE STUDY AT CALICUT MEDICAL COLLEGE

Calicut medical college is one of the 5 medical colleges in public sector in Kerala. This hospital has 1500 bed with 40 wards. This study was done by visiting the wards of hospital and observing the procedures of health care workers including waste management, conducting focus group discussions with health care workers (a) who are handling mercury based instruments like thermometers, sphygmomanometer (b) Persons who are handling waste (c) persons who are involved in repair works working in the hospital work shop.

For managing and monitoring hospital waste as well as to reduce the hospital borne infections a special wing for “House keeping ’ was established in the medical college from 2008. The special wing consists a team of health inspectors deputed from health service along with workers for biomedical waste management . None of them were aware about the hazards or any existing protocol for managing mercury waste. They are supervising the deployed manpower for waste management which consist of 250 workers in shifts of which majority are working on daily wage basis or contract. None of the workers have got formal training on mercury waste management.

There exist a system of accident register for recording injury with sharps and post exposure prophylaxis following exposure with HIV/HBV. The mercury spills were not recorded.

In the hospital nobody is using mercury free digital thermometer/ aneroid BP apparatus. Only few Doctors and nurses were heard about it. In Delhi it was 30-40% (Thejas, 2008) Only mercury based instruments were available in the hospital. Each ward has got minimum 3 BP apparatus.

Even though the hospital is following colour coded bins for biomedical waste management there is no written protocol or instructions for managing mercury waste. The mercury spillage from the thermometers and BP apparatus were handled by ward attenders. During this occasion they are wearing only single latex gloves instead of heavy duty rubber or double latex gloves. Thus the chance of mercury entering to their body through skin is high. They are mainly concerned with preventing injury with glass pieces of broken instruments. They sweep the spill in to the waste bins which were meant for infectious waste or general waste according to feasibility. Thus the mercury get mixed with other wastes and contaminate the surroundings and people. This was ultimately disposed by incineration thus the hazard gets dispersed as gas to the atmosphere and gets inhaled by human beings. In the hospital the general waste containing garbage is transferred to " Kudumbasree workers who ultimately converted them in to manure by composting which was very well appreciated as a model. By mixing mercury in the food waste the women involved in the process of composting are also unknowingly exposed to mercury toxicity.

The hospital is situated in the highest point in the corporation area hence during rainy season the probability of the waste to reach in the neighbouring areas and polluting water bodies are very high. Previous studies conducted by CWRDM documented well water contamination of Mayanad and Veliparamba , Chevayoor area by the liquid waste generated from medical college even reaching a perimeter of 2 kilometers away from the oxidation pond.

Workshop: Per month about 40 BP apparatus was brought to workshop for repair mainly due to breakage and leakage. Thus yearly 400-500 instruments are brought for repair. There is no mechanism for recycling the mercury waste. Some ward staff will collect the spilled mercury in bottles by using syringes and returned to work shop. Some of the staff complained of the damage/discoloration of their gold ornaments with mercury. Filling of each manometer requires 5ml of mercury. Annually 2 kilogram mercury was indented for purchase costing about 4000 rupees. The work shop workers are not provided with any protective equipment like gloves nor they are wearing it. There is no spillage management. They told that during the repair and refill procedures the surfaces and floors are contaminated with mercury. There is no procedure for validating the BP instruments.

RECOMMENDATIONS

Given the human health concern, it is important that awareness programmes must be launched to educate the populations about the risk and impact of mercury exposure. Strict norms to be made for the collection and containment of mercury in health care institutions.

Promote manufacture of alternatives for digital thermometers and blood pressure apparatus, non-mercury dental amalgams, through fiscal and non fiscal measures as well as awareness programs.

Clear Policy on Mercury usage- handling procedures, safeguards, spill clean up etc.

Introduce reporting formats to report and register any mercury Spills / leaks and complete Safety precautions against any possible mercury spill

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Perceptions and Practices of Waste Handling among the Women Solid Waste Workers - A Study in Thiruvananthapuram Corporation, Kerala

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INTRODUCTION

This study evaluates the perceptions and practices towards waste handling among the women employed as solid waste workers and their possible health risks as compared to a control group of women with a similar socio economic status, employed as housemaids. We observed a lapse in programme monitoring with respect to waste handling practices like segregation of waste at source by the owner (1.5%) and regular usage of Personal Protective Equipments (PPE) like gloves (9%), facemask (7%) etc. Strong awareness drives for the public along with periodic training of solid waste workers with essential health care support are all important to minimize direct health risks to the workers and ensure sustainability of the project.

Rapid population growth and economic development has led to a significant increase in waste generation. Approximately 70-80% of the volume of total waste generated would be domestic, of which upto 80% would be organic, particularly in low-income countries. The per capita waste generated ranges roughly from 100g in small towns to 500 g in large towns (Thiruvananthapuram - 550gm, Kochi - 530gm). Frequent collection and removal of waste is warranted due to its high biodegradable fraction and the tropical climate of our country (Pun et al., 2008; Joseph, 2002).

General public suffer the indirect health risks associated with solid waste such as breeding of disease vectors like mosquitoes, rats etc, but the direct health risks are borne by the solid waste workers (SWW). More than 20 diseases have been proved to be associated with improper solid waste management. Most common health hazards identified are intestinal and respiratory infections, hepatitis, skin disorders, lower back pain, hand and leg injuries etc. A study on the health of refuse workers in Thiruvananthapuram (1971) showed increased prevalence of respiratory diseases, skin diseases, jaundice and trachoma when compared to a control group (Anon, 2008). A Calcutta study demonstrated increased prevalence of chronic cough, jaundice, skin ulcers etc (Anon, 2006).

Personal hygiene is of utmost importance to combat such risks. Best practices like usage of personal protection equipments (PPE) such as gloves, face mask etc, washing hands before taking food are very important. Vaccination of workers against Hepatitis is also advisable (Dounias et al., 2005).

Directions contained in the Municipal Solid Waste (Management and Handling) Rules 2000 demand segregation of waste at source. Recommendations made by the expert committee constituted by the Hon. Supreme Court of India also called for activities like segregation of waste at source, door step collection of waste, conversion of organic waste to compost etc. Segregation of waste at source also helps to reduce the cost of waste management; provides additional income and the segregated organic waste can easily be converted to an alternate energy source.

As per the Biomedical Waste (Management and Handling) Rules 1998,transportation of the biomedical waste has to be arranged by the producers or their associations considering the health hazards and that should not be mixed with the municipal waste.

BACKGROUND

Capital City Clean City (CCCC) project of Thiruvananthapuram Corporation

Corporation had started the integrated waste management project (CCCC) in May 2006(29 wards) and extended this in a phased manner to the 86 wards of the Corporation. As per the Corporation records, 66 Kudumbasree units from 66 wards in 17 circles were registered and 817 women members are employed in the waste management project. Waste collection from the source is implemented through these Kudumbasree workers; an organized government supported Self Help Group (SHG). 10-15 women constitute an SHG and this is operated in an entrepreneurial mode. The Corporation and Kudumbasree act only as facilitators. Each unit was given a financial assistance of rupees 2.5 lakh including bank loan and subsidy for the purchase of three wheeler vehicle and other equipments required for waste collection like plastic trays, PPEs etc under SJSRY (Swarna Jayanthi Shahari Rozgar Yojana), a Government of India programme.

Two days' preliminary training about the programme was given which included topics on collection of waste, possible health risks, precautions to be taken etc. The women were advised to compulsorily wear uniform (green sari-blouse/churidar and cotton over coat) and use PPEs (gloves, mask and chappals). Corporation had supplied green bucket (15 L) for storing degradable waste and white one for putting recyclable waste to the houses/shops. The women were directed to collect segregated waste in plastic trays from each household daily to their three-wheeler vehicle and to unload the collected waste to the Corporation trucks at the loading points designated for them. These workers were permitted to collect Rs 30/- per household per month of which their dividends are taken after deducting the maintenance cost of the unit.

The collected waste is being brought to Vilappilsala plant, 13 km away from the city for treatment (composting) to produce organic manure from the degradable waste. The capacity of the treatment plant is up to 200 tonnes/ day. Landfill site is reported to be under construction.

Rationale of this study

Though the CCCC project was planned scientifically with the collection of segregated waste at source of origin and optimal usage of PPEs to avoid the possible health risks to the Solid Waste Workers (SWW), a slow discontinuance of practices advised to SWW was observed. Inherent risk of occupational health hazards to waste handlers together with inadequate provision of health check ups/ immunization coverage was important reasons to conduct this study. We assessed their perceptions, waste handling practices and associated health risks.

OBJECTIVES OF THE STUDY

Major objective

To conduct a health assessment of the solid waste workers and compare the same with a group of workers from a similar socio- economic class.

Minor objectives

- To study the perception and practice of the waste handling methods and the usage of best practices during waste handling
- To understand the impact of this vocation to their socio-economic situation.

METHODOLOGY

Study Design, Sample size and Sample Frame

Retrospective Cohort study was adopted. Sixty-six (66) cases and sixty six (66) - comparison groups were selected randomly for this study. Sample size was calculated in Epi Info 3.3.2 version with 99% confidence interval, 80% power and a morbidity prevalence of 28% among the solid waste pickers **(Calcutta study).**

Cases where Kudumbasree members working as SWWs, selected randomly from the total 817 women SWWs in Thiruvananthapuram Corporation since 2006. The control group comprised of women working as housemaids mostly from an urban slum in Thiruvananthapuram Corporation with a comparable socio economic status. The data collection was done from November 1st to December 31st 2008.

Data collection techniques and data Analysis

1) Semi structured questionnaire on demographic and socioeconomic status, perceptions about health risks, practices of waste handling etc.

2) Focus Group Discussion-2 Nos with 15 members each (in two units)

Data was entered in Microsoft Excel and analyzed in SPSS 15.0 version.

RESULTS AND DISCUSSION

This paper evaluates the perceptions of SWW about their work and the usage of best practices during solid waste handling.

Sample characteristics

Majority of the respondents among the SWWs (48.5%) and comparison group (34.8%) belonged to the age group of 34 to 43 years. Educational status was slightly higher among the SWW. Majority (48.5 percent) had 8 to 10 years of schooling against 33.3 percent among the comparison group. Only 15.2 percent of the SWW were illiterate as compared to 40.9 percent of the comparison group.

Socio economic status of solid waste workers

About three-fourth of the respondents in both the groups had own houses but 25.8 percent among the SWW had their houses in purambokku land. Remaining SWWs (27.3 %) had no land compared to only 12.1 percent in the comparison group. Majority of the comparison group were living in the flats given from government in an urban slum. One fourth of both the groups were dependent on public taps for drinking water. 9.1 percent of the SWW did not have any latrine facility against 3 percent in the comparison group.

Pre placement health check ups, training and the information conceived

There were no preplacement check ups and hence no baseline health status information available.83.3 percent SWWs had attended the two days training, 86.4 percent had reported information on health risks associated with solid waste handling, PPE usage etc while 80.3 percent were able to remember about immunizations. This warrants periodic trainings to this group as they are at relatively high risk for occupational diseases.

Waste handling practices

- Waste segregation:-Only 1.5 percent of the owners had given segregated waste. 68.2 percent of the SWW were segregating waste by themselves and 25.8 percent were sending unsegregated waste. SWW were not insisting segregation of waste at source for fear of losing clients.
- Mode of collection of waste: -57.6 percent collected waste from households in plastic carry bags and rest in trays/ buckets (Fig1). The project envisaged the use of plastic trays for collection of segregated waste but the SWW had discontinued this and started collecting waste in plastic carry bags for their convenience.

- Plastic bag segregation: -Majority SWW (75.8 %) had segregated the plastic bags from the waste and handed over the same separately to the trucks while the remaining were not.
- Number of houses for daily collection: - 42 percent SWW had less than 100 houses and 50 percent had houses between 100 & 150 for daily collection. They were not getting sufficient houses in some areas (below 100). They were ready to collect from more houses to ensure a reasonable income.

Their major complaint was regarding the quantity of solid waste collected per house. This was often too much for the charge of Rs 1/-day and they also had to handle unhygienic wastes. (sanitary waste, carcass of animals, faeces, and bio waste from clinics). Some of them reported difficulty in collecting the fee in certain localities.

Perceptions about their health risks

About 74.2 percent perceived some underlying health risks with their work. Health problems perceived were dermatitis, muscular- skeletal disorders such as backache, strain, falls, fractures etc, Tuberculosis, AIDS, malaria, cancer, stomach problems and respiratory illnesses. Most of them felt that these could be addressed through personal hygiene, usage of PPEs, keeping uniform out of their home etc. Some of

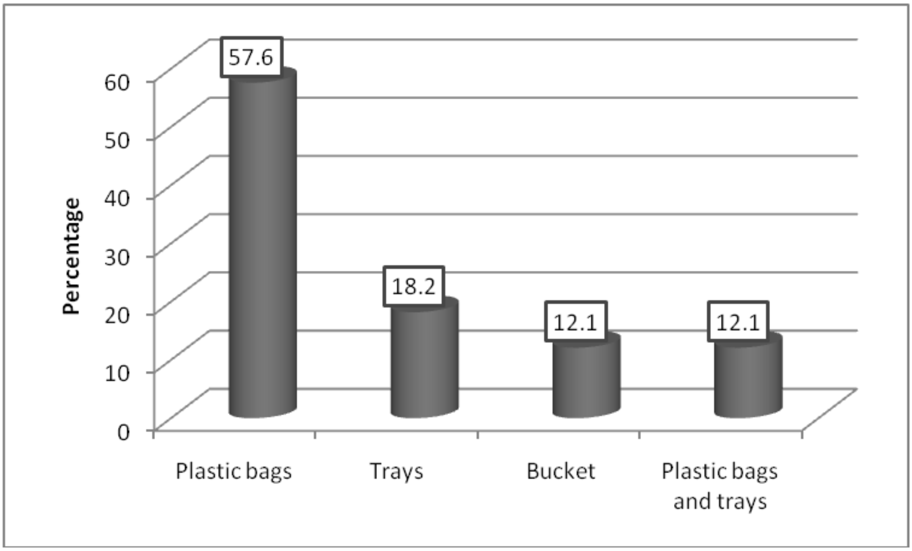

Fig1

Mode of collection of waste from houses

them anticipated no health risk in handling waste while a minority had no fear in handling waste without protection. Some of the SWWs had forgotten about the health risks and measures of precautions taught during the training. They were more concerned with the income through this vocation than health care issues due to their socio-economic backwardness.

Practice of PPE usage

As advised during the preplacement training, majority (96.6 percent) were using uniform and cotton overcoat during waste handling. Excluding the uniform, use of PPE was minimal (Table 1).Majority never used gloves (63.6 percent) and among the users majority were using plastic covers (27.3 percent) in place of gloves. Use of whistle is inevitable during the work and hence wearing facemask was reported to be difficult. A minority felt shyness to wear mask in public places. However 84.8 percent never used facemask. About 93.9 percent had the habit of regular use of ordinary chappals while the remaining never or occasionally used. Cotton overcoat or casual chappals do not serve the purpose of PPEs to this occupationally high-risk group. But majority preferred the use of gloves if they are supplied with quality gloves at free of cost. They could not afford the frequent purchase of PPEs and there were no support from the facilitators as well.

Their relatively higher education level/literacy rate, younger age etc compared to the comparison group could not be effectively converted to best practices during waste handling which shows the inadequacy of trainings, awareness and follow up of the programme with adequate support measures.

Health habits and health check ups

All the SWWs had ensured the habit of daily uniform washing and 97 percent ensured

Table 1
Usage of Personal Protective Equipments (PPE)

1	Usage of Uniform	Regular	64(96.9)
		Occasionally	2(3.03)
2	Usage of coat	Regular	64(96.9)
		Never	2(3.03)
3	Usage of gloves	Regular	9(13.6)
		Occasionally	15(22.7)
		Never	42(63.6)
4	Usage of mask	Regular	7(10.6)
		Occasionally	3(4.5)
		Never	56(84.8)
5	Usage of chappals	Regular	62(93.9)
		Occasionally	2(3.03)
		Never	2(3.03)

hand washing after waste handling. But 66.7 percent consumed food/water in between waste handling as they start their work quite early and have to postpone their lunch. Hand washing before food was reported to be done by 95.5 percent. (Table 2)

Only 22 percent had attended health check ups after starting this job.

Table 2
Health habits of SWWs

1	Washing uniform daily	Yes	66(100)
		No	0(0)
2	Hand washing after waste handling	Yes	64(97)
		No	2(3)
3	Consumption of food and water between waste handling	Yes	44(66.7)
		No	22(33.3)
4	Hand washing before food	Yes	63(95.5)
		No	3(4.5)

Majority of the SWWs (66.7 %) never had a health check up in their tenure while 31.8% attended a check up once in 12 months. According to these women, their common ailments included itching all over body, boils, losing nails, itching inside nostrils and eyes, joint pain in legs, non healing ulcers and wounds in legs and accidents by falling from vehicle. They have no holidays and do not get time off to attend the government hospital's OP timing, as they are not free in the morning hours.

Immunization status

Among the SWWs, 45.5 percent of the solid waste workers had Tetanus Toxoid coverage and 1.5 percent immunized against Hepatitis. They admitted that the usage of gloves is only when they have frequent injuries while segregating waste and domestic waste contains used syringe and needles

Their expectations from the job

They expect increased public awareness on waste segregation, better (Rs.50/per house) and prompt payment, better appreciation for their job etc through the intervention of Corporation/Kudumbasree/Resident Associations. They also anticipate incentives like small interest free loans, provision of houses to the homeless (27.3% land less), permanency of their job from corporation, financial / medical security for the sick/bedridden, provision of uniform, gloves, mask, lotion, soap, plastic trays, regular health check up, free vaccination and medical facilities.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The service of these SWWs were highly appreciated and benefited by the residents of the Corporation. The management practices followed by the SWW indicate an absence of compliance for precautionary measures, which could result in increased health risks to these workers. Their health risks (self reported through a questionnaire) were analysed in the subsequent part of the study and found to be high and statistically significant for injuries and accidents, skin and eye disorders. The exposure pathways for disease or contact pathways for injuries could be reduced through best practices. The health care support from Corporation was not adequate while none from Kudumbasree, probably because the project was designed in an entrepreneurial mode. These women being from a poor socio- economic background, we cannot expect better best practices without proper support and follow up. Though the project is scientifically deigned and implementation is in progress, monitoring lapses are evident from the stastus of waste handling practices and their perceptions. A minority perceives no health risks and totally avoids usage of PPEs/healthy habits. The unhygienic nature of their work definitely will demotivate them from keeping personal hygiene and hence this programme requires continous monitoring and evaluation and timely correction/modification.

Recommendations

1. Strong awareness programmes to reduce waste generation by different measures and to promote waste segregation at source of origin
2. Strategic health care support to ensure periodic training to SWW, supply of PPEs (water proof overcoats, gloves, masks, protective foot cover etc) through the Corporation / sponsors, health checkups atleast once in 3 months with medicines, immunizations and other health care measures, provision for insurance coverage etc.

3. Develop a system for epidemiological and medical surveillance on the health effects of the identified hazards to this group

ACKNOWLEDGEMENT

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Two-stage Anaerobic Digestion of Municipal Solid Waste Using Acid Phase Fermenters Coupled with CST Reactors with Natural / Synthetic Biofilm Support Systems.

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INTRODUCTION

About 75% of the MSW generated in urban India is collected and disposed without any processing. Improper disposal of organic solid waste has severe environmental and health consequence. Municipal solid waste (MSW) disposal without taking proper scientific methods is a major environmental problem (Mor *et al*., 2006). In Indian cities Municipal Solid Waste (MSW) generated mainly contains a significant fraction (30-50%) of biodegradable materials (Bhattacharya *et al.,* 2008). This can be used as a good resource for energy and manure generation. Anaerobic digestion is a bioconversion process that can be used to treat various organic wastes and recover bioenergy in the form of biogas, which contains mainly CH_4 and CO_2. Biogas generated by this way is found to be a clean, efficient and renewable source of energy.

Two-stage anaerobic digestion

Anaerobic digestion is mediated by a consortium of microorganism by a sequence of fermentation reactions which eventually stabilize and produce biogas from organic materials. The major group of microorganisms involved are broadly classified as volatile fatty acid (VFA) producers (acidogens) and VFA converters (acetogens and methanogens) Liu and Ghosh (1997). In conventional biogas plants all the three phases are operated in a single digester. The concept of phase separation involves operating the anaerobic digestion process in distinct phases. In some cases, the first two phase are operated simultaneously in a single reactor and methane phase run separately such process is known as ‘two-phase’, ’two-stage’ or ‘diphasic’ processes (Ramasamy and Abbasi, 1999).

Present work

In the present work, organic fraction of municipal solid waste (OFMSW) was used as a substrate in a two-stage anerobic fermentation system consisting acid phase fermenters (APFs) and Continuous Stirred Tank Reactors (CSTRs) as methane phase reactors. OFMSW was first fed into acid phase fermenters for the production of

VFAs, which was subsequently fed in to methane phase reactors /digesters (methanisers). CSTRs were used as methanisers in this study. As not many studies have been reported in the literature with the use of different materials as biofilm support system (BSS) in CSTRs for effective support to bacterial growth, an attempt has been made in this study to evaluate the performance of natural (coir fibre) and synthetic (nylon) substance as BSS in terms of biogas generation in CSTRs.

MATERIALS AND METHODS

Substrate and Inoculum

For acid phase studies, source sorted organic fraction of municipal solid waste (OFMSW) was used as the feed material and was collected from the municipal waste dump yard situated at Vadavathoor of Kottayam municipality, Kerala. The collected waste material was subjected to physical size reduction (1-2cm) processes before feeding into the reactors. In methane phase reactors a mixture of DCDS (digested cow-dung slurry) and FCDS (Fresh cow-dung slurry) was used as inoculum. The FCDS was prepared by mixing fresh cow-dung with water in 1:4 (w/v) ratios and the DCDS was collected from a plug flow biogas plant running in good condition, mixed with water in 1:4 (v/v) ratio. Both were allowed to settle for about 2 hours in a glass column, and then the supernatant was decanted and filtered through a cotton cloth. The filtrate of DCDS and FCDS were mixed in equal volume (1:1 ratio) and used as inoculum.

DIGESTERS

Acid phase fermenters (APFs)

The reactors in which hydrolytic and acid phase reactions were operated together are referred to as acid phase reactors. Plastic vessels of 5 litre capacity were used as acid phase fermenters (APFs) (Figure 1). Two fermenters were fabricated each one had a tap fixed at the bottom.

Continuously Stirred tank reactors (CSTRs)

One litre conical flask (Borosil glass) was fabricated in to a CSTR digester (Figure 2). Each CSTR had 2 outlets, one for gas and other for effluent and one inlet for the feed. The inlet was extended up to the bottom of the digester in order to prevent the

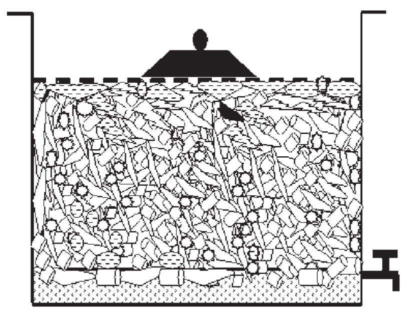

Fig.1 Schematic diagram of acid phase fementer (APF)

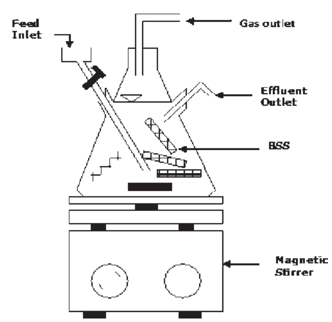

Fig.2 Stirred Tank Reactor with (BSS)

simultaneous escape of the influent itself while feeding. Five such CSTRs were fabricated and used in the present study. Each reactor was placed over a magnetic stirrer and teflon coated magnetic paddle was placed inside the reactor for stirring the reactor content. As these reactors were operated with continuous stirring they are referred as CSTRs (Continuous Stirred Tank Reactors).

Biofilm Support System (BSS)

Two kinds of biofilm support system (BSS) were used in this study. Out of which one was made up of synthetic material (nylon mesh) and the other one was natural coir fiber. The nylon BSS were made by rolling low density nylon meshes. They were then stitched using same material in order to maintain their cylindrical shape having 2 cm diameter and 10 cm length. Each one thus having a volume of 31.4 cm3. Two such nylon BSS were used in each reactors. The other type of BSS was made up of natural coir fiber. The coir fiber after removing the hard outer skin was cut in to small blocks, each measuring 5.25 cm length, 2 cm width; 1.5 cm height having a volume of 15.75 cm3. Four such blocks was used in each reactor.

Analytical methods

The moisture content, total solids (TS), volatile solids (VS), COD, total kjeldahl nitrogen (TKN) and ash content of the influent and effluent of the reactors were determined as per standard methods (APHA, 1998). pH was estimated using a digital pH meter. Volatile fatty acids (VFAs) were estimated by Diallo and Albertson method (1961).

DIGESTER OPERATION

Acid phase fermenters (APFs)

The APFs were operated with an HRT of two days. The reactor was loaded with 1 kilogram of OFMSW as feed and 1 litre tap water. Periodic stirring of the contents inside the reactor were done 4 times in a day using a plastic rod. After 48 hours the liquid portion of reactor was collected from tap fixed at the bottom of the APF. The liquid collected referred as bioleachate in the rest of the text- was analysed for its VFA content, then diluted and fed into CST reactors.

Continuous Stirred Tank Reactor (CSTR)

A total of five CSTRs, having 1-litre capacity were employed in this study. During the start-up phase, each CSTR was fed with one litre of mixed liquor (ML) consisting of bioleachate (VFA 1000±100 mg/l), FCDS and DCDS in the following proportions: bioleachate75%; FCDS 12.5% and DCDS 12.5%. Initially the CSTRs were operated at batch mode for 10 days. After 10th day, feeding was initiated and feed composition was maintained as that of ML used initially. For the next 45 days, the reactors were operated semi continuously (i.e. the CSTR were fed periodically) with a HRT (Hydraulic Retention Time) of 15 days. Accordingly, on each day the reactors were fed with 66.6ml of ML consisting bioleachate (75%), FCDS (12.5%) and DCDS (12.5%). After a successful completion of 3 cycles (45 days) with a HRT of 15 days, the composition of the feed was changed from ML to only bioleachate, that is, the FCDS and DCDS were eliminated from the feed thus the reactors were fed with bioleachate only consisting VFA. The HRT was maintained as 15 days. Periodic assessment of the reactor performance in terms of pH, VFA concentration in the effluent and effluent COD removal and biogas yield were also monitored.

RESULTS AND DISCUSSION

Table 1 gives the physicochemical characteristics of the OFMSW subjected as feed in APF reactors.

Table 1
Physicochemical characteristics of OFMSW

Constituents	Percentage composition
TS	7.6 %
VS	88.4 % (of TS)
Organic Carbon	37.4 %
Total Kjeldahl Nitrogen (TKN)	1.1 %
pH	6.4
C:N	34

From APF reactors about 900-1100 ml of bioleachate was extracted in every 48 hours. The VFA content in the bioleachate ranged from 2000 to 3500mg/L. The bioleachate produced from the APF was diluted with tap water in order to attain the VFA concentration of 1000+ 100 mg/L and fed into CSTRs. As more than 1500 mg/L of VFA concentration would affect the performance of CSTRs (Varal et al., 1977; Bindu and Ramasamy, 2008) it was adapted in this study to use bioleachate as feed with a VFA concentration of 1000 + 100 mg/L.

During the study period daily monitoring of gas production was carried out. Out of the five CSTRs, two were operated with coir fibre BSS, two with nylon BSS system and one as control having no BSS in it. Cumulative gas productions from the reactors were plotted in figure 1. It is noticed that the reactors with BSS have performed better than the control reactor which was having no BSS in it. Accordingly, the reactors with coir BSS produced 29.53% more biogas than the control reactor. Among the BSS reactors, the reactor with coir BSS have yielded 18.49% higher biogas than the nylon BSS reactors.

pH of the effluent samples ranges from 5.79 to 6.05 (Table 2). The ideal pH range for anaerobic digestion is very narrow (pH 6.8-7.2) and the growth rate of methanogens is greatly reduced below pH 6.6 (Mosey and Fernandes, 1989). It has been observed from the results that from 54th day the effluent pH seems to be within 6.91 and 7.44 in the digesters express a good methanogenic condition inside the reactors. There has been a considerable reduction in the values of TS and VS in the effluent compared with the influent. The results of VFA analysis indicated that an increase in the VFA concentration of effluent from the reactors was observed in the start up phase and it continued up to 54th day. This is mainly due to the contribution of VFA present in the FCDS and DCDS. When the feed of CSTR was shifted to bioleachate only, the situation has changed and it was found that reactor with coir BSS found more efficient in consuming VFA. In the case of percentage COD removal from the reactors at the initial stage the removal was found less and during the progress of the experiment all the reactors shows better removal.

Table 2
pH, TS, VS , VFA and % COD removal in CSTRs

Days	Reactor	*pH*		*TS %*		*VS as % of TS*		*VFA mg/L*		*% COD removal*
		Influent	*Effluent*	*Influent*	*Effluent*	*Influent*	*Effluent*	*Influent*	*Effluent*	
26th	*CSTR with Nylon BSS*	5.54	6.05	1.51	0.68	69.74	63.77	1250	1800	31.96
	CSTR with Coir BSS		5.79		0.58		60.34		1900	14.43
	CSTR without BSS		6.00		0.69		62.85		1900	26.8
54th	*CSTR with Nylon BSS*	5.56	7.01	0.62	0.6	70.65	59.01	1150	1100	41.96
	CSTR with Coir BSS		6.95		0.54		66.67		1150	55.36
	CSTR without BSS		7.12		0.39		48.71		1150	80.36
68th	*CSTR with Nylon BSS*	3.47	7.35	0.76	0.39	78.48	57.5	1150	1050	51.28
	CSTR with Coir BSS		7.32		0.18		88.9		850	39.74
	CSTR without BSS		7.26		0.3		45.17		950	62.82
82nd	*CSTR with Nylon BSS*	3.79	7.42	0.77	0.32	95.65	62.5	1000	900	55.29
	CSTR with Coir BSS		7.35		0.25		60.0		800	78.82
	CSTR without BSS		7.44		0.31		54.83		850	65.88
102nd	*CSTR with Nylon BSS*	3.61	6.91	1.22	0.16	63.76	63.9	1000	950	76.11
	CSTR with Coir BSS		7.10		0.86		62.85		900	40.29
	CSTR without BSS		6.98		0.13		73.02		950	41.79

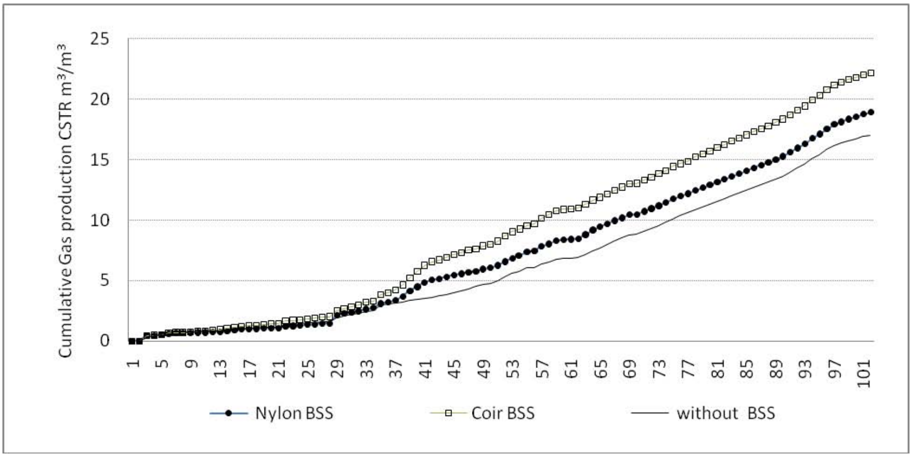

Fig 1

Cumulative biogas (average of two reactors for nylon BSS and coir BSS) yield of CSTRs

SUMMARY AND CONCLUSION

The biogas yield of different CSTRs, indicate that the reactors having BSS performed better than the control reactor which was having no BSS in it. Among the reactors with BSS, the reactors having coir fiber BSS have performed with higher gas yield than the reactors with nylon BSS. The result of the study showed that provision of support system (BSS) improved the CSTRs performance significantly. The enhancement in the performance of BSS reactors could be attributed to the rapid growth and attachment of microbes over the support system's surface. The growth of such surface-attached micro organisms brought about the efficient destruction of organic matter in BSS reactors leading to more biogas yield. Similar observation was reported by Sharma et al. (1994) in their studies on the treatment of petrochemical wastewaters.

Considerable increase in the performance of CSTRs with BSS was also reported by Ramasamy and Abbasi (1999) in his studies on diphasic anaerobic fermentation of aquatic weeds. In yet another study, the BSS augmented STRs treating dairy wastewater performed better than control reactors (Ramasamy and Abbasi, 2001). Rosili and Ramasamy (2003) in their work on rubber industry wastewater treatment with CSTRs also observed better performance of CSTRs with BSS than the control CSTR having no BSS in them.

CSTR with coir fiber BSS have shown the best biogas yield than all other CSTRs used in this study, this would be attributed to the highly porous nature of the coir fiber block, as these pores, would enhance the total surface area available for the microbial attachment and subsequent biofilm development.

ACKNOWLEDGEMENT

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Young Scientist's Award Presentations

Methylene Blue Removal from Aqueous Solution Using Zinc Oxide Nanoparticles

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INTRODUCTION

Material scientists and engineers have made significant developments in improving the methods of synthesis of nanomaterial solids. Some of the methods used for the synthesis of nonmaterials are gas condensation, vacuum deposition and vaporization, chemical vapor deposition (CVD) and chemical vapor condensation (CVC), mechanical attrition, sol-gel techniques, electrodeposition, etc. (Zhuand Zhou, 2008). Nanomaterials such as nanoparticles with high surface area to volume ratio could potentially be applied in pollution control, catalysis, water remediation, agriculture, clean energy and sun screens for protection against UV light. Over the last few decades, society has become increasingly sensitive towards the protection of the environment. The colour manufacturing industry represents a relatively small part of the overall chemical industry. Dyes and pigments are highly visible material. Thus even minor release into the environment may cause the appearance of colour, for example in open waters, which attracts the critical attention of public and local authorities (Pearce et al., 2003). A major source of release of colour into the environment is associated with the incomplete exhaustion of dyes onto textile fibre from an aqueous dyeing process and the need to reduce the amount of residual dye in textile effluent has thus become a major concern in recent years. Many dyes and their break down products may be toxic for living organisms (Bhatnagar and Jain, 2004; Bhattacharyya and Sharma, 2005). Dyes such as methylene blue are also harmful to aquatic life. So, it is necessary to remove any such dye from the wastewater before its disposal in to the natural waters. Research works had already been done in this direction. Dyes are mainly removed by physical and chemical methods such as coagulation, ultra-filtration, electro-chemical adsorption and photo-oxidation. But these methods are not commercially feasible since they are very costly. Adsorption is the most promising technique compared to other methods since dyes occur at low concentrations (Bhattacharyya and Sharma, 2005). Granulated activated carbon (GAC) or powdered activated carbon (PAC) is commonly used for dye removal (Waranusantigul et al., 2003; Ramakrishna and Viraraghavan, 1997). However, they are expensive and the regeneration or disposal of it has several problematic. So the need at the moment is efficient and cheap materials for dye removal.

The present study investigates the use of zinc oxide nanoparticle as a potential methylene blue adsorbent from aqueous solutions. MB was selected as a model pollutant because basic dyes constitutes approximately half of the textile industry waste and it is estimated that about 15% of the dye produced is released into the environment (Talarposhti et al., 2001; Walker and Weatherley, 1998). Various parameters affecting the adsorption have been investigated, and adsorption capacities and intensities of the adsorbents (Ramakrishna and Viraraghavan, 1997). Batch adsorption studies were conducted in order to determine whether these materials are suitable for water treatment applications. Since traditional technologies are ineffective and expensive, laboratory batch studies were conducted and the applicability of the Langmuir isotherm was examined. This helps to evaluate the adsorption capacity of the adsorbents.

MATERIALS AND METHODS

The Chemicals used are, methylene blue (3, 7-bis (dimethyl amino) phenazo thionium chloride), zinc sulphate (ZnSO4.7H20), sodium hydroxide (NaOH). All these chemicals were collected from Merck Specialities Pvt. Ltd, Mumbai.

Adsorbate solution

A stock solution of methylene blue was prepared by dissolving the required quantity of dye in deionised water. All working solutions of various concentrations were obtained by diluting the stock solution to desired concentration with distilled water and were used for the measurement of colour removal.

Adsorbents

Adsorbents used in this study were nanoparticles of zinc oxide. In this work nanoparticles were prepared by the one-step solid state reaction. In this method weighed quantity of ZnSO4.7H2O was ground for about 5 minutes and then mixed with required pre-determined amount of NaOH in 1:4 molar ratios. The final product was then filtered and dried into solid powders at 800 C.

Characterization of zinc oxide nanoparticles

The synthesized nanopowders were charecterised by X-ray diffraction (XRD), Scanning Electron Microscope (SEM), Infra red spectroscopy (IR), UV-Visible Spectrophotometer, and Thermo gravimetric analysis (TGA).

Batch adsorption studies

The batch adsorption studies were performed at room temperature. The biosorption capacity of known weight of adsorbents was determined by contacting 10mg/L of the adsorbate solution in a stoppered 250ml flask at the optimum temperature in a heavy rotary shaker for a known period of time at 150 rpm. After equilibrium, the filtrate was analysed for the concentration of dye remaining in the solution. It was analysed by the comparison of sample solution and standard solution of known concentrations by using UV-Visible spectrophotometer. The dye removal affinity of ZnO was determined from batch experiments. The effect of several parameters such as adsorbent dose, contact time and pH were studied. The pH of the adsorptive solution was adjusted using 0.1N of Hydrochloric acid or 0.1N Sodium hydroxide.

The results of these studies were used to obtain the optimum conditions for the maximum dye removal from aqueous solution. The Langmuir model was used to describe the equilibrium nature of methylene blue adsorption on to ZnO.

RESULTS AND DISCUSSIONS

Characterisation of Nanoparticles

Various techniques such as XRD, SEM, TGA and UV spectroscopic techniques were employed for the analysis of nanomaterials

Adsorption studies

Effect of Contact Time

Fig 1 shows the effect of contact time on adsorption of methylene blue using nano ZnO. A solution of 10mg/L methylene blue was used for the study. From the figure it is clear that the colour removal efficiency increases with increase in contact time and then, it tends to become constant after a certain period of contact time. It was observed that the dye removal efficiency of nano ZnO increased from 29% to 63% when contact time was increased from 10 min to 180min. It is evident from the results that, for the same concentration, the percentage removal of dye increases with increase of contact time till equilibrium was attained. The optimal contact time to attain equilibrium was found to be 180 min. This result is significant as equilibrium time is one of the important parameters of wastewater treatment.

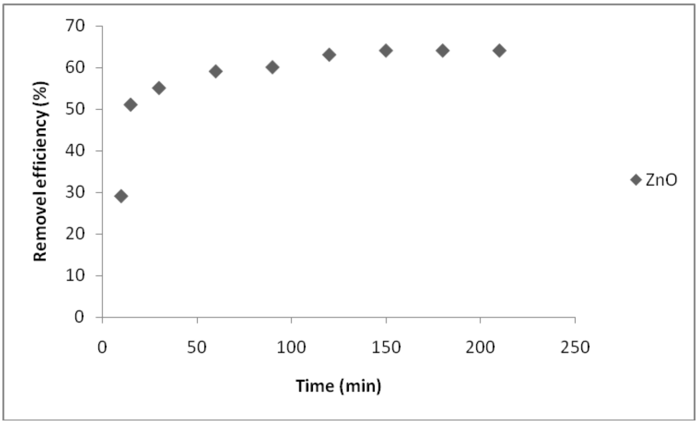

Fig 1
Effect of contact time on the removal of MB

Fig 2 shows the effect of pH on methylene blue removal by nano ZnO. It was observed that the uptake of MB by ZnO at pH 3.0 is 46%. The low adsorption of MB under acidic conditions was probably due to the presence of excess H+ ions competing with the dye cation MB+ for the adsorption sites. ZnO shows increase in dye adsorption from 46% to 70% as pH is increased from 3.0 to 8.0. The increase in the dye removal as the pH increase can be explained on the basis of a decrease in competition between proton and dye cations for the same functional groups and by the decrease in positive surface charge, which results in a lower electrostatic repulsion between the surface and MB+. This may be due to the lesser protonation on the surface of the adsorbent leading to the enhancement of MB adsorption.

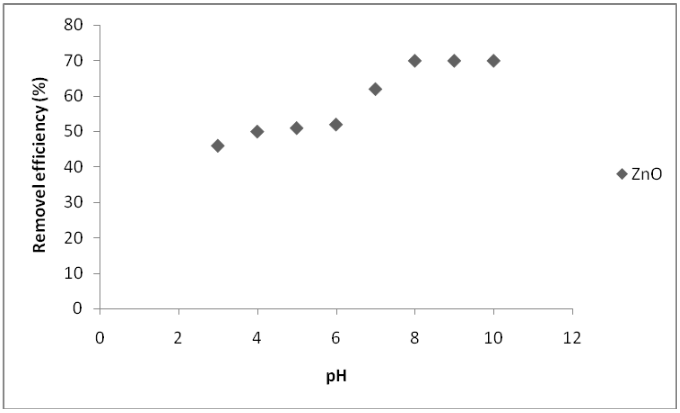

Fig 2
Effect of pH on the removal of MB

Effect of Dose

The effect of adsorbent dosage on the efficiency of MB removal using nano ZnO are shown in figure 3. A solution of 10mg/L initial concentration was used at different adsorbent dosage of 0.1g, 0.2g, 0.3g, 0.4g, 0.5g, 0.6g, 0.7g and 0.8g at 150 rpm for 3.0 h. From figure.5 it is clear that the amount of dye adsorbed varied with the adsorbent concentration and that with increasing adsorbent dosage MB removal increases. By using nano ZnO as adsorbent, the percentage removal of MB increased from 64% to 86% with an increase in adsorbent concentration from 0.1g to 1g. This is due to the increased availability of active adsorption sites arising as a result of increase in effective surface area or due to conglomeration of the adsorbent. Similar behaviour for the effect of adsorbent concentrations on MB sorption capacity was observed and discussed in the literature for other types of adsorbents (Dror, 2005; Mohsen, 2001; Mamadu and Savage, 2005).

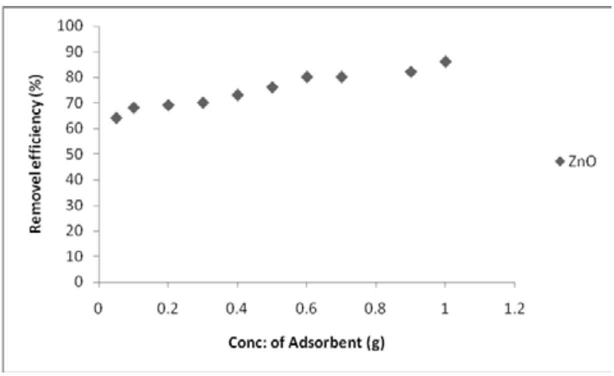

Fig 3
Effect of dose of adsorbent on the removal of MB

Adsorption isotherm

The Langmuir model was used to describe the equilibrium nature of methylene blue adsorption on to nanopowders [5]. The Langmuir isotherm model takes the form:

$$q_e = \frac{K_L C_e}{1+\alpha_L C_e}$$

Where qe (mg/g) is the amount of dye adsorbed onto the unit mass of the adsorbent to form a complete monolayer on the surface. KL is the Langmuir equilibrium constant which is related to the affinity of binding sites; Ce (mg/l) the solution phase dye concentration, and ?L is the Langmuir constant.

Fig 4 shows that the linearised equations of the Langmuir isotherm over the whole range of dose of all the three adsorbents were studied. The values of Langmuir constants ?L, KL and RL are calculated. The values of R2 are regarded as a measure of the goodness of fit of experimental data on the isotherm model. For the nano ZnO, in the Langmuir model, being very close to 1 are near perfect. Since the RL values lie between 0 and 1 for nano ZnO, it is seen that the adsorption of methylene blue is favorable. The adsorption capacity, indicated by the value of ?L, was seen to be 0.2574mg/g, and the energy of adsorption is indicated by KL was found to be 0.00695/mg. On the basis of regression analysis of the experimental data the adsorptive behaviour of MB on ZnO nanoparticles, are in good agreement with Langmuir model. These can be attributed to three main causes (i) the formation of monolayer coverage on the surface of nanoparticles with minimal interactions among molecules of substrate (ii) immobile and localized adsorption and (iii) all sites having equal adsorption energies. The shape of isotherms suggests that there are high energy adsorption sites to favour strong adsorption at low equilibrium concentrations for the nanoparticles. Ion exchange may be the principle mechanism for the removal of dye.

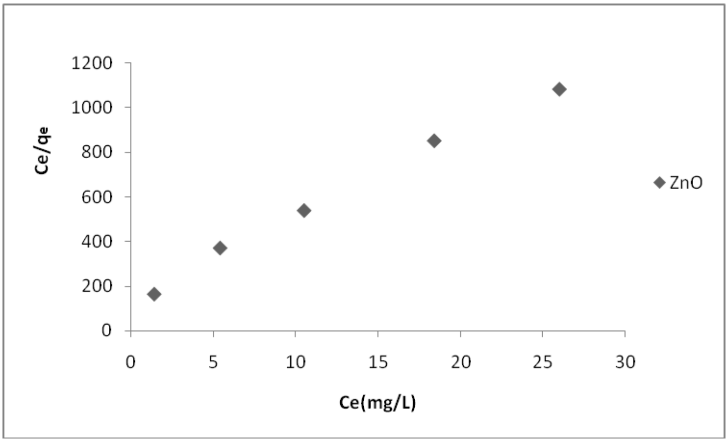

Fig 4
Langmuir isotherm of nano ZnO

CONCLUSION

In the area of water purification, nanotechnology offers the possibility of an efficient technique for the removal of pollutants and germs. The effectiveness of adsorption of dye from wastewaters has made it an ideal alternative to other expensive treatment methods. This study aims at the removal of methylene blue dye from aqueous solutions using ZnO nanomaterials and it was prepared by the one-step solid-state reaction. Characterisation was done using XRD, SEM, TGA, UV- VIS spectroscopic techniques, and FTIR spectra. The effects of adsorbent dosage, pH and contact time on MB adsorption by nanoparticle were studied. The result show that the dye removal efficiency increased with increase in the adsorbent dose. The optimal contact time to attain equilibrium was experimentally found to be 180 min and optimum pH value for dye adsorption was determined as 8.0. The equilibrium adsorption isotherm of MB on to the ZnO nanoparticles was well described by Langmuir model. We envision that nanomaterials will become critical components of industrial and public water purification systems as more progress is made towards the synthesis of cost-effective and environmentally acceptable functional materials. These experimental studies on adsorbents would be quite useful in developing an appropriate technology for the removal of dyes from contaminated industrial effluents.

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Remediation of Heavy Metals in Waste Water Contaminated Soils using Vetiver Plants

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INTRODUCTION

The quality of life is closely associated with the quality of environment. Due to fast urbanization with industrial and commercial development, in its wake has posed a major problem of safe disposal of industrial effluents in different parts of the country. Soils and waters are generally contaminated with heavy metals and other toxic wastes as a result of numerous anthropogenic activities primarily associated with industrial processes, manufacturing and disposal of industrial and domestic refuse (Kumar, 1991). One of the important toxic components of all small scale and large scale industrial effluents are heavy metals. From the polluted soils and waters the heavy metals enter into the food chain. Many innovative methods have been invented to clean the waste waters and soil, but they are usually been time consuming and expensive. Phytoremediation of waste waters and soil contaminated with different effluents, toxic chemicals and heavy metals offer a low cost method for remediation and some extracted metals may be recycled for value. It is the clean up of contaminated soils, sediments, or water primarily mediated by photosynthetic plants by various mechanisms (phytostabilization, phytoextraction, or rhizofiltration and phytovolatalization) which living plants alter the chemical composition of soil matrix into a harmless form, in which they are growing. Vetiver grass is a versatile hardy plant having stuff and erect stems, deep, extensive, fast growing and penetrating root systems and are highly tolerant to adverse climatic conditions [frost, heat, wave, temperature (5-55^{0}C), drought, flood and inundation], edaphic conditions, and highly tolerant to elevated levels of heavy metals [As, Cd, Cu, Pb, Hg, Ni, Se and Zn], herbicides, pesticides, and high efficiency in absorbing dissolved nitrogen, phosphorous, sulphate, As, Cd, Cu, Pb, Hg, Ni, Se and Zn (Zhen *et al.*,1997;Troung *et al.*, 1995 and Knoll,1997). The present study aims to find out the effiency of Vetiver plants for the remediation of heavy metals in soils contaminated with waste waters.

MATERIALS AND METHODS

Plant materials

Vetiver plants (*Vetiveria zizanioides* L.Nash) were collected from the garden in

Kariavattom Campus, University of Kerala, Thiruvananthapuram. The Vetiver plants were removed from the propagating soil and surface sterilized with distilled water to remove any adhering soil. Then the tops and roots of the Vetiver sprouts were pruned to 10 cm and 5 cm respectively.

Waste waters used for the experimental study and its sources.

The waste waters were collected from different stations in Thiruvananthapuram city and were used for phytoremediation studies using Vetiver plants. These includes waste waters from four different sources ie. Travancore Titanium Limited at Kochuveli; Automobile Service station at Pattom; Automobile spray painting workshop at Pazhavangadi in Thiruvananthapuram district and the raw domestic waste water from the Hotel at Kazhakkuttam. The temperature and pH of the waste waters were recorded at the collection point. For the determination of Dissolved Oxygen and Biological Oxygen Demand, samples were collected in the labeled BOD bottles and fixed with Winkler's reagent at the site. All these samples were brought to the laboratory and analyzed for various physico-chemical characteristics. All the bio-chemicals and chemicals used for the estimations were of analytical grade.

Experimental Design

The earthen pots with no drainage holes were used for planting the Vetiver plants and this prevented loss of any nutrients due to drainage or leachate from the pots. The healthy Vetiver sprouts were trasnsplanted into the labeled pots containing 3 kg of potting mixture (Prepared by mixing the soil, sand and cow dung in the ratio 1:1:1) and divided into five groups (Control and test groups). Then the plants were irrigated with tap water for 15 days. Waste water treatments to the test groups(T_1, T_2, T_3,and T_4) were started on the 15 th day of planting. The control plants were irrigated daily with tap water and the test groups were treated on alternate days with 250 ml of respective waste waters for next 45 days [T_1 by TTP effluent (1:1 dilution), T_2 by Service Station effluent, T_3 by Spray painting workshop effluent and T_4 by Domestic effluent] and tap water. Duplicates for test and control groups were also maintained during the study period. Therefore the duration of the experiment was for 60 days. All the study group plants were uprooted after 60 days, washed carefully with distilled water to remove any dust and soil adhered on the plants. The morphological changes (plant height, number of leaves, leaf area, and root length) and the total wet biomass of different test groups were determined immediately. The plant parts were carefully separated and the fresh samples were used for the analysis of pigments and biomolecules. The plant materials were also dried in the hot air oven at 70^0C for 24-36 hours. This oven dried samples were ground and used for the analysis of nutrients and heavy metals. The heavy metal content in the soils were determined in the begining and end of the experimental period.

Methodology

The various physico-chemical attributes of waste water samples were analyzed by following the procedure of APHA (2005) and Trivedy & Goel (1998). The biochemical parameters and heavy metal content in experimental plants were determined following the standard procedures of Sadasivam and Manikam (1996), and Gupta (1999). Analysis of the physico-chemical characteristics of soil samples were carried out by following the standard procedures described by Saxena (1994) and Trivedy &Goel (1998). The nutrients and heavy metal contents were determined using a Flame photometer (ELICO, Model CL 360) and an Atomic Absorption Spectrophotometer (ELICO, SL 194) respectively.

RESULTS AND DISCUSSION

Changes in the Water and Waste water Characteristics

The results of the physico-chemical characteristics of water and waste water are given in Table 1. In different waste waters analysed majority of the water quality

Table 1.
Physico-chemical Characteristics of Water and Waste waters

Water Quality Parameters	Samples				
	Tap water	E_1	E_2	E_3	E_4
Temperature (^0C)	27	57	27	26	28
Colour (Hazen Unit)	unobjec tionable	200	30	20	200
Odour	unobjec tionable	Pungent	Objecti onable	Objection able	Objectiona ble
Turbidity (NTU)	4.9	55.6	21.7	16.2	49.1
Conductivity (mS/cm)	--	ND	387	996	829
pH	6.8	1.6	6.92	5.38	4.21
TS (mg/L)	180	152840	3200	10416	29720
TDS (mg/L)	60	62460	647	867	1680
TSS (mg/L)	120	90280	2553	9549	28040
DO (mg/L)	6.8	ND	6.08	5.94	6.04
BOD (mg/L)	--	ND	0.42	0.41	5.84
COD (mg/L)	--	4000	450	2720	2080
Total Nitrogen (mg/L)	--	7.66	16.72	14.6	87.6
Total Phosphorous (mg/L)	--	0.8714	7.9875	12.7382	8.9031
Sulphate (mg/L)	135	ND	152.85	188.15	66.62
Chloride (mg/L)	125	ND	544.70	865.82	303.77
Calcium (mg/L)	42	ND	25.651	40.882	64.128
Magnesium (mg/L)	30	ND	11.872	14.132	38.983
Sodium (mg/L)	4.9	35.7	47.4	57.3	78.4
Potassium (mg/L)	7.6	49.2	170.0	248.3	187.6
Zinc (mg/L)	BDL	1.8	2.05	7.9	10.75
Copper	BDL	0.09	0.26	1.55	2.97

parameters ie. colour, turbidity, total solids, total dissolved solids, BOD, COD, nitrates, phosphates and heavy metals such as Zn, Cu, Cr and Pb are above the permissible standard limits for safe disposal to inland water bodies/ land as per the Indian Environmental Standards (Sharma & Dietz , 2006). In the present study the Zn content in waste waters E_1 and E_2 fall within the standard permissible limit. The waste waters E_3 (waste waters from automobile spray painting workshop) and E_4 (domestic waste waters) showed Zn value above the permissible concentration, and contain high amounts of Zn than the other waste waters collected. Studies by Om *et al.,* (1994) reported that majority of the industrial waste waters were rich in Zn contents. The Cu content in waste waters E_1, E_2, E_3 and E_4 analysed showed 0.09 mg/L, 0.26 mg/L, 1.55 mg/L and 2.97 mg/L respectively.

According to Indian Environmental Standards the maximum permissible range of Cr in industrial waste water which can be disposed directly into inland surface water body is 0.3 mg/L (Raman and Devotte, 2006). The result indicated that except in E_3 the other waste waters E_1, E_2 and E_4 reported high amounts of chromium. Adriano (1984) reported that domestic waste water contain 50 - 30,000 ppm of Cr. The recorded values of E_1, E_2, E_3 and E_4 were 0.06 mg/L, 2.6 mg/L, 4. mg/L and 0.04 mg/L Pb respectively. Studies reported that irrigation using heavy metals containing waste waters in soil resulting into build up of these metals in soil and there by enters into plant cells and animal cells through food chain and thus biomagnified it (Wolfyang *et al.,* 1995). So the waste waters should be treated to remove undesirable amounts of pollutants before it is disposed into the inland surface waters or to land.

Changes in Plant Characteristics

The results obtained for the total biomass and other morphological parameters were given in Table.2. From the results it could be noted that expcet in T_4 group the morphological parameters such as plant height, root length, number of leaves and total biomass showed a decrease compared to the control group.

Table 2
Morphological characteristics and Total Biomass
(Values are the mean ± SD of three replicates).

Groups	Plant Height (cm)	Root Length (cm)	Number of leaves	Total wet biomas (g)
Control	160 ± 2.0	120 ± 3.0	18 ± 2	65.6 ± 1.6
T_1	120 ± 2.0	48 ± 2.5	15 ± 1	37.9 ± 0.9
T_2	155 ± 1.7	71 ± 1.0	18 ± 1	63.7 ± 1.6
T_3	158 ± 2.0	77 ± 1.5	18 ± 2	64.3 ± 2.0
T_4	170 ± 2.5	130 ± 2.6	26 ± 1	70.9 ± 3.0

Chlorophylls and carotenoids are important photosynthetic pigments found in leaves. The pigment concentrations of both the control and test groups were estimated and the results are given in the Table 3. The results showed that all the test group plants except T_4 showed reduction in the concentration of total chlorophylls compared to that of the control plants. The T_1 plant showed significant depletion in the concentration of chlorophylls ('a', 'b' and total) than all the other remaining test groups. It might be due to the acidity of the soil resulting from the irrigation with acidic waste water (E_1). It was reported that in highly acidic environment, plant suffer from acid stress and it will affect the biosynthesis of chlorophylls in green plants (Zhou *et al.*, 2001). The decrease in chlorophyll contents leads to the decrease in photosynthesis of leaves, and thus the overall growth of the plants. Studies by Zengen and Kirbag (2007) reported that under heavy metal stress synthesis of photosynthetic pigments like chlorophylls and carotinoid contents were found decreased in several plant species. But a significant increase was noticed in the case of T_4 plants, which was irrigated with domestic waste water (E_4) and the value was recorded as 0.113 ± 0.01 mg /g FW. This may be due to the high nutrients in the domestic waste waters and tolerance of Vetiver grass.

Table 3
Concentrations of Chlorophylls and Carotenoids in Leaves
(Values are the mean ± SD of three replicates).

Groups	Chlorophyll 'a' (mg/g FW)	Chlorophyll 'b' (mg/g FW)	Total Chlorophyll (mg/g FW)	Total Carotenoids (mg/g FW)
Control	4.61 ± 0.02	2.14 ± 0.01	6.74 ± 0.06	0.092 ± 0.01
T_1	2.11 ± 0.04	1.15 ± 0.03	3.22 ± 0.05	0.001 ± 0.01
T_2	2.45 ± 0.01	3.71 ± 0.10	6.15 ± 0.10	0.067 ± 0.01
T_3	3.21 ± 0.20	3.13 ± 0.10	3.34 ± 0.20	0.066 ± 0.02
T_4	5.49 ± 0.10	8.74 ± 0.01	14.22 ± 0.07	0.113 ± 0.01

The concentration of biomolecules in both control and test group plants are given in Table 4. The results showed that, the amount of biomolecules such as carbohydrate and protein contents of the different test groups varied when compared to that of the control. It was also noted that carbohydrate content was found higher in roots than in leaves, and the protein content was found high in leaves. The carbohydrates and protein contents also showed significant reduction in T_1 plants. It may be due to the generation of acid stress resulting from the irrigation of soil with highly toxic and acidic waste water from the Titanium industry. The carbohydrate and protein content in T_2 and T_3 plants showed only slight decrease from the control and this might be due to the uptake of nutrients resulting from the application of waste waters E_2 and $E_{3,}$ and the plants absorbed the micro and macro nutrients in sufficient quantities for the synthesis of biomolecules to a certain extent. Study by Oncel *et*

Table 4
Concentrations of Carbohydrates and Proteins
(Values are the mean ± SD of three replicates).

Groups	Total Carbohydrates (mg/g FW)		Total Proteins (mg/g FW)	
	Leaf	Root	Leaf	Root
Control	30.08 ± 0.01	39.76 ± 0.06	32.71 ± 0.03	19.97 ± 0.03
T_1	26.14 ± 0.03	34.18 ± 0.05	28.34 ± 0.01	15.87 ± 0.04
T_2	30.06 ± 0.10	39.21 ± 0.05	32.12 ± 0.10	19.21 ± 0.10
T_3	29.92 ± 0.10	38.72 ± 0.01	32.26 ± 0.20	19.43 ± 0.07
T_4	35.21 ± 0.06	35.31 ± 0.02	38.11 ± 0.01	26.71 ± 0.30

al., (2000) reported that absorption of sufficient amounts of nutrients from the soil (Ca, Mg, Na, P, K, N etc) may aggravate the defense mechanism there by scavenging the activity of heavy metals induced stress.

The results of the concentration of heavy metals Zn, Cu, Cr, Cd and Pb in plant parts are presented in the Table 5. The results showed that the roots of Vetiver plants accumulate high amounts of heavy metals than leaves. The Zn content in the experiment plants was increased when compared to control plants. Zn is commonly found in all plant cells as it can act as a micronutrient, it play central metabolic roles in the plant body. But when it exceeds the tolerance limit, it exerts phytotoxic effects in plants (Willey, 2007). The T_4 plants showed highest amounts of Zn which may be due to the absorption of Zn from domestic waste water used for irrigation.

Table 5
Concentrations of Heavy Metals in Plants
(Values are the mean ± SD of three replicates).

Groups	Zn (μg/g DW)		Cu (μg/g DW)		Cr (μg/g DW)		Cd (μg/g DW)		Pb (μg/g DW)	
	Leaf	Root	Leaf	Root	Leaf	Root	Leaf	Root	Leaf	Root
Control	21.0	26.0	26.0	31.0	0.001	0.003	BDL	0.001	BDL	0.006
T_1	31.0	35.0	27.0	31.0	0. 01	0.06	0.001	0.006	4.0	6.0
T_2	40.0	44.0	33.0	36.0	2.60	3.70	20.0	26.0	27.0	31.0
T_3	43.0	48.0	35.0	37.0	0.70	0.90	21.0	26.0	31.0	36.0
T_4	47.0	52.0	41.0	44.0	8.40	10.30	3.0	6.0	3.0	5.0

Copper act as an important micronutrient in plant growth and functions. The normal range of Cu in plant tissue is 1-50 ppm DW. But in larger concentrations it become phytotoxic in nature, and resulted in stunted growth and variations in physio-biochemical processes (Ziuli *et al.,* 2003) such as decrease in the photosynthetic rate and chlorophyll contents, changes in the activity of enzymes, lipid peroxidation etc. (Khan *et al.,* 2001). From the results it was observed that the Cu content in the test plants also increased after the experimental period than the control plants. It was also revealed that all the four different waste waters used for irrigating the plants, supplied more than sufficient amount of Cu to the plants. The T_4 plant showed highest concentration of Cu in their leaves and this might be due to the phytoconcentration of Cu contributed from the soil containing domestic waste water (E_4).

Chromium is a very effective phytotoxic heavy metal which has no known function in plants. In general, plants have very low capacity to absorb Cr (Pendias, 1984). The results showed that the Vetiver plants accumulated considerably significant amounts of Cr in their leaves and roots. The increase in Cr content in all the test plants were resulted from the irrigation with waste waters. The Cr levels in all test groups were exceeded the normal limit and highest values were recorded in T_4 plant. This means highest amount of Cr was found in the soil which was treated with domestic waste water. From the study it was understood that the Vetiver grass can tolerate high levels of Cr pollution in soil and it can concentrate moderate levels of Cr in their tissues and remediate the heavy metal contamination in the soil.

The Cd content in the test plants increased compared to the control plants. Cd is a trace element and is phytotoxic to plants. Cd is always found in association with Zn, generally 0.5% of the Zn levels. Cd is present in the atmosphere due to industrial activities including automobile workshops, painting, battery manufacturing etc (Davis *et al.*, 1988). In the present study the highest level of Cd was reported in the test groups T_2 and T_3 and it was the result of irrigation with waste waters E_2 and E_3 during the experimental period. Both these waste waters were rich in Cd than the others. The low level of Cd on the T_1 plant indicated that the industrial waste water E_1 containing lower amounts of Cd than in other waste waters. Considerably significant level of Cd accumulation in T_4 plant was observed in the study and the results of effluent analysis also contains considerably higher amounts of Cd.

Pb is a phytotoxic heavy metal and it exerts serious damage in higher concentrations. In plants presence of Pb in higher quantity induced damages in photosynthetic pigments, changes in activity of antioxidant enzymes and lipid peroxidation produces and induces generation of reactive oxygen species (ROS) like free radicals, H_2O_2 etc.(Raven *at al.,* 2004). In control plants the leaves does not contain any detectable amounts of Pb, but in roots, the value was recorded as 0.006 mg/g DW. The Pb content in the T_1 and T_4 plants were found comparatively less than the other test groups. This may accounted from the low Pb content in the E_1 and E_4 which were used to irrigate them. The T_2 and T_3 plants reported high Pb content and T_3 reported more Pb than T_2. This was resulting from the dangerous levels of Pb content in the E_2 and E_3 used to irrigate T_2 and T_3. Abbasi *et al.*(1989) reported that the Pb accumulation in plants severely affected its growth and metabolic performances.

Changes in Soil Heavy metal content

Some of the heavy metals (Zn, Cu etc.) present in soil play a vital role as micronutrients. Presence of some others is phytotoxic to plants (Cr, Pb, Cd etc.). So it is very important to analyze the changes in the heavy metal contents in the soil. The changes in the concentration of heavy metals in soil before and after the experimental periods are given in the Table 6. The concentration of heavy metals in the soils before the experiment (Cu, Zn, Cd, Cr and Pb) was within the permissible limit. Zn and Cu are the two important micronutrients naturally present in the soil. Presence of Cd, Cr and Pb in the soil was also from the natural sources. But after the experimental period there was marked increase in the concentrations of all these five heavy metals. Reddy *et al.* (1999) reported that waste waters from automobile workshops, painting, and manufacture of fixatives etc release huge amount of heavy metals contaminated waste waters. Discharge of these untreated waste waters directly into soil creates build up of Pb, Cd, and Cr etc in soil. Bioconcentration of these heavy metals in food chain is a natural phenomena and the direct uptake by the plants play an initiative role in magnification.

Table 6
Concentrations of Heavy Metals in the Soils.

Groups	Zn (μ/g DW)		Cu(μ/g DW)		Cr (μ/g DW)		Cd (μ/g DW)		Pb (μ/g DW)	
	Before Expt.	After Expt.	Before Expt.	After Expt.	Before Expt.	After Expt.	Before Expt.	After Expt.	Before Expt.	After Expt.
Control	0.80	0.61	0.66	0.68	0.04	0.006	0.01	BDL	0.041	BDL
T_1	0.78	0.82	0.59	0.76	0.04	0.79	0.01	0.001	0.037	0.08
T_2	0.78	0.73	0.71	0.72	0.05	1.89	0.01	0.18	0.036	1.48
T_3	0.76	0.93	0.76	0.71	0.05	0.66	0.01	0.27	0.038	1.71
T_4	0.79	6.42	0.63	0.73	0.04	6.83	0.01	0.001	0.040	BDL

So the study revealed that the application of waste water containing higher quantities of organic and inorganic constituents including heavy metal ions make the soil unfit for plant growth. But due to the higher efficiency of the Vetiver plants to survive in the very harsh environment, it established their growth in there. It was also evident that the Vetiver plants can improve the soil quality by absorbing higher quantities of the nutrients and heavy metal ions from the contaminated soil. So these plants can be used effectively for the phytoremediation of soils and waters contaminated with nutrients and heavy metals especially zinc and lead.

CONCLUSION

The present experimental study showed that the waste water from Travancore Titanium Ltd, Auto mobile service station, Automobile spray painting workshop, and domestic activities contains undesirable physico-chemical parameters and contain different concentrations of heavy metals like Zn, Cu, Cd, Cr, and Pb. It was also found that the majority of the water quality parameters exceeded the standard permissible limit set by Indian Environmental Standards of NEERI, 2006. The evaluation of the morphological and biochemical changes in the Vetiver plants subjected to waste water irrigation showed changes in the morphological and biochemical parameters in all test group plants. The high nutrient and heavy metal contents in the plant parts revealed that, the Vetiver plant is a very good accumulator of nutrients and heavy metals especially Zn and Pb. The tendency of accumulation of different heavy metals in the leaves and roots of the Vetiver plants are in the order Zn> Cu> Pb> Cr>Cd, and the heavy metal accumulation was found to be highest in the roots. It was also noted that there was a reduction in the buildup of soil nutrients and heavy metals after the plant growth due to the absorption of these by the Vetiver plants, and these plants can be effectively used to recover the heavy metals and thereby enhance the economy of the State.

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Health hazards assessment among the solid waste workers of Thiruvananthapuram Corporation

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INTRODUCTION

This paper describes the health risks to which the solid waste workers are exposed to as a result of their work in comparison to a group of workers of similar socio-economic class. Other than the social discrimination solid waste workers face due to their employment, they are also exposed to an increased risk of developing skin disorders, injuries/accidents and eye disorders as evidenced by a risk ratio of 2.7,3.5 and 2.3 respectively which was found to be statistically significant . This employment attributed risk can be prevented through strategic planning, medical and legislative measures. While the engineering measures will help in protecting against exposures, the medical measures will help in early detection of the effects to these exposures. This can be partly achieved by developing an effective occupational health service and risk reduction measures for this group of workers. Also, regular awareness programs should be conducted to impart education regarding safer work procedures and use of personal protective devices.

The current solid waste management and disposal mechanisms has a potential of risk to human health and environment and has now emerged as a major public health problem which poses threat to humankind as well as the environment.

Solid waste can be classified into different types depending on their source: Household waste also referred to as municipal waste. Industrial waste as hazardous waste and Biomedical or Hospital waste as infectious waste.

Waste collection is a vital activity that happens all around the world and municipal solid waste removal is a job with an inherent risk associated with a variety of biological, chemical, mechanical, physical, and psychosocial hazards (Dorevitch andMarder, 2001). Solid waste segregation and disposal in developing countries is mostly labor intensive and is done manually with hand drawn carts when compared to mechanized waste disposal in developed countries. This poses an increased risk among the solid waste workers in developing countries to develop occupational hazards.

India produces 42.0 million tonnes of municipal solid waste annually at present and it poses a huge threat to the general public exposed. Per capita generation of waste varies from 200 gm to 600 gm per capita / day. Average generation rate at 0.4 kg per capita per day in 0.1 million plus towns.

Over 5 million people are estimated to die every year in the South from diseases related to the inadequate disposal of waste (UNDP, 1985). Only approximately between 25 and 55 per cent of all waste generated in the cities in the South is collected by municipal authorities (Englehardt et al., 2000).

A global relationship has been established between solid waste handling, exposure risk and health outcomes. Few epidemiologic studies done in India and elsewhere is discussed here. Studies have revealed that solid waste workers of poorer countries pose a greater risk to occupational hazards than that of developed countries due to various factors like poor waste handling mechanisms; collection is by labor-intensive systems with no protection. (Mauritius 1998). Solid Waste Workers in Denmark are 1.5 times more likely to have Occupational Disease and Injury than other workers ,6 times more likely to get infectious diseases and 2.6 times more likely to get allergic pulmonary disease (Poulsen et al., 1995).

A study done in Florida found that municipal solid waste workers risk to develop gastrointestinal disease was 2.0 times, infectious disease was 6.0 times, and allergic respiratory disease was 2.6 times higher than others (Englehardt et al., 2000). **A** study in Denmark with the occupational health database from National institute of Occupational Health revealed 5.6 times more relative risk for Accidents,1.3 times more relative risk for Injury,6 times more relative risk of Infectious Disease, 2.6 times more relative risk for Allergic Pulmonary Disease and 1.4 for Non-Allergic Pulmonary Disease more risk for Solid waste workers. Another study in Italy revealed an RR of 1.2 for Hepatitis among SWW (Cimino, 1975).

A study on the health of refuse workers in Thiruvananthapuram (1971) showed increased prevalence of respiratory diseases, skin diseases, jaundice and trachoma when compared to a control group.

Epidemiological surveys conducted on 400 waste pickers in Calcutta, compared with a control group of 50, indicated that waste pickers at open dumps were particularly vulnerable to increased incidence of respiratory diseases and parasitic infections. The waste pickers experienced a 71% incidence of respiratory disease, compared to only 34% in the control group (Van, 1997; Anon, 1996).

All these studies reveal the risk and the prevalence of diseases among solid waste workers.

BACKGROUND

Capital City Clean City project of Thiruvananthapuram Corporation

Thiruvananthapuram Corporation had started a project, Capital City Clean City project (CCCC) for integrated waste management since May 2006 in 29 wards initially and extended in a phased manner to the 86 wards of the Corporation. As per the records of Corporation 817 women members are working in the waste management project from 66 registered Kudumbasree units, an organized government supported Self Help Group (SHG) under State Povertyn Alleviation Mission. Waste collection from the source is implemented through the women workers of Kudumbasree; the 10-15 women together constitute an SHG (Klean well Kudumbasree unit) and operate in an entrepreneur mode. Corporation and Kudumbasree are only facilitators. Each unit was given a financial assistance of rupees 2.5 lakh for the purchase of vehicle and other equipments required for waste collection like plastic trays, PPEs etc.

Rationale for the study

Though the CCCC project was planned scientifically with the collection of segregated waste at source of origin and optimal usage of personal protective equipments (PPEs)to avoid any possible health risks to the Solid Waste Workers (SWW), the Corporation health authorities had observed slow discontinuance of segregation of waste at source and inadequate usage of PPEs by the SWW. Inherent risk of high prevalence of occupational health hazards to waste handlers and inadequate provision of health check ups, immunisation coverage etc also were important reasons for the Corporation authorities to recommend a study to evaluate their health risks, among the women workers and to suggest possible recommendations. Relatively little research has been published on either the exposures or the possible health effects of the solid waste worker in India.

The Study

Study was conducted in Thiruvananthapuram City Corporation of Kerala where the Capital City Clean City project (CCCC) for integrated waste management was implemented and the study duration was from November 1st to December 31st 2008

Methodology

Study design was a Retrospective Cohort study with solid waste workers working in Thiruvananthapuram Corporation for more than 2 years as cases, compared with Kudumbasree workers of similar socioeconomic status.

Sample size was calculated in Epi Info 3.3.2 version with 99% confidence interval, 80 % power and a morbidity prevalence of 28% among the solid waste pickers[10]

66 Nos. of solid waste workers (exposed) and 66 no. of comparison group (unexposed) were selected randomly for the study from the total 817 solid waste workers, working in Thiruvananthapuram Corporation since 2006. A comparison group was selected from women working as housemaids and of a comparable socio economic status from a slum in Thiruvananthapuram Corporation.

Data was collected by interview schedule using a Semi structured questionnaire, with questions to know the demographic details, socioeconomic status, occupational history, health information and reported health problems. Data entry was done in Microsoft Excel and analyzed in SPSS 15.0 version and Epi Info 3.3.2 version.

RESULTS

Sample characteristics reveal that majority of the respondents among the case and comparison group were between 34 to 43 years of age. About 48.5 % of the cases had 8 to 10 years of schooling when compared to 22% among the comparison group. Only 15.2% of the cases were illiterate when compared to 40% in the comparison group.

Socioeconomic characteristics of the sample reveal that 83.3% of the cases has a net income of Rs 1501 -3000 per month compared to only 31.8% in the comparison group. Nearly half of them in the comparison group had a net income of Rs 300-100 per month.

Pre –Employment Training

83.3% of the solid waste workers had pre-placement training while none of them had pre-placement check up before enrolment. About 86.4% of the solid waste workers had information on health risk and importance of personal hygiene. Only 80.3% of the cases had information on the importance of immunization like tetanus toxoid and hepatitis B vaccine.

Practice on Personal Protective Equipment usage (PPE)

Practices on Personal Protective Equipment were found to be highly inadequate among the sample studied. Majority (96.9%) of them use their uniform and coat (made up of cloth) regularly as personal protective equipment. About 63.6% of the solid waste workers never used any gloves during the waste segregation and handling process.22.7% reported occasional use of gloves while 13.6% reported regular usage of gloves.84.8% of the cases never used a mask while waste handling when compared to 10.6% of regular mask users.93.9% reported regular use of slippers while waste handling .

HEALTH HISTORY

Past medical History

60.6% of the cases reported no health problem before employment as solid waste workers, while 7.6% had hypertension, 6.1% had asthma, 6.1% had arthritis and 4.5% had diabetes.

Present Medical History

Information was collected on the reported health problems in a year from the solid waste workers on six broad disorder categories like injuries/accidents, skin disorder, respiratory diseases, musculoskeletal diseases, eye disorder and reproductive problems.

Injuries and accidents: About 77.2% of the solid waste workers had injuries or accidents during the job, of which 12.1% reported fracture ,47% reported to have less than 5 episodes of lacerations with needles and glass material in a year and 46.1% reported history of contusion after a fall at job.

Skin Disorders: 59% of the solid waste workers reported skin disorders of which 22.7% of them reported that they often had rashes and 13.6% often had fungal infections in a year.

Respiratory disorders: 45.5% of the solid waste workers reported to have some form of respiratory problems. Most of them reported that the frequency of respiratory illness has increased after taking up the job as solid waste workers. About 22.7% reported to have episodes of dust allergy often with 21.2% who developed dyspnea and 7.5% had episodes of asthma.

Table1
Risk ratios assessment of solid waste workers

Disorders		Case	Comparison	RR(95% CI)	P value
Injuries/Accidents	Yes	51	14	3.50(2.20-5.57)	0.00**
	No	15	52		
Skin disorders	Yes	39	7	2.7(1.93-3.77)	0.00**
	No	27	59		
Respiratory diseases	Yes	30	25	1.16(0.83-1.63)	0.377
	No	36	41		
Musculoskeletal diseases	Yes	56	50	1.37(0.81-2.3)	0.18
	No	10	16		
Eye disorders	Yes	26	3	2.3(1.75-3.3)	0.00**
	No	40	63		
Reproductive problems	Yes	0	0	—	—
	No	66	66		
Gastrointestinal disorders	Yes	0	0	—	—
	No	66	66		

*** p value of less than 0.05(statistically significant)*

Musculoskeletal disorders: 84.5% of the solid waste workers had some form of musculoskeletal disorders during the employment with 13.6% reported to have sprain sometimes. Strain was reported by 43.9% of the workers of which15.2% had always and 28.8% who often had a strain. Backache was reported by 75.5% of the solid waste workers of which 28.8% had always and 46.9% had often.

Eye disorders: 39.4% of the solid waste workers reported some form of eye disorders. Of the total number of solid waste workers who reported to have eye disorders,7.5% had episodes of eye soreness,13.6% had redness,21.2% had watering of eyes and 18.2% had itching of the eyes often.

Reproductive problems: None of the solid waste workers reported any reproductive problems after joining the current employment.

Solid waste workers were found to have a higher risk for injuries/accidents, skin disorders and eye disorders.

Solid waste workers were having 3.5 times higher risk than the comparison group to develop injuries and accidents and it was found to be statistically significant. Similarly the relative risk of solid waste workers for developing skin disorders and eye disorders were2.7 and 2.3 respectively.

DISCUSSION

Sample size for this study to estimate the relative risk for the solid waste workers when compared to another group of similar socioeconomic status was calculated by taking a morbidity prevalence of 28% as evidenced by a study done in Calcutta 11. .So the sample interviewed is adequate to establish the increased risk incurred by the solid waste workers when compared to the comparison. A comparison group of similar socioeconomic group was selected to avoid the confounding effect of Socio economic status on the outcome studied. Although the housing facilities were comparable in both the groups studied, 83.3% of the solid waste workers had an income of 1501-3000 per month when compared to only 31.8% in the comparison group. Majority of them (46.9%) in the comparison group earn only Rs 300-1000 per month.

Solid waste workers in Thiruvananthapuram Corporation work as registered unit of Kudumbasree with 10 to 15 members in a Klean well Kudumbasree unit. An amount of Rs 30 is collected per household for a month and the amount collected by each unit is divided among all. So each solid waste worker earns approximately 3000-3500 per month. The income generated is directly proportional to the number of households. So although majority of them are aware of the prevailing risk associated with work, financial gain is been overlooked.

None of them had pre-placement check up before enrolment; however pre-placement training, information on health risk and immunization was explained to about 86.4 % of them. Immunization had to be taken voluntarily by the solid waste workers with no mandatory vaccination certificates emphasized by either agency or Corporation. Vaccination coverage among the solid waste workers were1.5% and 45.5% for HbSag and TT respectively.

Past medical history reveals that majority of them (60.6%) did not have any health problems prior to the employment as solid waste workers. Hence it can be concluded that the increased risk for injuries/accidents, skin and eye disorder is attributed to the employment as solid waste worker itself .Since no pre-placement check up was done, those workers with history of arthritis (6%) and asthma(6%) were not informed on the extra precautionary measures that should be taken to prevent an exacerbation of disease ,which would have aggravated disease condition following the employment

Uniform (green sari) and cloth overcoat were used by 96.4% of the solid waste workers, however only 13.6% used gloves, 10.6% used masks and 93.3% used chappal regularly. 63.6% never used gloves and 84.8% never used mask Detailed information on the waste handling practice and perceptions were studied and are discussed in another paper.

Only 22.7% had periodic check up after being in employment and they go to public health institutions of their locality.

This study reveals that with the prevailing practice of inadequate use of personal protective equipment (PPE), there is a higher risk among the solid waste workers to develop all disorders except reproductive problems but the relative risk (RR) for injuries and accidents, eye and skin disorders were only found to be statistically significant with a p value of less than 0.05. Reproductive disorders were not reported among the SWW in this study as majority of the cases were between 34-43 years and have completed their family

All these throw light on the risk exposed by the solid waste workers and inadequacy of protection that they are provided medically, strategically and legislatively.

Suggestions for future research

The risk ratio estimated in this study is by reported health problems by the solid waste workers in the past 1 year and the interviewer bias is minimized by using a structured interview schedule. Future studies with laboratory tests are recommended to see the variation in biochemical markers among both SWW and the control group.

Recommendations and suggestions regarding solid waste workers

- Provide and make vaccination for hepatitis A and B, tetanus, and typhoid mandatory.
- Provide annual medical examinations.
- Provide protective clothing, face masks, glasses, shoes or boots, and gloves to all solid waste workers and make their usage mandatory.
- Improve the source storage of solid wastes in bags and covered dustbins and limit the weight of containers that are manually loaded.
- Provide health and safety plans for all solid waste processing and disposal facilities, including operational guidelines for waste handling and emergency procedures of first aid.
- Implement source segregation of non hazardous recyclable wastes and hazardous wastes.
- Develop training materials on occupational and environmental health and injury issues of solid waste management that are suitable for distribution to solid waste workers.

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Drinking Water and Fodder Quality Around Kanjikode Industrial Belt and its Impact on Cattle Health

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INTRODUCTION

Water is an essential component of the environment and it sustains life on the earth. Almost 70% of water in India is polluted due to the discharge of domestic sewage and industrial effluents into natural water sources such as rivers, streams and lakes (Smitha et al., 2007). Drinking water qualities for animals are equally important as for humans not only from the welfare aspect but also due to the indirect link to human health via food chain. Poor water quality can affect the health and thereby production performance of cattle. About 48 industries of various sectors are established in the Kanjikode area like distilleries, petroleum, steel, cement, paint colour, beer and soft drinks companies, fertilizers and chemicals manufacturing industries. This area is also populated by many small to medium income farmers and industrial workers who own a sizeable cattle population. Many of these industries are located on the bank of river which is also the main source of drinking water for cattle of that area. Industrial effluents are a major source for water pollution and can include waste materials like acids, alkalies, toxic metals, oil, grease, dyes, pesticides and even radioactive materials. The objective of the present study is to analyze the physico-chemical properties of ground water and pollution with heavy metals and its impact on cattle health of Kanjikode industrial belt.

MATERIALS AND METHODS

A survey was conducted among 62 Veterinary surgeons working in clinical field of Palakkad district by distributing a questionnaire and based on the feedback obtained,the Kanjikode area of the district was selected for the present study.Collected water samples from Kanjikode industrial belt from various water sources like river, wells, bore wells ,lake and well. These water samples were analysed for physico-chemical properties like temperature, PH, turbidity, alkalinity, total hardness, acidity, chlorides, salinity, oxygen, iron, sulphates and hydrogen sulphide levels (APHA,1995).The water samples are analyzed for heavy metals by atomic absorption spectrometry (AOAC,2003). Case study of the cattle diseases for the last five years in the Pudussery Veterinary hospital was also done.

RESULTS AND DISCUSSION

Due to scarcity of potable water in Palakkad district, cattle farmers are forced to depend on canal water which is mostly contaminated. Based on the evaluation of questionnaire the following observations are furnished (Trable 1).

Table 1

Feeding of Cattle (%)

Source of drinking water				Main type of feed given in Palakkad				
Well water	Canal water	River water	Others	Fodder	Paddy straw	Concentrates	Miscellaneous	Mix of all
66	22	11	1	12	25	6	2	55

The major source of drinking water to cattle is well water followed by canal water. This may result in free access of effluent contaminated canal water to cattle. The farmers are incorporating very low percentage of concentrates in cattle ration. Maintaining good nutritional status is essential to protect against pesticide toxicity (Garg, 2000). The low percentage of concentrate feeding cannot meet their requirement.

Fodder is the major source of pesticide toxicity cases reported in the hospital. The possible reason for this type of toxicity is careless disposal of pesticide by the farmers, accidental poisoning and indiscriminate use (Table 2).

Table 2
Toxicity cases (%)

Presence of industries			Source of toxicity					Reason for toxicity cases				Type of toxicity				
Yes	No	Not Sure	Water	Feed	Fodder	Drugs	Not Sure	Indiscriminate	Requisite use but highly toxic agent	Careless	Not Sure	Acute	Chronic	Accidental Poisioning	Environment	Not Sure
95	2	3	12	6	66	10	6	32	20	38	10	12	4	42	9	33

The most common body system affected is central nervous system (Table 3). This is similar to the findings reported by Sindhu *et al* (2006). The survey indicates higher chance of toxicity cases in Palakkad district.

Water samples were collected based on sampling procedures.The results of water sample analysis are given in Table 4 and 5.

Table 3
Disease Conditions Due To Pesticide Exposure (%)

Presence of disease due to pesticide		Body sytem affected by toxicity cases						Common cattle diseases					
Yes	No	Dermal	CNS	Reproductive System	Digestive System	Others	Not sure	GI Disorders	Respiratory Diseases	Mastitis	Non infectious type	Parasitic	Others
37	63	6	64	3	20	2	5	59	4	18	2	15	2

Table 4
Physico-chemical parameters in water

Sample No:	Temperature	pH value	Turbidity	Total alkalinity (mg/l)	Phenolphthalein alkalinity (mg/l)	Total hardness (mg/l as $CaCO_3$)	Calcium hardness (mg/l as $CaCO_3$)
1	28.0°C	7.5	viscous	440	0	274	100
2	29.0 °C	8.0	clear	224	144	404	132
3	27.5 °C	7.5	clear	660	0	552	220
4	27.0 °C	8.0	clear	1180	0	436	192
5	28.0 °C	7.5	clear	380	0	70	72
Mean	28.2 °C ± 1.0	7.6 ±0.2	-	506± 3.0	24± 2.0	309.25± 3.0	134.5± 2.2

Table 5
Chemical Properties of water samples

Sample No:	Chlorides (mg/l)	Salinity (g/l)	Oxygen (mg/l)	Iron (ppm)	HS (ppm)	Sulfates (ppm)
1	114.14	206.05	3.5	0.25	0	300
2	171.22	309.08	7.5	0.25	0	300
3	228.29	412.09	4.9	0.25	0	300
4	342.44	618.13	5.5	0	0	50
5	684.89	1236.25	6.5	0.5	0	80
mean	249.69± 4.0	450.72± 2.0	5.61± 0.01	0.218± 0.1	0	203.75± 2.0

Total alkalinity, total hardness, chlorides, salinity, oxygen, iron, and sulfates are found to be significantly more than desirable limits. (Sandhu and Brar, 2000). Heavy metal concentration in Water and Fodder are given in Table 6.

Table 6
Heavy metals Concetration in water and fodder

Sample	Heavy Metals (Mean)			
	Cadmium (ppm)	Lead (ppm)	Mercury (ppm)	Copper (ppm)
Water	0.05 ± 0.01	0.19 ± 0.03	Nil	0.01± .001
Fodder	1.6 ± 0.01	18.8 ± 0.03	Nil	0.01± .001

Case study of five years(Total 12144 cases) taken from the veterinary dispensary digestive disorders (37%), respiratory disorders (10.7%), and metabolic disorders (1%), deficiency diseases (3%), skin disorders (9%), parasitic diseases (27%), gynecological problems (4%), others (8%) and poisoning cases (0.3%).The toxic metals cause irritation in gastrointestinal tract causing ailments. Cadmium and lead chronically affecting the body causing reduced absorption of other essential minerals. In epithelial cells it cause irritation thereby causing skin disorders (Garg, 2000). The increased percentage of digestive ,deficiency and skin diseases correlates with the presence of toxic metals in drinking water and fodder.

CONCLUSION

The results of present investigation indicate that ground water and fodder quality is not suitable for drinking purpose of cattle of that area and causes chronic toxicity hazards.

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Polyurethane Foam as Filter Media in Up-flow Anaerobic Hybrid Reactors

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INTRODUCTION

The application of anaerobic processes is ideal in tropical countries like India, because of less energy consumption and low capital and operation costs, with the yield of energy in the form of biogas being the highlight. In this study, a laboratory scale Up-flow Anaerobic Hybrid Reactor (UAHR) being comprised of Upflow Anaerobic Sludge Blanket Reactor (UASB) and anaerobic filter was evaluated through its ability to remove organic matter from synthetic domestic wastewater at different biofilter depths corresponding to different hydraulic retention times (HRT). Effluent was treated in UAHR filled with flexible Polyurethane Foam (PUF) blocks, and the effectiveness of scrap PUF for the biological treatment of wastewater was studied by considering the percentage removal of COD at various HRT and filter media depths. During the study, HRT was reduced from 48 hours to 12 hours corresponding to various filter volumes (20, 25, 30, 35 and 40% of the reactor volume). Optimum performance of the reactor was achieved at HRT of 18 hours for a filter media volume of 35%. This hybrid system was studied to determine whether or not it could significantly increase the biomass-retaining capacity and performance of the overall system. The performance of reactor was studied using raw wastewater at optimum conditions. A reactor was designed for treatment of domestic wastewater for a small family consisting of five members.

Anaerobic bacteria are nature's methods to break down organic compounds to the base elements. The recent advancements in the microbial aspects blended with engineering understanding of anaerobic systems have led to the evolution of advanced anaerobic reactors. The advanced anaerobic reactors improved the economy of wastewater treatment due to the capability of providing long mean cell residence time under high organic loading rates.

An Up-flow Anaerobic Hybrid Reactor combines a lower section functionally identical to an UASBR and an up-flow anaerobic filter on top, the idea being to combine the strengths of each approach in a single tank. UAHR has been successfully applied to the treatment of a wide variety of wastewaters such as industrial cluster wastewater (Amit Kumar et al., 2008), distillery spent wash (Gupta et al., 2007), livestock industrial wastewater (Wang et al., 2005) etc. The hybrid reactors could also become a preferred option for certain chemical synthesis-based pharmaceutical wastewaters (Yalcin et al., 2007) due to the strong stability to changes in organic loadings. The main advantage of UAHR compared with that of UASBR is that it can resist the shock loading and remain stable at short HRT. The filter has not only a physical role for biomass retention and repression of sludge washout but has some biological activity, contributing to the COD reduction in a zone that in the classical UASBR is empty of biomass (Lew et al., 2004). The higher is the filter layer, the higher is the biomass retention capacity. However the higher the filter layer, the higher is the construction cost also. As far as the optimal amount of support material to be placed in a hybrid reactor is concerned, economic evaluation is very important. Also, it is very significant to determine the suitable, economical depth that allows the reactor to enough remove pollutant at different HRT of wastewater (Pawinee et al., 2003).

MATERIALS AND METHODS

Reactor

In this study, an acrylic reactor having a cross section of 150mm x 150mm and a total height of 67cm was used. The bottom-tapered portion was having a height of 8cm and upper tapered portion was having a height of 9cm, which collects the gas formed. The reactor was designed for up-flow operation and was having a volume (excluding the volume provided for gas collection) of 12 litres. The UAHR was fitted with two sampling ports along its length. One port was positioned in the zone of sludge bed and the other one, in the anaerobic filter zone. Fig. 1 shows the Experimental set-up.

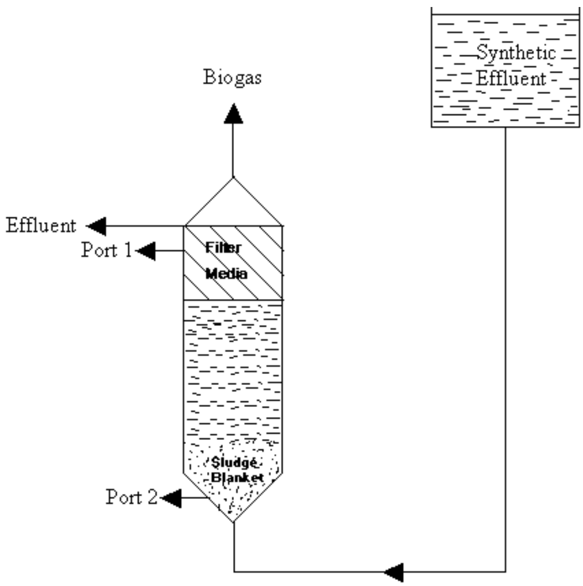

Fig 1
Experimental Set-up

Filter media

Polyurethane foam is a medium that possesses several desirable properties, which include high porosity, high specific surface area, appropriate pore size, low density, and an ability to sorb water (Joo-Hwa et al., 1996; William and Robert, 2000). The filter media consisted of polyurethane foam blocks, each having size, 2.5cm x 2.4 cm x 2.3cm, cut from scrap polyurethane foam sheets (Brand name – U Foam Pvt Ltd.) collected from a local furnishing shop in Trivandrum. The blocks were washed thoroughly and fed into the reactor. The properties of filter media are: Density 0.03866 g/cc and Porosity 85%.

Synthetic Wastewater

The synthetic wastewater whose strength corresponds to medium strength municipal wastewater (Metcalf and Eddy, 2003) was prepared daily using tap water. The influent was introduced continuously via a horizontal inlet at the base of the reactor. The composition of the synthetic wastewater is listed below in Table 1.

Table 1
Composition of Synthetic Wastewater

Sl. No.	Constituent	Concentration (g/l)
1	Dry Milk Powder	0.85
2	Ammonium Chloride	0.38
3	KH_2PO_4	0.07
4	K_2HPO_4	0.14
5	$NaHCO_3$	0.75

Methodology

The reactor was fed continuously with synthetic wastewater and anaerobic condition was maintained in the reactor. The HRT was fixed as 48 hours. The reactor was seeded with slurry collected from a biogas plant and a start-up time of 21 days was provided. The effect of HRT on the effluent quality was studied by bringing down the HRT from 48 hours to 12 hours; at filter volumes ranging from 20% to 40% and optimum conditions were achieved. Standard Methods (APHA, 1985) for the Examination of Water and Wastewater (1985) was used to analyse the characteristics of the influent and effluent. COD analysis was done using COD Reflux apparatus and alkalinity was measured using titration method. pH was measured using Digital pH meter. Biological samples were observed using a polarized optical microscope. The performance of the reactor was studied using raw wastewater at optimum conditions. Using the experimental data obtained, a reactor was designed for treatment of domestic wastewater for a small family consisting of five members.

RESULTS AND DISCUSSION

Analysis of Synthetic Wastewater

The synthetic wastewater was prepared daily using tap water and was analysed for various parameters and are given in Table 2.

Table 2
Characteristics of Synthetic Wastewater

Sl. No	Parameter	Value
1	pH	7.50
2	Turbidity	280 NTU
3	Temperature	29.5°C
4	5-day Biochemical Oxygen Demand	312 mg/l
5	Chemical Oxygen Demand	848 mg/l
6.	Total Suspended Solids	310 mg/l
7.	Alkalinity	415 mg/l
8.	Total Organic Carbon	403.3 mg/l

Determination of Optimum HRT and economical depth of filter media for the reactor

The variations in COD in the treated effluent at various HRTs and the corresponding percentage removal for each stage was evaluated. Initially, HRT of 48 hours was provided. Once stable-state conditions were reached for each experimental phase, the next decrease in HRT was implemented, thus reducing HRT upto 12 hours. When HRT was shortened upto 18 hours, an optimum COD removal of 90.5% was obtained. Further reduction of HRT did not yield appreciable reduction of COD. (Fig.2). Similarly a further increase in the filter media volume beyond 35% did not give a higher removal rate for COD. Hence the economical depth of filter can be fixed as 35% of reactor volume. pH of the effluent was found to be in near-neutral range (6.77 to 6.98). The biological examination of filter media revealed that polyurethane foam had high biomass retention with bacterial population, mainly cocci.

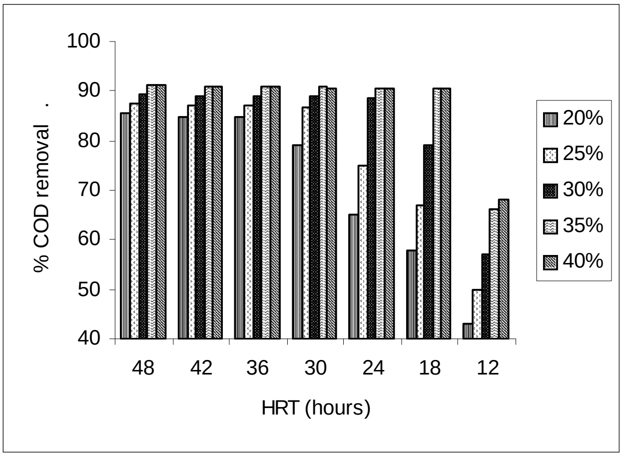

Fig 2
% Removal of COD with HRT

Design of pilot-scale reactor

The performance of UAHR was studied using raw wastewater collected from municipal sewage pumping station, Kuriathy, Thiruvananthapuram. Under optimum conditions, the reactor was found to remove 88.79% COD from raw wastewater. Assuming the percapita sewage generated as 90 l/capita/day, a pilot-scale UAHR having a total volume of 10,125 litres (inclusive of space provided for gas collection) utilizing 2,05,435 no,s of PUF blocks can be set-up to treat wastewater generated by a family of 5 members.

CONCLUSION

Anaerobic hybrid reactor can be successfully employed for wastewater treatment. The optimum COD removal efficiency of the reactor was found to be 90.5% corresponding to an optimum HRT of 18 hours (ie., organic loading rate – 1.131 g COD/l/d) for synthetic wastewater. The reactor removed 88.79% of COD from raw wastewater under optimum conditions. The results of the study also show that scrap PUF blocks can be effectively used as filter media in the treatment of wastewater due to its high biomass retention capacity and ease of availability.

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