Proceedings

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# KERALA ENVIRONMENT CONGRESS 2014


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Kerala State Council for Science, Technology and Environment

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Regional Resource Agency of Ministry of Environment and Forests
Government of India

*Collaborating Institutions for KEC 2014*

School of Marine Sciences,
Cochin University of Science and Technology, Ernakulam

Department of Botany, Maharaja's College, Ernakulam

PROCEEDINGS OF

# KERALA ENVIRONMENT CONGRESS 2014

NATIONAL WORKSHOP ON

## WATER AND ENERGY SECURITY ISSUES, CHALLENGES AND POTENTIALS

22nd & 23rd August, 2014
at E.M.S. Memorial Town Hall, Ernakulam

*Organised by*

CED

**CENTRE FOR ENVIRONMENT AND DEVELOPMENT**
THIRUVANANTHAPURAM

*Supported by*

National Bank for Agriculture and Rural Development
Kerala State Council for Science, Technology and Environment

*Proceedings of the*
**Kerala Environment Congress - 2014**

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***Published by***

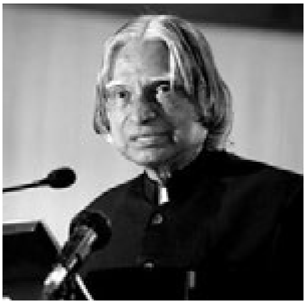
CED

Centre for Environment and Development
Thozhuvancode, Vattiyoorkavu
Thiruvananthapuram, Kerala, India-695013

***Design & Pre-press***
Godfrey's Graphics
Sasthamangalam, Thiruvananthapuram

***Printed at***
GK Printers, Kochi

# MESSAGE



**We, the weather makers,**

The six billion population of the world is faced with many challenges in sustenance and improving the quality of life especially when the human kind has been taking much more from the nature than what it is contributing. We have to understand the planet, its dynamic atmosphere and interaction processes in the basic form to adapt our lifestyle and for making the planet Earth a safer habitat for posterity by enriching and making it sustainable.

As you all are aware, Earth is experiencing both stratospheric cooling (due to changes in ozone layer) and tropospheric warming (due to increased green house gases). Also, I would like to refer Mr. Tim Flannery's book "THE WEATHER MAKERS" where the author begins pointing out that twentieth century has witnessed CO2 content in atmosphere going upto three parts per 10,000. It is reported that in the beginning of the twenty first century that CO2 content in atmosphere has already reached 6 to 10 parts per 10,000. The atmospheric science researchers are constantly working out the dynamic changes occurring in mesosphere, stratosphere, ionosphere, with reference to climate change. What are the possible solutions?

Today, the people of planet Earth, particularly the highly developed societies are indeed the 'weather makers'. These societies are responsible for generating the highest volume of green house gases, which directly affects troposphere and stratosphere.

**Sustainable Development**

The term "sustainable development" essentially refers to a balanced thinking on human development without causing long term damages to humanity and planet and ensuring progress despite population pressures and shortages of resources. Conservation and research for new avenues become part of such an approach to sustainability. Conservation brings in the concept of sharing the available with justice to all and new avenues call for research to find new means say of resources. The subject encompasses the entire gamut of human life – subsistence, nutrition, health, education, environment, energy, water, housing and above all a human value system. Hence research is called for in all areas including social welfare.

The 10th Kerala Environment Congress organized by Centre for Environment and Development, I understand aims at highlighting the issues of Water and Energy Security of the country and to suggest ways to make a balance between the availability and consumption of these resources. The Congress, I am sure will also formulate programs for bringing the attention of the people to the current situation and also finding viable solution through various technological, institutional and organizational interventions. The launching of Water and Energy Literacy and Learning (WELL) Program by the Centre for Environment and Development is of immense significance in this endeavour.

APJ Abdul Kalam

# KERALA ENVIRONMENT CONGRESS 2014

The Kerala Environment Congress (KEC) initiated by the Centre for Environment and Development(CED) in 2005 is entering in to its tenth year. The KEC was started with the objective of bringing together Scientists and Technologists, Policy Planners, Decision Makers, Development Managers and Students for sharing of knowledge, expertise and experience in subjects of high relevance to the sustainable development of the country. Nine Congresses have already completed based on different focal themes.

At the outset, CED takes this opportunity to place our heartfelt gratitude to all the individuals, institutions,organizations and governments for supporting us these years to organize the Kerala Environment Congress successfully.

CED an autonomous research, training and consultancy organisation established in 1993 at Thiruvananthapuram, Kerala is now expanded its coverage in to twelve states in the country and has wide network and collaboration with many state, national and international agencies. CED has been focusing both on environment and development related sectors bringing complementarities, leading to sustainable development. CED is working with 6 Program Areas viz., (i) Natural Resources and Environment Management (ii) Water, Sanitation and Health (iii) Climate Change and Energy Studies (iv) Urban and Rural Studies (v) Culture and Heritage Studies and (vi) Information and Knowledge Management.

CED has its Eastern Regional Campus at Bhubaneswar, Odisha and Regional Centre at Hyderabad. CED is the Centre of Excellence of Ministry of Urban Development, Government of India on Solid Waste and Waste Water Management, National Key Resource Centre on Water and Sanitation of Ministry of Drinking Water and Sanitation, Government of India and Regional Resource Agency of Ministry of Environment and Forests, Government of India. CED is recognized as a Scientific and Industrial Research Organisation (SIRO) by the Department of Scientific and Industrial Research, Government of India. The Centre has its activities spread over the states of Odisha, Andhra Pradesh, Jharkhand, Bihar, West Bengal, Maharashtra,Madhya Pr adesh,Gujarat,Uttarakhand,Pondicherry, Jammu Kashmir apart from Kerala. CED is providing technical support to many local self government institutions in the country for Water Supply Engineering, Solid Waste Management, Wastewater Management, GIS Mapping, Biodiversity Conservation, Urban Development, Energy and Environment Auditing, etc. CED initiated the Odisha Environment Congress in 2010 and has completed four Congresses.

During the last 22 years, CED has completed nearly 100 research, consultancy and training projects supported by different national and international agencies like the World Bank, UNDP, JICA, ADB, RNE, IDRC, Ministry of Environment and Forests, Ministry of Urban Development, Ministry of Science and Technology, Ministry of New and Renewable Energy, Ministry of Drinking Water and Sanitation, Kerala State Council for Science, Technology and Environment, Local Self Government Department, Kerala, Department of Housing and Urban Development, Odisha, Department of Municipal Administration and Urban Development, Andhra Pradesh, Andhra Pradesh Pollution Control Board and many other agencies.

The first Kerala Environment Congress was organised in 2005 at Kochi with the focal theme 'Coastal and Marine Environment' . The second Congress was held at Kozhikode in 2006 with the focal theme 'Forest Resources of Kerala' and the third KEC was organized in 2007 with 'Wetlands of Kerala' as the focal theme. The fourth Congress focused on the theme 'Environment Sanitation, Health and Hygiene' and the next one was held in 2009 with the focal theme 'Water Resources of Kerala'. The sixth, seventh and eighth Congresses were held in 2010, 2011 and 2012 with the focal themes 'Solid and Liquid Waste Management' , Energy and Environment and Agriculture and Environment respectively. The nineth Congress was held in Thiruvananthapuram with the focal theme "Culture, Heritage and Environment".All the nine Congresses were well received by the researchers, academicians, research students and policy-decision makers.KEC has its uniqueness that it targets not only researchers and academic people, but also the policy-decision makers which helps to the translation of scientific knowledge and information in to the development agenda of the governments.

This year's Kerala Environment Congress (10$^{th}$ KEC) is being organized on 22nd and 23rd, August, 2014 with the focal theme 'Water and Energy Security-Issues, Challenges and Potential's. The Congress includes Key Note Address, 2 Special Addresses and 11 Invited Paper Presentations, 2 Presentations on the Open Forum topic as well as 6 Presentations by young researchers to be considered for Young Scientist Award.

The Key Note Address of the Congress is dedicated to our beloved founder Chairman, Padmashree (Late) M.R.Kurup, who provided guidance and support to us which helped to the growth of CED to its present stage. This year's M.R.Kurup Memorial Key Note

Address will be delivered by Hon'ble Former President of India and distinguished scientist and great visionary , Dr A.P.J.Abdul Kalam. CED is highly blessed with his presence in the KEC and gratefully acknowledges his kindness and support to KEC by delivering Sri (Late)M.R.Kurup Memorial KeyNote Address.

The Young Scientist Award is instituted by CED in the name of our former friend and colleague( Late) Dr R. Satheesh, who had contributed a lot to develop academic and research programs in the field of Environment Management.

The final session of the Congress is an Open Forum in which we tries to discuss a topic of high relevance to the society and which can be taken up for implementation with the participation of the community. This Congress has identified the topic "Water and Energy Literacy and Learning (WELL) Program"which is an offshoot of the focal theme of the Congress. We invite people from all walks of life to participate in the Open Forum and intend to carry forward the suggestions and recommendations of the Open Forum with the participation of different individuals, institutions, governments and other organizations through networking and partnership .

We expect nearly 300 researchers, policy experts, decision makers, students and development thinkers to actively participate and contribute in the Congress.

This Proceedings Volume contains full papers of special addresses, invited presentations, student presentations and presentations on the theme of Open Forum prepared by eminent experts in the concerned field.

Financial assistance received from Research and Development Fund of National Bank for Agriculture and Rural Development (NABARD) towards printing of Proceedings of the workshop is gratefully acknowledged CED also gratefully acknowledges the support of the Kerala State Council for Science, Technology and Environment,Government of Kerala for sponsoring the KEC. CED takes this opportunity to place our sincere gratitude to all the institutions and friends supported us to organize this program and all the distinguished participants and other invitees who have been supporting us for the last ten years to make this program a success.

We hope that the deliberations in the Congress and the papers published in the Proceedings will help to evolve a strategy for Water and Energy Conservation and Management in our country.

**Dr Babu Ambat**
*Executive Director, CED*

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*Special Address*

# Energy Security: Issues, Challenges and Potentials

**Prof. V.K. Damodaran**
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## INTRODUCTION

It is essential for every citizen to feel secure about food, water, sanitation and energy needs. They are expected to be ensured sustainably in the immediate environs of his living. *Feng Shui* the Chinese words for expressing this primal necessity of humans, simply means hills and water – understandably, a water source right in front and a woods in the back. Human settlements in the early years depended on the vegetated hilly back grounds to give fruits, animals to hunt, firewood to cook and movement of air, while the water bodies ensured water for drinking, bathing and sanitation. But, with populations increasing almost uncontrollably, all these essentials were either in short supply or short changed on quality. As civilizations – most of them originated along the banks of rivers – demanded more and more to meet these and other basic necessities like shelter, moving from place to place, carrying materials, reducing drudgery etc, industrial practices came into being and the per capita resources converted or consumed, started increasing exponentially and currently even the local climate to which living beings got adjusted over millenniums have started changing for the worse.

## ISSUES IN ENERGY SECURITY

Basic resources and their availability in a sustainable manner are now threatened. Fresh water and a basic minimum of energy needed in the form of electricity and transportation fuel for ensuring a comfortable life for all are falling short of the rising demand. On the energy front, but for less than one-fourth of demand met through hydro power and nuclear power, the rest are met through increasing volumes of non-renewable and non-replenish able fossil forms like coal and oil. Scarcity, increasing cost of mining and transportation and political insecurities are hiking the costs of these beyond affordability. Such energy resources are also geographically distributed inequitably and commercially accessed in a highly skewed fashion. Therefore, for majority of the world population, access to them is denied or delayed, giving uncertainties on most of the nations' economic progress. India is also not an exception to this situation. Even as a country that can boast as the second largest population and the third largest resource user (Table 1), India's energy bills are unbearable and jeopardizing the essential investments in other sectors of development. Further, even with huge deposits of coal it has, India is unable to mine, clean and deliver adequate volumes of it to the user points like power stations and industries. The calorific value of most samples of Indian coal is very low, requiring it to be mixed with imported high quality coal for the more sensitive power plants. Ash content has been rising almost close to 45% and above, coal washeries are impractical due to lack of water in the mining regions and it becomes uneconomical to carry them around in ships and trains over thousands of kilometers.

**Table 1**
**India: energy and total resources use**

| Sl. No: | Country | Total Natural Resources % | Total Energy (MTOE) | Installed Cap. RE in 2013 (x'000 MW) |
|---|---|---|---|---|
| 1. | China | (1). 28 | (1). 2645 | (1) 378 |
| 2. | USA | (2). 13 | (2). 2225 | (2) 172 |
| 3. | India | (3). 7 | (3). 759 | 71 |
| 4. | Brazil | (4). 4 | (7). 268 | |
| 5. | Russia | (5). 3 | (4). 725 | |
| 6. | Japan | | (5). 469 | |
| 7. | Germany | | (6). 317 | (3) 84 |
| | Global Total | 100 | 13,078 | 1560 |

@ In brackets the global ranking
Constructed based REN 21 GSR 2014

## CHALLENGES IN ENERGY DEVELOPMENT

India has rightly emphasized the need to increase the energy efficiency and the Bureau of Energy Efficiency (BEE) and the Petroleum Conservation Research Association (PCRA) are contributing substantially to reduce the intensity of energy use in various sectors, in generation and in T&D. Yet, we have miles to go to reach closer to countries such as Japan, Germany, UK, France and Italy (84-96 [quantity of energy used per unit output] Vs India at 192).

India's determined efforts to reign in modern renewable energy sources such as wind power, solar photovoltaic, biomass power, small and micro hydro power, fuel cells, etc have been showing results with the level of RE used compared to the total electricity demand is at 12.7% and rising (Table 2). However, many of these sources are highly variable in output, cost/kW of installation is high, cost of energy produced per unit is above that of conventional, and current applications are inefficient in nature – leaving a viability gap, else their acceptance would have been highly promising.

**Table 2**
**India: Power (2014)**

| Sl. No: | Details/Technology | Capacity in MW |
|---|---|---|
| 1. | Installed Capacity (Power) as on 30.6.2014 | 2,49,488 |
| 2. | Captive Power with industries | 39,375 |
| 3. | Peak Demand | 1,35,453 |
| 4. | Max. Capacity Utilized at any time | 1,23,394 |
| 5. | Generation Million Units | 10,54,000 |
| 6. | Thermal Power Share | (69%) 1,72,286 |
| 7. | Hydropower Share | (16.4%) 40,730 |
| 8. | Renewable Power Share | (12.7%) 31,000 |
| 9. | Nuclear | (1.9%) 4,800 |

Cost wise, import of 133.3 MT (~80% of our oil needs) has cost India Rs 7,85,000 Crore and for import of coal of good quality needed, another Rs. 60,000 – all in Foreign exchange during the last year. The fact that one third of Indian homes (80.8 out of 247 million) is yet to get access to electricity is reason enough to expand our power development and deployment options with immediate effect.

Any further escalation of demand will adversely impact on our ability to close the gap between demand and supply as well as negatively affect the economy. Energy Sustainability as well as Energy Security considerations therefore, require that India tow a strong conservation and renewable dependant agenda with it.

## MODERN RENEWABLE ENERGY TECHNOLOGIES

In the 1950s and 1960s as well as partly during the 70s, India was one of the countries which had to depend heavily upon traditional biomass and modernization of their use patterns were mainly attempted during the 1980s. Their efficiencies were of the order of 8-10% for cooking applications and around 30% for industry and power related applications. Tens of Millions of homes were emitting low level of toxic pollutants in a distributed manner. Improvements to these traditional technologies, as well as putting to use newer technologies that would offer a new way of life for the un-served and underserved energy poor people is probably the answer. Globally, renewable energy and energy efficiency improvement drives are seriously pursued with target dates for completing the much awaited 'energy transition' in several countries.

However, each one of the countries who aspire to have substantial amounts of RE in its energy mix will have its own reasons for doing so. It could the development of a renewable energy industry, creation of new jobs, energy security, energy sustainability, improved energy access or reduced carbon foot print for themselves. At the end of 2013, the share of Renewable Energy in total energy used stood at 19% (according to GSR 2014 of REN 21), of which modern energy share was 10%. By 2030, countries are currently proposing to take this share threefold and reach 3x10 plus 9 or 39% - roughly 40% penetration.

## RENEWABLE ENERGY POTENTIALS

40% RE by 2030 is an attractive proposition. But, its realization will very much depend upon two essential support arms. They are:

1. Policy, which is clear, unbiased and flexible with a forward look, that can accommodate changes that will be necessitated by the growth of technologies and the cumulative economic progress associated with their stepped pattern of application.
2. Public awareness and education on the technologies and their effective and economic application, which will ensure that, to a large extent, local resources and skills for execution are utilized and families and enterprises will willingly invest in them as essential, bankable and profitable projects because they will be instrumental in elevating their quality of life.

Given that these are established, each local group and local government – distinctly different from the top down application associated hitherto with development projects – will feel that they are adequately empowered to drive the energy transition that will help people adapt to newer and newer impacts of climate change, mitigate the impacts of the ongoing changes, and create the healthy environment they have envisioned to live in, forgetting about continuing shortages and deciding on what forms of energy, in what measure, where and when rather than waiting for things to happen under a schema of entrusted decision makers deciding on their energy future.

Many cities, towns and institutions and governments in all parts of the world have been trying to figure out and declare the date of their achieving 100% RE penetration, and in India also similar studies have gone for the nation as a whole, and more specifically for certain states, including Kerala. For example, without considering the potentials from new strategies such as tapping micro algae as an economic substitute for the petroleum fuel for all its existing applications, newer technologies for harvesting the power in the sea waves, compressed air and hydrogen as independent fuels to run the automobiles, higher efficiencies of solar PV etc – which are round the corner now – WWF India and World Institute for Sustainable Energy (WISE), Pune have come out with recommendations in mid 2013for Kerala's 100% energy transition by 2050.

## WWF-WISE STUDY FOR KERALA

This GIS based study with adequate ground verification and reasonable and safe exclusions for the ecological sensitivities of actions, have worked the demand growth from 2011 to 2050 with Business As Usual (BAU) and arrived at a demand figure of 1300 Peta Joule (PJ) for all energy requirements by 2050 (WWF and WISE, 2013). With reasonable impetus given to the continuing energy efficiency drives, the possible curtailed demand was also worked out to be below 550 PJ. In the first and second decades of effort, the curtailment is only marginal. On the supply side several proven technologies were considered and their safest levels of outputs were considered, but major emphasis was given to new Solar PV and Solar Thermal as roof top mini plants and ground mounted larger ones in wastelands, plantations and grasslands; Wind electric as onshore and offshore plants again in available and permissible lands, small hydro, existing hydro, and biomass energy through gasification and biogas as well as through bio-oils and the total potentials estimated with current low efficiency levels itself show not only that 100% or above of the projected BAU demand could be met with RE over the next 35 years. The RE route electric power capacity itself is seen to be in excess of 66,000 MW. The possibility of demand falling – in Transport, Domestic, Commercial, Industrial, Agricultural and Public & other sub sectors gives better confidence to boldly go forward in this direction.

The potential is therefore proved beyond doubt. Kerala can be energy secure with sustainable energy resources from within the borders of Kerala itself.

**RECOMMENDATIONS FOR A FASTER 'ENERGIEWENDE' IN KERALA/INDIA**

The following recommendations are offered after having a preliminary socio-cultural and techno-economic analysis of the energy transition potential as above, for its faster realization with public who are expected to be empowered in due course; the ongoing effective de-centralization of governance in Kerala duly considered:

Such a transition work should be ably supported by 4 activity arms:-

1. Sensitization and Awareness creation for decision makers including local governments, neighborhood groups, public, students, women groups, professionals and ground level skilled workers
2. Re-work out and prioritize strategies, technologies and methods of implemention, financing including incentives (rather than subsidies) that can be followed
3. Conduct R&D at CED as well as at other sister institutions and willing partner research groups to evolve easily replicable methods of RE penetration with different strata of the society and for different kinds of institutions
4. Carry out demonstration projects for each of the technologies, their different types of applications and evolve ways of smooth transfer of technology and easy replication of models under demo

**THE STRATEGY (In lieu of CONCLUSIONS)**

1. The activity under this proposed program will have better acceptance and may succeed faster, if it is cast as a national campaign on mission mode
2. Governments – Central and State – should give support through formulation of policies and permission to government personalities in work under the subject areas covered to join the campaign at all levels as volunteers and mentors, especially during the sensitization and awareness campaign phase
3. The projects under demo should be able to reveal the interdependence of the energy, water, food and sanitation and the benefits of integration
4. Better if it is initiated at least in two states with different administration experiences and geographically wide apart, and then support its aided replication in the then ready states and regions
5. The activity arms 1 and 4 should go hand in hand and continuous monitoring and upgrading where needed should be built-in in the initial phase

6. It should be possible for the local people to tie up with local government funds for their activities under the areas covered in this mission, once the benefits are proven through the initial demos
7. The innovation and enterprising spirit of the students, youth and women groups should be activated so that such a mission will be able to create jobs, new enterprises and industries to meet the needs efficiently at local levels
8. Implementation, operation and maintenance of everything under the program should be in the hands of the local people, cutting above the political ceilings

Most successful energy conservation and energy transition efforts have succeeded in projects where people were involved at all stages – German Energiewende, Cuban Revolucion Energetica, Chinese RE Push forward, Japan's Energy Efficiency drive and the Korean technological push, all of recent years – with concerted awareness programs and pro-active policy support.

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# Water Security: Issues and Solutions in the Indian Context

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## INTRODUCTION

### Water Security and Sustainability Issues

Water security may be broadly defined as the assured availability of a reliable quantity and quality of water for livelihood - food, health, energy, production and ecosystem services, coupled with an acceptable level of water-related risks. Sustainable development in any sector directly or indirectly depends on the water security in the region, watershed or river basin. Water security also means addressing environmental protection and the negative impacts of poor management. It is also concerned with ending fragmented responsibility for water and integrating water resources management across all sectors – planning, finance, agriculture, energy, tourism, industry, education and health. Water along with food and energy forms a critical part of the 'new security agenda' and redefines the understanding of security as a basis for policy-response and long-term planning. A water secure world reduces poverty, advances education, and increases living standards. We aspire for a world where there is an improved quality of life for all, especially for the most vulnerable - women and children - who benefit most from good water governance.

Sustainable development revolves around four spheres: economic development, environmental management, institutional structures and often ignored social development (Fig. 1). It calls for trade-offs that are made between often conflicting elements within these spheres in order to ensure continued, sustained development while at the same time preserving the ability of the environment to support current and future ecological as well as human demands. In this context, the definition of sustainability by the World Commission on Environment and Development given in its report on *Our Common Future* is relevant: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In order to achieve the goal of sustainable utilization of freshwater resources, new approaches to water and river basin management are envisaged and introduced. One approach gaining acceptability, even though it has been identified many years ago, is the ‘ecosystem’ approach or ‘holistic’ approach. The Integrated Water Resources Management (IWRM), as enunciated at the Dublin Conference, is suggested as a way out to tide over the existing problems in the water sector and to move on to face the future challenges, especially in the context of emerging climate change.

Integrated Water Resources Management (IWRM) is a systematic process for the sustainable development, allocation and monitoring of water resource use. The principles of IWRM evolved at the Dublin Conference (1992) are:

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment;
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers;
3. Women play a central role in the provision, management and safeguarding of water; and
4. Water has an economic value in all its competing uses and should be recognized as an economic good.

Though all these principles are relevant in the context of sustainable development of other natural resources also, water is a common factor in the sustainable development of all these resources. The key issues to be analyzed in the context of water are: (i) growing water crisis and the need for urgent action; (ii) water governance crisis and associated factors; (iii) securing water for people; (iv) securing water for food; (v) gender disparities in the sector; and (vi) protection of vital ecosystems.

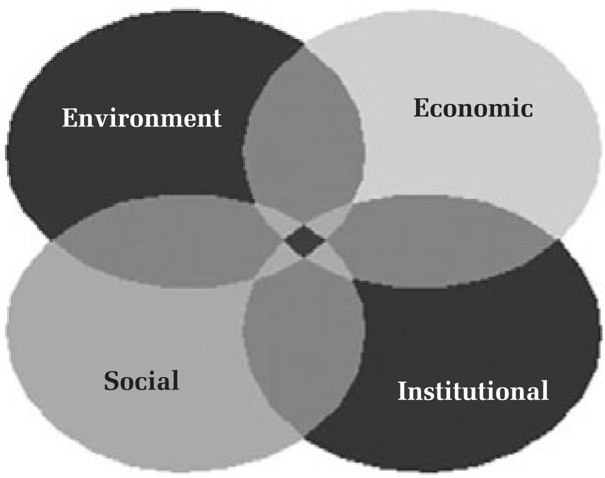


**Fig.1**
**Sustainable development: action within the spheres of environmental management and economic, social and institutional development**

## World Scenario

In spite of the fact that freshwater is a finite resource, in absolute terms there is no shortage for it world-wide. But, according to UN-Water, the total usable freshwater supply for ecosystems and humans is only about 200,000 $km^3$ – less than one percent (<1%) of all freshwater sources. It is interesting to note that water use has been growing at more than twice the rate of population increase in the past century. The water withdrawals are predicted to increase by 50 and 18 percent by 2025 in the developing and developed countries respectively. By 2025, 800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions.

According to an online article in *Nature* (2010), about 80% of the world population (5.6 billion in 2011) lives in areas with threats to water security. The water security is a shared threat to human beings and nature and it is pandemic. Human water-management strategies can be detrimental to wildlife, such as migrating fish. The levels of threat in regions with intensive agriculture and dense population, such as the US and Europe, are high. It is estimated that during 2010-2015, ca US$800 billion will be required to cover the annual global investment in water infrastructure. Wise management of water resources has to jointly take care of biodiversity conservation and human water security. For example, preserving flood plains rather than constructing flood-control reservoirs would provide a cost-effective way to control floods while protecting the biodiversity and wildlife in such areas.

Based on the map published by the Consultative Group on International Agricultural Research (CGIAR), the countries and regions mostly suffering from water stress are North Africa, the Middle East, India, Central Asia, China, Chile, South Africa and Australia. Water scarcity is on the increase in South Asia. More than 50 countries on five continents are said to be at risk of conflict over water. One such conspicuous case is the Southeastern Anatolia Project in Turkey on the Euphrates, which is expected to have serious consequences on the water supply schemes in Syria and Iraq. There are also several provincial conflicts reported from Australia, India, the US and the UK. Most of the solutions suggested to tide over the problem are not cost-effective. However, modern technologies like Seawater Greenhouse for desalination of sea water for agricultural purposes in water-scarce areas are providing rays of hope.

## Indian Scenario

The major challenges to the water management of India are the spatial and temporal variation of water availability, growing population, booming economy and subsequent changes in water use pattern, failure to build water partnerships and the over enthusiasm of government departments to control the activities in water management through their inefficient organizational structure and procedural mechanisms. The era of infrastructure development after Independence was followed by an era of inefficient operation and management of these water assets. There is also paucity of fund to maintain the existing systems and to enhance the potential. The slow pace in water resources management has its impact on the economy of the country and the welfare of the people. The failures of government made the communities to go for alternatives, which were not often scientifically planned and implemented. There has also been a reluctance to build up on the lessons learnt from the past or from the experiences of other countries involved in solving similar problems. The assets of the country, namely the community, private sector and innovative attitude were not properly made use of in the water sector. All these call for a different strategy to achieve sustainable development of water resources. The paper highlights the water scenario of India and the achievements of water management in the country. It also makes an attempt to project the future scenarios which require special attention of water managers. The problems are brought to light and strategies to overcome them are proposed. The principles of IWRM are presented and the need for ecosystem conservation brought to light. Integrated River Basin Management has been discussed since it is expected to help in ecosystem approach for water management.

**WATER RESOURCES STATUS AND UTILIZATION PATTERN IN INDIA**

India receives an average annual precipitation of 4000 BMC, including snowfall. The average annual water potential of the rivers of the country is 1869 BMC. It is estimated that the total utilizable surface and ground water potential is 690 BMC and 432 BMC respectively, adding up to 1122 BMC. The rainfall in India is highly seasonal and 50% of this is received in just 15 days; 90% of the rivers are seasonal and flow only for around 4 months (World Bank, 2005).

The growth in population and the changes in water use pattern mainly due to development are responsible for the escalation of water demand in the domestic and industrial sectors. The per capita water consumption is assumed to increase from 85 LPCD to 125 and 170 LPCD in 2025 and 2050 respectively. There are several urban and rural pockets in India where people are not having access to potable water. The present water demand for domestic purpose is estimated to be 42 BMC, which would go up to 107 BMC in 2050. According to certain official estimates, water supply and sanitation coverage is 89% and 34% respectively (CWC, 2003). However, actual field conditions indicate that the country has to go a long way to fulfill the millennium development goals.

An estimate made by the National Commission on Integrated Water Resources Development (NCIWRD, 1999) has projected the industrial water demand to 30, 101 and 151 BMC in 2000, 2025 and 2050 respectively. An analysis considering global trends shows much higher values.

There have been several attempts to construct large-scale water storage structures after independence to help the agrarian community and also to increase food production. This trend was started even during the colonial period as evidenced by the evolution of a tradition in irrigation in the Indo-Gangectic plain of the north and the construction of structures like the Mullaperiyar dam, more than a century ago in the far south. The live storage capacity of the country is estimated at 418.05 BMC and the capacity of completed, under-construction and under-consideration projects are 220.76, 84.32 and 112.97 BMC respectively (CWC, 2004). The initiatives in India during the First Five Year Plans have considerably helped in food security and poverty reduction especially in water-scarce areas. Major and medium projects completed during the pre-plan period, up to the Ninth Plan and ongoing in the Tenth Plan are 217, 928 and 383 respectively. All these considerably helped in the

Green Revolution, which transformed India from a country with food grain deficit to one with food surplus. But, most of these projects were not properly operated and maintained and therefore calls for large investments to make them functional in future. The tendency has been to "build-neglect-rebuild".

The irrigation potential at the time of independence was 22.6 Mha. The ultimate irrigation potential of the country is 114 Mha of which 109 Mha has been already created and 85 Mha utilized. The total irrigation potential created so far through major and medium surface water projects work out to 37 Mha and utilized is 31 Mha. Surface water based minor irrigation projects created a potential of 18 Mha of which 14 Mha is utilized. Groundwater based minor irrigation projects created a potential of 55Mha of which 44 Mha is utilized. Around 240 projects are included in the Command Area Development (CAD) programme with a culturable command area of 23 Mha and total irrigation potential of 22 Mha. Gross and net area irrigated as per the statistics of 2000 has been 76 Mha and 57 Mha respectively. Canals, tanks, wells and other sources cater to an area of 18, 3, 34, 3 Mha respectively. Food grain production from 122 Mha in the country works out to 212 million tons. The food security of the country is very much dependent on the most important input to agriculture, namely water.

The report on India's Water Economy by the World Bank (2005) highlights that while industrialized countries harness 80% of their economically viable hydro-power potential, India has utilized only 20%, despite its large potential in the Himalayan region and increasing need for power. At present, only 17% of electricity generation is met by hydro, though it is comparatively environment-friendly.

The quality and quantity of water for the aquatic eco-systems are at a low level. This has led to more demand for the purposes of environment and eco-system management. Certain estimates show that minimum flow requirement of 12-30% of the mean annual run-off is needed for this purpose; one estimate shows 46% for the Brahmaputra basin and another estimate shows 7% for the Mahi basin.

The problems with regard to water availability would be enhanced due to global climate change, especially due to glacial melting in the Indo-Gangetic plain, fluctuations in the rainfall pattern in the interior parts of the sub-continent and sea level rise in the coastal and inland eco-systems. The water managers should be prepared to face these challenges from now on, and planning has to consider this additional constraint.

## COMPARATIVE PICTURE OF WATER MANAGEMENT PRACTICES

The people of India were adapted to the vagaries of rainfall and variations in water availability. As a community, they lived on the banks of rivers in the past. The Indus valley civilization and the hymns pertaining to the Seven Rivers of North-West India as well as the statements in the epics highlight their dependence on rivers. They developed several management practices suitable for their habitat, making use of their imagination and innovativeness. The tanks of Tamil Nadu and Karnataka, *surangams* (horizontal wells) of Kerala, *tankas* of Rajasthan, bamboo based rainwater harvesting structures of the North East and the checkdams constructed at different parts of the country as reflected in Kautilya's *Arthashasthra* are all pointers to the ingenuity of the Indians in the past in conserving and optimally utilizing the water resources. However, increasing population and economic boom presented several challenges to the water managers.

During the past century and a half, India has heavily invested on large-scale water resource development schemes. These schemes have helped to a great extent in achieving food security, upliftment of the poor and enhancing the national economy. Certain arid zones prospered and recorded high economic growth. It is observed that poverty in irrigated districts is one-third that of un-irrigated districts. The first Prime Minister of India rightly called *dams* as 'temples of modern India'. People in the arid zones especially the poor and agrarian community, have considerably gained from these initiatives in the earlier part of the Five Year Plans.

It may be observed that rich countries in the arid region like the US and Australia have stored 5000 cubic meters per capita, while developing countries like China, South Africa and Mexico have storage capacities of 1000 cubic meters per capita. India's water storage capacity is only 200 cubic meters per person, which according to World Bank report (2005) is only 30 days of rainfall, compared to 900 days in major river basins of developed countries in the arid zones. In India, poverty in irrigated districts is one third of un-irrigated districts. The situation with regard to hydro-power generation is also not different, while the industrialized countries make use of 80% of their viable hydro-power potential, India has utilized a modest 20%, though the country has considerable potential for hydro-electric power generation.

**CHALLENGES FACED BY WATER MANAGERS**

There has been a general consensus that the water management systems in the country are not sustainable and require considerable paradigm shift. The way it is generally managed by the government, lack of coordination among the stakeholder departments and users and the lacuna in the organizational and procedural mechanisms have muddled water management sector in the country. The government with its tax revenues and water cess may find it difficult to manage the systems without the support of the stakeholders and private sector. Instead of the role of provider, government has to play the role of a watchdog and facilitator. Not only that finances are not available either to operate and maintain the existing infrastructure, but also funds are not available to go for new infrastructure. This will lead to a condition where economic growth is not possible, because of lack of adequate water supply.

The duty of the government is not only to provide water to the people, but also to maintain the eco-systems, especially the aquatic eco-systems. This is not only needed for food and health, but also for sustaining the water resources of the country. The thickly populated belts in India, and some of the States as a whole as in the case of Kerala are facing considerable water quality problems, caused by discharges of untreated human waste. It is also to be noted that chemical contaminants like fluoride, arsenic and selenium cause very serious health problems in the country. An estimate shows that 70 million people in 20 States are at risk due to excess fluoride and around 10 million people are affected by arsenic in groundwater. The increase in concentration levels of chloride, TDS, nitrate and iron in groundwater are threats to sustainable drinking water supply. The coastal belts are affected by salinity and the problem increases by over-exploitation. The industrial effluents discharged without treatment to the natural water bodies and the overuse of agrochemicals are significant threats to the aquatic eco-systems. One of the studies of World Bank points out that the total costs of environmental damage in India is of the order of Rs. 45000 crores per year, which works out to 4.5 % of the GDP. Further, 59% of this is the result of health impacts due to water pollution (World Bank, 1995).

The sanitation scenario of the country is very poor, considerably poorer than its neighbours like Sri Lanka. The estimates show that 64% of urban dwellers in India lack access to toilets and excreta disposal systems in urban areas vary from 48% to 70%. Sixty per cent of Class-I cities and 80% of small urban centers do not have sewerage systems. Even in the ones that have some system in place, coverage is very poor. According to Central Pollution Control Board (CPCB), the total waste water generated in 300 Class- I cities is about 15800 MLD and the treatment capacity is only 3750 MLD (Arghyam, 2007; CPCB, 1989). It is also sad to note that the metro cities of the country hardly have capacities to treat 30% of its sewerage and most of these cities have only facilities for primary treatment. Therefore, all the untreated and partially treated municipal wastewater joins the freshwater sources, causing severe pollution.

India looked at water management as an engineering challenge in the initial phases after Independence; later they faced considerable problems related to operation and maintenance. In fact, government considered the users as subjects. There was no incentive, entitlements, and participation of stakeholders. There was also no competition, no part for private sector, no accountability, and pricing did not exist in some areas. All these led to people taking care of their own needs for water in their own ways. For example, people went in for large scale exploitation of groundwater through bore wells and tube wells, without knowing the consequences of such measures. There are more than 20 million tube wells in the country today, most of them dug by individuals as stand-alone systems to achieve self-sufficiency in water supply. More than 50% of irrigation in the country is from groundwater sources. On the other hand, the urban middle class went in for purchasing bottles and barrels of water from the market to meet their day to day requirements. The estimates show that 80% of water for domestic purpose comes from groundwater sources. There is still another community of poor in the urban areas which gets their supply of water from the vendors at high costs; these vendors considerably exploited groundwater sources. In this business, the government also played a role by engaging private parties to supply water in areas facing water shortage by making use of trucks. The truck owners often exaggerated the number of trips made by them and charged the government heavily. This partnership has drained the coffers of the government. The industries in their turn went in for captive alternatives. These were costly and at times at the cost of the neighbourhood. All these show the pathetic state of water management in the country, which will finally lead to conditions which are not sustainable.

Though India has become self sufficient from the point of view of food production, there are several basins which are deficit from the point of view of food production.

Optimal use of water resources of these basins has to be ensured on a war footing. Almost 15% of the aquifers are in a critical condition. Water is mined from the groundwater sources for food production in several of the districts in the arid and semi-arid zones. Thickly populated belts and industrial complexes are facing shortage of water. Major symptoms of water shortage are evidenced from the water conflicts among different geographical and administrative units and different stakeholders themselves. The inter-state water disputes are on the increase. The tribunals take considerable time and the procedures cost large amount of money till the final award comes out, which often does not satisfy the stakeholder States. The Krishna and Cauvery disputes are some examples of inter-state water conflicts. The Governments often go for short term measures without proper planning to solve the problems to satisfy the communities. More projects are taken up at the cost of somebody else in the neighbourhood. All these have caused damages to the water resources of India.

## STRATEGIES FOR SCIENTIFIC WATER MANAGEMENT IN INDIA

There is a need to focus on developing a set of instruments such as policies, enactments, entitlements, organizational and procedural mechanisms and economic tools. The government should encourage the stakeholders and partnerships in the water sector. More incentives should be made available for the communities, especially those who are in great need of water for essential purposes. The secrecy in water culture has to be ended and more transparency brought in. Along with the social, economic and institutional factors, stress should be given to environment. As far as possible, local people are to be made the first beneficiaries of major water resources projects. The focus on supply side alone is not going to solve the problem. The resource base also has to be in prime focus. The over-exploitation of groundwater sources by the communities, industries and vendors has to be controlled. Mismanagement of urban water resources will have to be regulated and Integrated Urban Management Programmes initiated. Such steps call for coordination and unification of different departments and agencies involved in water resources development and management. Instead of focusing on command and control, the government should serve as a facilitator. The major assets of the country are the communities, private sector and the innovations of the past, which need to be strengthened through partnerships. The experiences of the past and also those of other countries having similar problems may have to come for the help of the managers in the water resources sector. The reforms have to be brought about not mainly by the bureaucrats, but by incorporating all those interested and involved in water resources management. In the quasi-federal system of the country, it may not be always possible to follow the systems prevailing in other federal states of the world. The lessons learnt by the treaties signed between India and Pakistan and India and Bangladesh should come for the aid of resolving inter-state issues within the country. Considering the various social, economic and environmental peculiarities of the country, initiatives should focus on integrated water resources management in line with the thinking at the Dublin Conference and Agenda 21 of the Rio Conference.

## RELEVANCE OF INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)

Integrated Water Resources Management (IWRM) in line with the Dublin Conference (1992) has to be introduced in the country. Two aspects of IWRM are highlighted, namely relevance of ecosystem management and integrated river basin management (James-Saci-Waters, 2010).

**Ecosystems in the Context of IWRM**

The ecosystems within a river basin can be broadly classified into terrestrial and aquatic. For convenience of treatment in the context of a river basin, these can be classified into upstream and downstream ecosystems.

The terrestrial ecosystems both natural like forests and grasslands and manmade like agricultural and urban systems contribute considerably to the hydrologic regime and the water management of the river basin. In fact, the ecosystems have their role in soil, water and biomass management of a watershed/ river basin. When compared to the aquatic ecosystems, terrestrial systems are comparatively dry from the point of view of hydrologic regime, rich as a biochemical source and low to medium in net primary productivity. Aquatic ecosystems are often flooded with water serving as a sink for bio-chemicals, with low primary productivity. On the other hand, wetlands are usually found at the interface between truly terrestrial ecosystems (such as upland forests and grasslands) and aquatic ecosystems (such as deep lakes and oceans) making them different from each, but highly dependent on both (Mitsch and Gooselink,1986) . The coastal ecosystems, especially coastal wetlands, are very much dependent on the water, sediments and biochemical transport from upstream reaches. These to a very great extent depend on the characteristics and the state of management of the upstream ecosystems and their communication with the sea, depending on the particular case.

The water balance based on blue-green water, upstream-downstream requirements and human–ecosystem needs will depend on the conservation and management of different ecosystems. Five generic systems are covered here, namely forests, cultivated and urban ecosystems, inland wetlands and coral islands.

The terrestrial ecosystems on the upstream of a river basin are important in the context of rainwater harvesting, groundwater recharge and for maintaining the stream flows during the lean season. Some of these contribute to food production, urban needs and biodiversity. Aquatic ecosystems are important from the point of view of food, fuel, medicinal plants, timber and biodiversity. Above all, these are important because of their recharging abilities, conservation of water and flood containing capacity. Therefore, this inter-connected web of terrestrial and aquatic ecosystems has to be conserved properly to serve as an 'environmental reserve' and to achieve this, scientific water management is necessary. IWRM, aiming at holistic approach or ecosystem approach, is important in the context of ecosystem conservation and management.

***Environmental Reserve: Forest Ecosystem***

Among the hydrologic functions of vegetal cover are: breaking the impact of rainfall; direct interception of a part of precipitation by the aerial portions of the plants; dissipation of soil moisture by transpiration; reduction in the loss of soil moisture by evaporation; binding the soil against erosion; and holding some moisture by the 'blotter' effect of litter (FAO, 1962).

The influence of vegetation upon infiltration and soil water storage is due to the effect of organic matter on and in the soil and to plant roots. Repeated measurements have shown a positive correlation between the quantity of organic matter present in soil and its water holding capacity. The studies in different parts of the world have shown that the water absorption capacity reduces due to forest fires and heavy use and trampling of soil. Such disturbed soils showed one-third of the rate of absorption of undisturbed forests.

Channels left by decayed roots also perform an important function in percolation and storage of water. Also, the growing tips force a way into minute cracks in the soil granules and through small passages between soil grains. When the roots die, they soon decay, leaving channels through which water may pass through the soil. The soil under relatively undisturbed forest and range cover is home for much animal life. Many animals, including most of the rodents and insects, dwell or borrow in soil. Fungus mycelia grow downwards and increase the lines of cleavage. These activities are conducive to the development and maintenance of a relatively high water-absorptive capacity. Any modification to the plant cover and surface soil by cultivation, burning, or over-grazing induces conditions favorable to the optimum development of these soil fauna and flora and results in a reduction in the capacity of the soil to take up water.

Water occupies the soil in three forms: hydroscopic (held in small pore spaces), capillary (tightly held on to soil particles) and gravitational (drained from larger pore spaces). Precipitation reaching the soil surface, which does not infiltrate or pond in small depressions, moves downhill over the soil surface as overland flow (Hewlett and Nutter,1969). Vegetation increases surface roughness, and litter particles on the soil surface form small dams and obstructions which slow down the velocity of overland flow and discourage concentration in rills and gullies.

Soil erosion may be broadly classified into: sheet erosion and channel erosion – the latter includes rill and gully erosion. Vegetation acts to reduce erosion by slowing down the velocity of water flowing over the soil surface. Some erosion is caused by overland flow; the effects of vegetation in reducing and retarding overland flow also operate to reduce erosion. Moreover, interception by canopy reduces the energy of rain drops.

Studies were conducted in three clusters of watersheds in the forest areas of the western ghats of south-west India to understand the role played by the forests in water management of this humid tropical region with an average rainfall of 3000 mm. Three watersheds, one each with 60% and more canopy, between 30 and 60% of canopy and less than 30% canopy constituted each of the three clusters; the clusters were selected at Peruvannamuzhy in Kozhikode and Vazhani and Chimoni in Trichur districts of Kerala. Based on the data collected from the field, following general observations were made:

(i) The annual and monsoon runoff from a unit area of exploited watershed (less than 30% canopy) is more than that of other two in all the individual clusters; discharge from dense forest watershed (more than 60% canopy) lasts longer than the other watersheds after the monsoon season; the runoff coefficient with respect to rainfall is very high for exploited watersheds; the unit hydrographs of one-year duration show that lag time subsequent to a storm in a dense watershed is 35% more than that of the exploited watershed.

(ii) Based on the observations of throughfall and stemflow, it is seen that the average interception from a typical mixed forest watershed of western ghats is 10% of the rainfall.

(iii) The quantification of bed load accumulated at the weir sites on the downstream of the watersheds shows that the bed load accumulation at the exploited watersheds is more than six times that of dense forest watersheds.

(iv) In all the seasons at all the depths considered, maximum soil moisture was observed in the dense forest watershed followed by other exploited watersheds in each of the clusters.

(v) The water balance study indicates that the deficit during the summer months of January-May is more in the exploited watersheds of each cluster than the forest watersheds (James et al, 1987).

***Agricultural Ecosystem: Land-water Linkages***

There should be a shift from the present land/water dichotomy, apparent in UNCED Agenda 21, towards an integral concept of the land as a system traversed by water, with land use depending on access to water (among other factors) and at the same time, affecting the passing water in its pathways, seasonality, yield and quality.

Man depends on access to water in the landscape for several parallel functions. These include human and community health and well-being; biomass production; other forms of socio-economic production; the maintenance of habitats for ecological protection; and the transport of soluble and solid materials such as nutrients, pollutants and sediments. The water passing through a landscape is influenced by human activities in that landscape, and may therefore present problems which must be anticipated and met by mitigating measures (FAO, 1993).

Water may sustain land use but may also be a constraint on land use and socio-economic and biomass production. At the same time, land use influences water characteristics by its partitioning of incoming rainfall between the vertical return flow to the atmosphere as evaporation and evapotranspiration, and the horizontal flow to aquifers and rivers, classified as ‘blue water’. The various functions related to human activities, also affect both physical and chemical characteristics of water (Falkenmark, 1993).

For his use of natural resources, man must manipulate the landscape that contains them. Natural laws operating in that landscape produce side effects, often designated as ‘environmental impacts’. For instance, changes in land use alter two ‘joints’, or boundaries in the soil profile that determine the partitioning of incoming water. The first of these boundaries, at the soil surface, serves as a division between overland flows and infiltration. The other, in the root zone, is a partition between the “green water” accessible in the root zone, later to be used in plant production, and the surplus water that flows on to recharge aquifers or other water bodies.

The characteristics of land and anthropogenic activities will have an impact on the land-based phases of the hydrologic cycle. The human interventions cascades through the water cycle, producing secondary effects on terrestrial, aquatic and marine ecosystems, and thus the sustainability of the environment and of natural resources development and management. The resulting problem profiles are quite different in different hydroclimatic regions - their occurrence and weight as well as severity.

There has been a lack of understanding on the linkages between the hydrological, geomorphological, and pedological processes and the plant nutrients dynamics at landscape level, as well as the implications of soil and water resources conservation and development in the whole river basin environment.

The degree of holism hinges on the definition of "Land"; one such definition is given below:

*"Land is a delineable portion of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associate groundwater and geohydrological reserve, the plant and animal populations, the human settlement pattern and the physical results of past and present human activity (terracing, water storage or drainage structures, roads, etc)"* (Sombroek, 1994).

In this holistic approach, a unit of land has both a vertical aspect - from atmospheric climate down to groundwater resources, and a horizontal aspect - an identifiable repetitive sequence of soil, terrain, hydrological and vegetation or land use elements ("landscape", "land unit", or "terroir" units). Mineral resources and deeper geohydrological resources (confined aquifers) would, however, be excluded from land attributes.

It is possible in this definition of *land* to integrate all compartments vertically: from groundwater-related qualities through qualities of soil profile, soil surface, slope position and vegetation cover, to overhead climatic qualities. It is also necessary to integrate all aspects horizontally at the landscape level, in which approach physical geographers take into account typical, micro-geographically repetitive elements of terrain, top or plateau, scarp or upper slope, main slope, lower slope or spring-line, bottomland or flood plain, with their mutual influences whether natural or under current land use. This influence can be in the sense of internal hydrology (for instance, rainfall traversing into soil of the plateau and surfacing at the springline, including the lateral movement of chemical substances such as salts and silica), or the surface transport of soil material through erosion from upper slopes and accumulating in the bottomland or flood plain (Falkenmark 1993). Both these influences can be detrimental or positive at the receiving end, depending on the rate of transport and the prevailing climatic conditions. The lateral influence also relates to chemical soil fertility. Nutrients may be transferred down-slope by natural processes, or from outlying land to arable fields near homesteads in traditional farming systems.

The watershed is the natural integrator of all the hydrologic phenomena pertaining to its boundaries, and as such, it is a logical unit for planning optimal development of soil, water and even bio-resources. There has been a tendency to focus integrated management of land, water and agriculture based on a small watershed. From the hydrological point of view, a distinct characteristic of a small watershed is that the effect of overland flow rather than the effect of channel flow is a dominating factor affecting the peak runoff.

***Population Pressure: Urban Ecosystem***

As the land surface is developed for urban use, a region is transformed from the natural state to a totally manmade state. New structures add large amount of impervious areas to the watershed, which in general increase slopes and considerably diminish the water storage capability. As the area covered by structures approaches 100%, the amount of vegetation, natural surface and infiltration will all approach zero. The improvements to the drainage system may reduce the lag-time (between the rainfall and peak runoff) of the hydrograph to one-eighth that of natural channels. The lag-time reduction, combined with an increased storm runoff resulting from impervious surfaces, increases the flood peaks by a factor that ranges from two to nearly eight (ASCE/UNESCO, 1998).

As an area becomes impervious, infiltration is reduced and subsurface runoff is lost to surface runoff. The volume of water lost by an urban basin to surface runoff would directly depend upon its percent of imperviousness. Several case studies are available on these aspects. In exceptional cases, base flow may increase in urban streams due to the watering of lawns and gardens, sewage effluents, and deliberate transfers of water from other watersheds (Johannus and Haagsma, 1995). The sediment in streams results from erosion of soils by overland (sheet) erosion, and by scouring of ditches and stream channels. Within urban areas, increase in storm runoff adds high peaks of energy which augment the natural erosive forces and greatly accelerate erosion. Any unprotected ground surface may easily be scoured. Streams are filled with sediment-laden water and their cross-sectional areas may be enlarged. This process produces several changes in the physical and biological characteristics of the stream channel. These changes include deposition within the channel, destruction of flow and increased flooding, shifting configurations of the channel bottom, blanketing of bottom dwelling flora and fauna, alteration of the flora and fauna as a result of changes of light transmission and abrasive effects of sediment, and alteration of species of fish as a result of changes produced in the flora and fauna upon which the fish depend.

High suspended sediment concentrations are probably indicative of: (i) land surface disturbance somewhere in the watershed; (ii) accumulation of dust and the first flush effect; and (iii) scouring of the stream channel itself. Several researchers have shown that without a doubt, nowhere in the process of urbanization is erosion as violent as in the construction phase.

The entry of pollutants into a flowing stream sets off a progressive series of physical, chemical and biological events in the downstream waters. Their nature is governed by the character and quantity of the polluting substance. If one were to take dissolved oxygen measurement at various points along a river flowing downstream, one would derive a dissolved oxygen sag curve. From before the point of sewage entry (at mile 0) to the $15^{th}$ mile downstream, generally the bacterial composition proceeds mainly by aerobisis. From the $15^{th}$ mile to about $30^{th}$ mile, bacterial decomposition occurs by means of anaerobisis; after this point, aerobic conditions return.

The urban landuse patterns can be divided into five principal settings: (i) construction, (ii) industry, (iii) commerce, (iv) streets and roads, (v) residential sections. Construction activities themselves can be divided into several phases. Many industries have a significant effect on quality of air, stormwater, streamflow, and groundwater. Exposed surfaces may accumulate pollutants generated by automobile traffic, litter, dustfall, and spills. Automobiles contribute to several pollutants. Hospitals, markets and residential areas also contribute to the pollution load, both chemical and biological, of the urban areas.

The clearing of vegetation decreases the capacity of the watershed to capture moisture, increasing the runoff. The loss of vegetation also destabilizes stream bank vegetation and reduces the shade produced by the canopy. Increased solar pollution raises stream water temperatures during the summer months, destroying the habitat of fish and disrupting the ecosystem. Conversion from predominantly vegetated landuse to urban uses may result in tremendous reductions in the absorption capacity of watersheds. The increased volumes of runoff also travel more quickly to surface waters, which in turn produce higher peak flows and velocities. Flooding may occur as flows exceed natural, designed, or available system capacities, threatening homes and business located along the stream. Pollutants such as oil, gas, fertilizers and pesticide adversely affect fish, wildlife, plants, and may impact on drinking water sources.

### *Modifying the Hydrologic Regime: Inland Wetlands*

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water intermittently or all through the year. Wetlands must have one or more of the three attributes: (i) atleast periodically, the land supports predominantly hydrophytes; (ii) the substrate is predominantly undrained hydric soil; and (iii) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year (Mitsch and Gosselink, 1993). The wetlands can be broadly classified into inland fresh and saline as well as coastal fresh and saline areas.

Wetlands are among the most important ecosystems of the Earth. On a short-time scale, wetlands are useful as sources, sinks, and transformers of a multitude of chemical, biological and genetic materials. They have been found to cleanse polluted water, prevent floods, protect shorelines and recharge aquifers. Furthermore, wetlands provide unique habitats for a wide variety of flora and fauna. Some scientists have rightly called the wetlands as the ‘nature’s kidneys’.

Hydrology is probably the single-most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. A conceptual model showing the direct and indirect effects of hydrology on wetlands is given in Fig 2. The hydrologic conditions can directly modify or change chemical and physical properties such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties and pH. Biotic control mechanisms of wetlands include peat building, sediment trapping, water-shading and transpiration. These processes decrease the frequency of floods, reduce erosion, and control evaporation.

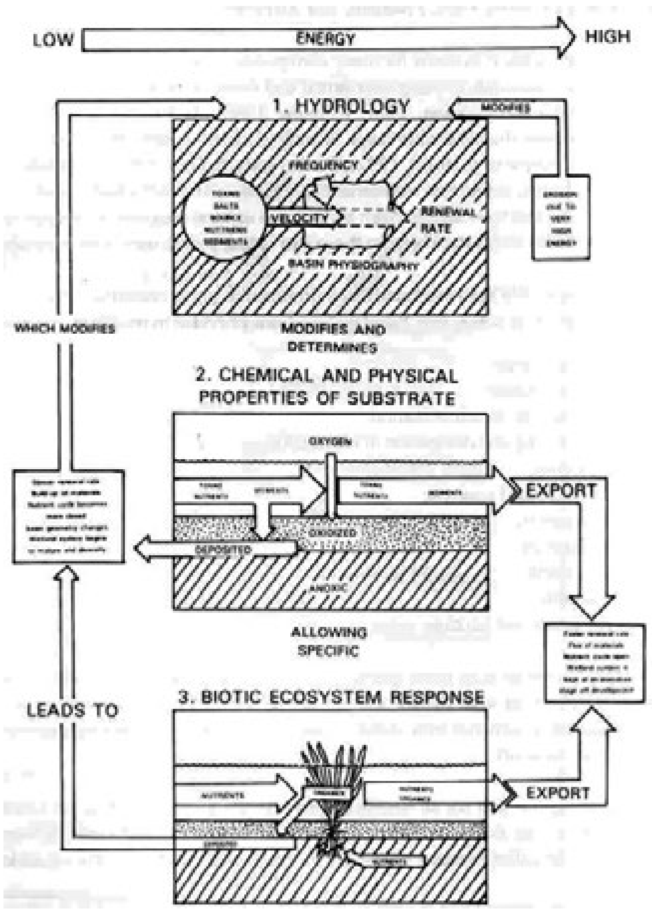


**Fig 2**
**A conceptual model – impact of hydrology on wetlands**

Hydrology leads to a unique vegetation composition but can limit or enhance species richness. Primary productivity is enhanced by flowing conditions and pulsing hydroperiod, and is often depressed by stagnant conditions. Organic accumulation is controlled by hydrology, through the influence on the primary productivity, decomposition, and export of particulate organic matter. Nutrient cycling and nutrient availability are both significantly influenced by the hydrologic conditions. Different species have different physiological response to flooding. Large trees show greater tolerance to flooding than do seedlings.

The important values and attributes of the wetlands from the IWRM point of view are: (i) containing the floods and regulating the flows; (ii) purifying the water; (iii) recharging the groundwater; (iv) maintaining the summer flows; (v) providing an aquatic ecosystem for biodiversity; and (vi) encouraging water sports and tourism.

***Fresh Water Scarcity: Island Ecosystems***

Small coral islands of less than 5 square kilometer area like the ones in Maldives and Lakshadweep do not have fresh water sources to meet their requirements and those of the tourists visiting their islands. Often, there are no surface water bodies like streams and rivers. A limited quantity of water is available as groundwater for the utilization of the local population. The total population of 62000 people living in the 10 inhabited islands of Lakshadweep requires about 3.5 million litres of fresh water per day. This need is increasing day by day due to increasing population and changes in water use pattern. Due to high permeability of these coral islands and limited subterranean storage space above the mean sea level, a substantial portion of the infiltrated water percolated into the sea. The outflow coupled with the consumptive uses leaves only a fraction of the infiltrated water as an effective recharge to the shallow aquifer. The water in such shallow aquifers often gets contaminated by human wastes and other sources from the thickly populated areas in the islands.

A study of the islands of Lakshadweep showed that the total population in the 10 inhabited islands of an average area of less than 5 sq km is 62000. Most of them do not have proper sanitation facilities and 60% of the wells are within 10 m distance from the leach pits. Around 90% of the wells, main source of fresh water in these islands, are bacterially contaminated and this calls for frequent disinfection and sanitization of the wells of these islands. Bacterial contamination is at its peak in the rainy season – June-October. It is a matter of great concern that about 50% of the population suffer from stomach and intestinal disorders and skin diseases. A participatory project funded by India- Canada Environment Facility provided drinking water facility to 20% of the total population of Lakshadweep Islands

In the coral islands, groundwater occurs under phreatic condition. Fresh groundwater floats as a lens over the brackish water overlying the saline water. The sea water is in hydraulic continuity with the groundwater and this is evidenced from the influence of tidal action in the wells of the islands. The depth of groundwater level varies from 1 to 5 m. The strategy for water management in the coral islands calls for control of water use, prevention of electrical lifting devices, sanitization of wells, more sanitation facilities, introduction of rain water harvesting structures, desalination plants wherever essential. Moreover, there is a great need to come out with policies and regulatory mechanisms along with creation of awareness among the local people and tourists. A separate strategy for water conservation of small coral islands has to be evolved to conserve these sensitive ecosystems (CWRDM, ICEF and LA,2006).

**Integrated River Basin Management**

***Shifting Paradigms***

The last few decades have witnessed the recognition that the Earth's resources are finite and call for implementation strategies which ensure the maintenance of these resources for future generations. At the same time, development is undoubtedly a desirable economic and social objective which seems to achieve or maximize a number of attributes such as: increased income, improvements in health and nutrition status, educational achievements, access to resources and a 'fairer' distribution of income (Pearce et al, 1990). The World Conservation Strategy (WCS) acknowledged that 'development and conservation are equally necessary for our survival' (IUCN, 1980). The strategies outlined by WCS include: (i) the maintenance of essential ecological processes within 'life support ecosystems' such as agricultural land and soil, forests, and coastal and freshwater wetlands; (ii) the preservation of genetic diversity; and (iii) the promotion of sustainable utilization of species and ecosystems. The concept of 'eco-development' advanced by the WCS was brought into the realm of political development by the establishment of the World Commission on Environment and Development in 1983. Several new paradigms are being propounded to achieve the goal of sustainable development of natural resources, one such being 'ecosystem' approach. The concept of a 'holistic approach' is relatively easy to preach but difficult to practise, mainly because it encompasses not only the domains of physical and natural sciences but also that of social sciences. To achieve success in natural resources management for sustainability, it is necessary to carefully plan for bringing together the two important components, namely (i) the complex web of interactions in nature, and (ii) still more complex web of interrelationships among human needs, expectations and value systems. In such an approach, sustainability calls for due consideration of economic, social, environmental and institutional aspects.

It is worthwhile to note that the UN General Assembly held in June 1997, while examining the progress on sustainable development, made a call for the formulation and implementation of policies and programmes for integrated watershed (basin) management. In such a river basin management, it is essential to ensure the involvement of all stakeholders, encourage the public participation, raise public awareness, build capacity and develop appropriate institutional structures. All these will help in building a consensus and resolving conflicts of interests; such exercises are essential for effective natural resources management.

### *Need for Integrated River Basin Management*

In line with the recommendations of the International Conference on Water and Environment - 1992, Chapter 18 of Agenda 21 of Rio Conference stressed the need for integrated water management. The emphasis was also on the need for water resources assessment, protecting freshwater from over-exploitation and pollution, improvements in drinking water supply and sanitation, impact of urban development, water for food security and implications of climatic change.

The integrated water resources management is based on the concept of water being an integral part of an ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilisation (UN, 1992). The World Bank (1996) states that degrading the quantity and quality of water in rivers, lakes, wetlands and aquifers can inextricably alter the water resources system and its associated biota, affecting present and future generations. The holistic management of freshwater as a finate and vulnerable resource, and the integration of sectoral water plans and programmes within the framework of national economic and social policy, are of paramount importance to ensure sustainable use of water.

The inter-connected nature of river systems means that successful water management requires the adoption of methodologies which consider all the activities within an area instead of focusing on only one or perhaps a small number of limited objectives.

The river basin provides the natural unit for such an approach. According to Young et al (1994), the fact that water interacts with and, to a large extent, controls other natural components within a basin such as soils, vegetation and wildlife suggests that human activities, which are so strongly influenced by water availability and quality, might best be coordinated within administrative structure which reflect river basins. This management approach should enable the incorporation of both upstream and downstream considerations into decision making and subsequently the management of water resources. It should also help to avoid the problems associated with the isolated, often short-slighted, use of water- land resources in one area which often have knock on impacts elsewhere within the river basins. In the context of a river basin, it is a natural integrator of all hydrologic processes within its boundaries and therefore a rational and ideal unit for soil, water and biomass management. These resources are closely linked and can be rightly designated as a 'trinity' in the context of a basin/watershed. If one among this trinity, namely, the bioresources is overexploited by deforestation, more soil erosion and degradation will take place; this in turn will have its impact on water balance and *flora* and *fauna* as such.

One of the attempts made in Philippines to achieve basin-wide management is worth mentioning. The National Power Corporation of Philippines is in full control of Angat River Basin, and has succeeded in achieving multiple objectives. These include: (i) maintenance of the watershed's capacity to support and sustain the generation of electricity by maintaining adequate forest cover and minimize, if not control, soil erosion; (ii) regulating land use activities and controlling exploitation of forest resources; (iii) improving socio-economic conditions of human population within the river basin and ensuring their participation in watershed management and protection; and (iv) generating income from agricultural plantations to partially subsidise the cost of watershed management and development.

Another attempt towards achieving integrated river basin management in Asia has been done in the Mekong basin of 7,95,000 km$^2$ area; the river is the longest in Southeast Asia and twelth longest in the world. The six riparian countries of the river include China, Cambodia, Vietnam, Laos, Thailand and Myanmar. The governments of Cambodia, Laos, Thailand and Vietnam gave birth to Mekong Secretariat. In 1995, an international agreement was signed by the lower riparian countries, brokered by UNDP. The Council of Ministers of Mekong River Commission is supported by senior water officials in a Joint-Committee, who are in turn, aided by experts and technical staff of the Mekong River Commission Secretariat. The diagnostic study carried out has helped in coming out with Mekong Basin Development Plan.

### *Requirements for integrated river basin management*

In order to accomplish the objectives of integrated river basin management there are a number of fundamental needs and requirements. Sustainable development of water environment requires a step-by-step approach which, by following a number of pathways and combining asset management, catchment management and land-use planning and control, will shift the emphasis from single function investment in water resource development to integrated river basin management. The pathways to sustainable development of water environment are given in Fig 3. Along these paths a series of approaches and actions can be adopted in order to most appropriately integrate wetlands into river basin management. Some of them are described hereunder.

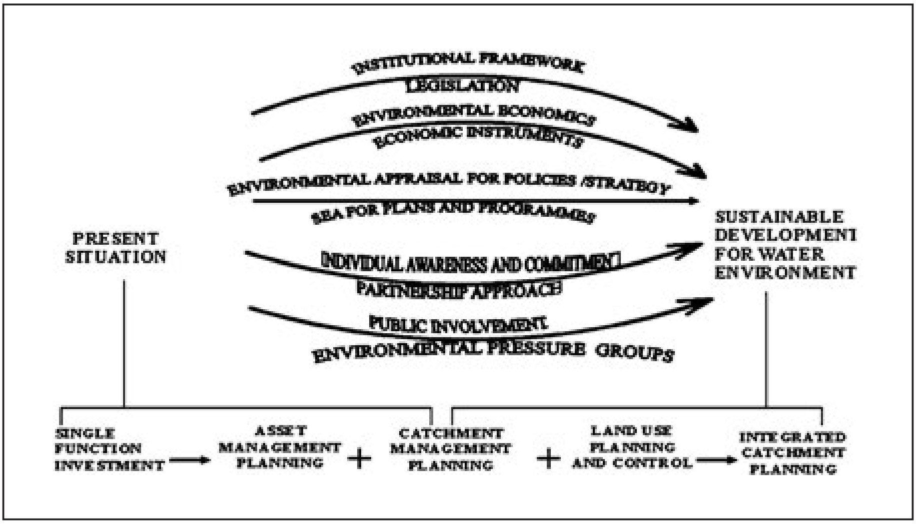


**Fig. 3**
**Pathways to sustainable development of water environment**

The Environmental Impact assessment (EIA), which is relevant in the context of river basin management, is a method of identifying (i) the impacts of human activities on human and natural environment; and (ii) option to reduce or mitigate adverse impacts. The main objectives of EIA are: (i) to disclose significant environmental effects to the decision-makers and public; (ii) to identify ways to avoid or reduce the damage; (iii) to prevent environmental damage by requiring implementation of feasible alternatives or mitigation measures; (iv) to disclose to the public reasons for agency approval of projects with significant environmental effects; (v) to foster inter-agency coordination; and (vi) to enhance public participation. The EIA now includes also social impact assessment, and risk analysis and a broader consideration of environmental management relevant to the project. Two questions deserve consideration in this context: (i) who are all responsible for the implementation of EIA recommendations? (ii) Can an impartial outside agency carrying out the EIA know all the implications of the project?

Cost Benefit Analysis (CBA) is a tool for calculating the net impact of the project on society and economic welfare by measuring all costs and benefits of the project. It is broader than a Financial Appraisal (FA), which identify the commercial return from the project. The results of CBA are almost always expressed in monitory terms. Most of the earlier water resources projects in developing countries were cleared by the Government of India considering the social benefits, presented in a qualitative manner in the proposals. In some cases, the command area of irrigation projects were exaggerated; later, it was found that water does not flow to some parts of these added-on command areas mostly at a higher elevation.

It is essential that the complementary nature of EIA and CBA is recognized: EIA is an integral part of the decision-making process; CBA includes cost and benefits of environmental impacts and options for mitigation. The decision-maker requires an analysis of the economic, environmental and social costs and benefits of policy and project options. The elements of such an integrated assessment are: (i) cost benefit analysis from the national perspective; (ii) cost benefit analysis from the regional perspective; (iii) environmental impact analysis; and (iv) social impact analysis. EIA has to be carried out at both the policy and project level. At the policy level, it is often referred to as Strategic Environmental Assessment (SEA).

Integrated river basin management calls for planners and environmental managers to work with, and for, the entire community of water users in the basin. To achieve this, one has to move away from past management structures and plans, which were meant to benefit limited population of the basin. Public awareness programmes should target at the general public, NGOs, government departments and others responsible for river basin management, such as farmers.

Water policy statements form an integral part for the implementation of integrated river basin management. It may be difficult, if not impossible, to prescribe a single legal framework for integrated river basin management. However, water and environmental laws should: (i) base water management on river basins; (ii) incorporate sustainable management principles; (iii) require integrated water and environmental management planning; (iv) prevent fragmented departmental water allocation and use decisions; (v) ensure integrated economic and environmental policy and project appraisals; (vi) establish water management institutions as outlined in this paper; (vii) and establish enforceable incentives for environmentally sustainable water use.

**WAY AHEAD**

The following action plans may help in ensuring water security in the country:

- Water sharing agreements between nations and states are to be drafted considering all relevant aspects.
- Irrigation efficiency is to be improved and conjunctive use of surface and ground water to be ensured wherever feasible.
- Existing stored potential to be optimally utilized and maintenance and operation scientifically carried out.
- Ground water exploitation and mining are to be restricted by law.
- Sewage and industrial effluents are to be properly treated before discharging in to the water bodies.
- Proper water treatments have to be carried out and wastage in water supply is to be brought down.
- Traditional and modern rain water harvesting and water conservation measures are to be adopted.
- Local level water sources are to be conserved and judiciously made use of.

- Pollution monitoring has to be regularly done and preventive measures including disincentives and incentives have to be implemented on time.
- Hydro-power potential is to be optimally utilized giving due consideration to the environment.
- Possibilities for water partnerships and participatory development and management of water resources have to be probed and Government has to play the role of facilitator.
- Water allocation has to consider all the requirements, especially the needs of ecosystems and biodiversity.
- Planning processes in the water sector have to consider the impact of climate change.
- Awareness creation has to be a continuous process to be taken up by all stake-holders in the water sector.
- Institutional and procedural mechanisms are to be improved keeping in view the expected outcome.
- Stake-holders should be made aware of the fact that freshwater is a finite resource and it is an economic good.
- Gender issues in the water sector have to be properly addressed.
- Proper policies have to be in place and necessary laws are to be enacted and implemented.

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# *Invited Presentations*

# Water, Energy and Food Security in Kerala

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## INTRODUCTION

Growing global population, along with the changing lifestyles, puts increased demands on water, energy and food. These scarce resources have to be put to judicious use lest breakdown in the world order becomes imminent. Recognition of the interdependencies in this regard is of paramount importance for states like Kerala which are vulnerable to the 'Water – Energy – Food' imbalances. An attempt is made in this paper to map the scenario in this respect and to suggest measures for ensuring sustainability in natural resources management and development.

## WATER SECURITY

Kerala faces various issues in its water sector, a contradiction, which is understood to be due to various management issues with respect to water conservation, development, regulation and sectoral administration. Though these issues are addressed seriously in the Kerala State Water Policy brought out in 2008, the policy propositions are not followed up systematically towards an implementation framework.

### Rainfall and Water Availability

Kerala receives about 3070 mm of average annual rainfall which is one of the highest received by any climatic regions of India. The rainfall in Kerala is on the decline on a long term basis (1871-2005). Though Kerala has an overall water surplus, the temporal variation of rainfall leads to water deficit in almost all the regions especially during December to April. The importance of water balance at the local level and the requirement of commensurate water conservation needs are yet to be considered seriously. With about 80% of agricultural crops being rain fed, rain water conservation and water use efficiency are assuming added significance. Kerala had experienced 53 drought years out of 110 (1901-2010) of which 17 were moderate, 19 large, 13 severe and 4 disastrous droughts. The period 1981 -2000 experienced 7 droughts and the number of disastrous droughts was also more (2) during 1991-2000. The frequency of droughts is severe in the recent decades. Aridity index over Kerala has increased by 3.37% in the last five decades indicating that Kerala is moving towards dryness. All major crops are affected due to erratic rains and ensuing dry spells/droughts occurred in recent years. The severe drought of summer 1983 resulted in reduced nut yield of coconut from Feb 1984 to January 1985. The maximum reduction in nut yield (64.1%) was observed in July 1984. Rainfall data (1927-2008) and temperature data (1950-2008) analyses done at RARS Pattambi revealed that during the period 2003-08, the annual mean temperature increased by 0.5$^0$C and 0.42$^0$C respectively during June and July. Delayed onset of south-west monsoon and reduced rainfall were observed resulting in decreased yield of rice to the tune of 670 kg per hectare in *Kharif* and 864 kg per hectare in *Rabi*.

**Surface Water Scenario**

The surface water resource potential of Kerala is spread over in 44 rivers, 236 springs, 50445 ponds, 9 lakes with freshwater, 53 reservoirs, 150 check dam storages etc. All these storages are under environmental stress of varying magnitude. The deterioration of water quality is also on the increase, at places to a very dangerous level, mainly due to high level of pollutant discharges due to multitudes of activities under the primary, secondary and tertiary development sectors.

**Ground Water Scenario**

The latest estimate (2008-09) on the groundwater resource potential of Kerala brought out by the Groundwater Evaluation Committee in 2012 indicates that the total available resource is 6029 MCM and the average level of development is 47 percentage annually. Based on the stage of groundwater development, 126 blocks out of 152 in the State falls under safe category. Among the rest of the blocks, one is over exploited, three are critical and 22 are semi-critical. An estimate of Kerala Water Authority in 2003 stated that 48% of the total 45 lakh wells of the State dries up during summer. In a recent study by the Center of Excellence in Environmental Economics (2014), it has been predicted that the State will experience severe water scarcity by 2021 (Santhosh, 2014). The study has projected a gap of 1268 mm$^3$ (1268 billion litres) between supply and demand for 2021 on the basis of current level of rainfall, storage and available groundwater.

The hydrological importance of the river systems, wetlands, ponds, tanks, irrigation canal network, etc. on sustaining the groundwater system is either not understood locally or not taken seriously at the grass root level and therefore the environmental abuse is on the increase. The adverse impact of indiscriminate pumping on the aquifer environment, especially in the case of open wells is increasing dangerously particularly in laterite, alluvial and weathered rock aquifers. Generally, the groundwater users are not found literate about the safe yield, water quality and upkeep of wells and importance of recharge of wells etc. There are about 8400 canal irrigation schemes and 52000 lift irrigation schemes in the State. A total of 4.09 lakh hectare of land is brought under irrigation by 2012. Coconut tops among the major crop supported by irrigation (37%) followed by paddy (31%), banana (9%) arecanut (8%) and vegetable (4%). However, due to various reasons, efficiency of the sector is not commensurable with the investment, capability, requirements, resource constraints and technological advancement.

Though the irrigation infrastructure of the State has grown considerably well, the user participation is inadequate and the maintenance service delivery is not commensurable with the system requirement. The requirement for improving the irrigation efficiency is not addressed adequately. The existence of the irrigation systems are seemingly by default. The details regarding the irrigation sources and crops irrigated in Kerala are given in Tables 1 and 2.

**Table 1**
**Area irrigated in Ha. (Source –wise)**

| Sl. No. | Source | 2010-11 | 2011-12 | 2012-13 |
|---|---|---|---|---|
| 1 | Government canals | 85825 | 81737 | 80718 |
| 2 | Private canals | 5584 | 1971 | 2457 |
| 3 | Tanks | 51064 | 47112 | 43558 |
| 4 | Wells | 137716 | 137193 | 122338 |
| 5 | Other sources | 134824 | 140901 | 146797 |
| 6 | **Total** | **415013** | **408914** | **395868** |
| 7 | Gross irrigated area | 466038 | 490585 | 457896 |
| 8 | Net area irrigated to Net area Sown (%) | 20 | 20.04 | 19.32 |
| 9 | Gross irrigated area to Gross cropped area (%) | 18 | 18.43 | 17.67 |
| 10 | Irrigated area under paddy to total irrigated area | 32 | 31.24 | 32.09 |

**Table 2**
**Area irrigated in Ha. (Crop-wise)**

| Sl. No. | Crops | 2010-11 | 2011-12 | 2012-13 |
|---|---|---|---|---|
| 1 | Paddy | 150491 | 153236 | 146938 |
| 2 | Tubers | 21328 | 15162 | 619 |
| 3 | Vegetables | 15581 | 17481 | 21019 |
| 4 | Coconut | 161503 | 181774 | 164491 |
| 5 | Areca nut | 36434 | 39094 | 36040 |
| 6 | Nutmeg / clove | 14049 | 15249 | 15733 |
| 7 | Other Spices and condiments | 8813 | 5234 | 496 |
| 8 | Banana | 41796 | 44190 | 44336 |
| 9 | Betel leaves | 450 | 330 | 325 |
| 10 | Sugarcane | 571 | 418 | 1697 |
| 11 | Others | 15022 | 18417 | 26202 |
| **Total** | | **466038** | **490585** | **457896** |

## ENERGY SECURITY

Electricity consumption in the agricultural sector constitutes only 2% of the total electricity consumed in the State. Annual electricity sale to the agricultural sector constituted 0.24 BU in 2007-08. One of the major areas of energy consumption in the agriculture sector is water pumping. The population of agricultural pumpsets is around 4.3 lakhs accounting for an annual consumption of 0.24 BU. Another area of major energy use in agriculture is fertilizers. Tractors and tillers numbering around 15000 used in agriculture in the State also consume energy. With agricultural mechanization spreading wide in the State, energy use for agriculture is also going to increase. The Energy Report – Kerala (WWF-India and WISE, 2013), based on the recent study, projected that while the existing pattern of growth would lead to overdependence on fossil fuels, aggressive interventions in energy efficiency, energy conservation and carrier substitution can curtail demand significantly. More importantly, the curtailed demand scenario has the potential to drastically reduce the State's dependence of fossil fuels to achieve a near 100% renewable energy supply by 2050, the Report concludes.

## FOOD SECURITY

The Food and Agriculture Organization (FAO) of the United Nations defines food security as the "Physical, Social and Economic access for all people to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2002).

For ensuring food security, water security and energy security are indispensable. Food and agriculture are by far the largest consumers of water. They require 1000 times more than we use to drink and 100 times more than we use to meet basic personal needs with upto 70% of water we take from rivers and groundwater going into irrigation. Food security issues will cause concern due to population growth and migration from rural to urban environment. A growing population will need more food, and thus more water and energy. We have to face the challenge of feeding the hungry by being more efficient and productive in our use of water and energy, while still respecting the resource base and demand from competing sectors. The International Covenant on Economic, Social and Cultural Rights (2002) asserts: "In case of competing uses, priority in allocation must be given to the right to water for personal and domestic use as well as to the prevention of starvation and disease".

The bulk of global food production (Cereals, oils, livestock and fish) is dependent upon a whole range of agricultural systems in which water is a critical factor of production (World Bank, 2001). A large proportion of cereals are not produced for direct human consumption (50% for food, 44% for animal feed and rest to other uses).

Irrigated land with inadequate or non-existing drainage infrastructure is being gradually lost to salinization that results in lowering yields. 80% increase in yield is expected from intensification and 20% from area expansion world over. Intensive forms of livestock production have led to a strong demand for cereals used as animal feed and production is rising steadily to meet this demand.

The future increase of fish supply will have to come from aquaculture which has been growing at 10% per year. Major factors affecting both the sustainability of capture fisheries and the expansion of aquaculture will be improved management in the sector and a better understanding of aquatic ecosystems as well as prevention and better management of environmental impacts affecting fishery resources and aquatic biodiversity.

A comparison of water requirements for the production of various food items reveals the interdependence between water and food security (Table 3).

**Table 3**
**Water requirement equivalent of main food products**

| Product | Unit | Equivalent water in $m^3$ per unit |
|---|---|---|
| Cattle | head | 4000 |
| Sheep and Goats | head | 500 |
| Fresh beef | kg | 15 |
| Fresh lamb | kg | 10 |
| Fresh poultry | kg | 6 |
| Cereals | kg | 1.5 |
| Citrus fruits | kg | 1 |
| Palm oil | kg | 2 |
| Pulses, roots and tubers | kg | 1 |

## WATER USE EFFICIENCY

The amount of water involved in food production is significant and most of it is provided directly by rainfall. Most water used by agriculture stems from rainfall stored in the soil profile and only about 15% water for crops is provided through irrigation. Only about 40% of water withdrawn from rivers, lakes and aquifers for agriculture effectively contributes to crop production, the remainder being lost to evaporation, deep infiltration or the growth of weeds.

## FOOD SECURITY IN KERALA

Kerala Agriculture has been undergoing structural changes over the years. The State has seen steady decline in the area under cultivation of food crops namely paddy, pulses and tapioca from the mid 1970's. Out of a gross cropped area of 20.71 lakh hectares (about 53% of the total geographic area of the State), food crops comprising rice, pulses and tapioca occupy only 11.74% of the cropped area. Rice, the staple food crop of Kerala, is almost disappearing from the State. From nearly 9 lakh hectares in 1970's the rice area has declined to 1.97 lakh hectares in 2012-13 (SPB Kerala, 2013). The rice ecosystem has been proved to be a reservoir of rainwater allowing copious groundwater recharge in the subsequent seasons. With rice fields vanishing from the State, not only is the State at the risk of food insecurity but of water insecurity too.

The traditional food crops like tapioca and other tubers which contributed to the food and nutrition basket of the poor rural households are also disappearing leaving the Kerala State more vulnerable in the matter of food and nutritional security.

Over the years, Kerala has become more of a consumer state than being a producer state. Huge quantities of food materials including rice, meat, egg, milk, vegetables and fruits are now imported from the neighbouring states. The integrated farming system which is predominant in the State provides immense scope for the integrated use of energy and water to build up a synergy among the various crop-animal-fish combinations in the homesteads of Kerala.

**WAY FORWARD**

Conservation of water and energy play a crucial role in food security of the State. In order to ensure water security, conservation plan has to be prepared at the level of micro-watersheds and integrated on the basis of sub watersheds and finally at river basin level. Based on this, intervention plans have to be prepared and implemented with the help of Local Self Governments. Rice lands have to be redeemed to enable the State to be more water and food safe. Rainwater harvesting, soil and water conservation, conservation agriculture such as minimal tillage, zero tillage, organic agriculture, etc. can help in increasing water use efficiency. Robust, drought resistant varieties, genetic engineering, precision agriculture, integrated pest management,integrated nutrient management, System of Rice Intensification, micro-irrigation and fertigation techniques can also be employed to increase productivity of food crops. Water users' associations and group farming approaches can also boost rational water use for food production. Latest technologies such as laser levelling, rain guns, etc. also help in realizing the ideal of '*more crop per drop*'. Initiation of water budgeting, popularization of micro-irrigation technologies, water harvesting measures, selective farm mechanization, use of solar, wind and hybrid technologies based high volume output pumps, etc. are some measures to promote water, energy and food safety in the State sustainably. The model projects of the Kerala State Irrigation Infrastructure Development Corporation being implemented now in Pulpally and Mullankolly Panchayaths of Wayanad district of the State and in the Urban Agricultural Project in Trivandrum City are welcome interventions in this regard. The emerging interest seen in the Kerala society to promote homestead based and hygienic production of vegetables, tubers, fruits, milk, meat, eggs and fish is a sure sign of progress in the food security front. Policy support to such efforts will help the Kerala State to attain water, energy and food security with the active participation of all the concerned stakeholder groups. Some of the policy prescriptions in this context are the following:

1. Preservation and sustainable use of water should be the motto of all crop production programmes of the state.
2. Water budgeting should be adopted in a watershed basis.
3. Rain water harvesting and aquifer recharge should be given priority for ensuring the stability and supply of water.

4. Farm ponds and Thalakkualams need to be promoted and protected.
5. Sub surface dykes are to be constructed at possible places for the ground water recharge
6. The irrigation canals of Kerala are to be structurally reset for the prevention of seepage loss of water.
7. The activities of the Committee on the release of irrigation water should be in deeds than in words.
8. All interstate water sharing agreements have to be reviewed to promote thrust areas of irrigation development.
9. Irrigated agriculture being the largest water demanding sector, special attention has to be given for creating and sustaining irrigation infrastructure.
10. Energy-efficient small farm machinery must be promoted prudently.

## CONCLUSION

In order to ensure food security, green revolution in the 21$^{st}$ century would need to be more complex than the 20$^{th}$ century one, shifting from an 'Input Intensive' model that is using more water, fertilizer, pesticide and energy, to one that is 'knowledge intensive'. Ecologically integrated approaches such as integrated pest management, integrated nutrient management, minimum tillage, organic agriculture, precision farming, micro-irrigation, etc. have to be promoted. Thiswill require change on many fronts including a significant investment in research and extension that is assisting farmers to put changes in place. Knowledge will be the key, worldwide, to ensure water, energy and food security sustainably.

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# Water and Energy Security in Industrial Sector

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## INTRODUCTION

Water and energy security is vital for the sustainability of industries as both are indispensable for the manufacturing process and the availability at the affordable price determines the global competitiveness . It is predicted that rainfall variability alone could push over12 million people into absolute poverty, while some predictions indicate that climate change could increase global malnutrition by up to 25% by 2080 (UN Water, 2013). Water withdrawals are predicted to increase by 50 percent by 2025 in developing countries, and 18 percent in developed countries.

It is estimated that 97.2% of water on our planet occurs in sea and nearly 2% occurs in ice bodies. The remaining 0.8 % occurs as ground water and surface water. Out of these 0.8 %, one third is in the form of surface water and two third in the form of ground water. Precisely 99.2% of water available on the earth is unsuitable for direct use because it is either saline or occurs as solid ice in inaccessible places. So only the remaining 0.8% of water is available for direct exploitation. This limited source becomes more precious when the demand is growing at an alarming rate. As per Report of the Working group on Water Database Development and Management for 12$^{th}$ Five Year Plan , average water resource potential in India is 1869.4 Billion Cubic Meters ( BCM) out of which usable Surface water is 690 BCM and Ground water is 431.3 BCM totalling to 1121 .3 BCM, which is about 4 per cent of global water supply**.** Water usage has been predicted to undergo significant change, by 89% in agriculture, 6% in industry and 5% in domestic use in 2000 to 81%, 11, & 8% respectively in 2025 and 71%, 18% & 11% respectively in 2050. Water security is defined as “The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability.”

Energy is a critical input into all economic activities and rapid inclusive growth is only possible, if reliable energy is made available everywhere at affordable prices. It is essential not only for domestic, agriculture, industry and commercial and business but also for household lighting and for providing basic needs and for achieving sustainable development. The IEA defines energy security as “the uninterrupted availability of energy sources at an affordable price” . Energy security is one of the major issues faced by nations all over the world and can be defined in terms of the physical availability of energy to satisfy demand at a given price. The security problem, therefore, involves a supply risk and a price risk, governed by internal and external consequences.

Total installed capacity of power in India as on 30-6-2014 is 249488.32 MW of which thermal contribute 69.05%, nuclear 1.93%, hydro 16.32%, and renewable 12.70% (Fig. 1). Renewable energy sources comprises of small hydro power (3803.68 MW), wind power(21136.40 MW), co generation (4013.55 MW ), waste to energy (106.58 MW) and solar power (2631.93 MW).

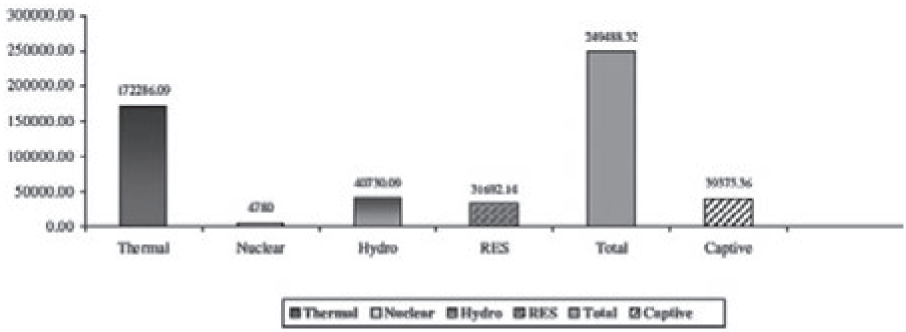



**Fig. 1**
**Total Installed capacity of Power in India**
(Source : Central Electricity Authority data)

Average Peak load power deficit is 3.7 % and varies up to 24.6 % between States. Transmission and distribution loss comes to 23.65 per cent and there is scope for further reduction. In order to attain required power to match with the present phase of development, 12th Plan Target to achieve 88,537 MW, while achievement so far is only 41,698.91 MW. India is the fourth-largest consumer of crude oil and petroleum products in the world after China, the United States, and Russia and about 78 percentage of oil is imported. Concerns on energy insecurity are mounting up due to fast depletion of oil and other fossil fuels, overdependence on foreign sources of energy and unstable political environment including terrorism prevailing in oil supplying countries.

## WATER SECURITY

With its continuously declining per capita water availability, India stands “water stressed” and is close to being categorized “water scarce” (A situation of per capita water availability falling below 1,700 m3, indicated as water stressed and per capita water availability falling below 1,000 m3 is termed water scarce). The water scenario is now fast-changing as a result of increasing population, rising demand for irrigation to raise high-yielding varieties of crops, rapid urbanization and industrialization, electricity generation, impact of global warming and erratic rainfall. Water demand in India is expected to grow annually by 2.8 per cent to reach 1,500 BCM by 2030. Asian Development Bank in its draft report on "Water Operational Framework 2011-2020", explicitly cautioned that by 2030, water shortages are likely to aggregate 40% in developing Asia and that in India demand will exceed supply by 50%.

Government of India, in its National Water Mission (NWM) under the National Action Plan on Climate Change (NAPCC), has emphasized the need to develop a framework for optimizing water use efficiency by 20 per cent, through regulatory mechanisms with differential entitlements and pricing. It further emphasizes the need to focus on integrated water resource management through water conservation, wastewater minimization, etc. This would require various sectors, including industries, to optimize their practices ensuring conservation, recycling, and reuse. Agriculture is the largest consumer of water in India, and in 2010, it accounted for about 85 per cent of the total demand, followed by industry at 9 per cent, and the domestic sector at 6 per cent. Water requirements of various sectors of Indian industries had almost doubled during the last decade and are expected to increase more than threefold by 2050. As per Central Pollution Control Board (CPCB), the water consumption in Indian industry is about eight per cent of the total fresh water use in the country and total industrial wastewater discharge about 83,048 MLD. Hence, civic bodies are encouraging industry to treat sewage and use it for their processes, rather than draw from the scarce water resources. As per World Bank, the water demand for industrial use and energy production will grow to 228 BCM in 2025.

**Industrial water use**

The industrial segment uses water for its heating and cooling processes after which 80 per cent of it is discharged as waste water and effluent. Thermal power, petroleum & refinery, textiles, pulp and paper and iron and steel are highly water-intensive sectors where water is primarily used in heat transfer. In power plants, refineries, chemical industries and steel plants, chemical industries and steel plants, water is the most cost-effective medium to produce steam in boilers to produce electricity. In air-conditioning and cooling tower units, there is no better means to lower the temperature. The ISO-14001, the prevailing industry standard followed by most responsible and large industrial players makes it mandatory to install zero liquid discharge plants. In distilleries where water is an integral part of the process, through zero discharge treated effluent is used for bio-composting using agricultural residues and even municipal solid wastes. Waste water from Refinery Sector is reused as make-up water for fire fighting, green belt development and other non-potable purposes.

The industrial water use in India as on 2011 estimated by Centre for Science and environment based on the waste water discharged data published by CPCB in "Water quality in India (Status and trends) 1990-2001 is given in Table 1.

**Table 1**
**Industrial water use in India**

| Sector | Proportion of Water consumption In the industry (%) |
|---|---|
| Thermal power plant | 87.87 |
| Engineering | 5.05 |
| Paper and Pulp | 2.26 |
| Textiles | 2.07 |
| Steel | 1.29 |
| Sugar | 0.49 |
| Fertilizer | 0.18 |
| Others | 0.78 |
| Total | 100.00 |

Source: http://www.cseindia.org/userfiles/industrial_water_challenges.pdf

Water consumption depends on the type of industry. Whereas thermal power, textiles, pulp and paper and iron and steel are highly water intensive sectors, industrial sectors like chlor-alkali, cement, copper and zinc and plastics require little water. Data on actual water consumption in India is absent. However, the data on wastewater discharge by various industrial sectors in the country is available. The data on wastewater discharge has been compiled by CPCB. According to CPCB, the total wastewater discharged by all major industrial sources is 83,048 million litres per day (MLD). This includes 66,700 MLD of cooling water discharged by thermal power plants (TPPs). Out of the remaining 16,348 MLD of waste water, TPPs generates another 7,275 MLD as boiler blow down water and overflow from ash pond.

According to CPCB the annual water consumption in Indian industry is 40 billion cubic meters and the annual wastewater discharge is about 30.7 billion cubic metre. Therefore, the overall ratio of wastewater discharged to freshwater consumption in Indian industry works out to be about 0.77. That is, for every cubic meter of water consumed by Indian industry, 0.77 cubic meters of wastewater is discharged. Considering this, CSE has estimated the possible water consumption in various industrial sectors in India. Water is required, often in large volumes, by industries as process inputs in most industries. In other cases, like food and beverage and chlor-alkali industry, water is used as a raw material: turned into a manufactured product and exported out of the local water system.

However, in most industries it is essentially used as input and mass and heat transfer media. In these industries a very small fraction of water is actually consumed and lost. Most of the water is actually meant for non-consumptive process uses and is ultimately discharged as effluent. Industry requires water of good quality for its use, and for this it uses cleaner upstream water. However, the water it discharges is always of lower quality than the feed water and this wastewater is discharged downstream. At best the wastewater discharged represents a quality that can be recycled for lower grade of industrial use.

**Case study by Federation of Indian Chambers of Commerce and Industry (FICCI) on Water use in Indian Industry in 2011**

FICCI Water Mission undertook a survey with its member companies to gauge the Important Indian companies attach to water, its conservation and management. Responses were obtained from companies belonging to the sectors - Agriculture, Automobile, Cements, Chemicals, Engineering and Construction, Food Processing, FMCG, Health Care, Hospitality, Infrastructure, IT Services, Manufacturing, Mining, Power, Pharmaceuticals, Real Estate, Petroleum and Natural Gas, Steel and Textiles. Surface water is the major source of water for the industries (41%) followed by groundwater (35%) and municipal water (24%).

The major findings of the study are:

- Water availability and use

  77% of the industries mention of the easy availability of water for running their operations. Out of this 17% of the respondents have to pay a high price for getting water. In case of the remaining 23% industries who state that water is not easily available, 64% have to pay a high price for getting water

- Risks associated with water

  60% of the respondents agree that availability of water is affecting adversely their business today - the figure rises to 87% after 10 years. This is a major concern for industries belonging to the sectors like thermal power plants, chemicals, textiles, cement and manufacturing. While inadequate availability is the major risk facing the industries (37%), others agree that poor water quality is another major risk in the running of business (14%). Sectors like pharmaceuticals, power, food processing and agriculture feel the impact of poor water quality. High costs for obtaining water are hindering the business interest of smaller industries and the ones which are located in the drought regions of the country. Almost all the industries surveyed indicate inadequate that availability of water having the maximum potential to impact business.

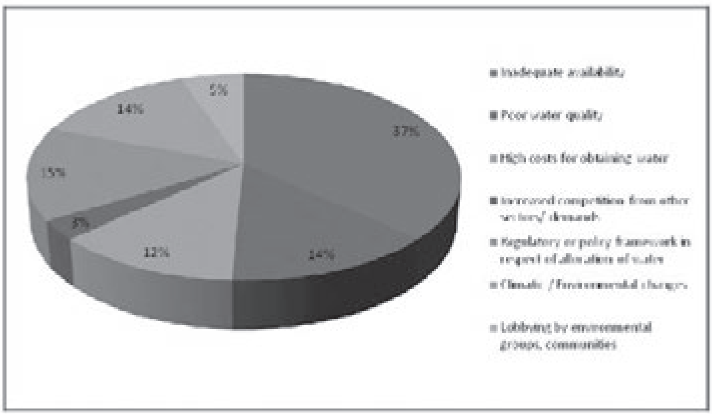



**Fig. 2**

**Risk associated with water** [Source: FICCI (2011)]

**Water treatment and reuse**

Nearly 80% of the industries surveyed have reported to have undertaken waste water treatment and reuse in their companies . A large percentage of industries (24%) use treated wastewater for industrial process like ash handling (in case of thermal power plants); washing of ore. Treated waste water is also used for flushing toilets, cleaning, fire-fighting and dust suppression activities.

**Recommendations**

Industrial survey reiterates the need for efficient use of water resources and the following recommendations needs consideration and adoption.

- Water audit to be made mandatory. Industries to undertake periodical water audits to understand the complete water use pattern in their operations and look for water saving measures
- Implement water harvesting to the extent possible
- Adopt water conservation
- Exchange best practices and results of current research in industrial waste water recycle/reuse process water in to clean water at affordable costs
- Invest in research and development for developing innovative technologies for cost effective effluent treatment
- Establish benchmarks for water consumption in various types of industries
- Devise tax credit equal to a percentage of fixed capital expenditure on projects or activities that promote water conservation / reduce consumption of potable water as done in Singapore
- Instead of uniform volumetric water tariffs , introduce tiered water tariffs ,also known as Increasing Block Tariffs (IBTs).Under IBTs , a base line water use can be set for small , medium and large commercial users and tired rates only increase as a user moves above its baseline as is prevalent in United States

**ENERGY SECURITY**

In the context of the energy security, it is vital that one has to (i) use energy wisely and efficiently, not waste it; (ii) learn to be more conscious of the appropriateness of each energy use; (iii) continue to expand R and D efforts to overcome the technological problems facing the energy industry and open up new energy resources; (iv) regulate, streamline and consolidate the policies and procedures for energy activities; (v) think of an energy establishment at the national level to effectively and centrally co-ordinate the wide range of energy policies; and (vi) ensure the accelerated development of the domestic resources base. All these exercise and even more are essential to tackle the energy insecurity and energy problems in an orderly way, irrespective of whether aiming at near term development and priorities or at long range solution. Conservation means avoidance of waste; but more accurately, it means optimal use of available energy source to achieve high efficiency vis-à-vis low specific energy consumption. Essentially, there are three ways of conserving energy: by not doing things; by doing things, but reducing quantity of energy and by doing things as before but using less energy through improved efficiency. The first two options mostly related to housekeeping measures and not to production process and can be enforced quickly in case of emergency. The third option can be adopted with industrial processes which would require substantial capital expenditure and once it is implemented, does not require continued exhortation or austerity. It is therefore likely to be the most effective in the longer term.

Energy is a basic need for different purposes in industrial facilities around the world. Energy is consumed in the industry sector by diverse group of industries, including manufacturing, mining and construction and for wide range of activities such as processing and assembling, space conditioning and lighting. The industrial sector is extremely diverse and includes wide range of activities. This sector is particularly energy intensive, as it requires energy to extract natural resources, convert them into raw materials and manufacture finished products. Energy use in industry sector varies widely between countries and industries. Energy use in industry depends principally on level of technology used, the maturity of plants, the sectoral concentration, the capacity utilization and structure of sub sectors. Further, energy intensity is determined by the type of process used to produce the commodity, the vintage of the equipment used and the efficiency of production, including operating conditions. In industry, energy efficiency can be improved by different approaches as follows; energy saving by management; energy saving by technologies; and energy saving by polices and regulations. Of this energy management and its programme play significant role in industry.

Industry demands substantial amounts of energy in the forms of electricity, heat and mechanical services. Industry accounts for about one-third of the world's final energy demand; around 60.0 per cent of the industrial demand is from developing countries. Industry's total energy use continues to grow as a result of expanding production volumes, a trend that is likely to continue in the coming decades as living standards rise in developing countries. Industries are also facing constraints like restricted access to energy and curbs on $CO_2$ emissions. As such, improving industrial energy efficiency is a clear pre-requisite for long-term financial growth and sustainability. As per BP Energy Outlook 2030, industrial energy consumption grew by 9.90 per cent in the last decade and accounted for about 80.0 per cent of final energy demand growth. Industry accounts for 60.0 per cent of projected growth of final demand by 2030. Energy efficiency will continue to improve globally at 2.0 per cent per annum compared to 1.60 per cent for last 20 years. Organizations focusing on energy efficiency initiatives will have an edge towards global competency. The Kyoto Protocol objectives for the OECD countries and constraints on energy security for importing countries, have raised the mportance given to energy efficiency policies. In developing countries, energy efficiency can help to alleviate the financial burden of oil imports, reduce energy investment requirement and make the best use of existing supply capacities to improve the access to energy.

**Energy Intensity, $CO_2$ Emission T & D Losses and Per Capita Energy Consumption**

In an industrial context, energy intensity is measured as the ratio of energy consumption per unit of production. Japan has the lowest energy intensity. Main reason is the adoption of energy efficiency improvement in energy intensive industries viz., steel, chemical, cement and paper and increase in share of nuclear power combined with a reduction in the share of power production from coal has led to a rapid reduction in CO2 emission. In France, nuclear power is the principal energy source, with a stable share of over 40.0 per cent of total consumption. The Energy Intensity and $CO_2$ Emission in various Countries in 2011 is given in table 2.

**Table 2**
**Energy Intensity and $CO_2$ Emission in various Countries – 2011**

| Sl. No. | Country | Energy Intensity | $CO_2$ Emission (in gm $CO_2$/kWh) | Electricity T&D losses (%) | Per capita Electricity Consumption |
|---|---|---|---|---|---|
| 1 | Japan | 84 | 438 | 5 | 8399 |
| 2 | Germany | 86 | 433 | 5 | 7083 |
| 3 | UK | 87 | 435 | 8 | 5518 |
| 4 | France | 95 | 83 | 7 | 7318 |
| 5 | Italy | 96 | 375 | 6 | 5393 |
| 6 | USA | 137 | 508 | 6 | 13727 |
| 7 | Australia | 176 | 928 | 7 | 10514 |
| 8 | Canada | 187 | 181 | 8.3 | 16406 |
| 9 | India | 192 | 963 | 23 | 673 |
| 10 | China | 234 | 842 | 6.2 | 3312 |
| 11 | Russia | 268 | 341 | 11 | 6533 |

Source: Trends in global energy efficient report (Chirstopher Walts and Enerdata, 2011)

Oil meets 30.0 per cent of energy needs and its share are decreasing. $CO_2$ emission is substantially low. In India and China, energy intensity and $CO_2$ emission is on the higher side which shows there is considerable scope for energy efficiency improvement.

The percentage share of energy cost in the total cost and percentage energy conservation potential of some selected industries (Table 3). Share of energy cost is high in ferroalloys; it is about 36.5 per cent. Cement and Aluminium industries have share of 34.9 per cent and 34.2 per cent respectively. Sugar and refinery industries have the least share of 3.4 per cent and 1.0 per cent respectively. It is evident that percentage of energy saving potential of Indian industries is ranging from minimum 8.0 to 10.0 per cent and at maximum of 25.0 to 30.0 per cent. The conservation potential is high in sugar industry ranges from 25.0 to 30.0 per cent. Textile and pulp and paper industries have energy saving potential of 20.0 to 25.0 per cent. Industries like iron and steel, aluminium, refineries and ferroalloys have energy saving potential of 8.0 to 10.0 per cent. Based on the above, it is understood that Indian Industries are having a fruitful scope of energy conservation potential. Thus, the present thrust and need is to use appropriate technology and save the energy as much as possible. The energy use in industries can be reduced by adopting: energy audit; energy efficient factory and street lighting; waste heat utilisation from furnace and boilers; diesel generator (dg) sets; energy efficient air compressors, pumps motors; power factor improvement system; use of non-conventional energy sources; co-generation; process change, technical up-gradation; energy monitoring and accounting; training for energy auditors/ energy managers ; energy management policy; and replacement of conventional fan regulators and electronic chokes .

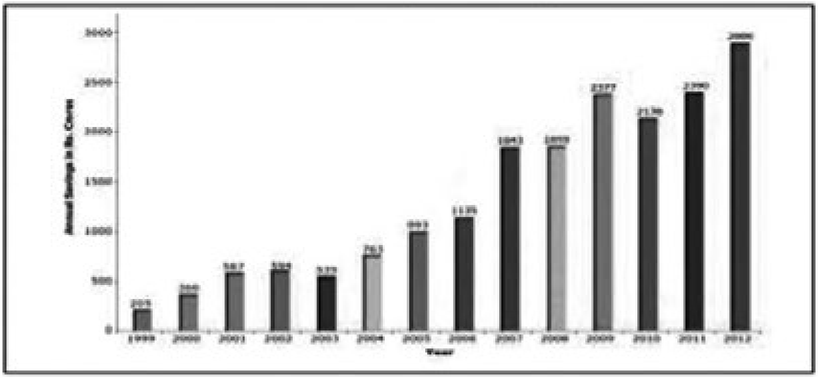
**Table 3**
**Energy saving potential of selected Indian Industries (%)**

| Name of Industry | Share of Energy Cost in Total Cost | Energy Conservation Potential |
|---|---|---|
| Iron and Steel | 15.8 | 8-10 |
| Pesticides | 18.3 | 10-15 |
| Textiles | 10.9 | 20-25 |
| Cements | 34.9 | 10-15 |
| Pulp and Paper | 22.8 | 20-25 |
| Aluminium | 34.2 | 8-10 |
| Ferrous Foundry | 10.5 | 15-20 |
| Petrochemical | 12.7 | 10-15 |
| Ceramics | 33.7 | 15-20 |
| Glass | 32.5 | 15-20 |
| Refineries | 1.0 | 8-10 |
| Ferro - Alloys | 36.5 | 8-10 |
| Sugar | 3.4 | 25-30 |

Source: National productivity council data

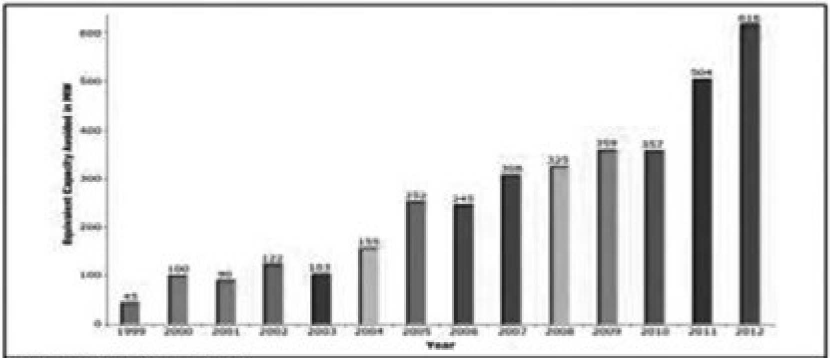
### Energy Conservation Award Scheme in India

MoP Energy Conservation Award Scheme started in 1999 with the participation of 123 numbers of industrial units in India. It has further increased to 773 in 2012. Energy Savings in monetary items increased from Rs. 205 crore in 1999 to Rs.2886 crore in 2012 (Figure 3). Avoided capacity due to energy conservation initiative in industry is 616 MW (Figure 4). One time investment made on energy conservation efforts by investing Rs.1948 cr, in the last 14 years, the participating industrial units saved Rs.18675 cr and the investments made on energy efficiency projects recovered back in 16 months. In energy terms, 22133 million kWh of electric power, 33.65 lakh kilo litre of oil, 149.53 lakh MT of coal and 228709 billion cubic metre of gas was saved through the adoption of energy conservation measures of participating units.



Source: GoI: MoP, 2013.

**Fig. 3**
**Annual Money Saving by Participating Units in the National Energy Conservation Award Scheme (1999-2012)**



Source: GoI: MoP, 2013.

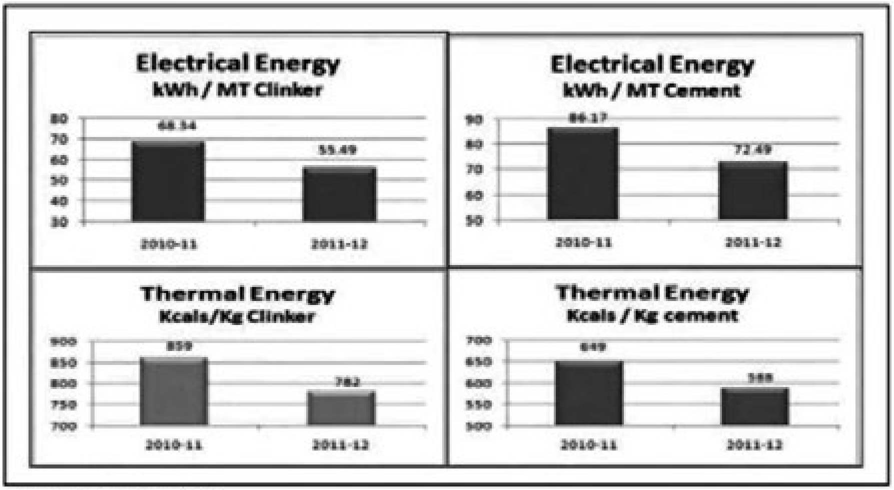
**Fig. 4**
**Electrical Energy Savings in Terms of Equivalent Avoided Capacity (MW)**

**Case study: Dalmia Cement (Bharat) Limited (DCBL):**
**First Prize Winner of National Energy Conservation Award, 2012**

India is the second largest cement market in the world, which produces about 6.0 per cent of the world's cement. Modern Indian cement plants are state of the art and comparable to the best in the world. About 97.9 per cent of the total production capacity is based on modern, energy-efficient and environment friendly dry process technology. Only 0.5 per cent of the capacity is based on the wet process and the remaining 1.6 per cent on others, like the semi-dry process, which are inefficient compared to the dry process technology. Implementing various energy efficient and new technology measures, like roller process, vertical roller mills, process control equipment and high-efficiency pollution control technologies, has helped the industry to reduce energy consumption and increase savings in materials. Apart from this, efforts are being made to use alternative fuels and industry wastes and recover waste heat from the process.

The cement industry is a highly energy-intensive industry, whose energy costs include 35.0 to 45.0 per cent of the total manufacturing costs. The Indian cement industry is very energy efficient compared to other cement manufacturing countries. The specific energy consumption and specific thermal consumption of the cement industry has been constantly decreasing over the past decades. Some of the Indian plants are operating with the world's best specific energy consumption values of 59–60 kWh/ton of cement and 665 kcal/kg clinker. These are comparable with best cement plants in Japan. Various energy audit studies have estimated that at least 5.0 to 10.0 per cent energy saving is possible in both thermal and electrical energy consumption in cement plants through the adoption of various energy conservation measures.

Dalmia Cement (Bharat) Limited (DCBL), Ariyalur unit is part of Dalmia Bharat Enterprises, a diversified group with a chronicle of 7 decades. This Greenfield project of DCBL was commissioned in February 2010. It is has a single kiln with a five stage pre-heater and inline calciner, with a capacity of 2.0 MTPA clinker and 3.0 MTPA cement. It manufactures ordinary Portland cement as well as Portland Pozzolana Cement. Power is drawn from the Captive power plant with grid backup and excess power is exported to grid. Grinding is done through vertical roller mills. The focus of the plant is safety, environment and energy conservation. Integrated Management System Certification obtained for ISO 9001, 14001 and OHSAS 18001 from DNV within a record period of 6 months. Energy consumption in DCBL is presented in the Fig. 5




Source: DCBL, 2012.

**Figure 5**
**Energy consumption in DCBL**

**Cross Functional Teams (CFT):** Factory is divided into zones and each CFT monitors all activities of the zone including safety, environment, energy conservation and productivity. Continuous improvement is the 'Theme' and achieved through benchmarking and visits to cluster units. Energy committee continuously measure, analyse, monitor data and improve energy saving in unit level, and group level for continuous improvement. Energy conservation achievements of the organization for the year 2011-12 are given below:

Reduction of thermal energy consumption - 69 kcals/kg of Clinker by

Optimization of cooler for maximum heat recuperation (TAD temp > 975 °C);

- Reducing the excess air in the pre-heater exit (exit O2 less than 3.0 per cent);
- Reducing the variation in the quality/chemical parameters in the limestone pile and in kiln feed using Cross Belt Analyzer (CBA) and XRF;
- Increasing the flame momentum in kiln; and
- Removal of coating in the kiln inlet duct by the installation of Air blasters and UT pump, leading to stable kiln operation.

Total Investment for energy conservation made by the DCBL is Rs.34 lakh and the resulted savings made was Rs. 639 lakh per annum. Reduction of diesel consumption from 1.16 to 0.74 ltr/ton of cement is achieved. In addition to the power saving, consumption of fly ash was maintained at 30.0 per cent and thus replacing 3.0 per cent clinker resulting in additional cost saving of Rs.300 lakh. Innovative in house modification in raw mill and cement mill, cooler optimization, installation of VFD for kiln cooling fan has also reduced power consumption.

**Energy Management in Kerala Centric Industries**

Kerala has abundant natural resources like cashew, rubber, coir, ayurvedic medicinal plants, fishery, china clay etc. They have a long tradition in their utilization, with various industries which are involved in processing of these resources into either value added produces or manufacturing of new products that are exported to different countries all over the world. Price competitiveness is a critical factor for sustained export and this is particularly true in the case Kerala Centric Industries (KCI).

The scope for fuel substitution in KCIs in Kerala is given in Table 4.

Quick scanning of Table 4 provides the following conclusion viz. In the cashew industry, biomass is used in all industries. Pollution is high since biomass heaters are not properly maintained. There is a lot of scope for solar drying in the production process in the cashew industry. However, energy audit is not done in cashew industry. Energy cost in the cashew industry can be further reduced; in the rubber industry, energy cost can be reduced, if energy audit can be done. In case of MRMPCS3, non-renewable fuel can be substituted by biomass; In case of coir industry, biomass heating can be used in three industries; In the ayurvedic industry, there is scope for changing fuel to biomass and solar energy; In the fishery industry, biomass and solar energy can be substituted; and in case of China clay industry, substantial energy cost can be reduced by changing fuel to biomass and solar energy.

**Table 4**
**Scope for Fuel Substitution in KCIs in Kerala**

| Sl. No. | Organization | Energy composition | | Energy Audit conducted | Biomass used | Scope of fuel substitution |
|---|---|---|---|---|---|---|
| | | Non-renewable (%) | Renewable Energy (%) | | | |
| **Rubber Industry (n = 6)** | | | | | | |
| 1 | MRMCS 1 | 15.8 | 84.2 | No | Yes | Biomass heater |
| 2 | EPL 2 | 28.5 | 71.5 | No | Yes | Biomass heater |
| 3 | MRMPCS 3 | 100 | NA | Yes | No | Biomass heater |
| 4 | KLL 4 | 36.1 | 63.9 | Yes | Yes | Biomass heater |
| 5 | PMCSL 5 | 29.9 | 70.1 | Yes | Yes | Biomass heater |
| 6 | KSCRMF 6 | 35 | 65 | Yes | Yes | Biomass heater |
| **Coir Industry (n = 6)** | | | | | | |
| 7 | William 1 | 100.00 | NA | No | No | Biomass heater |
| 8 | Palm fibre 2 | 8.1 | 91.9 | Yes | Yes | Biomass heater |
| 9 | DC Mills 3 | 100 | NA | No | No | Biomass heater |
| 10 | Hindustan 4 | 100 | NA | No | No | Biomass heater |
| 11 | Foam Mattings 5 | 22.17 | 77.83 | Yes | Yes | Biomass heater |
| 12 | Coirfed 6 | 5.84 | 94.16 | No | Yes | Biomass heater |
| **Ayurveda Industry (n = 4)** | | | | | | |
| 13 | SDP 1 | 6.4 | 93.6 | No | Yes | Solar drier |
| 14 | Oushadi 2 | 99.63 | 3.7 | No | Yes | Biomass heater |
| 15 | Kottakkal 3 | 100 | NA | Yes | No | Biomass heater |
| 16 | AV Pharmacy 4 | 9.1 | 90.9 | Yes | Yes | Solar drier |
| **China Clay Industry (n=4)** | | | | | | |
| 17 | Kecer 1 | 3.7 | 96.3 | No | Yes | Solar drier |
| 18 | KCCPL 2 | 14.8 | 85.2 | No | Yes | Solar drier |
| 19 | Ashapura 3 | 7.69 | 92.31 | No | Yes | Solar drier |
| 20 | EICL 4 | 100.00 | NA | Yes | No | Biomass heater, solar drier |

Source: Computed from the primary data drawn from the industrial visit.

## Energy Analysis

Energy analysis (Table 5) of some industries shows that;

- Energy intensity varies from 0.56 -20.68
- Energy cost/kg of production varies from Rs. 2.06-15.99
- Energy cost/ total cost of production varies from 1.10-42.00 %

**Table 5**
**Energy analysis**

| Sector | Energy Intensity kWh/kg | Energy cost/kg of production (Rs/kg) | Energy cost/total cost of production (%) |
|---|---|---|---|
| Rubber | 0.64-1.78 | 2.29-2.87 | 1.10-1.40 |
| Coir | 1.14-6.03 | 4.69-11.44 | 2.10-6.60 |
| Ayurveda | 3.53-20.68 | 6.78-15.99 | 3.80-15.80 |
| China Clay | 0.56-2.62 | 2.06-3.68 | 22.60-42.00 |

Source: survey data

***Rubber:*** Energy cost can be reduced by using energy efficient biomass gasifiers, waste heat recovery system to pre-heat biomass fuel, improving power factor and proper maintenance of machineries. It is recommended for maintaining good thermal insulation. In this industry major energy consuming area is drier. Since thermal insulation deteriorates over time, damaged insulation, causes heat loss for which install adequate insulation of economic thickness in the interior walls of drier; insulate weather proof exterior walls by cladding or other treatment that prevents water infiltration; and insulate major uninsulated equipments/process areas

***Coir:*** Biomass gasifiers can be used for heat energy generation for drying purpose instead of furnace oil/ diesel by which present fuel cost can be reduced substantially. Retrofitting for obsolete machinery could enhance energy efficiency. Further, study shows that energy conservation awareness creation among employees and housekeeping could help in saving large quantity of energy.

***Ayurveda:*** Replacement of fossil fuel based boilers with energy efficient biomass boiler, installation of flow meters and monitoring system, efficiency improvement in steam distribution system, for drying and lighting etc., could reduce energy intensity and energy cost and thereby reducing the overall cost of production.

***China clay:*** All the China clay Industries adopt costly process to purify the discoloured mined clay. Purified china clay is used as raw material in paper mills for paper coating purpose. Energy cost can be reduced by fuel substitution with biomass, using variable speed drive for heavy machineries, power factor improvement and adoption of renewable energy technologies.

**Recommendations**

- ***Industries should have an energy and water policy:***

  Industries to frame energy and water policy, which are to be communicated to all stakeholders and employees and evaluate its implementation during their board meetings.

- ***Industries should have provisions in the budget for energy and water conservation:***

  Industries should take special care for providing sufficient funds for energy and water conservation, while framing budget for its utilization and implementation.

- ***Documentation of energy and water consumption and utilization:***

  Proper documentation of different forms of energy and water used in terms of quantity, cost and its utilization are required. Continuous monitoring, evaluation and implementation of energy efficiency enhancement initiatives are essential for sustainability.

- ***Set targets for reducing energy consumption:***

  Industries should target in lowering energy and water consumption and $CO_2$ emission per unit of GDP by a specific per cent for a particular period.

- ***Conduct energy and water audit:***

  Energy share in overall production costs varies between 8.00 to 40.0 per cent in an industry, depending on the process involved. Similarly share of water consumption varies from 1.00 to 87.00 per cent depending upon the nature of process involved. Government can offer incentives to conduct preliminary energy and water audit.

- ***Utilise Renewable energy to the extent possible*:**

  Biomass energy can reduce fossil fuel cost up to 40.00 percent. Use solar energy for lighting and heating purpose

- ***Formulate financial and fiscal Incentives:***

  Government may aim at encouraging investment in energy efficient equipment and water saving processes by reducing the investment cost, either directly (financial incentives/ subsidies for energy audits/soft loans for investment) or indirectly (fiscal incentives ) to reduce the annual income tax paid by consumers when purchasing energy efficient /water saving equipment/ investing in energy efficiency. Low interest loans are to be made available for industries as a promotional initiative.

**CONCLUSION**

Water and energy security are vital for the sustainability of the industries and for global competitiveness. Higher cost of water and energy lead to higher cost of production, resulting in unviable operations. There is a need to limit industrial water pollution, manage wastewater and protect and improve the quality of water thus enabling needs to be met safely. Good water governance is essential for achieving water security. Policies are needed on water planning, allocation and pricing, aimed at increasing water security through increased water efficiency in industrial, agricultural and domestic water use.

Renewable energy production continued to grow at an estimated 26.4% of the world's power generating capacity by 2015 and will account for nearly half of the increase in global power generation to 2035, with variable sources – wind and solar photovoltaics – making up 45% of the expansion in renewables which ensures energy security. Energy demand is rising in the emerging economies, particularly in China, India and the Middle East, which drive global energy use to one-third higher than in the past. As the source of two-thirds of global greenhouse-gas emissions, the energy sector will be pivotal in determining whether or not climate change goals are achieved.

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# Water and Energy Security for Transportation

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## INTRODUCTION

Water and Energy are two important requirements in any kind of transportation operations. Water is required for different types of activities in transportation sector – for the use of vessels operations to other basic needs. The energy requirement for transportation sector is increasing day by day as in the case of other sectors. This is mainly due to rapid increase in travel needs of people to phenomenal growth of vehicle ownership, resulting in spurt of different forms of transportation in road, rail and water transport systems. At the same time, the availability of the water and energy resources is very much limited.

The different kinds of energy use have increased tremendously during the past decades. This has mainly affected the fossil fuel resources, as the growth of motorised vehicles have reached alarming proportions, and also transportation of huge volumes of passengers and freight traffic. In India, the public transport system is very basic compared to many other countries and this has resulted in larger share of personal vehicles in the cities and towns.

The above mentioned aspects have been affecting the Water and Energy Security of the country. Viable Options to reduce the use of these resources in transportation sector has to be thought of. There are several options like use of water transport, wherever it is available, for efficient and effective utilisation of energy, promote public transport system thereby reducing the share of individual vehicles to a greater extent.

In Kerala, there is vast scope for augmentation of inland water transport system for cargo movement and passenger transportation. This will also ensure better connectivity to port - hinterland regions. Promotion of water transport has many advantages, especially in the growth of traditional industries, fisheries development, employment generation, tourism and decongestion of roads. This will also give a fillip to the growth of other sectors of economy.

## WATERWAY NETWORK IN INDIA

Inland navigation is widely recognised as energy efficient, eco-friendly and cost effective mode of transport. India is bestowed with navigable waterways comprising of rivers, canals, lakes and backwaters. Nearly 14,500 km of waterways in the country is navigable for passenger and cargo movement. Annually, around 55 million tonnes of cargo is being moved by water transport in the country. The total cargo moved in tonnes-km by the waterways was just 0.1% of the total inland traffic in India, compared to 21% in United States. The cargo movement by inland navigation is confined to few waterways in the states like Goa, Maharashtra, West Bengal, Assam and Kerala.

The advantage of water transport lies in its capacity to move bulk cargo at cheaper cost. Development of waterways has enormous potentials in tourism and decongestion of roads. However, the potentials of this sector are largely under-utilised, because most of the waterways suffer from lack of maintenance of facilities resulting in siltation of channel and erosion of banks. Other issues that constrained its operation are bottleneck situation created by unscientific construction of bridges and other cross structures, encroachments, and lack of road and rail-head connectivity to water transport terminals. Hence, it is essential that the navigable waterways are developed on priority basis so that the waterways become operational, not only for movement of men and materials, but also to harness its potentials in other sectors of economy.

As a part of the Government of India policy to develop and harness the potential of waterways in the country, the following six waterways have been declared as National Waterways:

a) National Waterway No. 1 - The Ganga River system from Allahabad - Haldia (1620 km)

b) National Waterway No. 2 - The Brahmaputra River system (891 km) in Assam

c) National Waterway No. 3 - The West Coast Canal system (205 km) in Kerala

d) National Waterway No. 4 - Godavari - Krishna River from Kakinada – Pondy (1095 km)

e) National Waterway No. 5 - Brahmani - East Coast canal - Mahanadi River (623 km)

f) National Waterway No. 6 - Barak River between Lakhipur and Bhanga in (121 km).

Also, in order to provide an impetus to the development of inland water transport mode, an 'Inland Water Transport Policy' has been announced which provided several fiscal concessions for encouraging BOT projects in development of infrastructure and operation of inland vessels.

## WATERWAYS IN KERALA - POTENTIALS AND PROSPECTS

Transportation system of Kerala consists of road, rail, water and air transport. The state has 1.52 lakh km of roads, on which 85 lakh motor vehicles ply. Motor vehicle population has been growing @ 14% per year, resulting in heavy strain on the road system. Kerala is one of the few states in the country which has the higher road density compared to national average. Again, the state has the distinction of having 100% road connectivity to its villages by motorable, all weather road.

Kerala is favourably placed with 585 km long coastal line, 44 rivers, 30 backwaters and its estuaries, 960 km long canals and 1680 km long waterway network. The West Coast Canal used to be the primary navigation route till the recent past. However, hardly 20% of them are in usable condition now, leaving the remaining in relative disuse due to long neglect and competition from other speedier modes of transport.

Waterways which were earlier navigable are, now rendered unserviceable due to lack of attention and periodic maintenance. Canal bank erosion and siltation have reduced the draft which has contributed to gradual reduction in traffic. Maintenance dredging and side protection works have not been done in most sections for decades. Use of waterways thus, got restricted to those areas where other forms of transport could not serve the people. A stage has come to restore the navigability and effective utilisation of waterways in the state. Improving the quality of environment by reducing automobile emissions, benefits to fishing industry, tourism, irrigation, and better mechanism for flood control are some of the advantages to the society as a result of waterway development.

**West Coast Canal**

The West Coast Canal (WCC), the lifeline of Kerala, starts from Kovalam in Trivandrum and ends at Hosdurg in Kasargod with a total length of 637 km. The WCC from Kollam to Kottappuram (Thrissur district) along with Udyogamandal and Champakara canals in Cochin region was declared as National Waterway No.3. Efforts are underway to extend the National Waterway network up to Kovalam in the south and Kasargod in the north. Techno-economic feasibility study by NATPAC estimated that 24% of goods moved by road can be diverted to waterways, if the West Coast Canal becomes navigable.

**Feeder canals**

There are many feeder canals to the WCC which are operational now for passenger services and Houseboat operations. These can be effectively used for cargo movement, if fairway development and periodical maintenances are carried out. As such, passenger ferries and small crafts are operated in these canals. To make these canals navigable, sufficient width and draft are to be provided. Adequate bank protection is required to reduce tidal disturbance caused to people living adjacent to the canals. Out of 1000 km of canals in Kerala, improvements are suggested to the following canal routes (Table 1).

**Development of backwaters**

There are more than 30 backwaters and estuaries in Kerala. A number of settlements and market activities thrive along these regions. Some of the important backwaters are: a) Ashtamudi lake, b) Kayamkulam kayal, c) Vembanadu lake system, d) Kuttanadu - Pamba backwaters, e) Cochin backwaters, f) Chettuva kayal, g) Ponnani – Biyam kayal, h) Elathoor backwater, i) Valapatnam backwater, j) Neeleswaram backwater, k) Valiyaparamba - Cheruvathoor backwaters, l) Chandragiri backwaters

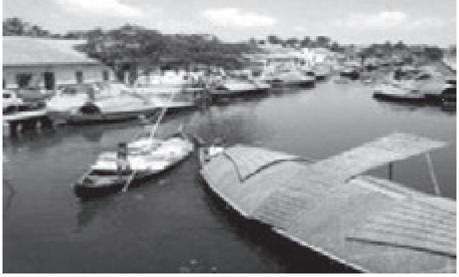
**Table 1**
**Navigable canal routes in Kerala State**

| Sl No. | Navigable route | Distance (in Km) |
|---|---|---|
| 1 | Ernakulam - Alappuzha | 73.6 |
| 2 | Alappuzha - Kollam | 78.4 |
| 3 | Alappuzha - Kottayam | 28.8 |
| 4 | Alappuzha - Changanassery | 32.0 |
| 5 | Kottayam - Amabalapuzha | 43.0 |
| 6 | Changanassery – Neelamperoor | 27.0 |
| 7 | Kollam - Kadampuzha | 23.4 |
| 8 | Alappuzha -Pulikeezhu | 38.4 |
| 9 | Alappuzha - Mannar | 40.0 |
| 10 | Muhama - Kumarakom | 9.6 |
| 11 | Vaikom - Athirampuzha | 31.2 |
| 12 | Vaikom - Pallipuram | 3.0 |
| 13 | Changanassery - Paipad | 42.0 |
| 14 | Changanassery - Neerettapuram | 9.0 |
| 15 | Changanassery - Pulikeezhu | 21.0 |
| | **Total** | **500.4** |

As waterways connect en-route settlements in backwater region, they provide stimuli to develop small scale and cottage industries in rural areas. It plays an important role in socio-economic uplift by providing employment opportunities, connectivity, promotion of tourism potentials and augmentation of water supply in the region. It is recommended that these kayals are to be developed in phased manner. A minimum draft of 2.0 meter is required to make it navigable for operation of barges and houseboats. Towards this, provision of navigational aids and channel markings are essential in wider canals and backwaters.

**Advantages of waterway development**

**A scene of cargo movement by traditional country boats in Alappuzha canals in 1970s**



Inland Water Transport (IWT) is energy efficient, most economical and environment friendly mode of transportation. Water transport, makes the least demand on energy resources. It is an established fact that it requires less power to move an equivalent tonnage on water. One Horse Power is known to move 150 kg of cargo on road, 500 kg on rail and 4000 kg on water. Hence the cost of transportation of cargo per tonne-km is the lowest in the case of water transport.

The West Coast Canal traverses through densely populated coastal region. Majority of the people living in the region are poor farmers, fishermen and marginal workers engaged in traditional activities like coir, cashew, brick making, sand mining etc. Any attempt to revive the waterways will have positive impact on the economic well-being of these people. The economic activities that would come up around boat jetties / landing places would provide the much needed employment to the people of the locality.

**Waterway development: Potentials and Priorities**

With increase in fuel prices, improvement of overall performance of a vessel is necessary for conserving the scarce petroleum resources. Wind and solar energy could effectively be used in water transport. R&D efforts should be focussed towards design of vessel that could be propelled by both engine power and solar energy. Similarly, solar panels could be constructed over the non-navigable sections of canals to tap the solar energy and also to minimize the evaporation loss of waterways.

An optimal mix of road, rail and water transport will provide an efficient transport infrastructure in the State. While the thrust so far has been in developing the road and rail sectors, there is an urgent need to actively promote the inland navigation system so that it takes a reasonable share in the inter-modal distribution of traffic.

According to estimates, the share of water transport in the state is hardly 2% of cargo traffic and less than 1% of passenger traffic. With revival of waterways and inter-modal distribution of traffic, this could easily be increased to 5% of total freight traffic by 2020 and 15% by 2030. Similarly, a reasonable share of 6 to 10% of the passenger traffic by IWT mode could be achieved in the next 10 years. Hence, a major thrust needs to be given to this sustainable and energy efficient mode of transport.

**ENERGY REQUIREMENTS IN TRANSPORT SECTOR – NATIONAL PERSPECTIVE**

Transportation sector is the major consumer of energy, especially the petroleum fuels. In India, almost 95% of petrol and 80% of diesel are consumed in this sector. The vehicle population has grown from 50 million in 2003 to 130 million in 2013. Given the limited nature of petroleum reserves, the importance of alternative fuels has already been felt in all sectors of economy. While demand for mobility continues to grow rapidly, fewer and fewer sources of fossil oil deposits are being explored. The mobility of people and freight movement must not be allowed to depend exclusively on petroleum oils.

Reducing dependency on fossil fuels is a long-term strategy. While forecasts of alternative fuel use are risky, there are sufficiently encouraging signs to suggest that a significant reduction in petrol and diesel through fuel shift can be achieved in the coming years. Considering the increasing trend of motorization, transport sector is the one which has high potential for energy savings through fuel substitution, energy efficiency and greater use of renewable sources of energy. The energy requirement in transport sector is expected to be met through renewable energy sources. To realize this as an option, renewable energy technologies would have to become commercially viable.

## Transportation energy requirements – Kerala perspectives

Kerala is one of the few states in the country where all major modes of transportation (road, rail, water and air transport) are in operation. Over 85 lakh motor vehicles are on the road in Kerala. There is a concern that the growth of motor vehicles in the state has reached 14% per annum. The vehicle population is gets doubled in every 6½ years.

Road is the most preferred mode of transport for freight movement in Kerala which carried almost 88% of the total freight traffic, followed by railways (10%) and water transport (2%) of total cargo movement. The Planning Commission study, the share of freight traffic by major modes of transport in Kerala is presented in Table 2.

**Table 2**
**Freight traffic by modes in Kerala (2007-08)**

| Mode of transport | Freight traffic (tonne) | Percent |
|---|---|---|
| Road | 103,336 | 88 |
| Rail | 11,109 | 10 |
| Water | 2,598 | 2 |
| Air traffic | 8 | -- |
| Total | 117,052 | 100 |

## Petroleum fuel consumption in Kerala

Transportation sector accounts for over 75% of the petroleum fuels requirements of the state. Daily consumption of petroleum oils in Kerala is estimated as given below:

a) Diesel - 13,47,000 tonnes

b) Petrol - 4,30,000 tonnes.

c) LPG - 4,12,000 tonnes

A major share of petroleum fuel is consumed in road and rail transport sector. In the case of LPG, domestic consumption has far exceeded the transportation sector. There are few thousand vehicles powered by LPG in the state. The pattern of the energy consumption in the state is substantially different from that of other states. Over dependence on road based transport coupled with a well-connected rail and waterway network led to *'lower than average energy footprint'* in the state. This also means *'lower than average'* energy share of transport in the total energy mix.

## ENERGY SECURITY IN TRANSPORTATION SECTOR

Fuel crisis of the past and the present turmoil in oil exporting countries in the Gulf, have raised serious doubts regarding the continued availability and dependency on petroleum fuels. To foster energy security and sustainability, use of renewable and cleaner fuels is necessary. Renewable Energy (RE) sources like bio-diesel, sugarcane derived ethanol, propane, hydrogen, electricity, fuel cells and solar energy can be commercially exploited for vehicle propulsion.

An year after the Law enforcing CNG as the future fuel for the National Capital Region, massive demand-supply deficit had forced the authorities to re-look at the logic behind dependence on single fuel source for urban transport for a city like Delhi. This has emphasized the need to explore and experiment the efficacy of alternative fuels like ultra low sulphur diesel, LPG, ethanol / methanol etc. and address the whole issue of energy security so that the dependence on petroleum fuel is minimized. The alternative fuels should be such that it is sustainable in terms of environment friendliness, affordable, renewable source and continued availability in large scale.

### Cleaner and green fuel

Research in renewable energy sources indicate that cleaner fuels like bio-diesel, natural gas and sugarcane derived ethanol could well, be used as transportation fuel. The Department of Non-conventional Energy Sources (DNES) of Govt. of India tried out methanol and ethanol, both renewable resources, as substitutes for diesel in public transport buses in Delhi. The DNES project had two objectives: i) to minimize the level of air pollution in cities, and ii) gradually to reduce the over-dependence on diesel. Based on the field trials, it is possible to substitute 15 - 20% of diesel with methanol or ethanol through dual fuel mode which also results in about one-third reduction in smoke emission. The transport authorities in other states have been advised to try out the dual fuel. One of the advantages is that it eliminates the smoke emission completely which means a major reprieve for the environment of our cities.

### Future energy sources for transportation

It is likely that newer technologies based on electricity, fuel cell, propane, hydrogen or solar power may take over the vehicle propulsion. It is expected that the present I.C engine technology will continue to dominate the road transport for next 5-10 years, beyond that, fuel-cell technology could well be a viable option and hydrogen, as a long-term possibility.

The advantage of hydrogen over conventional fuel is that it is abundant in water and solar energy. Hydrogen as a fuel does not produce carbon residue. It is eco-friendly with zero emission. Cost competitive technology for producing hydrogen from water through electrolysis process is being developed. However, a number of barriers remain to be overcome before hydrogen can be considered for widespread application.

## POTENTIAL OPTIONS FOR ENERGY SECURITY

In view of the environmental pollution due to exhaust emissions in road transport, use of cleaner fuels such as CNG and auto-gas are to be encouraged. The immediate option before us is to popularize CNG as transport fuel all over the country, because it emits just 10-15% carbon monoxide (CO) compared to 50-60% from petrol vehicles. The Ministry of Road Transport and Ministry of Petroleum have already permitted the use of auto-gas / CNG as fuel for transport vehicles with the release of amendments to Motor Vehicles Act and LPG Control Order.

## Technology driven energy security in transport sector

### *Electric and battery powered vehicles*

Use of electricity in vehicles can come either from energy stored in a battery or from the conversion of chemical energy in a fuel-cell to electricity. While electric motors are highly efficient in converting energy into motive power, storage remains a problem. It is clear that advanced batteries having high energy densities and reasonable cost are available to power the electric-vehicles. Automobile manufacturers are convinced that future holds good for fuel-cell technology. Use of fuel cells has many advantages over the other alternatives especially in terms of energy security and pollution aspects.

Battery vehicles have come into focus because of their oil-free and pollution-free operation. This vehicle with a range of 60 to 80 km per charge could be used for city trips. As such, battery vehicles are used at airports, railway stations, theme parks etc. The batteries can be recharged at night. Incentives like cheaper power tariffs during off-peak hours and night-time could encourage the use of such vehicles.

### *Gas powered vehicles*

Gas powered vehicle has already hit the market. There are thousands of vehicles running on CNG in different cities of the country. CNG vehicles are popular in Delhi, Mumbai, Vadodara and Tripura. CNG buses have undergone extensive field trials. More popular in this regard are the cars which are running on LPG or auto-gas.

Besides cheaper running costs, there is yet another advantage that a CNG vehicle is "environment friendly". Exhaust emissions from petrol vehicles contain 60% CO which is highly harmful pollutant to human and animals. In contrast, emissions from gas powered vehicles are safe for the environment, because it contains just 10-15% CO.

### *Solar powered vehicles*

Solar energy has not been extensively used in transport sector except for supplying energy to fixed appliances on the road. Solar panels fixed on vehicle rooftop can be used for propulsion of vehicles. The problem with solar powered vehicle is that initial cost is very expensive and inconvenient during operation. However, there is no recurring cost involved for operation. As such, the operating cost of this mode is not available for comparison with other alternative fuels.

## Encouraging non-motorized transport

Generally, about 30% of the trips are performed by walk in urban areas. Walking and cycling have negligible impact on the environment. Encouraging the use of non motorized transport (NMT) modes for short distance travel, not only conserves energy, but also has greater benefits in keeping health fitness of the travelers. The strategy to promote NMT is to provide adequate footpath and cycle track for their safe travel in cities. Integration of pedestrian and cyclist access with bus stops/railway stations will increase the patronage of public transport system. This would also reduce the share of personal vehicles on the road, thereby improving the traffic conditions in congested areas. Promoting NMT modes are among the potential strategies to reduce the number of personal vehicles thereby reducing the energy consumption in road transport sector.

**Promotion of public transport system**

An effective way to reduce traffic congestion in cities is to provide adequate and reliable public transport services. This will reduce the fuel consumption and pollution levels by shifting commuters from using private vehicles to public buses and trains. Potentials of water transport for passenger, tourist and cargo movement could be exploited, wherever it exists. Simultaneously, introduction of Mass transit systems like Metro-rail, Mono-rail, Bus Rapid Transit System, Hybrid buses powered by fuel cells and Commuter Rail System need to be initiated to cities to reduce the dependency on personal vehicles.

**SUMMARY**

**Waterway development**

The benefits of inland navigation can be harnessed only when coastal shipping is properly integrated with IWT system. Suggested actions for revival of waterways and bring life back on the waters of Kerala:

- Classification of waterways and canal system similar to classification of roads
- Increased plan allocation for periodical maintenance of water-bodies/ canal front
- Modernization of boat jetties, cargo terminals, facilities for river-front / canal walk to promote tourism and leisure time activities
- Setting up a permanent mechanism to ensure quality standard of the waterways, safety of vessels, regulations and control measures
- Empowered Committee approach being followed for Thiruvananthapuram City Development can be followed here for speedy actions on project implementation.

The government should act as a facilitator to attract private sector participation, especially in developing transhipment facilities, fleet management, operation and maintenance of the facilities. For development and maintenance of facilities along the waterways, the '*Vazhiyoram Concept*' being adopted by Kerala Tourism Department can be followed by providing adequate subsidy to private entrepreneurs.

**Energy security in transportation sector**

To combat global warming, the existing levels of $CO_2$ emissions should be drastically cut by at least 33% in the next 10 years. The strategies should include reducing the use of fossil oils, and increasing the share of renewable energy, fuel efficient vehicles and restriction on over-aged vehicles.

Technology develops fast. What may be the best technology today may become obsolete in another decade. Despite the advances made so far, ample scope remains for future development. The Government must take up technological improvements in areas such as vehicle design, alternative fuel and strict enforcement of emission norms so that the environment in which we live is kept clean, safe and aesthetically pleasing for succeeding generation to benefit from.

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"**If there is one part of India which is crying out for an integral approach to its infrastructure problems, it is the alluvial plain of the Kerala backwaters**"

*- Comment made by Dutch Mission which visited Kerala in 1987*

# Water and Energy Security and Healthcare Sector

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## INTRODUCTION

Water and energy are two essential commodities for the welfare of the society and the fairness in the distribution of these shall indicate the stage of civilization of the society. Unfortunately, in India, especially in its Hindi heartland, we see a skewed distribution of these essential commodities that adversely affect the neediest sections, the rural poor. The present pattern of sourcing these entities is not sustainable and rather hazardous to the environment and the health of the community in the long run. Thus India faces the dual challenge of expanding the coverage of water and energy to the needy masses, at the same time shifting the sourcing of these commodities into a more eco-friendly and sustainable mode. Jacobson and Delucchi in their landmark articles in *Health Policy* argues that we have enough where-with-all to change into renewable energy sources and the barriers to this is not technological nor economic but social and political (Jacobson and Delucchi, 2011; Delucchi and Jacobson, 2011).

Taking a positive note from the above mentioned articles, I plan to argue in this article that public health advocates in India should take cognizance of the present day realities and come out of their cosy comforts of the clinical world to rise up to the hardest challenges of the present day realities. Attributing infectious aetiologies to excess childhood mortality during winter months might help the vaccine manufacturers, not the public. Solutions to some of the public health enigma could be a simple logical fix that can be achieved with the help of people from other disciplines, rather than a costly, medical intervention. I shall try to argue this, taking the example, so excess death in winter in the later part of this article, using empirical data from two population cohorts, one from Athiyannur (part of the Athiyannur Sree Chitra Action (ASA) initiative) in Thiruvananthapuram and the other from Vadu (part of INDEPTH network) in Pune in this article. I hope that this would be one of a pioneer attempt to introduce the notions of new public health in India.

## TRADITIONAL APPROACH TO PUBLIC HEALTH IN INDIA

Public health in India is largely considered as an extension of the Community Medicine departments in Medical colleges; some of the well-functioning ones being highly medically oriented. Most of the faculty members are medical, and generally only the medical doctors can head the department, which makes the few non-medical members, who are generally statisticians, sociologists or entomologists, rather powerless. This public health is rather seen as taking clinical medicine to the community. The whole thinking pattern is highly medicalised, community interventions are an extension of medical therapeutic care! The best example would be the way we have planned our Revised Tuberculosis Control Programme (RNTCP). Under its highly acclaimed Directly Observed Treatment Short Course (DOTS) regimen, the potential patients are being screened, treatment started and maintained with the help of community workers. Basically, this is a task shifting from the *ideal highly qualified doctors* to less expensive auxiliary health workers, necessitated by economic constraints. In the *ideal situation (?),* they would have appointed sufficient doctors to treat all tuberculosis patients! What I am trying to point out here is that there is no earnest attempt to block the transmission of tuberculosis, by applying any non-medical ways in our national programme. Social engineering aspects like reduction of overcrowding, fighting off poverty, better dwelling, occupational improvements, promotion of respiratory hygiene, better nutrition, and better ventilation in schools, day care centres and working places, other improved architectural and town planning designs, etc. is totally discarded in the highly medical oriented public health approach. In the early twenty-first century itself, a more multi-disciplinary approach called *the new public health* has emerged in the West, but in India we continue to linger on our medical bias (Pati *et al.,* 2014).

It is in this context that I see the discourses on water and energy security as an entry point to the new public health approach. Water has been linked to public health from time immemorial, thanks to its direct linkages with waterborne diseases which are treatable medical conditions. Recognition of more issues like water washed diseases (e.g. Scabies), water related diseases (e.g. Vector borne diseases), etc. have prompted us to regard safe water supply initiatives as hardcore public health interventions. Still, the traditional public health advocates are happily stuck at the level of provision of safe drinking water, and unwilling to accept or rather uncomfortable to go beyond to address the issues of watershed management and water security in the larger community or social level. Its linkages with agriculture, industry, culture and other wider societal concerns are too complicated for the medical profession; naturally the medically oriented public health professionals are a bit timid towards extending the scope of discussions beyond a point. Even for the highly endemic water borne diseases like Hepatitis A, we are opting for vaccination, Rota virus vaccine (to prevent viral diarrhea in children) being the latest addition of the new government to the so called public health armamentarium.(BBC News 2014) These kinds of highly segmented, regimented approaches have restrained our ability to go beyond the restrictive realms of medical profession and seek out ingenious ways to tackle the issues, in its totality with the help of learning from other disciplines. (Committee on the Ocean’s Role in Human Health 1999) It is high time that the new public health advocates seek out help from other fields of science, and encourage a multi-disciplinary learning-cum-teaching approach to solve the issues. The recent introduction of the public health technologies module at Achutha Menon Centre for the Master of Public Health course is a direction in that line.

## THE ISSUE OF WATER SCARCITY

Water scarcity is a major environmental and health hazard in many parts of India, and this is going to become more acute and widespread in the near future. In addition to the household necessities, our agrarian communities need water for agriculture, animal husbandry, village industry and for their everyday activity. Governments have, at least on paper, realized the importance of fair distribution of water for household activities; that is how they have launched the national initiative on Rajiv Gandhi Drinking Water Mission. But we are not yet that successful in convincing the planners the dare need for water conservation and harvesting, although a few piece meal efforts, by way of rooftop water harvesting, drip irrigation initiatives, etc. are in place. I believe that the main reason for getting planners priority for household water distribution is its strong linkage with ill-health, water borne diseases and childhood mortality. Public health advocates were successful in highlighting this need and getting a knee jerk reaction from the authorities to take efforts for household water supply; but we should not have left it there. The cause of health could have been an entry point, and we should have built a comprehensive package for water preservation and harvesting.

It is intriguing that the issue of energy security was not found in the main discourses in public health till very recently. Whatever little that was being discussed was hovering around air pollution and its consequences due to cooking fuel, vehicular exhausts, and the indirect health effects of power plants etc. Recent health literature from the West highlights the direct effect of lack of heating facility at home and childhood mortality, but there are not many papers on this direction from India(Fowler *et al.,* 2014). One of the prime reasons for having higher child mortality rates in the northern states (colder) compared to the southern ones could be the near total lack of any sort of heating options in the extreme low temperatures during winter season. Unfortunately this is not being analyzed or discussed in the health sector; rather we are trying to find reason with potential infectious entities.

## ON WATER SECURITY

The motto of water and energy security demands more comprehensive approach than the medicalised public health. It is beyond water borne diseases and air pollution that could be addressed by provision of household water supply or clean air. It demands an overwhelming change in the way we address our very notions of health, well-being and prosperity. Around 80-85% of our body is made of water, and we should get it replenished on a daily basis, the imbalance in its quality or quantity leads to ill-health. Moreover, water is an essential commodity in our household and sufficient quantity of water is needed for drinking and non-drinking purposes. At the societal level water is essential for agriculture, industry, transportation, power generation and entertainment modalities. It is quite true that all household activities linger around water and similarly almost all human societal activities have linkages with water or water sources. No wonder that our earlier civilizations were built around river beds. We are left with only limited amounts of surface water for all these disparate activities, the rapid depletion of which and the resultant water scarcity and potential water wars linger eternal fear in us. It is quite unfortunate that our present day notions of development demands increased per capita consumption of water. These lopsided views on development needs to the corrected and prudent use of water should be made fashionable. Each and every individual, from children to the elders should be made aware of the amounts of water, that they use, and encouraged to reduce the quantity, limit wastage, reuse for other purposes by way of undertaking water auditing at the household level. In general, people should be encouraged, or rather coarsened to build roof top air, water harvesting, make rain ditches to collect water for ground water recharge, use drip irrigation for agriculture, wherever it is possible. Stringent and effective steps should be taken to avoid pollution of water bodies, fair and equitable distribution of this essential commodity and gender equity in its access and use. It is heartening to note the recent scientific revelation that the earth crust has sufficient quantities of fresh water storage, although we are not yet sure that it would be available for human consumption in the near future (Schmandt *et al.,* 2014). There are amble evidence that indiscriminate deforestation, continued destruction of marshy land buffers, encroachment of river and other water bodies will results in frequent and devastating floods, causing mortality and lingering morbidity by many outbreaks of diseases.

## GLOBAL WARMING AND ITS POTENTIAL EFFECTS ON PUBLIC HEALTH

Uncontrolled burning of petroleum products for energy production adds to nature's green gas emissions from the decomposition of its flora and fauna. The use and misuse of firewood for cooking and heating purposes in the households of vast rural areas, along with the methane emissions from our livestock herds adds to this phenomenon of global warming with devastating consequences. Many small island countries with huge human inhabitants (e.g. Maldives) might sunk under sea due to the melting of polar glaciers and sudden climatic fluctuations due to unexpected changes in underwater ocean currents can occur; this could make fertile lands to barren ones and vice versa. It could even have direct health effects by way of spreading vector borne diseases like dengue and malaria to newer areas, spread of other infectious agents due to tropical storms and storm surges that washes in foreign algae and dino-flagellates into tropical shores. It has been documented that the devastation would be more acute and severe in poor countries, because they are compromised in infrastructure, have huge infectious load to start with, have limited resources and hardly any preparedness to face the sudden climatic challenges (Delucchi and Jacobson, 2011). The chronic effects of such climatic outlast would be more pronounced devastating the area with frequent floods or droughts (National Research Council (U.S.), 1999). It is high time that public health agencies work along with marine scientists and experts to chart out ways and means of addressing this impending challenge.

One major aspect of addressing energy security from the public health angle would be looking at our sources and uses of energy. Human civilization could be regarded as the success stories of our efforts to harness energy sources and take control of its storage and transportation. Professor Ivan Robert and Phil Edwards, both Professors in London School of Public Health and Tropical Medicine, argue in their book titled *The energy glut; the politics of fatness in an overheating world* that humans started to became sedentary, obese and redundant, when we started using the fossil fuels for energy.(Roberts 2010) Not only we disregard renewable energy, we have forgotten to utilize our own body functions; so there are over one billion people who are overweight in this ever heating-up world. In order to address these issues, public health advocates need to go beyond the limited medical armamentarium and harness advances in other scientific and technological disciplines. Limiting technological fix alone to energy impasse might fail, as it is proven in case of water conservation, both water and energy security will demand earnest socio-cultural intervention to modify human behavior.

Let us quickly go through the ways and means of conserving energy to safeguard public health. Our needs for energy could be broadly classified into three, for electricity, for transportation and for heating/cooling. Firstly energy from fossil fuels (petroleum products) should be limited to the possible extent, as it pollutes air and adds to the green house effect; secondly nuclear power plants should be done away with, as its radioactive wastes take almost a century to disintegrate, even if one is willing to live with the high (15%) proportion of radiation leakages from the plants and thirdly energy from bio-fuels should be kept to the minimum possible, as its carbon foot prints are much higher than other renewable sources. Till now we do not have the where-with-all to harvest nuclear fusion energy and it might take up to a century before we can safely use that technology. Fortunately experts ascertain that judicious and intelligent use of already available options of Wind Water and Solar (WWS) energy shall be sufficient to address all the energy needs of today and the future.(Jacobson and Delucchi 2011) Better town planning, efficient public transport systems, and more efficient and less polluting vehicles (eg.hydrogen fuel cell vehicles -HFCV), good roads and disciplined traffic, restoration of water ways wherever possible, curtailment of fuel subsidies and an energy conscious society are the ways of reducing the use of fossil fuels. The available renewable energy sources of WWS like windmills, small scale hydroelectric plants, geothermal units, tidal turbines, solar photovoltaic cells (PV), concentrated solar power(CSP), etc should be judiciously used to meet the energy needs for electricity, heating/cooling and transportation.

The energy needs of transportation can be greatly reduced by means of using electric cars and HFCVs and judicious use of video conferencing, social media and other tools of informatics (Blow, 2012). The highest levels of inequity is seen in use of energy for cooling/heating; which is almost nil in the most wanted rural areas of tropical countries like India. Because of our location near the equator we have the extremes of weather conditions; very high temperature in summer and very low temperature in winter. Naturally dwelling units, especially those of poor people, are not fully equipped to safeguard these extreme climatic switching, resulting in excess mortality and morbidity during winter as well as during hot summer. Unfortunately there is no official mechanism to monitor such a trend in India, even the official data from Civil Registration Systems (CRS) of deaths in India are not being tabulated in a monthly basis to look at this (Fowler *et al.,* 2014). Using some available empirical data, I am putting forward my hypothesis that part of the higher rates of infant and child mortality in the northern states in India are due to inadequate heating/cooling options, because of unavailability or unequal distribution of energy. So in order to safeguard public health, we not only need to limit our energy needs, but use more energy (ideally WWS energy) in rural areas for heating /cooling option. Our scientists and industry people should be encouraged to explore the various options of WWS energy, which are acceptable to the people in question.

## CASE STUDIES

I here present a simple analysis of the verbal autopsy database from two different population cohorts in India, one from the field practice area of Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST) in Thiruvananthapuram called the ASA initiative in Kerala and another from the Vadu Rural Health Programme situated around the Shirdi Sai Baba Rural Hospital in Pune, which is an initiative of the KEM Hospital Mumbai and its Research Centre. Data from one grama panchayat, the Athiyannur Grama Panchayat having a population of 23,525 spread over an area of 12.44 sq km during the period from Jan 2011 to Dec 2013 was used for this analysis from the Thiruvananthapuram site. There were a total of 495 deaths during this period, giving an average death rate of seven per thousand population, which is similar to the state average of Kerala, one of the lowest rates in India. There was no infant or child death under the age of five years during the period, and only one death was reported in the age group below 14 years of age. Kerala is having tropical monsoon climate with a mild summer from Mar-May with a temperature range of 32-36°C, a heavy rainy season from Jun-Aug with a temperature range of 19-30°C, a mild winter from Nov-Feb with a temperature range of 18-28°C and a north east or Reverse Monsoon during October November with evening rains. Quite naturally we did not expect any seasonal fluctuation in death rates in Kerala. Even the death rates in elderly are not showing much seasonal fluctuation as evident from Fig. 1.

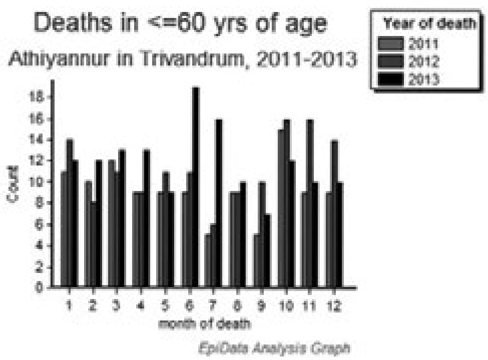


**Fig. 1**
**Seasonal distribution of deaths in ASA initiative**

Vadu project covers a population of 140,000 spread across 22 villages in Pune, in Maharashtra, and has a hot semi-arid climate. It has summer in Mar-May with a temperature range of 30-38°C, a Monsoon (the rainy season from Jun-Oct, with a temperature range of 22-28°C and a cold winter from Nov-Jan with a temperature range of 10-28°C. Fig 2 & 3 shows a relative clustering of deaths among under fives and elderly during the relatively cold months of winter and rainy season in Vadu. This highlights the importance of climatic conditions in the mortality and potential morbidity in these vulnerable sections of the population. Pune is not typical of the districts with extreme temperature fluctuation, but was selected for this analysis as it had the verbal autopsy data which is available for analysis. On extending this analysis to northern districts with extremes of temperature, we can expect most profound evidence to substantiate my hypothesis. This implies that we need to provide better heating/cooling options for rural areas in India. This should be done with renewable energy (preferably WWS) and done in such a way that it is acceptable to the society and the community would be able to take care of its maintenance.

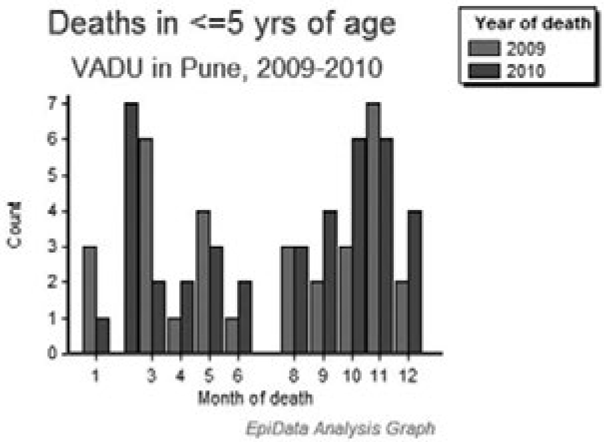


**Fig. 2**
**Seasonal distribution of deaths among under fives in Vadu**

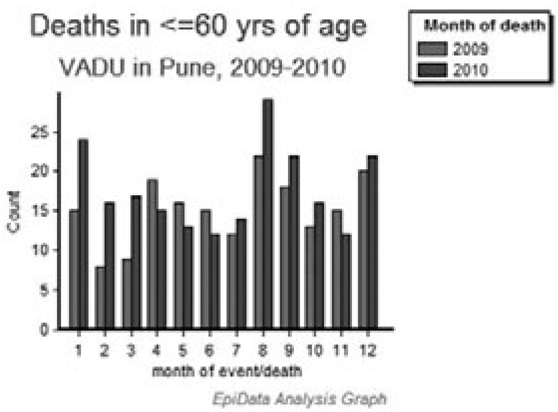


**Fig. 3**
**Seasonal distribution of deaths among 60 +yrs old in Vadu**

## CONCLUSION

This way of simple logical solutions will have huge positive impacts on the health and welfare of the people and we shall be able to have huge savings by way of avoiding early mortality and devastating morbidity. Along with this we should make prudent use of water and energy as a fashionable thing in the society, which shall get replicated amongst the masses. Interdisciplinary teams should be formed to work out simple, technically sound and sustainable solutions which should be propagated to the community through community leaders and opinion makers. Thus to a great extent people can be entrusted to safeguard their health to a great extent.

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# Water and Energy Security in Tourism Sector

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## INTRODUCTION

Globally, tourism industry has attained prestigious position owing to its rapid and spectacular growth over the last few decades. Global tourist arrivals are predicted to reach 1 billion in 2012 and 1.8 billion by 2030 – up from 940 million in 2010 (UNWTO, 2011). The potential for tourism to generate jobs, economic growth and foreign exchange, means it is harnessed as a development driver by countries all over the world. But ironically, with the rapid development of tourism all over the world; lots of the people and environmentalists are becoming more and more concerned about its impact on environment.

For tourism to be truly sustainable, its development and management must be premised upon a respect for human rights, including the right to safe drinking water and sanitation for the entire population. In many cases, one finds that tourism development is negatively impacting the quality, availability and accessibility of freshwater for local people, depleting precious electric energy, causing pollution of air water and soil - amounting to an infringement of their basic rights.

Almost all tourist destinations today are highly dependent on tourism as a means to generate jobs and economic growth. However, tourism cannot fulfill its potential as a contributor to poverty alleviation and sustainable development while it so often causes the unsustainable depletion and inequitable appropriation of resources.

PATA (Pacific Asia Travel Association) and WTO had devoted a full time conference at Bali in 1993, to discuss the relationship between tourism and environment. As a result many countries have enacted the laws relating to preservation of environment (Gee and Lurie, 1993). India is one of such nations, which have enacted such legislation and has set up a separate Ministry of Environment and Forest to monitor the land use from the environmental perspective.

## WATER RESOURCES CHALLENGES IN TOURISM SECTOR

Typically, tourism development is most intense in coastal areas and on islands, where potable water is scarce, while peak tourist seasons coincide with the driest months of the year. However, while hotels may have the money and resources to ensure their guests enjoy several showers a day, swimming pools, lush landscaped gardens and even golf courses, neighbouring households, small businesses and agricultural producers often regularly endure severe water scarcity.

A lack of access to clean water and sanitation both exacerbates poverty and is itself the result of poverty. Breaking this vicious cycle in the interest of sustainable development has been identified as a priority by the international community for many years. For example, the Millennium Development Goals (MDGs) set a target of halving by 2015 the proportion of the population without access to water and sanitation (UN, 2000). However, today some 884 million people remain without access to safe water (UNGA, 2010), while every year 1.8 million people – most of them children – die from diarrhea related diseases (WHO). In fact, more children die every year from lack of access to clean water and sanitation than die from AIDS, malaria and measles combined (UNGA, 2010).

More often than not, such water scarcity is not due to a physical absence of water, but is caused by inadequate or non-existent infrastructure, depleted or polluted groundwater supplies, and a lack of resources to secure water from other sources.

Just three per cent of the Earth's water is fresh and some 70 per cent of this is frozen in the polar icecaps. Meanwhile, water demand has tripled in the last 50 years. Changing rainfall patterns, rising sea levels and deforestation, the impacts of mining, intensive farming and other water-hungry industries, as well as rapid population growth and urbanization, are placing unprecedented pressure on this precious resource.

Tourism development is generally poorly planned and regulated throughout our country. The government's drive towards highend tourism, often characterised by star resorts place an intense burden on the already strained freshwater resources and infrastructure. Such high-end tourism typically consumes greater volumes of water up to 1,335 litres per room per day (over 600 lpcd) than smaller guesthouses - 573 litres of water per room perday (over 250 lpcd). Currently the standard being used in India is BIS 1172: 1993, reaffirmed in 1998. This specifies a consideration of use of the following:

- For communities with a population of between 20,000 to 100,000 — 100 to 150 litres per head per day.
- For communities with a population of over 100,000 — 150 to 200 litres per head per day.

Traditionally, most of our rural households access water via wells – either private or community-owned. However, as the quantity and quality of well water declines, households become increasingly dependent upon piped government supply. Yet this supply is irregular, erratic and of poor quality. Furthermore, many large hotels and resort complexes reportedly attach large pipes to the mains supply, which siphon off the bulk of the water while further decreasing pressure and availability for neighbouring communities. Many hotels also dig their own boreholes, which directly deplete local groundwater. Others purchase water from private water tanker trucks – an increasingly ubiquitous sight on roads even in places like Kerala, which has a bountiful 3000mm of rainfall annually.

**Approach towards balancing tourism and water resources management**

While it is a fact that policy level decisions are needed to ensure change on a regional level, it is perhaps very important and the need of the day that individual projects – particularly mid level and high end – are made conscious about sensitive responsible utilisation of the resources in the place where they build and if possible try and enhance the quality of living of the local community too..

Blessed with over 3000mm of rain fall and over 200 days of sunshine, tourism initiatives in coastal India can set a new bench mark for achieving water self sufficiency and energy efficiency with a combination of proper design and efficient operation.

**ENERGY CHALLENGES IN TOURISM SECTOR**

Though on a broader perspective, energy requirement of the tourism sector is only a small component compared to agriculture, industrial uses etc, there are often situations that lead to pressure on the systems particularly in destinations.

Energy consumption in Tourism Sector is in multiple modes – the major component being energy for transport. Tourism represents 5% of total emissions, including 2% attributable to air travel.

Globally, collectively, the international community strives to limit warming to a maximum of 2 degrees, compared with pre-industrial levels, by the year 2100. To maximize our chances of getting there, it has been calculated that global emissions need to decrease by 50% by 2050, compared to 1990.

If emissions related to tourism are left unchecked, they will double in the coming 25 years, despite the measures already taken.

**Hotels and Resorts**

Energy is typically a very significant operating cost for hotels.When combined, proper strategic planning and investments, tight controls, staff training andcustomer communication can very quickly enhance sustainability and improve profitability.

Advances in technology, and the high cost of energy, have made energy efficiency programs and investments not only easy to implement and affordable, but quite simply unavoidable. They make plenty of sense, even from a pure business perspective.

**CASE STUDIES: WATER MANAGEMENT**

Inspiration, with over 18 years of experience in the field of ecology sensitive design and constructions has been consciously trying to integrate concepts of Total Water Management and relevant applications of Renewable Energy in the projects that we design and build – and we have responded to some of the best names in tourism industry especially in South India.

Total water management envisages:

a. Creation of a Water budget plan and devising strategies for optmising usage of water at the planning stage onwards.

b. Rain water harvesting and storage for non monsoon periods.

c. Recycling and reuse of waste water for non potable end uses.

**Case 1 : BTH Sarovaram at Kochi**

One of our first attempts to integrate the concept of total water management on a commercial project was for BTH Sarovaram at Kochi. The project involved installing dual plumbing distribution system, creation of a rain water harvesting lake of capacity 50 lac liters and a system to recycle over 50000 liters of water every day for reuse for gardening.

**Case 2: CGH Earth Swa Swara at Gokarna**

CGH Earth Swa Swara at Gokarna is bigger scale approach in this direction. The Swa Swara, voted among the 100 Best Spas in the World, situated on Om Beach, 6 km away from Gokarna Town, Karnataka accommodates 24 Luxurious Courtyard Villas, Ayurvedic Spa, Restaurant, Library Bar, Music Room, Craft Centre, Swimming Pool, Art Gallery, Exhibition Hall, Yoga Space and related accommodation facilities for staff of 60.

From the initial planning stage, it was obvious that one of the main constraints in the site was lack of availability of potable water.

After considering the various options, M/s 'Inspiration' recommended that the best option would be to integrate the concept of Total on site water management for the project at the design stage itself: which would focus on self sufficiency in water usage for the resort.

The measures included:

- Creation of a reservoir with an impermeable lining to collect and store the bountiful rainwater for the dry months.
- Steps to utilise the surplus water to recharge the ground water table.
- Gokarna does not have a centralized sewerage system and hence the need for a properly designed on the site treatment of sewage and waste water to prevent contamination of ground water in the few surface wells on the site.
- Recycling of treated wastewater for non potable end uses such as flushing, gardening etc to conserve use of the harvested rain water.

The resort required an average quantity of 32000 liters of potable water and 22000 liters for irrigation and other purposes. Studying the micro climate of the area, months of June, July and August have 82% rain. Constructing a catchment lake that stores about 15 million liters of water could provide water for 180 dry days. The resort also gives back 25000 -30000 liters of domestic waste water /day.

***Detailed Design***

With such a large volume to be provided, the reservoir / lake had to be a major landscape feature on the site- its design and constructional detailing demanded an excellent aesthetic quality, besides structural soundness. A free flowing form was chosen based on the site levels, layout and master plan (Fig. 1).

The free flowing form demanded a flexible material for lining. The lining had to be almost perfectly impermeable to prevent seepage losses, be resistant to ultra violet radiation and rodent attack, be non- toxic and be able to withstand any unforeseen uplift due to hydrostatic pressure.

Mr.V.N.Gore of Geoscience Services, Mumbai was the structural consultant for the lake. Based on the soil investigation reports and detailed site studies, Mr.Gore recommended that the critical criteria for the lining would be control of hydrostatic pressure in the lateritic soil from the vast catchment, impermeability of the membrane and last but not the least, the aesthetic appeal.

The detailed design encompassed the following:

- Depth of excavation of lake bed to be limited to the level of hitting hard laterite to optimize on costs.
- Excavation to be done in a slope of 1 in 1.5 to naturally protect the sides of the reservoir.
- Network of underdrainage below the lining of the lake to release hydrostatic pressure formation below the impermeable liner membrane and uplift.
- Lining of lake with 2 layers of LDPE fabric liners – the main liner being 300 micron and top layer with 150 micron LDPE.
- The floor of the lake was to be protected by a layer of 100mm of sand.
- The sides were to be protected by pitching with random laterite masonry in a lean mortar.
- Toe walls at the base of the lake would protect the pitching in position.
- An overflow weir to divert the overflow from the lake in a controlled manner to the lower side of the`lake.
- Collection of water from the underdrainage network.
- A network of subsurface filter drains of various sections to drain the catchment within the site and bring filtered water to the lake.
- A network of trench drains and filter tank to catch the water from the external catchment, filter it and let it into the lake as additional source.
- Protective embankments on the sides of the lake to prevent unfiltered run offs into the lake.

Detailed cost estimates for each of the above items were taken. In comparison to a reservoir with ferrocement or RCC lining, the cost for the lake at Swa swara claims the following significant merits.

- The cost was only about 1/3rd that of a conventional r.c.c lining.
- Being flexible materials – LDPE and laterite, it gave tremendous design and construction flexibility.
- The construction required only semi-skilled/unskilled local labour and very little of mechanical equipment and tools.
- The depth was fixed at 3 – 3.3 metres on an average since below this depth was hard lateritic rock which would be very difficult to excavate and blasting was to be avoided. There was also the concern that deeper storage may give rise to anaerobic conditions i.e oxygen starvation. Based on the consumption recharge profile, the corresponding area was fixed at 4200 square metres.

**Fig. 1**
**Water Management in Cgh Earth Swa Swara at Gokarna**

***Subsurface filter drains***

The rain water falling on the roofs as well as the surface run-off from the site is channelised to the lake for recharging it. The conventional storm water drains for surface drainage, besides being expensive; need recurring cleaning and maintenance for satisfactory performance.

**Fig. 2**
**Subsurface filter drains**

A typical sub surface filter drain consists of a trench lined with non woven polypropylene fabric, filled with graded filter media having a perforated drainage pipe inside Fig. 2. After wrapping the media with PP fabric, the top part of the trench is filled with coarse sand and random laterite. The top surface is finished with a layer of rounded pebbles and where the drains cross vehicular roads, dry open jointed laterite pitching is provided.

***The lake ecosystem***

The lake has been developed as close to a natural ecosystem as is possible. There is very restricted activity in the lake. While swimming is totally avoided, passive recreation like boating on small coracles can be tried.

Controlled aquaculture with grass carp takes care of the algae control; to ensure that the fish feed on the algae, feeding of fishes by guests / staff is to be totally discouraged.

### *Purification of water from the lake*

The purification system for the harvested rain water consists of a simple pressure sand filtration, activated carbon filtration and chlorination for disinfection.

### *Treatment and recycling of waste water*

In order to optimise the usage of water, the black and grey water (sewage and sullage water from kitchens and bathrooms) is treated and reused for gardening and other non-potable end uses. The system adopted is known as the DEWATS approach (Decentralised Waste water Treatment System). The black water and grey water from the cottages and various blocks are collected in settler tanks. The primary treatment takes place in these settlers.

Within the settler, two main treatment processes take place. First, a mechanical treatment retains contaminants by sedimentation/ floatation and the waste water from the clarified layer flows through the outlet. Second, through biological treatment, the remaining organic pollutants are partly decomposed by micro-organisms. For the Kitchen and the Ayurveda Block, oil separators have been installed prior to the Settler to remove excess of oil from the waste water. The collected waste oil is mixed with other bio degradable solid wastes and fed to the bio gas plant installed.

From these settlers, the effluent is taken to the Anaerobic Baffled Reactor for secondary stage of treatment.In secondary treatment, biological and natural chemical processes are used to digest and remove most of the organic matter.

**Fig. 3**
**Planted Gravel Filter for tertiary treatment**

Several up flow chambers are constructed in series to help digest difficult degradable substances. The sewage flow is directed from top to bottom and up again. During the process the fresh influent is mixed and inoculated for digestion with the active blanket deposit of suspended particles and microorganisms occurring naturally at the bottom (activated sludge) of each chamber in such conditions.

The BOD reduction rate of the baffled reactor is about 75 –85%. The pathogen reduction is in the range of 40 – 75%. The Baffled Reactor is resistant to shock load and variable inflow, the operation and maintenance is simple.

The Horizontal Planted Garvel Filter (also called Root Zone System) forms the tertiary treatment (Fig.3). The planted gravel filter acts through the combined working of the filter material, the plants and the roots in the device. The Horizontal gravel filter is made of reed planted filter bodies consisting of graded gravel. The normal depth is 60cm. The main removal mechanisms are biological conversion, physical filtration and chemical adsorption. Mechanisms of BOD removal are mainly aerobic and anoxic.

After the planted filter, the treated water with BOD less than 30 mg/l is ready for collection for recycling for gardening. The treated water is collected in the Polishing Pond (Fig. 4)where it becomes “living water again” by undergoing further biological treatment, through natural UV exposure and flowing through an open water body, with all the necessary natural elements such as fish, frogs, dragonflies and different aquatic plants.

**Fig. 4**
**Polishing Pond**

At this stage the recycled wastewater can be reused without posing any treat to human handling. It is valuable for irrigation; the water is high in nutrient contents and beneficial to plant growth.

**Significant Achievements of Project**

It is probably among the best examples for total on site water management as one of its strong concepts from the design stage. This had definite advantages that we could treat the system to blend with the landscape, make the most of the levels in the site.

It has helped prove that with the right balance of sensitivity and technology, very high end tourism can be successfully promoted even in very fragile eco systems.

**CASE STUDY: ENERGY MANAGEMENT**

**Pearl Beach Mararikulam: an attempt towards energy self sufficiency**

An initiative of M/s Muthoot Group along with international partners M/s Raxa Collective, Pearl Beach Mararikulam is a project where we have attempted to plan from the design stage systems to make the project entirely self sufficient in its energy requirements with a combination of the following steps:

- All buildings have been designed bio climatically to ensure optimum use of energy – both embodied energy as well as energy usage within the building.
- All lights are with LED.
- All equipment including Air conditioners, Kitchen equipment etc. have been carefully chosen which use least energy for operation.
- The main panel designed such as to initially install solar photovoltaics without battery back up to minimizes day time loads.
- At a later stage this can be completely changed over to a battery and DG back up to ensure total self sufficiency.

**POLICY INTERVENTIONS**

While examples like discussed earlier bring to light the concepts of integrating water and energy management efficiency into individual tourism projects, it is of utmost importance to formulate policies and good practices, which will ensure overall sustainability of the tourism sector. Often one finds the tendency of lop sided choices when it comes to infrastructure planning. The key sectors that need to be improved are water supply, sanitation and energy followed by proper public transport networks.

The policy recommendations suggested water and energy management in tourism sector are:

a. Governments should uphold their international legal obligations to fulfill and protect the right to water and sanitation of citizens as a priority. Governments should issue guidelines to tourism businesses operating locally and overseas on their business responsibility to respect human rights.

b. Destination governments should implement clear regulatory and institutional frameworks for sustainable, equitable, integrated water and tourism planning and management. Transgressors should be penalised; good practicies should be championed.

c. Land use planning should be based on assessments of water resources and infrastructure, and tourism carrying capacities established. These should take into account livelihood needs, food security, population growth, climate change, and wider watershed degradation of the region.

d. Make it mandatory for users of more than 10000 lters per day to have Total Water Management plans in position before giving permits.

e. Ensure strictly that the same is being operated and maintained regularly.

f. Engage larger resorts to sponsor upkeep of water bodies in their localities. These would not only ensure their upkeep but also enhance 'touristic' value.

g. For smaller hotels/ establishments, local bodies can work out cluster level water management strategies.

h. There are several abandoned quarries available. These get filled with rainwater and are often used by local people to take bath, wash etc. Without due care, most often due to dumping of wastes and industrial effluents the water gets polluted along with high rate of algal growth. Such quarries could be converted to rain water harvesting reservoirs, with systems to treat and distribute.

## CONCLUSION

While it is needed that stringent norms are imposed on individual projects, a macro change towards sustainable tourism would need definite commitment from the part of decision makers on the following:

a. Proper Carrying Capacity based Master Plans to be made mandatory for all tourism destinations defining land use planning for various tourism activities while respecting the rights of the local community, built and natural heritage of the region, additional burden on the infrastructure particularly water, transportation and energy needs.

b. New projects to be envisaged and permitted only within the perspective of the Master Plan.

c. While it is important to cross subsidise the expenses towards infrastructure use by High End properties, it is equally important to educate and get involved mid and budget hotels, tour operators also in ensuring efficient utilization of available resources.

d. An integrated team comprising of representatives from various stake holders to review and ensure proper implementation of the Master Plan at the ground level to be made mandatory – the Eco Development Societies could be involved in this..

e. Investors to be sensitized that while it is meritorious to make their individual properties efficient in water and energy usage, it is needed to think beyond and respect the rights of local population on the resources that they have been enjoying for centuries.

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# Virtual Water: The Unknown Knowns

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## INTRODUCTION

By the mid-1990's, the phrase "virtual water" introduced by Tony Allan found a place in water resource literature, when he pondered over the possibility of importing virtual water as a partial solution to problems of water scarcity in the Middle East (Allan, 1993; 1994; 1998). However, the concept of 'embedded water' introduced in prior to 1993, did not gain any degree of credibility/acceptance. The virtual water or VW of a product or produce is defined as the freshwater "embodied" in the former not in real sense, but virtually. In other words, VW by definition is "the water required for manufacturing a product, cultivating a agro-produce or rendering a service". In other words, it refers to the volume of water consumed or wasted during the production of the product/produce or service and measured over its full production chain. A famous adage attributed to Allan (2003; 2011) runs like "a thousand tons of water is necessary to produce a ton of wheat".

Hence VW, a term encompassing water, food, and trade, is a successful instrument or concept by which water deficit economies can remedy their deficits. Also, VW, central to the strategic commodity food, is unable to escape a contentious role in any discourse on the political economy of food security. The potential role of VW is so contentious that those actually managing water and developing water policy in water scarce economies ensure that the concept is kept out of water policy-making discussions (Allan, 2001). Import of water-intensive commodities reduces water demand, whereas export of water-intensive commodities raises national water demand and thus elevates water scarcity locally. By underscoring the importance of water content of crops/produce, VW is shifting the focus of the discourse from "'local water use efficiency' at user level and 'water allocation efficiency' at river basin level" to "global water use efficiency" (Hoekstra and Hung, 2005; Beadon and Page, 2010).

## VIRTUAL WATER VS WATER FOOTPRINT

The VW in a product refers to the water volume embodied only in the product whereas the water footprint (WF) of a product is the total volume of freshwater either consumed and/or polluted through the various steps in the production chain. Therefore WF of a product is a multi-dimensional indicator, whereas VW implies only a volume. The combined WF of the consumers in a nation is defined as the total amount of freshwater that is used to produce the product consumed by the citizens of the nation. The national WF is calculated as “the sum total of domestic water resources use plus nation’s gross virtual water import minus the nation’s gross virtual-water export”.

The components of VW, i.e., “green” and “blue” waters, have been studied in depth. “Green water” denotes effective rainfall or soil moisture used directly by plants, while “blue water” denotes water in rivers, lakes, aquifers, or reservoirs (Falkenmark and Rockström, 2004; Rost *et al.*, 2008). In other words, blue water is the water that can be delivered for irrigation or for alternative uses, while green water is essentially extracted directly from the soil profile.

## UNDERSTANDING VIRTUAL WATER FLOWS

VW differs from direct water use, in that the consumer does not perceive it and once used in production, it is embodied in consumable commodities. For purposes of analyzing flows of VW, it is important to keep in mind that VW is passed on between intermediate consumers, before it reaches the final user beyond which its flow ceases. Similarly, the VW flow between two nations or provinces within the nation is the volume of virtual water contained in the traded product between the nations or regions. The analysis of Global VW flows was introduced by Hoekstra and Hung (2002), Hoekstra (2003), Chapagain and Hoekstra (2003) and Zimmer and Renault (2003). Hoekstra and Chapagain (2008) estimated that the global VW flow is of the order of 1625 billion $m^3$/yr during 1997-2001, of which 61% (i.e., 987 billion $m^3$/yr) was linked to trade of crops and crop products, 17% (i.e., 276 billion $m^3$/yr) to livestock and livestock products and the remaining 22% (362 billion $m^3$/yr) to industrial products.

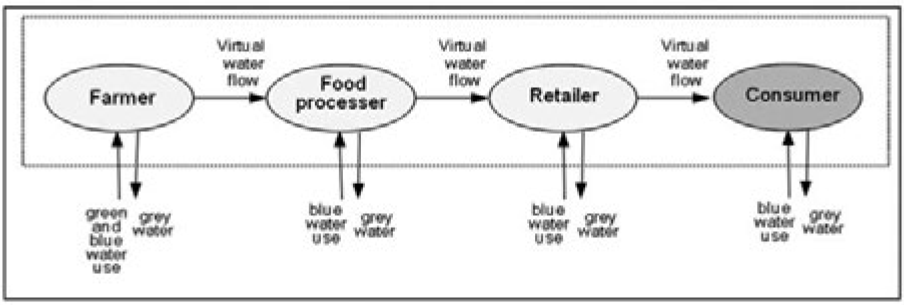


**Fig.1**
**Schematic of virtual water flows** (After Hoekstra et al., 2011)

## VIRTUAL WATER TRADE

Rising water demand due to population growth, industrial development and urbanization, warranted economically efficient use of water resources. It is predicted that by 2025, two-thirds of the world population could be under "*stress conditions*" (500-1000 $m^3$ $y^{-1}$ per capita), and 1800 million people are expected to be living in countries or regions with "*absolute water scarcity*" (<500 $m^3$ $y^{-1}$ per capita). Concept of VW and its trade that ensued are bestowed with widespread optimism for its perceived potential or promise to solve water insecurity, but at the same time circumventing major political and social costs. By "VW trade" what is meant is the trade of water in virtual form or state, when a product or produce is traded between two provinces within a nation or between nations. Again, VW allows governments to conceal or tide over water scarcity by importing water intensive crops. Chapagain and Hoekstra (2004) published "The Water Footprint of Nations" – a first global study – analyzing VW flows among the nations during 1997-2001 and based on international trade of crop, livestock and industrial products.

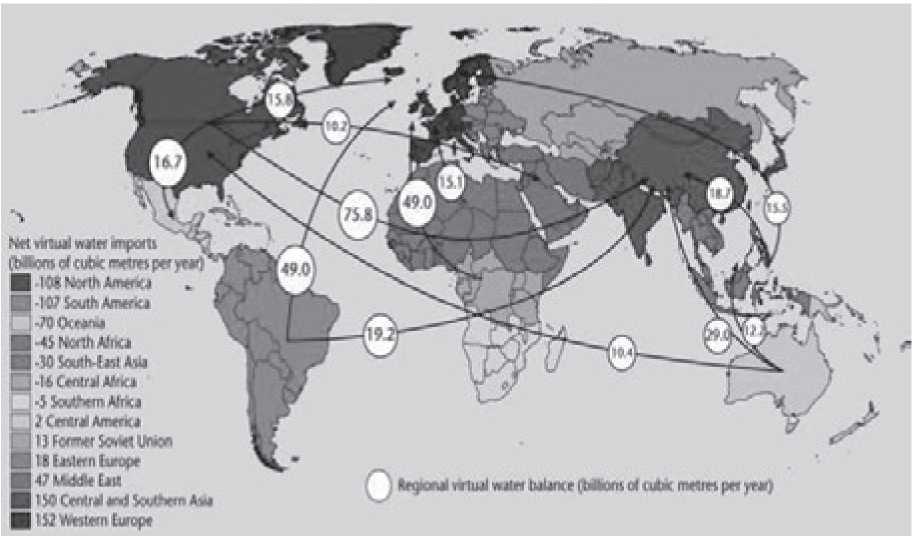


**Fig. 2**
**Net global VW imports, 1997-2001** (After Hoekstra and Chapagain, 2008)

A recent report (Proceedings of the National Academy of Sciences, 2012) revealed that China is the country with largest water footprint of consumption in the world (1,368 $Gm^3/yr$), followed by India (1,145 $Gm^3$ $y^{-1}$) and the United States (821 $Gm^3$ $y^{-1}$). But the major gross VW exporters are the United States (314 $Gm^3$ $y^{-1}$), China (143 $Gm^3$ $y^{-1}$), India (125 $Gm^3$ $y^{-1}$), Brazil (112 $Gm^3$ $y^{-1}$), Argentina (98 $Gm^3$ $y^{-1}$), Canada (91 $Gm^3 y^{-1}$), Australia (89 $Gm^3$ $y^{-1}$), Indonesia (72 $Gm^3 y^{-1}$), France (65 $Gm^3$ $y^{-1}$) and Germany (64 $Gm^3$ $y^{-1}$). The United States, Pakistan, India, Australia, Uzbekistan, China, and Turkey are also the largest blue virtual water exporters, accounting for 49 per cent of the global blue virtual water export. Yet all of these countries are partially under water stress, which raises the question whether or not the implicit or explicit choice to utilize the limited national blue water resources for export products is sustainable and most efficient.

**Virtual water trade in India**

In India, with a rapidly growing population and improving living standards, the water requirement of India is increasing while the per capita availability of water resources is declining day by day. According to FAO (2010), during 2001-2005, India exported 228.61 $Gm^3$ of VW (average= 45.72 $Gm^3$ $y^{-1}$) and imported 358.27 $Gm^3$ of VW (average = 71.65 $Gm^3$ $y^{-1}$). In fact, India was a net importer of 25.93 $Gm^3$/yr of virtual water related to crop and livestock products during the same time frame.

Based on certain assumptions about interstate movement of agricultural products, Kampman (2007) estimated the mean annual import (or export) of virtual water among the Indian states (see Fig.3). According to Kampman (2007) the states of Punjab, Uttar Pradesh and Haryana are the largest exporters of VW while Bihar, Kerala, Gujarat, Maharashtra, Jharkhand and Odisha are the frontline importers. The current state of inter-state VW trade is tending to aggravate scarcities in already water scarce states, with VW flowing from water scarce to water rich regions and in the direction opposite to the proposed physical transfers (Kampman et al., 2008; Kumar and Jain, 2007; Verma et al., 2009). Instead of a prescription of water endowments, VW flows are influenced by several other factors such as per capita availability of arable land and more importantly by biases in food and agriculture policies of the Government of India like for e.g., procurement patterns of the Food Corporation of India. In order to have a comprehensive understanding of virtual water trade, non-water factors of production need to be taken into consideration.

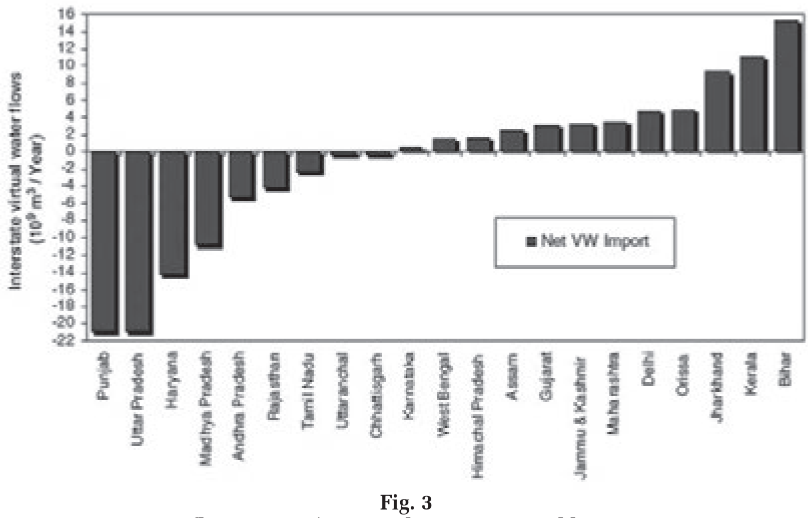


**Fig. 3**
**Inter-state VW flows ($10^9 m^3$/yr) in India, as estimated by Kampman (2007)**

## VIRTUAL WATER IN CROP AND ANIMAL PRODUCTS

The VW content of animal products is far higher than that of crop products. Animals need to be fed and watered right through their lives. The total amount of real and VW consumed by animals and the water expended during processing are proportionately partitioned among the diverse animal products. This proportional allocation may also occur in terms of weight or more frequently, by using the market value. As per the estimates of Mekonnen and Hoekstra (2011) the ready-to-eat animal products have an estimated VW content of 3,000 to 15,000 litres/kg product, as against about 1,000 to 3,000 litres/kg product for ready-to-use crop products. As the VW content is significantly higher for cotton, coffee beans and cocoa beans, these plant products clearly stand apart as an exception.

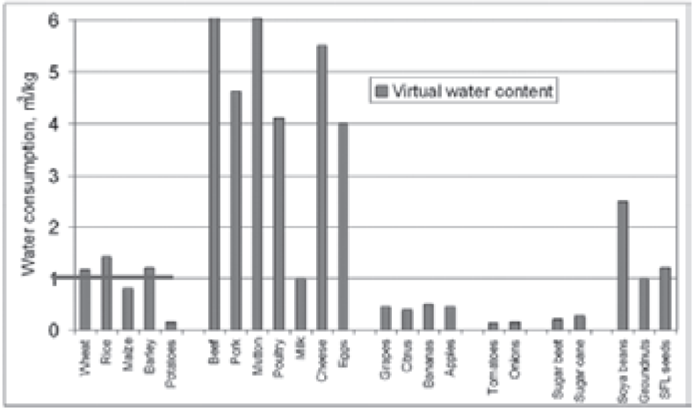


**Fig. 4**
**Global average crop water consumptive use, m³/kg**

The VW content of products strongly vary from place to place, and is strongly influenced by climate, level of technology in farming and consequent yield. The units used so far to express the VW content of various products are in terms of cubic meters of water/ ton of product. For example, global average VW content of rice (paddy) is 2291m$^3$/ton while it is 1334m$^3$/ton for wheat. VW content of (broken) rice in the shop is 3420m$^3$/ton. A consumer might be more interested in knowing how much water a product consumes per unit of consumption. Table 1 is the global average of VW for selected products. Tables 2, 3 and 4 depict the average VW in selected crop and animal products in India.

**Table 1**
**Global average VW content of selected products per unit of product**

| Product | VW, liter | Product | VW, liter |
|---|---|---|---|
| Black tea (250 ml) | 35 | Bread (30g) | 40 |
| Beer (250 ml) | 75 | Potato (100g) | 25 |
| Wine (125 ml) | 120 | Apple (100g) | 70 |
| Black coffee (125 ml) | 140 | Orange (100g) | 50 |
| Orange juice (250 ml) | 170 | Egg (40g) | 135 |
| Apple juice (250 ml) | 190 | Potato chips (200g) | 185 |
| Milk (200 ml) | 200 | Hamburger (150g) | 2000 |

**Table 2**
**Average VW in some crop and animal products, India** (Chapagain and Hoekstra, 2004)

| Category | VW (m³/ton) | Category | VW (m³/ton) |
|---|---|---|---|
| Rice (Paddy) | 2850 | Beef | 16482 |
| Rice (Broken) | 4254 | Pork | 4397 |
| Wheat | 1654 | Goat meat | 5187 |
| Maize | 1937 | Sheep meat | 6692 |
| Soybeans | 4124 | Chicken meat | 7736 |
| Barley | 1966 | Eggs | 7531 |
| Sorghum | 4053 | Milk (fat<1%) | 1369 |
| Millet | 3269 | Milk (fat>6%) | 2547 |
| Sugarcane | 159 | Milk powder | 6368 |
| Coffee (green) | 12180 | Cheese | 6793 |
| Coffee (roasted) | 14500 | Buttermilk | 2068 |
| Tea (powder) | 7002 | Yogurt | 1592 |
| Sugar (refined) | 1391 | Leather (bovine) | 17710 |

**Table 3**
**Average VW in crop products, India** (Chapagain and Hoekstra, 2004)

| Type | VW in (m³/ton) | Category | VW in (m³/ton) |
|---|---|---|---|
| Potato | 213 | Banana | 415 |
| Sweet potato | 277 | Orange | 364 |
| Beans (green) | 487 | Lemon | 611 |
| Urad/ Mung Dal | 3078 | Grapefruit | 411 |
| Pea (green) | 178 | Apple | 1812 |
| Chick pea | 2712 | Pear | 1287 |
| Pigeon pea | 4066 | Apricot | 2424 |
| Cabbage | 180 | Cherry | 2532 |
| Onion (fresh) | 214 | Peach | 1564 |
| Tomato | 302 | Plum | 1907 |
| Cauliflower | 100 | Watermelon | 362 |
| Pumpkin | 238 | Mango | 1525 |
| Cucumber | 357 | Pineapple | 305 |
| Carrot | 197 | Papaya | 922 |
| Garlic | 1268 | Strawberry | 296 |
| Ginger | 1556 | Cashew nut | 15340 |
| Pepper | 8333 | Groundnut (in shell) | 3420 |

**Table 4**
**Average VW in some edible oils, India** (Chapagain and Hoekstra, 2004)

| Category | VW content ($m^3$/ton) |
|---|---|
| Coconut oil | 3051 |
| Groundnut oil | 8875 |
| Olive oil | 21106 |
| Palm oil | 5169 |
| Sunflower oil | 8541 |
| Linseed oil | 19159 |
| Mustard oil | 4643 |

**Level of Virtual water in Fish and sea food**

Fish and sea food contribute hugely to the global food supply and trade accounting for 14.33 % (Table 5). Although, during its life cycle, sea food does not warrant fresh water consumption, processing and import of sea food call for a large share of virtual water and hence needs to be addressed. On comparison, animal based food stuff (like beef, pork, poultry, eggs and milk) has a virtual water equivalence of around 5 m3/kg. The sea food account for ~8.0% of the global virtual water budget and 14 percent of the global virtual water trade (Zimmer and Renault, 2003).

**Table 5**
**Comparison of global VW trade, 2000 CY**
(Adapted from Hoekstra, 2003)

| Global VW trade (from perspective of importing countries) | VW Volume ($bm^3$/yr) | Percentage (%) |
|---|---|---|
| Vegetable produces | 795 | 59.33 |
| Animal products | 180 | 13.43 |
| Meat | 173 | 12.91 |
| Fish and Sea food | 192 | 14.33 |
| Total | 1340 | |

**CONCLUSION**

The question of 'how much water one *eats* every day?' might sound strange but true if paid some more thought. Estimates by the Water Footprint Network (WFN), show that the water needed in the production of industrial products one uses daily, such as paper, cotton and clothes, amounts to ~450 l $d^{-1}$. WFN scientists determined that globally 92% of the water one use is invisible and embedded in their food. Research shows that an Italian eats nearly 5,600 litres each day; Brazilian 5,200 litres daily, an Indian 2700 litres and a US citizen consumes 6500 litres/day. Water expert Tony Allan warns: "what we eat and what we do not waste will enable us to be globally water secure". Sensible food consumption and natural resource-aware trade should become two of the principal commandments for our 21st century society if we want to build a sustainable future. In light of the existing water scarcity and imbalances in water availability at globally and regionally, a sustainable virtual water trade is utmost important in bringing water use efficiency. A shift towards water conservation and water demand management is essential for the sustainability of water resources and the environment, as well as economic efficiency and social development.

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# Water and Energy Security: Impact of Environmental Pollution

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## INTRODUCTION

If one is to identify the most precious material on Earth it will be none other than water. More than 70% of the Earth's surface is covered by water. Though water can be seen to be the most abundant, 97.5% of it is salt water and only 2.5% is fresh water. Of the fresh water nearly 70% is frozen in the icecaps of Antarctica and Greenland and ~29% as soil moisture or as deep underground aquifers which are not accessible to human use. Only less than 1% of the World's fresh water (~0.007% of all water on earth), which is distributed in lakes, rivers, reservoirs and those underground sources that can be tapped at an affordable cost and which is regularly renewed by rain and snowfall, is available for human use on a sustainable basis.

The Water Cycle plays a central and integrative role in the dynamics of the Earth System. It is a key regulator of biogeophysical processes. Its physical state is closely linked to energy exchange within the global climate system. Water is essential to the maintenance of both terrestrial and aquatic ecosystems, providing habitat for aquatic species, many of which are important protein resources for humans. The movement of water through the hydrological cycle comprises the largest flow of any material in the biosphere. Inland water ecosystems are exposed to critical pressure due to competing claims and growing interdependencies. Water use patterns affect ecological resilience while emerging over-exploitation of water resources demand new initiatives to maintain or restore the integrity of the water cycle at different scales. Linkages of global water systems to the regional and local socio-economic context, in particular the vulnerability context of the livelihoods of the poor, need to be understood in order to identify new water management strategies that can deal appropriately with these dilemmas. Water scarcity can occur with diverse hydrological and social dynamics, in different freshwater sources, and the nature of problems and scope of monitoring and management systems need much further study. Global socio-economic forces play into shaping both regional and local scarcity and capabilities to negotiate new water allocation options.

## WATER SECURITY

At this point of time the World Population has crossed 7.25 billion and on each day approximately 2 lakhs are added to this (Table 1).

**Table 1**
**Population growth statistics**

| Birth | | Death | | Population growth | |
|---|---|---|---|---|---|
| **Today** | **This year** | **Today** | **This year** | **Today** | **This year** |
| 312,116 | 78,014,574 | 128,783 | 32,189,749 | 183,333 | 45,824,824 |

Of the total population, 787 million lack safe water and every 21 seconds one child dies of water borne diseases (15 secs in 2009) and 443 million school days are lost each year due to water-related illness. Diarrhoea, the second leading cause of death among children under five in the world. Around 1.5 million deaths each year - nearly one in five – are caused by diarrhoea. It kills more children than malaria, AIDS, and measles combined, about 4100 children under the age of five on each day from diarrhoea globally (UNICEF, WHO 2009). Malnutrition, due to dirty water, inadequate sanitation, and hygiene, is estimated to lead to death in an additional 2,350 children under the age of five each day (WHO, 2008). 90% of the deaths due to diarrheal diseases are children under 5 years old, mostly in developing countries (UN Water, 2008).

The analysis of the Worldwide water consumption indicates that 70% of the fresh water is used for agriculture, 20% for industry and 10% for domestic use. Freshwater withdrawals is increasing by 64 billion cubic meters a year and the demand for fresh water have a threefold increase during the last 50 years. The fast growing population (about 80 million per year), the life style which necessitates a higher water consumption per capita, new agricultural tasks like biofuels ( about 4,000 litres of water are needed to produce a single litre of biofuel, new industrial and energy demands. Water borne and water associated diseases constitute almost 80 % of the diseases in developing countries and about 3 million deaths per year.

Water security is the development and management of the available resources of water and equitable, efficient and integrated utilisation of the resource base for the sustenance, survival and well being of the human being and the environment or Water security contains the harnessing of the potential of water to provide enough safe, affordable water to lead a clean, healthy and productive life along with protection of the natural environment. Water security thus contains elements of cooperation and sharing of river basins and aquifers by the various water users for the protection of vital eco-systems from pollution and other threats. Water security is an essential prerequisite for any effective poverty reduction strategy, environmental sanitation, wastewater management and flood control. It also means addressing to the destructive effects of water – the damage caused by floods, droughts, landslides, erosion, pollution and water-borne diseases in view of the increase in climatic variability. In short the water security includes energy security, food security, issues connected with climate change, floods and draughts, urbanisation and human relations and culture. The biggest concern over the water security is on the ever increasing environment pollution which reduces the utility of fresh water resources.

## ENERGY SECURITY

International Energy Agency defines energy security as “the uninterrupted availability of energy sources at an affordable price. Energy security has many aspects: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance” . Energy security concerns become ever more important. To provide solid economic growth and to maintain levels of economic performance, energy must be readily available, affordable and able to provide a reliable source of power without vulnerability to long- or short-term disruptions

Energy security is often discussed in terms of the stock and availability of the fossil fuels or nuclear energy. The new turn to the renewable energy more or less totally depends on the solar energy and hydropower. In both cases water is the main theme and water security shall be the main agenda.

Water is considered to be the most important capturer of the solar energy, thereby keeping the earth sustainable to life. This includes direct absorption of solar radiation by all the three forms of water – ice, liquid and vapour – available over the earth surface and the role as facilitator and party to the biosphere. In addition to this water was the key resources for the generation of electricity. Hydropower supplies at least 50 per cent of electricity production in 66 countries, and 19 per cent in 24 countries. Worldwide, small hydropower development is expected to grow by a further 60 per cent by 2010 transboundary water issues One hundred and forty-five nations have territory within a transboundary basin, and 21 lie entirely within one. In the last half century, approximately 200 treaties have been signed concerning transboundary water basins culture In nearly all the world’s major religions, water is attributed important symbolic and ceremonial properties sanitation One dollar invested in water supply and sanitation can provide an economic return of up to 34 times, depending on the region pollution In developing countries, more than 90 per cent of sewage and 70 per cent of industrial wastewater is dumped untreated into surface water agriculture Irrigation increases yields of most crops by 100 to 400 per cent. Over the next 30 years, 70 per cent of gains in cereal production will come from irrigated land.

## ENVIRONMENTAL POLLUTION

The recent trend to use shallow groundwater as an important source of water for irrigation has led, in most places, to over-pumping of aquifers and pollution from agrochemicals. The inappropriate use of fertilizers and pesticides in agricultural operations results in pollution of drinking water, rivers and lakes. The use of wastewater and sewage in many of the poor and developing countries for irrigation without proper treatment exposes farmers and food consumers to parasites and organic and chemical contaminants.

Today, 50 percent of the world's population lives in urban areas and, with changing demographics characterised by massive migration into cities, by 2025 the percentage is projected to be 60 percent. Urban water and wastewater management is a serious threat in most developing countries.

The study, conducted by institutions across the globe, is the first to simultaneously look at all types of human intervention on freshwater – from dams and reservoirs to irrigation and pollution. It paints a devastating picture of a world whose rivers are in serious decline. The world's rivers are so badly affected by human activity that the water security of almost 5 billion people, and the survival of thousands of aquatic species, are under threat. Even the world's great rivers, such as the Yangtze, the Nile and the Ganges, are suffering serious biodiversity and water security stress. Despite their size, more than 30 of the 47 largest rivers showed at least moderate threats to water security, due to a range of human impacts such as pollution and irrigation. Globally between 10,000 and 20,000 aquatic wildlife species are at risk or face extinction because of the human degradation of global rivers.

Pollutants enter the water environment from two main types of sources – Point sources and Non point sources

**Point sources**

A point source is a single, identifiable source of pollution (Wikipedia), such as a pipe or a drain. The U.S. Environmental Protection Agency (EPA) defines point source pollution as "any single identifiable source of pollution from which pollutants are discharged such as a pipe, ditch, ship or factory smokestack". Factories and sewage treatment plants are two common types of point sources. Industrial wastes are generally discharged to rivers and adjacent water bodies with or without proper treatment. Factories, including oil refineries, pulp and paper mills, and chemical, electronics and automobile manufacturers, discharge one or more pollutants through the effluents. The effluents from the factories are discharged into a waterbody either directly or after treatment and in some cases to the sewage treatment plants for treatment. Sewage treatment plants treat human wastes and send the treated effluent to a stream or river. Mixing of wastes of the factories and sewage treatment plants with urban runoff in a combined sewer system also has been reported. Runoff refers to stormwater that flows over surfaces like driveways and lawns. As the water crosses these surfaces, it picks up chemicals and pollutants. This untreated, polluted water then runs directly into a sewer system. During heavy rains a combined sewer system may not be able handle the volume of water, and some of the combined runoff and raw sewage will overflow from the system, discharging directly into the nearest waterbody without being treated.

A number of the chemicals discharged by point sources are harmless, but others are toxic to people and wildlife. The impact of the discharge on the aquatic environment depends on a number of factors, including the type of chemical, its concentration, the timing of its release, weather conditions, and the organisms living in the area.

The Discharges from large farms that raise livestock, such as cows, pigs and chickens, are also belong to point source pollution. If the animals' waste materials are not properly treated, these substances enter nearby waterbodies as raw sewage, radically adding to the level and rate of pollution.

**Nonpoint sources**

Non-point sources of pollution are generally referred as 'diffuse' pollution and includes those inputs and impacts which occur over a wide area and are not easily attributed to a single source. They are often associated with particular land uses, as opposed to individual point source discharges. Urbanisation and many of the developmental activities rely on excessive utilisation of water resulting in release of a high load of nonpoint water discharges without any consideration of the environmental and aquatic conditions. Excess nonpoint source pollution impacts the overall quality of life, and subsequently can drive property values down. Although the concentration of some pollutants from runoff may be lower than the concentration from a point source, the total amount of a pollutant delivered from nonpoint sources may be higher because the pollutants come from many places. The major non point sources are from the land use character of urbanisation, agriculture, forestry, damming, industries and mining. The destruction of mangroves and wet lands also has significant contribution to non point sources.

***Urban land use:*** In our urban areas rainfall run-off as stormwater is one of the major nonpoint sources of pollution impacting the water quality of our waterways and bays. Stormwater from street surfaces is often contaminated with discharges from urban domestic wastes, automobiles, dust and the faeces of animals and soil and sediment run-off from construction sites. In industrial areas it may contain discharges which are more toxic.

***Agricultural land use:*** In farming areas non-point sources of pollution include pesticides, fertilisers, animal manure and soil washed into streams in rainfall run-off. Where stock are given access to stream banks they may foul the water and accelerate erosion. Also

- Increases soil erosion due to the physical disturbance of soil and vegetation due to ploughing, overgrazing, logging and road building. This effects the murkiness and the amount of salts and minerals in water;
- Increases nutrients due to fertilisers and excreta, which contribute worrying amounts of nitrates and phosphates to water supplies (this can cause eutrophication);
- Increased pesticide use.

***Forestry land use:*** Forestry operations may contribute to non-point source pollution of streams by increasing soil erosion and sediment run-off. Clearing land for agriculture and urban growth often leads to water pollution. When soil is stripped of its protective vegetation it becomes prone to soil erosion. This leads to an increase in the murkiness of the water.

***Damming of Rivers:*** Damming of rivers have an impact on water in the following ways:

- Water flowing out of dams:
- has reduced suspended material as a large amount settles to the bottom of dams;
- is depleted of nutrients; and
- is often more saline with detrimental effects on downstream agriculture and fisheries.

- Enhanced eutrophication due to the water spending a longer time in the dam.
- Increased evaporation in dams, especially those with a large surface area.

***Destruction of Wetlands:*** Wetlands are nature's way of cleaning water as well as natural damming of water, holding back water in rainy season and release it in draught season. Destruction of wetlands:

- Destroys the habitat of many birds and fish;
- Removes the natural filters capable of storing and degrading many pollutants, such as phosphorus and heavy metals;
- Destroys natural dams and causes flooding further downstream.

***Mining:*** Mines produce waste that:

- can increase the amount of minerals and salts in the water (too much can cause health problems);
- can affect the pH of the water (whether it is acid, neutral or alkaline);
- can increase the murkiness of the water.

***Energy Use:*** As human populations increase, more energy is required for human activities such as cooking, lighting, etc. The majority of our energy in South Africa comes from the burning of coal at power stations and results in greatly increased emissions of sulphur and nitrogen oxides into the atmosphere. These gases are the main cause of acid rain. Also the release of carbon dioxide, from the burning of coal, increases global warming.

**Following are some facts on water pollution:**

- Seven billion Kgs of garbage, mostly plastic, is dumped into the ocean every year.
- The Ganges River in India is one the most polluted rivers in the world with sewage, trash, food, and animal remains.
- According to United States Environmental Protection Agency (U.S. EPA) estimates, 1.2 trillion gallons of untreated sewage, stormwater, and industrial waste is dumped into U.S. waters annually.
- About 700 million people globally drink contaminated water.
- Aquatic animals face an extinction rate of five times more than that of terrestrial animals.
- Over 30 billion tons of urban sewage is discharged into lakes, rivers and oceans every year.
- The massive oil spill that was caused by British Petroleum (BP) in the year 2010 caused over 1,000 animals to die. Many of them are in the endangered species list.
- According to UNICEF, more than 3,000 children die every day all over the world due to consumption of contaminated drinking water.
- Pollution is one of the biggest killers in the world, affecting over 100 million people.

- Lack of proper sanitation in water leads to diseases like cholera, malaria and diarrhoea.
- At least 320 million people in China do not have access to clean drinking water
- Non-point source pollution is often more difficult to control than point source pollution. In urban areas the provision of reticulated sewerage systems and adequate street cleaning are important measures, while in farming and forestry areas, soil conservation practices and the controlled application of pesticides and fertilisers are necessary if pollution of waterways is to be avoided.

## IMPACT OF ENVIRONMENTAL POLLUTION ON WATER SECURITY

The global concerns over the sustainability of freshwater resources - occasioning scarcities, limited access and uncertain provision - are a reflection of increasing competition for water and the higher risk this brings in the social structure of society especially in the livelihoods of poor. With increase in water scarcity competition intensifies and its value rises and conflicts arise regarding the allocation of water between different social groups, activities and sectors. The above discussion on the environmental pollution clearly states that the pollution has evolved as an integral part of each and every human activity and it seriously affect the various water resources leading to significant scarcity in water. When you consider the contribution of pollution to the global climate change and the impact on the hydrological cycle, the impact of environmental pollution becomes the hottest topic in water and energy security considerations.

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WWAP, *World Water Assessment Programme*. http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/

# Relevance of Climate Change Projection for India

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## INTRODUCTION

For a developing agrarian country like India facing hydrologic variability due to climate change will make water security difficult and costly to achieve. Climate change may also reintroduce water security challenges. In addition, some part of the country will have to cope with droughts and/or the growing risk of flooding.Thus, reliable projections of future climate change and possible changes in extreme weather events are crucial for agro-economic states of India.However, large uncertainty exists in projections of Asian monsoon precipitation. General Circulation Models (GCMs) often fail to capture the fine-scale structures that affect regional climate due to their coarse resolution. This aspect partially accounts for the deficiencies shown by GCMs in reproducing important aspects of the regional distribution of the Indian summer monsoon rainfall. In this study, a very high-resolution global climate model is used for climate change projection. This model was jointly developed by Japan Meteorological Agency (JMA) and Meteorological Research Institute (MRI), Japan (Mizuta et al., 2006; Kitoh et al., 2009). At the highest resolution, the model has an approximate grid size of 20-km and 60 layers in the vertical with the model top at 0.1 hPa. The simulation at this resolution is hereafter referred to as MRI-AGCM3.1S. The same model but with a different physical representation of deep convection is referred to as MRI-AGCM3.2S. The lower resolution (~60-km) versions of these two models are referred to as MRI-AGCM3.1H and MRI-AGCM3.2H respectively (Rajendran et al., 2013).

Three additional simulations of the model were performed at two lower resolutions of 120-km grid size (with 40 vertical layers) and 180-km grid size with 40 vertical layers, using the same boundary forcing (hereafter referred to as MRI-AGCM3.1H, MRI-AGCM3.1M and MRI-AGCM3.1L, respectively).

Two cases of 25-year simulations for the present-day (1979-2003) and future (2075-2099) corresponding to the IPCC Special Report on Emissions Scenarios (SRES) A1B scenarioare performed for each model configuration. For the present-day climate simulation (PDC), observed sea surface temperature (SST) and sea ice concentration (SIC) from the Hadley Centre HadISST (Rayner et al. 2003) data setfor 1979-2003 are prescribed. The SST and SIC boundary conditions for the projected future climate (PFC) time-slice experiment are estimatedusing the Coupled Model Inter- comparison Project phase 3 (CMIP3)multi-model SST data (Rajendran and Kitoh, 2008). Using the outputs of SST and SIC from different CMIP3 models, the estimation method uses a multi-model ensemble technique to incorporate the effects of future climate change along with realistic present-day interannual variability.

The validation data for the present-day rainfall simulations are taken from the daily India Meteorological Department (IMD) gridded rainfall data (Rajeevan et al. 2006) on $0.5^\circ \times 0.5^\circ$ grid for the period 1979-2007. For rainfall validation, we have also used the Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation (APHRODITE) precipitation data set (Yatagai et al. 2009) from 1951 to 2007 on $0.25^\circ \times 0.25^\circ$ grid.

**PRESENT-DAY CLIMATE**

Fig 1 reveals numerous regional details of the summer mean (June, July, August, September average, referred to as JJAS) rainfall over India based on two observations (APHRODITE and IMD rainfall for the period 1979-2003). The boundaries of six homogeneous regions of Indiaviz., Peninsular India (I), West Central India (II), Northwest India (III), Hilly Regions of India (IV), Central Northeast India (V), and Northeast India (VI) are also depicted. The major rainfall centres include meridionally oriented orographic maximum along the west coast of the Indian Peninsula, relative maxima over the central Indian region, parts of the Indo-Gangetic plain and the Northeast region.

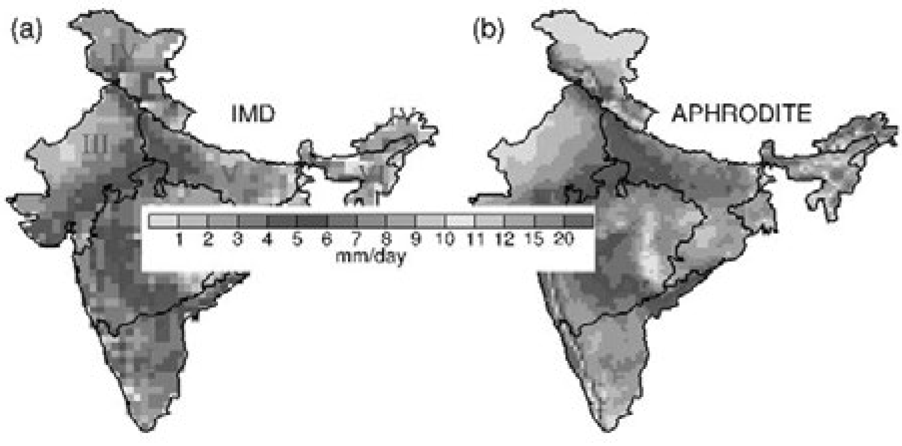


**Fig. 1**
**JJAS mean rainfall over India mm/day from IMD (a) and APHRODITE (b).**

The narrow west coast orographic region has two distinct topographical and climatic features: to the west lies a coastal plain with heavy rainfall (windward side) and to the east lies a plateau with less rainfall (leeward side). The moisture-laden monsoon winds cause heavy rainfall on the windward side of the range, distinguishing it from the much drier leeward side. Most of the west-coast rainfall occurs during June-September, there being comparatively less rainfall during the rest of the year. This illustrates the requirement for ultra high resolution in GCMs to provide important regional characteristics, especially in the context of orographic precipitation. There is a close comparison between the two data sets in representing the prominent features of summer mean rainfall and its spatial gradient over India.

The MRI-AGCM3.2S captures many aspects of the regional distribution of observed rainfall especially the rainfall over parts of core monsoon region of West Central and Central Northeast regions (Fig. 2). On the southeast part of the Peninsular India and Northwest India, precipitation is relatively weak as in observation. However, there is a slight rainfall underestimation over southeastern parts of Central Northeast India around West Bengal. In comparison, all lower resolution simulations fail to simulate the west coast orographic rainbelt and rainfall over Northeast India and Hilly Regions. In terms of intensity, location and extent of the major rainbelts and relative distribution of high and low rainfall, MRI-AGCM3.2S tends to give improved simulation (compared to the lower resolution simulation shown in Fig. 2b) especially over the west coast, and Northeast and Hilly Region of India. Regional details of rainfall over core monsoon zone are also closer to observation in MRI-AGCM3.2S.

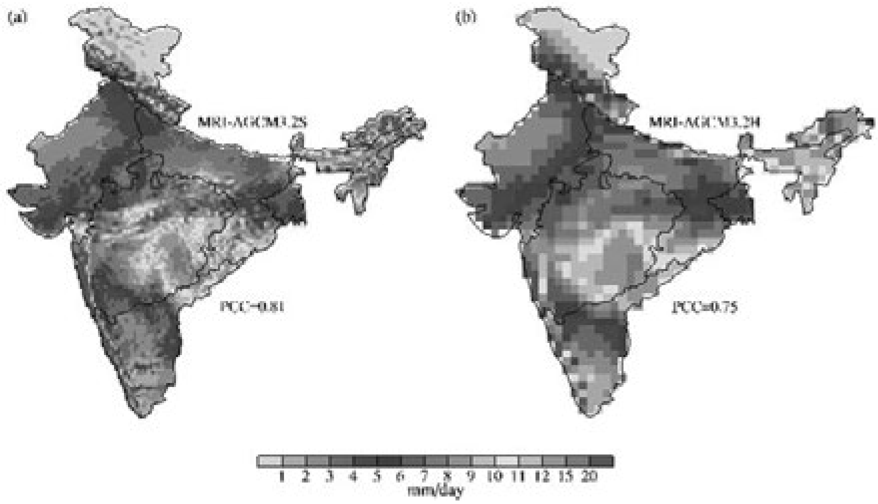


**Fig. 2**
**Same as Fig.1, but for PDC simulations of the MRI-AGCM3.2S (a) and MRI-AGCM3.2H (b).**

### Rainfall Seasonal Cycle over Homogeneous Regions

The primary manifestation of Indian monsoon, which is crucial for an accurate simulation of the mean monsoon and its variability, is the seasonal variation with distinct seasonality in precipitation (Gadgil and Sajani, 1998). Mean rainfall seasonal cycles for homogeneous regions of India from IMD observation and high resolution PDC simulations are shown in Fig. 3. Over all regions, except the Hilly Regions, there are marked seasonality in observed precipitation associated with the summer monsoon. The sudden enhancement in monthly precipitation associated with the onset phase, persistence of intense rainfall during June to September and the sharp reduction after the withdrawal in September are well manifested in observation and simulated by the models. The model shows reasonable skill in capturing the phases of rainfall annual variation with some quantitative differences. In some cases, simulations show a tendency for overestimating the mean rainfall and MRI-AGCM3.2S simulation is able to bring down this anomaly (e.g., Regions I, II and III).

Observed and simulated mean, standard deviation, and PCC (Inset Table in Fig. 3) for different regions show that over Peninsular India (Region I) and Northwest India (Region III), scheme makes the summer mean and variability of rainfall closer to observation. For West Central India (Region II), the new scheme improves the variability (with a slight overestimation in mean rainfall), but sensitivity to higher resolution appears to have contributed towards improved spatial distribution (higher PCC). For Regions V and VI, MRI-AGCM3.2S still has some deficiency as can be seen from the low PCCs for all the simulations. Over all, there are noticeable improvements in the simulation of mean, variability and annual variation of regional rainfall in MRI-AGCM3.2S.

## PROJECTED FUTURE CLIMATE CHANGE

At the end of the 21$^{st}$ century, the model predicts a significant increase in precipitation over most of the areas of the country where rainfall is rather strong during the monsoon season (Fig. 4). However, in the southern half of the west coast of the peninsula, parts of eastern India and the Jammu-Kashmir region, future decrease in rainfall has been projected (Rajendran et al. 2012). For example, the projections for the state of Kerala show reduction in future monsoon rainfall especially over the western coast. In addition, there is large spatial heterogeneity within the state. So far, IPCC future scenarios for the Indian summer monsoon rainfall even using high-resolution regional climate models have projected relatively uniform climate change over the whole country. But, the ultra-high resolution global model projected changes indicate an overall intensification of the all-India monsoon rainfall with strong regional modulations in the future, in response to the anticipated increase in concentration and resultant widespread warming of the surface temperature.

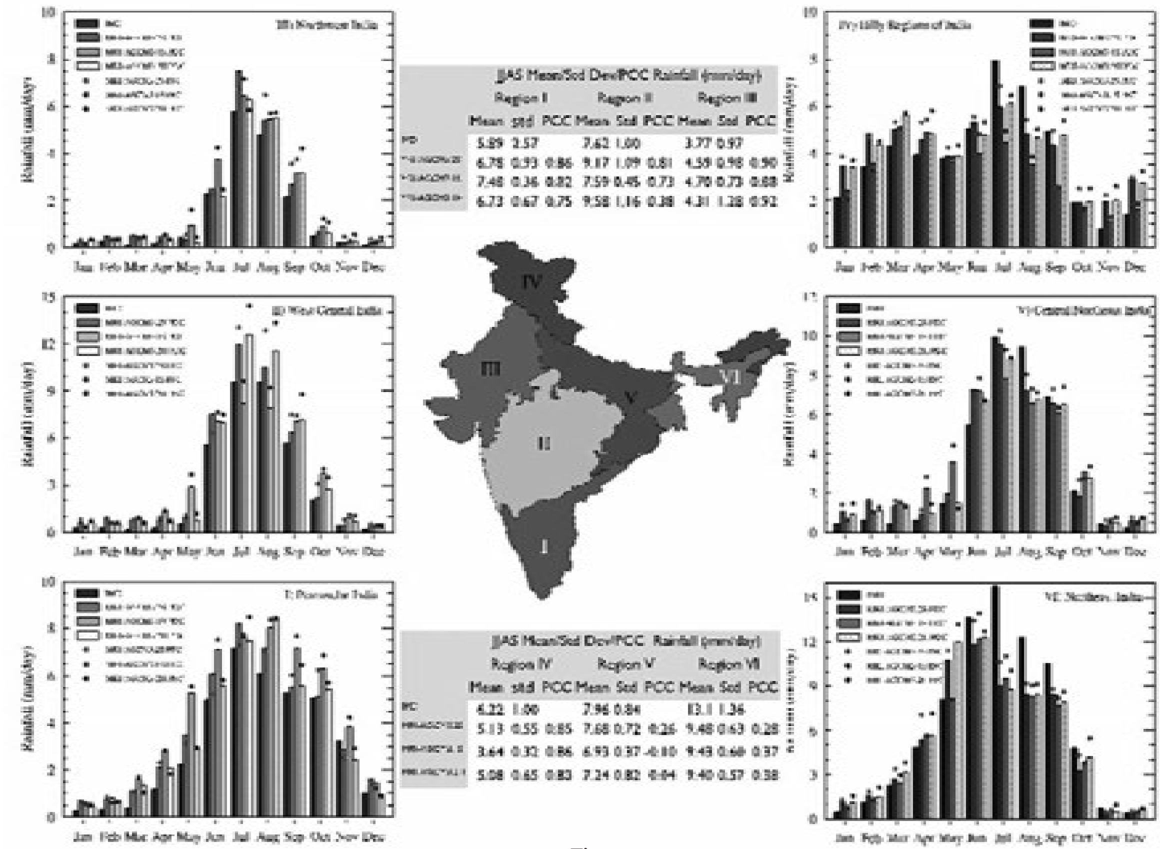


**Fig. 3**

**Observation and PDC and PFC simulations of MRI-AGCM3.2S, MRI-AGCM3.1S, and MRI-AGCM3.2H.** (Observed and simulated mean and standard deviation, and PCC for PDC simulations are given in tables)

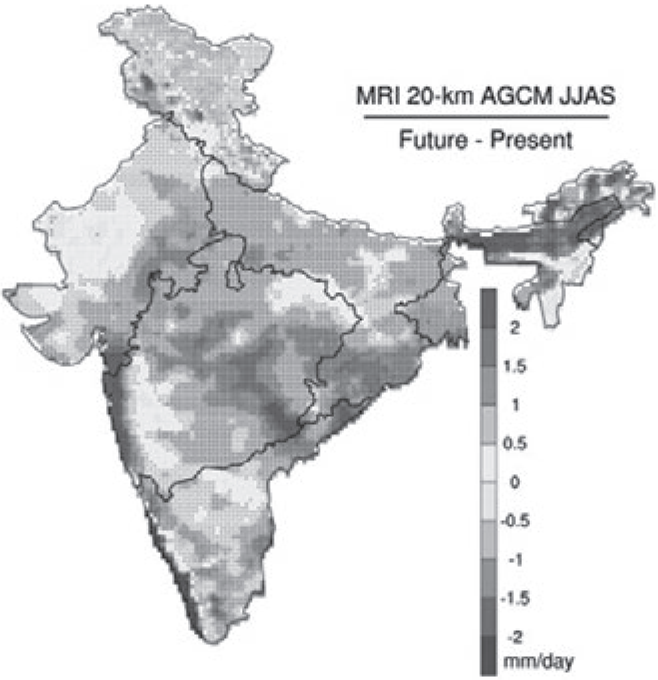


**Fig. 4**
**JJAS mean difference in rainfall between future projection and present-day simulation of the 20-km model (MRI-AGCM3.1S) over India.**

## Climate Change Impact on Extreme Events

We analyzed indices derived from daily maximum temperature and daily precipitation from MRI-AGCM3.2S, MRI-AGCM3.1S and MRI-AGCM3.2H, as recommended by World Meteorological Organization/World Climate Research Programme on Climate Variability and Predictability (WMO/WCRP CLIVAR) Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI)(Alexander et al. 2006) based on indices of occurrence of warm days (TX90p), very wet days (R95p) and extremely wet days (R99p). TX90p represents the warmest decile for maximum temperature and precipitation indices represent rainfall falling above the 95$^{th}$(R95p) and 99$^{th}$(R99p) percentiles, which includes the most extreme precipitation events.

## Warm Days and Hot Events

TX90p is defined as the number of days with maximum temperature above 90-percentile value estimated from a base period (PDC simulation). If $TX_{ij}$ is the daily maximum temperature on day i in period j and $TX_{in}90$ is the calendar day 90$^{th}$percentile centered on a 5-day window for the base period. The occurrence of warm days is determined where $TX_{ij} > TX_{in}90$. During the monsoon season, increase in hot events is not as strong as in March/April (not shown), due to the feedback of widespread increase in future rainfall. Projections indicate that during

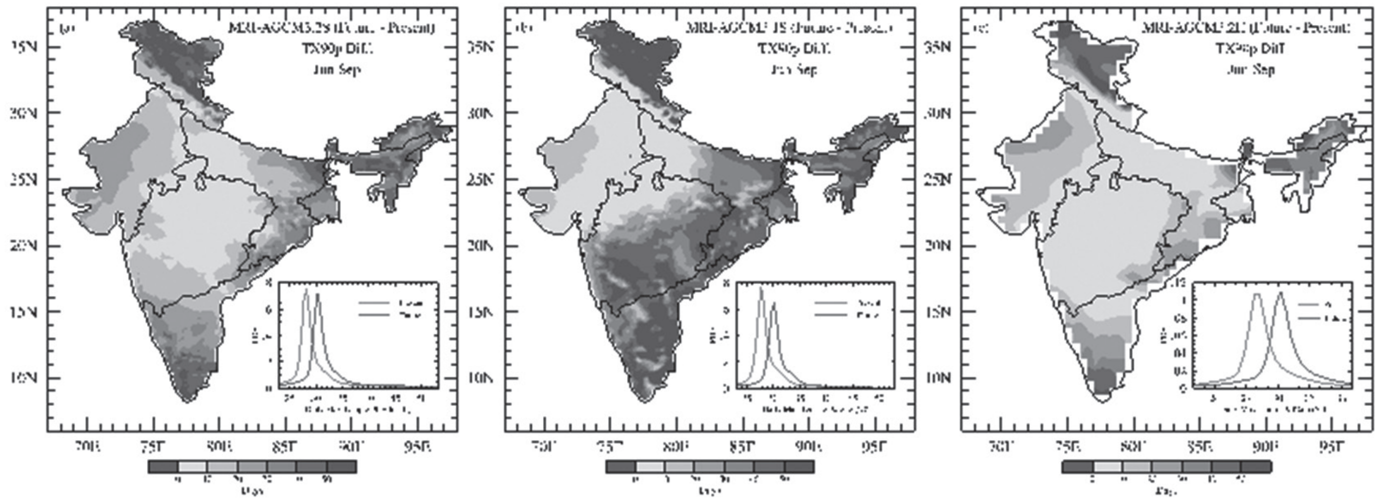


**Fig. 5**

**Future changes in number of days in JJAS with daily maximum temperature greater than 90 percentile, between PFC and PDC simulations of MRI-AGCM3.2S, MRI-AGCM3.1S and MRI-AGCM3.2H. In inset: probability density functions (PDFs) of daily maximum temperature above 90 percentile in JJAS.**

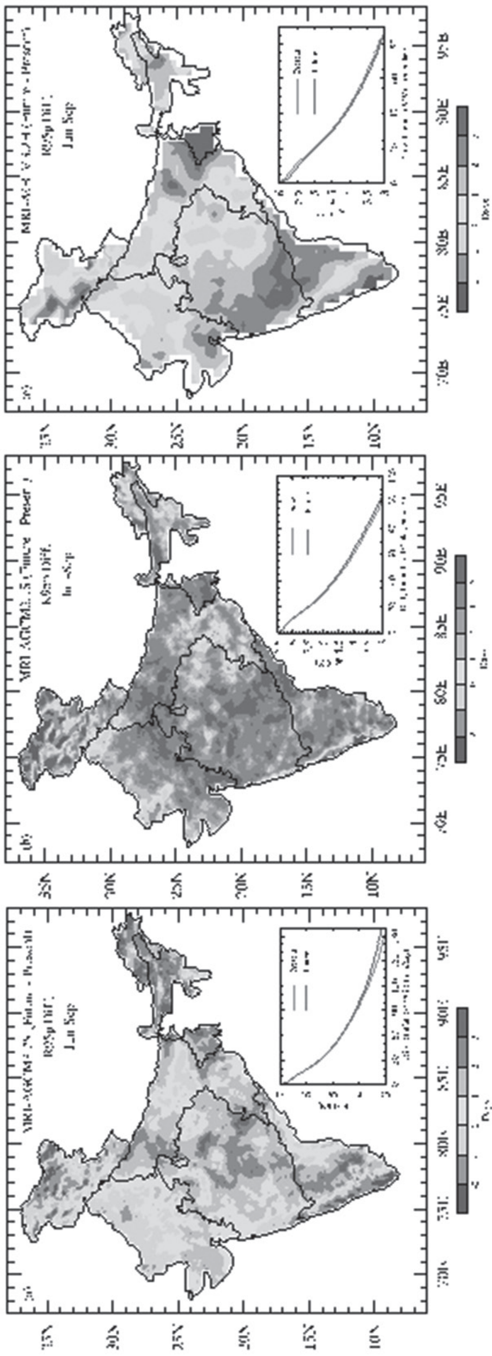

**Fig. 6**

**Changes in number of days in JJAS with precipitation greater than 95 percentile between PFC and PDC simulations of MRI-AGCM3.2S, MRI-AGCM3.1S and MRI-AGCM3.2H.**

**Inset: Frequency distribution of daily mean precipitation above 95 percentile in JJAS.**

monsoon (JJAS), the number of warm days and extreme hot-events (TX90p) will be increased in future (Fig. 5) over the entire country. As seen in the case of the annual cycle of monthly mean temperature, in the end of the 21$^{st}$century, simulations also predict an increase of maximum temperature (TXx) throughout the year (not shown). Figure 5 also shows the probability density functions (PDFs) for the daily maximum temperature above 90 percentile for JJAS season. PDFs were produced by binning daily maximum temperature above the threshold of 90-percentile, during JJAS of the whole period. The mean and standard deviation of PDC PDF is different from those of PFC simulation, indicating a clear shift towards warmer conditions at the end of the century. Differences between the distributions for the occurrence of warm days in the present day climate (PDC) and future warming climate (PFC) suggest that there will be warming of extreme maximum temperatures in future. The pattern of number of warm days with temperatures greater than 90 percentile in JJAS, appears to have been caused in part by the summer surface-moisture-precipitation feedback in the time-slice experiment.

### Rainfall Extremes

The patterns of changes in number of extreme precipitation events (R95p, Fig. 6) correspond well to those of seasonal mean precipitation, especially for peaks in frequency over West Central India and Central Northeast, and reduction over the west coast and parts of Northwest India and Jammu-Kashmir. The patterns suggest a weakening of the west coast orographic rain, due in part to the changes in the extreme precipitation regime. In contrast, over West Central India and Central Northeast India, positive changes in seasonal mean precipitation were associated with positive changes in the frequency of extreme rainy days. For very heavy precipitation, many coastal areas except the west coast, exhibits substantial increase in occurrence, with peak positive changes over northern parts of the west coast around Bombay and east coast. Frequency distributions of daily rainfall above 95 percentile from PDC and PFC simulations are also shown in Fig. 6 (inset). Intensification of extreme rainfall events (R99p) also occurs in projected future climate (not shown).

## ACKNOWLEDGEMENTS

The authors thank Prof. J Srinivasan for the inspiration to analyze different climate change scenarios and derive projection with some confidence. Research grants from Department of Environment and Climate Change, Government of Kerala (R-1-166) and collaborative research project with MRI and DCCC (R-8-118) are acknowledged. AK is thankful to KAKUSHIN and SOUSEI Programs for supporting collaborations for climate change studies. The authors acknowledge the help of Dr. R Mizuta of MRI.

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# Water and Energy Conservation, Auditing and Management

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## INTRODUCTION

Techniques for efficient use and conservation of energy and water, applicable to various equipments, systems, process and socio-economic sectors are reasonably known to majority of practising professionals. Manuals, technical literature and studies on methods such as energy and water audits, operation and maintenance practices for identifying and implementing the conservation opportunities, emerging technologies and management aspects are available in the publications of Government and Non Government agencies engaged in such services and in the brochures of Original Equipment Manufacturers (OEMs) or industrial process vendors and in research publications.

In this article efficient use of energy and water is discussed from the perspective of several international organisations with an intention that readers may be able to revisit the policies, programmes and projects being rolled out for further improvisations and convergence.

## WATER CONSERVATION AND WATER USE EFFICIENCY

United State Environmental Protection Agency states that: “Earth may be known as the “water planet”, but even though about 70% of its surface is covered by water, less than 1% is available for human use. Water supplies are finite and it is important to protect this critical and precious resource”.

Public water systems face a number of challenges including aging infrastructure, water quantity and quality concerns and inadequate resources. These challenges may be magnified by changes in population, local climate, and ground water and river water depletion.

Water scarcity and distribution related issues necessitate rational use of water. Lowering of water by end-users leads to clean water for future generations, reduction in the energy required for water and wastewater services and decrease in the need and expense for water infrastructure.

Meeting the recurring drought condition calls for important information about the drought, conservation, watering restrictions and measures to protect and sustain much needed water supply and resources.

Water supply is also a very energy intensive system as water move through many process and steps before it reaches customers' taps, public water supply including treatment and sewer treatment and disposal.

**Water use Efficiency versus Water Conservation**

"Water efficiency" means using improved technologies and practices that deliver equal or better service with less water. Leak detection programs, especially in large plants and public water supply network, large campus etc. can reduce the amount of water, pressure, and energy required to deliver the same amount of water to consumers' taps.

"Water conservation" has been associated with curtailment of water use and doing "less" with less water, typically during a water shortage, such as a drought; for example, minimizing lawn watering in order to conserve water.

Improving water efficiency reduces operating costs viz., pumping and treatment, and reduces the need to develop new supplies and expand our water infrastructure. It also reduces withdrawals from limited freshwater supplies, leaving more water for future use and improving the ambient water quality and aquatic habitat.

More and more utilities are using water efficiency and consumer conservation programs to increase the sustainability of their supplies. Case studies demonstrate substantial opportunities to improve efficiency through supply-side practices, such as accurate meter reading and leak detection and repair programs, demand-side strategies and conservation-based water rates (tariff) and public education programs.

One of the important Supply-side Strategies for Water Suppliers is accounting for water. Metering helps to identify losses due to leakage and provides the foundation to build an equitable rate structure to ensure adequate revenue to operate the system. Water Loss Control is a very important strategy as various studies indicate that, on average, 10 % to 60% percent of the water treated is lost to leaks. Accounting for water and minimizing water loss are critical functions for any water utility that wants to be sustainable.

**Water audits**

Water audits analyze a facility's water use and identify ways to make it more efficient. Audits are applicable to domestic, sanitary, landscaping, and water use for industrial process, water use for power plants to identify ways to increase a facility's water-use efficiency and to reduce water use intensity.

Detailed water balance audit typically traces the flow of water from the site of water withdrawal or treatment, through the water distribution system, and into customer properties and end-use applications.

Thermal power plants are one of the major consumers for water as shown in Table 1.

**Table 1**
**Water withdrawn and consumed for power plant cooling**
(in gallons of water required per megawatt-hour of electricity produced)

| | Once-Through | | Recirculating | | Dry-Cooling | |
|---|---|---|---|---|---|---|
| | Withdrawal | Con-sumption | With-drawal | Consump-tion | With-drawal | Consump-tion |
| **Coal** (Conventional) | 25,000 -50,000 | 100 - 317 | 500 - 1,200 | 480 – 1,100 | N/A | N/A |
| **Natural Gas** Combined Cycle | 7,500 - 20,000 | 20 - 100 | 150 - 283 | 130 - 300 | 0 - 4 | 0 - 4 |
| **Nuclear** | 25,000 -60,000 | 100 - 400 | 800 - 2,600 | 600 - 800 | N/A | N/A |
| **Solar Thermal** (trough) | N/A | N/A | 725 - 1,109 | 725 – 1,109 | 43 - 79 | 43 - 79 |

Source: Macknick et.al (2012)

### WaterSense” labelled products

“WaterSense” labelled products is a programme designed by US Environmental Protection Agency (EPA). “WaterSense” helps people save water with a product label and tips for saving water. Products carrying the “WaterSense” label perform well, help save money, and encourage innovation in manufacturing. “WaterSense” also partners with irrigation professionals and irrigation certification programs to promote water-efficient landscape irrigation practices. Similar water efficiency labelled or categorised fixtures and appliances schemes are in operation in several other countries as well.

### Major points for identifying and implementing water use

The major points for identifying and implementing water use efficiency comprises of:

- Water intake and treatment and pumping system efficiency
- Leaks, Repairs and Water loss minimisation
- Efficient Fixtures and Appliances
- Sector specific approach for water use efficiency: Domestic, Business, Commercial, Industrial, Transport, Agriculture, Irrigation, Swimming pools etc.
- Efficient landscaping, Xeriscape
- Gray Water utilisation, Maximise recycling and re-use, Zero discharge

### GLOBAL PROGRAMMES ON WATER CONSERVATION

Many countries, especially several States in USA has following programmes for water conservation:

i. The Leak Notification and Management Program: Proactively alert customers to potential water leaks on their property.

ii. Continuous survey and state of art repair/replacement strategy
iii. Free water saving kits to consumers
iv. Comprehensive Water Reuse Program (CWRP): Provides for a discounted water and sewer rate for “black water” or “grey water” recycling system and for meeting fixture and appliance efficiency standard compliance.
v. Automated Meter Reading
vi. Water Loss Audit and Water balance study
viii. Water use rules and regulations
viii. Draught and water scarcity management programmes
ix. Water conservations manuals and awareness and capacity building programmes
x. Guidance and Methodology for Reporting on Water Conservation and Water Use
xi. Codes and Standards - Statutory directives

As per International Finance Corporation, which is the private sector lending arm of the World Bank group, Water and sanitation infrastructure would require $12 trillion in global investment by 2030

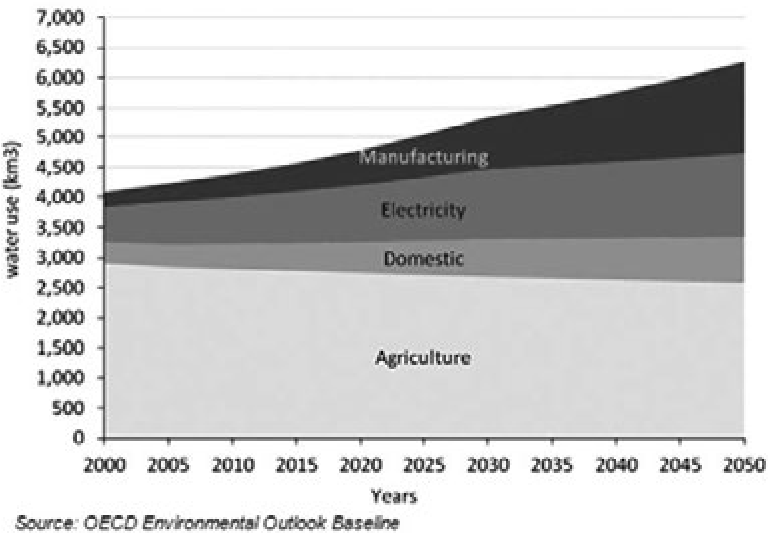


**Fig.1**
**World Water Use by sector**

One of the important UN Report states that without efficiency gains, global demand for water will outstrip currently accessible supplies by 40 per cent by 2030 (The 2030 Water Resources Group, 2009). Historical levels of improvement in water productivity as well as increases in supply are expected to address 40% of this gap, but the remaining 60% need to come from investment in infrastructure, water-policy reform and in the development of new technology (UNEP, 2011).

Today, energy uses about 8% of all freshwater withdrawn worldwide and as much as 40% of freshwater withdrawn in some developed countries (World Economic Forum, 2011). Energy demand on present trends will increase by one-third from 2010 to 2035, with 90% happening in non-OECD countries (IEA, 2012). Water needs for energy production are set to grow at twice the rate of energy demand (IEA, 2012; National Geographic, 2013).

## ENERGY CONSERVATION AND ENERGY EFFICIENCY

Energy conservation and Energy Efficiency are often used interchangeably. Energy conservation means using less energy and is usually a behavioural change, like turning the lights off when the room is unoccupied, setting the thermostat lower or not leaving appliances on standby. Conservation certainly reduces energy use, but its impact on comfort, safety or productivity shall be factored into.

Energy efficiency means using energy more effectively which is mostly a technological change. Efficiency maintains the same level of output (e.g. light level, temperature, ventilation, air quality) but uses less energy to achieve it. But the level of output is rationalised in quantifiable terms based on acceptable standards and/or by instrumented trails, experiments and tests. For example: the lighting level required, boiler efficiency test. Efficient use of energy includes advanced controls and instrumentation, cogeneration, tri-generation, retrofits and replacements for enhancing energy efficiency and recovery from waste energy for productive application such as waste heat recovery for preheating the charge/material, air or water.

Energy rationing is designed to force energy conservation as an alternative to price mechanisms in energy markets. Because of its economic consequences energy rationing is used as method of last resort, often at times of emergency such as an energy crisis. “Load shedding” is a common form of energy rationing used when electricity markets cannot keep up to demand, particularly peak demand. Tradable “energy quotas” is an energy rationing system designed to enable nations to reduce their emissions of greenhouse gases along with their use of oil, gas and coal, and to ensure fair access to energy for all.

Broadly, Energy Conservation can be defined as reduction in the amount of energy consumed in an equipment, process, system, or by an organization or society, through economy, elimination of waste, and rational use. The objective of conservation encompass energy security, energy import bill minimisation, demand-supply balance, mitigation of green house gas emission and other environmental impacts, energy intensity reduction, productivity improvements and absolute reduction in energy bills.

### Norms and Indices

Energy efficiency may be viewed as a change in the level of “net benefits (useful output) per unit of energy input”. Net benefits are linked to a diverse range of areas, including economic growth, more comfortable living, quality time and working lifestyles, higher level food processing, energy security, health and environmental outcomes.

Normative indices for internal benchmarking for monitoring and verification, such as Specific Energy Consumption and Energy Efficiency Ratios are practised with well laid protocols and procedures. Examples include energy per square metre of floor area in the building sector, energy used per tonne of production in industry and energy used per tonne-km (or passenger-km) in transport. At macroeconomic level indicative index could be the effect on energy, viz., the energy: GDP ratio of a changing socio-economic structure. Rather than unequivocal quantitative measure of energy efficiency, a suite of indicators relevant to the specific context is derived.

**Energy Audit**

The Energy Conservation Act, 2001 of India define Energy Audit as : "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption"

Energy audit has begun to play a more significant role in managing energy. Energy Audit is an effective technique to identify and implement energy conservation opportunities and benchmarking energy use efficiency in any facility. Energy audits can encompass a variety of surveying and critical observations, instrumented trials and tests, engineering and statistical computations, in consultation with standards and reference materials for detailed analysis of energy usage within a building or facility and its equipment, system and process.

Detailed energy audit of process plants and unit operations can employ mass and energy balances, which is very important and fundamental for the process control and for optimising energy consumption. The increasing availability of on-line data with advanced instrumentation and power of computers enable execution of very complex mass and energy balances for process management to maximise product yields and to optimise energy consumption.

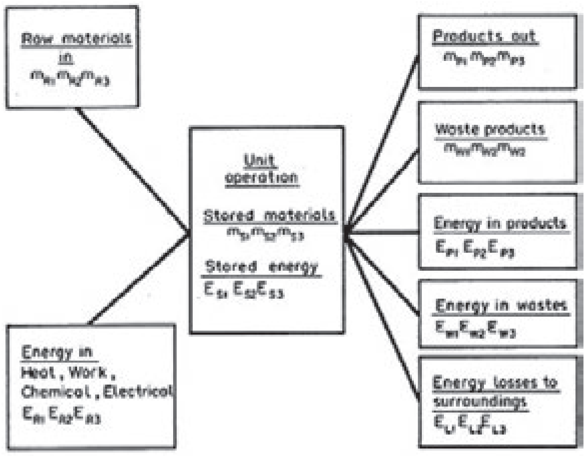


**Fig. 2**
**Mass and energy balance**

Several organisations and Government Departments such as Department of Energy (DoE), UK National Standards Body (BSI) etc. has published Energy Audit Manuals, Guidebooks and Handbooks. For example: BS EN 16247-1 - Energy Audits - has been developed with input from energy experts including members of the Energy Institute, Institute of Chemical Engineers, and Energy Services and Technology Association (ESTA). This standard was created in response to the 2006 European Union (EU) directive on energy end-use efficiency and energy services. The internationally recognised energy management system standard, ISO 50001:2011 identifies the need for clear energy auditing.

Energy audit typically begins with a review of historical and current data pertaining to purchased energy Vis-à-Vis activity or output of the facility and benchmarking energy use. This sets the stage for an onsite inspection of the energy use practises followed by critical observations and instrumented tests and trials. The main outcome of an energy audit is a list of recommended energy efficiency measures (EEMs), with their associated energy savings potential and an assessment of their detailed techno-economics and cost – benefit

**ISO 50001:2011 – Energy Management System**

ISO 50001 is based on the management system model of continual improvement. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management. ISO 50001:2011 provides a framework of requirements for organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the policy works, and
- Continually improve energy management.

**Overview of some country specifics points on Energy Efficiency**

In USA, twenty-five states have enacted long-term (3+ years) binding energy savings targets or energy efficiency resource standards (EERS). These 25 states make up nearly 60% of electricity sales in the United States. If each of these states maintains its current EERS target out to 2020, the total annual savings would be equivalent to over 6% of projected nationwide energy sales of 2020, or the combined electricity consumption of Ohio, Minnesota, and Rhode Island.

Thailand has been able to transition smoothly from readiness activities such as capacity building, awareness raising and demonstration to large-scale investments. It is now embarking on a 20-year energy efficiency development plan funded through the Energy Conservation Promotion Fund, which aims to reduce the country's overall energy consumption by 20 percent by 2030.

The European Commission directive 2012/27/EU on energy efficiency established a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020, 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date. All EU-28 countries are thus required to use energy more efficiently at all stages of the energy chain – from the transformation of energy and its distribution to its final consumption.

China has a long term target to reduce the carbon intensity of the economy by 40-45% from 2005 levels by 2020. China also has binding targets to reduce energy intensity by 16% from 2010 levels by 2015 and carbon intensity by 17% from 2010 levels by 2015. China has a target to reduce coal consumption as a percentage of primary energy to below 65% by 2017.

Government of Australia encourages large energy-using businesses to improve their energy efficiency by requiring businesses to identify, evaluate and report cost effective energy savings opportunities. The Government also supports the establishment of standards, programs and innovative practices to improve energy efficiency and provides Australian households and businesses with economical solutions to live and work more sustainably.

## Energy efficiency markets and investments

Energy efficiency markets deliver goods and services that reduce the energy required to fuel our economies. The International Energy Agency (IEA) estimates that investment in key energy efficiency markets worldwide totalled up to USD 300 billion in 2011. This is a conservative estimate based on an assessment of direct and leveraged investment in identifiable energy efficiency initiatives by the public sector, multilateral finance institutions and major private institutions. In 2011, total investment in energy efficiency was similar in magnitude to supply-side investment in renewable or fossil fuel electricity generation. However, investment in energy efficiency is still less than two-thirds of the level of fossil fuel subsidies. Investment in energy efficiency is distributed unevenly across countries and energy-consuming sectors (buildings, domestic appliances, transport and industry).

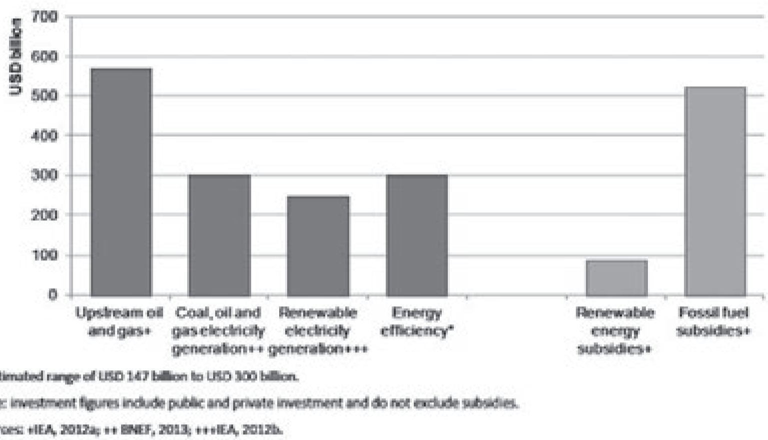


**Fig. 3**
**Global levels of investment and subsidy in selected areas, 2011**

International Energy Agency states that Energy efficiency investments made since 1974 have had a major cumulative impact on annual energy use, resulting in avoided energy consumption of 63 exajoules (EJ) (1.52 billion tonnes of oil-equivalent) in these 11 IEA member countries in 2010 . This amount was larger than the consumption of oil (43 EJ), electricity or natural gas (22 EJ each) in these countries in 2010 alone. This reflects an increase in energy efficiency investments over several decades, and the continued delivery of energy savings from these investments, net of any rebound effect. The size and duration of energy savings are affected by various factors, including the lifetime of the investment, and the extent to which disposable income generated from avoided energy consumption is spent on additional energy services (the rebound effect).

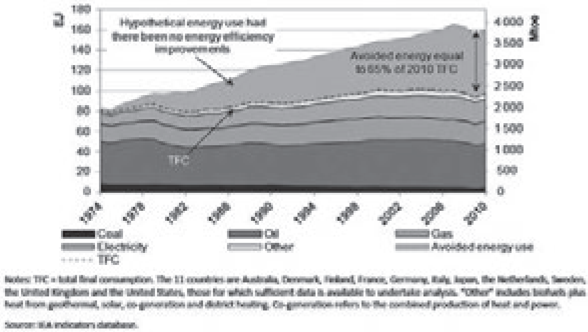


**Fig. 4**
**Avoided energy use from energy efficiency in 11 IEA member countries**

As per the analysis of International Energy Agency, 15 IEA member countries reveals the important role that energy efficiency has played in reducing energy intensity over the past two decades , alongside structural developments in their economies, and how this has allowed these countries to generate more GDP for each unit of energy consumed.

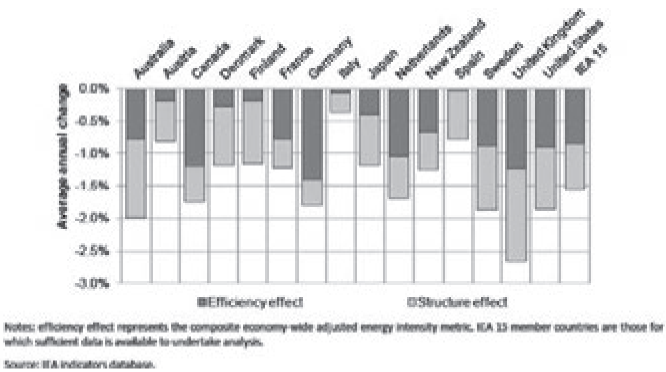


**Fig.5**
**Change in aggregate intensity, decomposed into structure and efficiency effects, 1990-2010**

**CONCLUSION**

Energy and Water use Efficiency and Conservation contribute to the sustainable development objectives. "Sustainability," in reference to energy and environmental activities, is defined as "provisions that meet the needs of the present without compromising the ability of future generations to meet their needs". (Brundtland Report, 1987). Sustainable energy sources are most often identified with renewable energies, such as hydroelectric, solar, wind, geothermal, biomass, and tidal, as well as technologies that improve energy efficiency.

It is emphasised that maximising the end-use efficiency of energy using equipment, systems and/or process form prerequisite for any renewable energy application. Development of appropriate sustainability index and sustainability auditing is strongly linked with efficient use of energy and water.

For systematic approach, the following points may be integrated in designing the policies and programmes:

i. Tracking the development of energy efficiency

ii. Identify the drivers for and response to energy efficiency changes

iii. Monitor the progress towards the targets and goals in the strategy.

The rebound effect of efficiency enhancement and conservation measures is an area of debate. The 'rebound' effect is that the implementation of an energy saving measure releases resources but in medium to long term this may result increase in consumption. For example: since fuel-efficient vehicles make travel cheaper, consumers may choose to buy more such cars or drive further and/or more often, thereby offsetting some of the energy savings achieved.

In a world where demand for water is on the road to outstripping supply, many companies and habitats are struggling to find the water they need to run their businesses. Rising global population and growing economies are placing higher demands on already-depleted water supplies. Agricultural runoff and other forms of pollution are exacerbating the scarcity of water that is clean enough for human and industrial use in some regions, and changes in climate may worsen the problem. Scarcity is raising prices and increasing the level of regulation and competition among stakeholders for access to water. As the world's forests and grasslands are degraded or removed, the threats to our water supplies grow. The roots of trees and other native vegetation filter water, prevent erosion and slow water down, helping keep flow levels steady. Without this protective system, lakes and rivers are exposed to soil run-off, chemicals and other debris carried across the land by rain and snowmelt. To continue operating, efficient and effective rational use of water and maintaining the water resources in most sectors is essential.

Thus, the Energy and Water management calls for continuous upgrading of the technical and management skills required for:

i. identifying and managing opportunities in the energy and water sector in the sustainable global environment.

ii. capacity building including focussed research and development in energy, water and environmental management sectors

iii. acquiring and development of advanced effective tools required to synthesise strategies/ solutions to energy and environmental problems.

iv. developing a critical understanding of the complex environment and ability to integrate various multi-disciplinary components to reach conclusions in holistic problems of sustainable energy generation and utilisation and water cycle management.

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# Integrated Policy Framework on Water and Energy Resources for the State of Kerala: An Approach Paper

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## INTRODUCTION

Responsibility and duty to protect life and ensure livelihood to individual citizen is vested with the States under rule of law. The new generation rights concept is an extension of this basic notion and hence right to clean air, drinking water, clean and healthy environment, shelter, nutritious food etc. became essential rights of individual under this concern[1]. The constitutional mandate as the State to raise the standard of living and to improve public health is envisaged as a directive[2]. In addition to this, the State shall endeavor to protect and improve environment and to safeguard forest and wild life[3]. The power, responsibility and functions of the state to frame policies, to legislate laws, to take decisions, and to implement those measures for the protection and enjoyment of such resources are inevitable part of rule of law in the country.

Environment resources, including soil, water, forest and other such materials are to be treated as community property. The government is to be considered as the trustee of those community property. Authorities and designated individuals, as part of the government, have a duty to serve as the trustee or manger of community property[4].They have a function to maintain, manage and utilize such properties for the common benefit of the community at large. While doing so they are bound to provide maximum care and caution in the responsive function. Those who violate such precautionary duty or responsibility shall be made liable to pay compensation, to remedy the damage or injury sustained, to be accountable with respect to the act or omission alleged upon them[5]. On the strong foundation of 4 P ideology – Public Trust Doctrine, Precautionary Principle, Polluter Pays Principle, Public Accountability

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[1]*Article 21 of the Constitution of India 1950*

[2]*Article 47 of the Constitution of India 1950*

[3]*Article 49 A of the Constitution of India 1950*

[4]*M C Mehta v. Kamalnath (1997)1 SCC 388*

[5]*Vellore Citizen Welfare Forum v. Union of India (1996) 5 Sec 47*

Principle, the modern environment management policy and sustainable development policy is doing well in making of the law [6].

When the court is called upon to give effect to the Directive Principle and the Fundamental Duty, the court is not strong in its shoulders and says that priorities are a matter of policy and so it is a matter for the policy - making authority. The least that the court may do is to examine whether appropriate consideration are born in mind and irrelevancies excluded. In appropriate cases, the court may go further, but how much further will depend on the circumstances of the case. Hence policy making, law making and their enforcement become the essential functions of the state under the rule of law, and which will be examined by the supreme judiciary as well as the people at large through the socio-political auditing. So the analysis of water and energy policy making and legislation in that respect is highly relevant for the time being.

**WATER POLICY ANALYSIS**

As a scarce natural resource, water is fundamental to the life, livelihood, food security and sustainable development. But India has very limited source of utilizable quantity of water, with uneven distribution over time and space. Water mismanagement, wastage, inefficient use, and pollution of water sources, low availability of utilizable water and increasing need of water quantity etc causes and deeps the water conflicts among the people. In cognizance of all such factors, the National Policy on Water Resources was proposed during 2012. Its aim is to frame adequate legislation, create the system of laws, establish institute for implementation of policy framework etc. But it is only a unified national perspective document. Its practicability depends on numerous factors in the national and local policy.

Relevant considerations for the National Water Policy 2012 are the following;

i. Water Security
ii. Water Governance
iii. Sustainable availability of water
iv. Ground water issues
v. Access to safe water for drinking and domestic purpose
vi. Community Water Resources
vii Multi disciplinary water resources project
viii. Inter-Regional, Inter-State, Intra- State, Inter-Sectoral Water Stakeholds
ix. Maintenance of existing infrastructure, construction of drainage and water flow system.
x. Sanitation and hygiene
xi. Public consciousness
xii. Scientific training and planning
xiii. Holistic – Inter disciplinary approach
xiv. Effective consultation with stakeholders by decision making
xv. Characteristics of catchments and consequent impact of human interventions.

[6]*M.C. Mehta v. Union of India (1997) 3 SCC 715*

Let us examine the basic principles on which the national water policy is derived and formulated, as enumerated as follows;

- Human, social and economic need based planning, development and management of water resources
- Equity and social justice in allocation and use of water
- Good governance, transparency, participation, accountability in decision making
- Common pool community resource under public trust doctrine.
- Due consideration to ecological needs
- Pre-emptive need of drinking and domestic purpose
- Enhancing availability of utilizable water.
- Water Management on the basis of climatic changes

Ideological base of the policy faces the paradox in its implementation process. Ultimately the process ends in water pricing and economic regulation on water utility. Volumetric basis determination of water price to meet equity, efficiency and economic principle is suggested here. Principle of differential pricing for recycling and reuse of water, overdrawal of ground water, extraction of surface water etc. also proposed by this policy. There by the essential natural resources, water, also becomes a consumable, marketable and price able product for the neo-liberal economic system in our era.

Regarding conservation, protection and improvements of river corridors water bodies and water infrastructure there is no specific proposal placed by the national policy. Scientific planning, public participation, quality conservation infrastructure etc. are suggested by the policy. But no effective implementation measure is proposed by the policy makers in this highly complex and conflicting sector .Without financial and manpower resources this real enforcement of the policy becomes futile.

Regarding all components of water resource projects the policy statement conceive a *pari passu* manner treated and intends an immediate accrual of benefit without any gap between potential created and potential utilized. This proposal intents to change the policy towards the expenditure and returns from water projects. There we can assure the withdrawal of the government and induction of profit motive institutions in this field.

Land, soil, energy and water management with scientific inputs from local, research and scientific institutions has been prescribed by the national policy so as to evolve different agricultural strategies and improve soil and water productivity. Here the policy makers seek to increase productivity but not to strengthen conservation. That itself denote the change in the policy outlook. At the same time the policy provisions are silent about the present intentional attack on soil and water resources for private profit collection. The policy never proposes any legal measure to curb those commissions or omissions which derails the environment concern in natural resources utility. A minority population holds on maximum enjoyment of such resources and majority loses their right to choice right to development and right to development. Effective policy measure and legal instrumentalities are essential in this regard.

Certain ideal mechanisms are incorporated in the national water policy regarding urban and rural drinking water supply service. Preparation and publication of water accounts, conduct of water audit, techno-economic feasibility assurance, integrated effluent or sewage treatment and enforcement of water quality cess as well as sewerage charges are also proposed by the policy. Water withdrawal only with return of treated effluent is also mentioned here. But without public investment and governmental funding how these measures can be implemented? What shall be the institutional mechanism for realizing all those functions? Rationalization in incentive and subsidy measures, how it can be materialized? Such questions are not at all answered by the national water policy.

Regarding institutional arrangement for water policy implementation a forum at National level to deliberate water related issues, in order to evolve consensus, co-operative, reconciliation decision on such issues, has been proposed by the national policy framework. In such a sector with micro and macro differences the extent of such a forum is doubtful. Yet another suggestion is the establishment of Central Water Disputed Tribunal to resolve disputes on water in equitable manner. Where as it is highly suspicious, the end result from the function of a Tribunal within the existing judicial frame work of the country. Ultimately delay, repetition, cost hike, complexity etc. in the procedure will jeopardize the remedial measures and the access to justice may be restricted here. In addition to that integrated water resources management mechanism with river basin or sub-basin unit approach, especially in the case of transboundary Rivers and disputed water resources, will not be fruitful in the present social system of the nation. Even in the case of intra water resource disputes, adjudicatory process never works with adequate efficacy and efficiency.

Finally, the policy document suggests for National Water Board for action plan preparation on the policy and which shall be approved by the National Water Resources Council. Here is the presence of another conflicting issue, that is regarding the equity, legality and representative character of such national institutions, justice administration within and among the interested parties can be observed. But such authorities further adjudication possibilities etc are debatable points. Adequate redrafting and reforms in the State water policy according to the concern of the proposed national policy is also suggested. Including Kerala, the States are not keen on such revision or revisit to water policy due to their political and administrative constrains. This will provide much scope and role to the pressure groups to uphold their vested motives.

Thorough examinations of the existing laws, institutions and functionaries, established in the State of Kerala, will provide amble evidences for the said conclusion. A department oriented, bureaucratic, anti people and unenforceable legislative, administrative and judicial conformation will not work in such a hot issue, water policy implementation. Hence effective consultation with stakeholders, grass root level participation of general public, lead role of local government institutions, constructive reorganization of water basin oriented institutional mechanism etc. shall lead us to a favourable result.

## ENERGY POLICY TODAY AND TOMORROW

The Integrated energy policy – 2003 denotes that, we are energy secure when we can supply life line energy to all our citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected. Certain key words are there in this statement, such as

- Life line energy to all citizens
- Safe and convenient energy
- Competitive prices
- Reasonable disruptions and shocks

Availability and access to clean, efficient and sustainable energy sources I the basic concern on the challenge and confronting goal to address poverty in the State. Energy as a critical and key driving element of development can stimulate economic, social land physical development, critical improvement of social life, upliftment of individual status. Apart from other natural resources, energy is a cross cutting input that facilitate effective and efficient service delivery in other basic amenities. Higher need and lower purchasing power is the paradox in shifting from less efficient fuel or energy mix towards high efficiency commercial fuel and energy resources. The national energy policy never incorporated any practical solution to address this shift and its impacts.

UN itself has declared 2012 as energy year and proposed to bring out all possible efforts together in all sectors of the social so as to succeed the energy objectives for 2030, including

- Ensure universal access to modern energy services
- Double the global rate of improvement in energy efficiency
- Double the share of renewable energy in the global energy mix

According to International Energy Agency (IEA), status report 95% of people in developing countries who live without access to clean energy resources 84% out of that who live in rural area. To overcome the issues related to the denial of such energy resources, the national government as well international community shall take concerted action and efforts. In India percapita electricity consumption is of around 7 34 kwh, which is very low compared to the global average of 2,782 and China average 2471 kwh. In India 67% of population depends on solid fuels such as firewood, cow dung, biomass etc. Use of cleaner energy resources is co-related with income levels and affordability factors.

Energy security at the household level, ensure assured supply of clean energy fuels at an affordable price for various household activities faces with the threat of physical availability of clean energy resources. Traditional sources such as biomass, wood, cattle dung, crop residue, kerosene, etc keeps wide gap between mass perception and real situation before the policy makers. Access, price, micro level supply, macro-level demand, gaps in micro-macro energy base, etc. leads us to much decentralized, locally sustainable, solution based approach in energy policy.

Here we can see a paradigm shift, that is from government or public service and energy programs to differentiate private enterprises oriented energy projects. Planning with respect to micro-parameters and micro – complexities is another important element in this regard. By that the responsibility on mini – micro energy projects, their planning, implementation, monitoring, sustainability etc shall be shifted from the State to the local government institutions. But LSG institutions are very weak in their technical and economical base in this regard. Though the Rural Electricity Supply Technology Mission launched during 2002, their objectives never achieved till today due to different resources.

The Electricity Act 2003 seeks to bring qualitative and quantitative transformation of the electricity sector through the liberal frame work. The legislations looking forward for a power sector dissociated from the government as producer, provider, supplier and regulator. As an enactment its objective is to consolidate laws relating to generation, transmission, distribution, trading and utility of power. The Act has a mission to address following points.

- Conducive development of electricity industry
- Protecting the consumer interests
- Rationalization of electricity tariff
- Ensure transparent policies on subsidies and incentives
- Efficient environmentally benign policies
- Constitution of Electricity Authorities and Regulatory Commissions
- Establish Electricity Appellate Tribunal

The enforcement and practice of such a law with much private participation in energy productivity, generation, distribution and consumption, with higher concern on competitive efforts and environmental feasibility has only virtual conceptualization but no practical reality. The option is give to the Government to tap private investment and increase efficiency in energy delivery. This will lead to unscrupulous economic practices and resources exploitation.

There we can see the relevance and scope of the formulations and implementation of a national as well as state level electricity (energy) policy. Unfortunately we have not formulated any such document in consultation with the stakeholders like State governments, commissions, consumers, co-operatives trade unions, users associations, local government institutions, civil society organizations etc.. In an era with de-licensed energy generation, distribution and consumption pattern, it is very essential to draft a detailed energy policy document for India.

Following points shall be taken into consideration in such a policy making

- Focus on Integrated energy policy framework
- Integrated Rural Energy policy
- Institutional partnership framework and integrated sectoral energy services including generation, distribution and supply
- Shift from massive electricity infrastructure to household availability of energy

- Key performance indicator for adequate and quality energy availability
- Future road map to the targeted group
- Instead of capital subsidy, shift to hybrid subsidy delivery mechanism
- Encouraging participatory projects in energy sector
- Structural barriers and regulatory measures
- Key steps to household level energy security in India
- Planning and Implementation of feasible and viable projects
- Financial capacity and accountability
- Governance, Practices and enforcement instrumentality

Thus it is evident from the above discussion the State of Kerala has ample opportunity to conceive, evolve, implement, monitor and reform integrated water resources and energy resources policy for the forthcoming era.

Legal measures are also essentially formulated and enforced for the said purpose. The following key elements shall be envisaged in such a policy and legal tool for the State of Kerala.

i. People centered, decentralized watersheds based, river basin oriented database of water resources and local level energy resources mapping.

ii. Maintaining the life of natural river systems and other waterbodies, natural energy resources through hybrid mix for each consolidated society in the state.

iii. Improvement of water quality and quality energy sources through recycling, reuse and reduction of pollution

iv. Uniform standards for classification, processing, coding and information system for water and energy resources with micro level database and user friendly administration of the information system

v. Higher efficiency demand management, conservation and utilization mechanisms

vi. Efficient environment impact assessment and audit measures with effective cost benefit analysis for public security

vii. Prioritization of consumption and conservation matters

viii. Institutional mechanisms, with adequate functional powers, responsibilities, duties and accountability

ix. Regulatory measures, penalties and sanctions for violation or contravention of legal prescriptions

x. Appellate authorities and remedial measures to administer responsive administration of the deriving policy and legislation.

Through such comprehensive policy and legal measures, in connection with water and energy sector we can make a successful effort in the natural environment resource management and conservation for the future generation.

*Young Scientist Award Presentations*

# Treatment and Reuse of Greywater for Sustainable Water Management: Issues, Challenges and Potentials

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## INTRODUCTION

Scarcity of freshwater is emerging as one of the most pressing problems facing the country in the 21st centuary. The stress on freshwater resources are increasing day by day as a result of increasing population, industrialisation, urbanisation, improvement in living standards and the consequent pollution of water bodies. The situation is getting worse as the country strives to attain a developed nation status by 2020. For example the per capita surface water availability in India during the years 1991 and 2001 were 2300 $m^3$ and 1980 $m^3$ respectively, and these are projected to reduce to 1401 $m^3$ by the year 2025 and further to 1191 $m^3$ by the year 2050 (Kumar *et al*., 2005). This being the situation, in many parts of the country people use potable quality water for non potable purposes such as washing, flusing toilet, gardening etc. In this context, it is high time to think about cost effective, easy to operate, safe and sustainable solutions to the present day water crisis.

One approach which has gained popularity in recent years is the separation of grey water from general sewage, for the purpose of onsite treatment and reuse (Maimon *et al*., 2010). Grey water is defined as household wastewater without the input from toilets and generally includes water from sources such as baths, showers, hand wash basins, washing machines, dishwashers and kitchen sinks (Jefferson *et al.,* 2004). The amount of wastewater generated in a household varies greatly and is influenced by the factors such as the number of occupants, age distribution of the occupants, lifestyle characteristics, water usage patterns, cost of water and the climate (WHO, 2006). From the total water use, 80% is discharged as wastewater and the total volume of grey water from an average household represents about 60% of the total wastewater generated (WHO, 2006). Therefore around 50% of the water consumption can be reduced by recycling of grey water. The average per capita water use in India is 135 L per day (UNDP, 2006) and it varies from 148 L to183 L in Kerala (Harikumar and Bindhya Mol, 2012). Hence the separate collection, treatment and reuse of greywater will help to reduce the demand on freshwater resources which are depleting, reduce the expenditure on freshwater by the resident, helps to meet the increasing water demand projected in the future in a sustainable way and it will also act as an efficient pollutant barriers and protect the environment from pollution load (Ericksson and Donner, 2010; Maimon *et al.*, 2010).

Motivated from the above mentioned facts, several technologies (physical, chemical and biological) were developed for the treatment of grey water and tested with varying degrees of success. However many of the high technology wastewater treatment systems are not suitable for developing countries due to high investment and maintenance cost. Hence the challenge is to develop a simple and cost effective technique for the treatment of grey water. A survey of the related literature also indicates the application of cost effective technologies has not been extensively investigated for grey water treatment and recycling. Hence the present study examines the treatment of grey water using the Nutrient Film Technique (NFT) system planted with *Salvinia molesta*. The NFT systems consists of shallow raceways (RWs) in which the plants are cultured hydroponically. The root zone or rhizosphere is said to be the active reaction zone where physicochemical and biological processes take place that are induced by the interaction of plants, microorganisms and the pollutants (Abbasi and Ramasamy, 1999; Stottmeister *et al*. 2003; Bindu et al., 2010). The plant rhizosphere stimulate microbial community density and activity by providing root surface for microbial growth, a source of carbon compounds thorough root exudates and a micro-aerobic environment via root oxygen release. Removal of pollutants from an NFT system was enhanced by the combined action of plant uptake, microbial degradation and settling (Bindu *et al.,* 2008; 2010; Ignatius et al., 2014).

## MATERIALS AND METHODS

### Bioagent: Collection and Preparation

The plant, *Salvinia molesta* D. Mitch used as bioagent in the present study belongs to pteridophytes. The fern was collected from water bodies near Mahatma Gandhi University campus, washed with running tap water and then with distilled water and allowed to acclimatize in the laboratory conditions in plastic tanks (stock culture). For the experiments plants of uniform size and weight (6.0g) were selected from this stock culture.

### Analytical Methods

The grey water was collected from the student hostels of Mahatma Gandhi University. It was allowed to settle over night and the supernatant was used in the rest of the experiments. The grey water samples were analysed periodically starting from zero hour for the following parameters, pH, TDS, $NO_3^-$ –N, $PO_4^{3-}$ –P, and COD. All analyses were completed within 24h of sampling following the procedures described in standard methods (APHA, 1998). The biomass and chlorophyll content of the plants were analysed before and after the experiment and the changes were recorded.

### Experimental Design

The entire experiment was conducted with a photoperiod of 14 hours (light to dark ratio 14:10) (Aryalakshmi *et al*., 2014) with average light intensity of 1000 lux by providing florescent lamps and average day temperature of 29±3°C.

### Nutrient Film Technique (NFT) experiment

In the present study, raceways of 1m long, 0.15m wide and 0.15m deep made out of glass were used. Each raceway was filled with 2.5 litres of grey water. To this 25 plants (*S. molesta*) of more or less uniform size and weight (6.0g fresh weight) selected from the stock culture were introduced. Another set of raceways were maintained as unplanted control and yet another set of raceways were operated as planted control in which instead of grey water, nutrient medium was used. All the raceways were placed with a gentle slope (1.0 %) so that the grey water flows from the upstream end through the root system of the plants to the discharge end of the raceway. Multi-channelled peristaltic pumps (Miclins, PP - 20EX - 4C) were used to maintain a constant flow of grey water at 7 ml/minute, so that the greywater in the raceways was recycled four times a day through the root zone of plants. Each experiment consisted of two runs of 5 days each. The plants were allowed to remain in the raceways till the end of the experiment, i.e. for 10 days. However after each run of 5 days the greywater was drained completely from the raceways and new grey water of the same concentration was introduced. At the end of the each run, one plant from anterior, middle and posterior end of the raceways were collected and analysed for the changes in biomass and chlorophyll content. The total volume of the grey water was kept constant in all raceways by adding distilled water periodically on the eve of each sampling day in order to compensate the water loss through evapo-transpiration.

## RESULTS AND DISCUSSION

### Nutrient Film Technique (NFT) Experiment

The pH of the grey water was 7.56 initially and it increased to 7.8 in the planted system and 7.7 in the control (without plants) system (Table 1). The results of other parameters are discussed below.

**Table 1**
**Characteristics of the Grey water before and after treatment**

| Parameters | Before treatment | After treatment | |
|---|---|---|---|
| | | Planted | Control |
| pH | 7.56 | 7.825 | 7.69 |
| Nitrate-nitrogen (mg/l) | 0.835 | 0.067 | 0.741 |
| Phosphate-phosphorus (mg/l) | 2.42 | 0.525 | 1.99 |
| Chemical Oxygen Demand(mg/l) | 523 | 172.5 | 424 |

#### *Nitrate-Nitrogen*

The nutrient removal efficiencies of the NFT systems were assessed on the basis of the percentage reduction of nutrients from the effluent coming out of the Raceways (RWs). It was observed that there was a linear relationship between duration of experiment and removal of nitrogen. The average removal of Nitrate-nitrogen was 92% in the planted raceways and 10% in the unplanted control raceways (Figure 1). Thus it was evident that the RWs planted with *S. molesta* have performed with better removal of $NO_3^-$ -N with 82% more removal than the unplanted control. Similar results of higher nitrogen removal in planted RWs were reported (Vaillant *et al.,* 2002, 2003; Monnet *et al.,* 2002). It was reported that Nitrate-nitrogen can be reduced by denitrification, plant uptake and conversion to bacteria cell (Al-Omari and Fayyad, 2003; Bindu *et al.,* 2008).

### *Phosphate-Phosphorus*

Planted RWs have performed with better removal of $PO_4^{3-}$ -P than the unplanted control. The average removal of $PO_4^{3-}$ -P in the planted RWs were 78% whereas in the control RWs it was 18% only (Figure 1). Which shows that the planted system have removed 60% more $PO_4^{3-}$ -P than the control. Brix *et al.,* (2001) reported that sorption of phosphorus to the bed material was the major removal mechanism for phosphorus removal in subsurface flow CWs followed by incorporation into organisms (biofilms & plants) and subsequent accumulation of organic matter in the system. However in NFT system since there is no bed material, the majority of phosphorus removal could be attributed to plant uptake and microbial assimilation. The better removal of phosphorus in the planted systems observed in the present study supports this view. The main role of plants with respect to removal of phosphorus is direct uptake and provision of suitable conditions for microorganisms to thrive at their rhizosphere and use phosphorus as a nutrient (Mbuligwe, 2004).

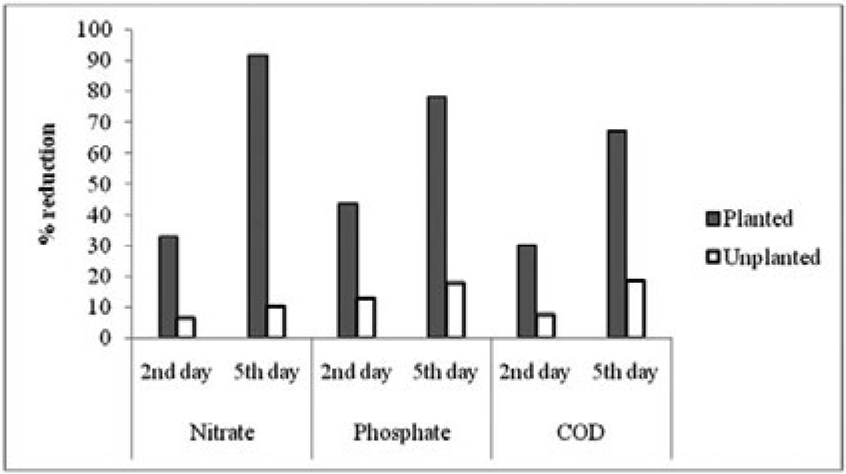


**Fig. 1**
**Comparison of reduction in Nitrate, Phosphate and COD during the NFT Experiment (%)**

### *Chemical Oxygen Demand*

The initial COD of the greywater was 523 mg $O_2$/l which was reduced to 172.5 and 424 mg $O_2$/l in the planted and control RWs (Table 1). The average reduction in COD in the planted RWs was 67% compared to 19% in the control RWs (Figure 1). The result shows the significance of plants in the RWs in the removal of COD.

Similar observations of higher COD removal with planted constructed wetlands over the control wetlands had been reported (Kaseva, 2004; Mbuligwe, 2004; Bindu *et al.,* 2008). The plant root system and the associated microorganisms act together to remove / degrade the organic matter present in the greywater. The planted systems had the dual advantage of extra surface area provided by the root system and the increased the supply of oxygen at the rhizosphere-both these factors have enhanced the microbial activities (Bindu *et al.,* 2008). Vaillant *et al.,* (2002) reported that the COD were removed by filtration and adsorption of solids; the solids trapped in the root systems were then decomposed and mineralized by rhizosphere bacteria.

### *Biomass and Chlorophyll*

The plant samples were collected after each run and analysed for changes in biomass and chlorophyll content. An increase in both the parameters was observed during the experiment. The biomass increase was 5.9% whereas the chlorophyll was increased by 11%. The increase in both the parameters indicates that the plant could survive well in the given concentration of grey water.

## CONCLUSION

The overall results of this study indicate that the plant species (*S. molesta*) tested in this study could survive well in grey water. The planted raceways performed better in terms of reduction in Nitrate, Phosphate, and COD than the control raceways. As mentioned earlier the planted raceways had the dual advantage of extra surface area provided by the root like structures for the attached growth of microbes and the increased supply of oxygen from the plants - both these factors have facilitated the enhanced microbial activities. In addition to this, the uptake by plants also resulted in better performance of planted raceways.

Based on the results of this study the following conclusions are drawn:

1. The performance of *S. molesta* in the NFT system in terms of COD and nutrient removal is encouraging and comparable with the reported values. However, a scaled-up study needs to be performed for the confirmation of the present findings.
2. The findings also indicate the scope for future research using *S. molesta* along with other plants in a poly-culture approach in order to fully explore the potential of the NFT system.
3. The result of the present study indicates that the NFT system is a promising method for the treatment of grey water. However, a more detailed study has to be carried out to investigate the performance of such NFT systems in treating wastewater, contaminated with emerging pollutants and pathogenic microorganisms.

## ACKNOWLEDGMENTS

Mr. Arun Babu V thankfully acknowledges Department of Science and Technology (DST), Government of India for the financial support through DST-INSPIRE fellowship. Mr. Ignatius Antony acknowledges support of UGC (FIP). The authors also thank DST-FIST and DST – PURSE programme for the financial support.

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# The incidence of Extended Spectrum Beta Lactamase (ESBL) produicng *E coli* in the Ramsar Site, Sasthamcottah Freshwater Lake

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## INTRODUCTION

Surveillance data show that resistance in *E. coli* is consistently highest for antimicrobial agents that have been in use the longest time in human and veterinary medicine (Oteo et. Al, 2005). In the last few years, the emergence and wide dissemination of E. *coli* strains showing resistance to broad-spectrum of antimicrobial agents has been reported (Sahm et.al., 2001; Blondeau, 2004). The multi drug resistance of different enterobacterial species is becoming a severe problem due to the presence of transferable plasmids encoding multidrug resistance and their dissemination among different bacterial species (Vincent et.al., 2010). Extended-spectrum beta-lactamase (ESBL)-producing *E-coli* plays an important role as a source of the corresponding resistance genes (Blondeau, 2004). ESBLs genes are also plasmid-encoded and can easily be transmitted by conjugation to other bacteria, even across species barriers. In addition, various resistance genes are located in or close to mobile genetic elements such as insertion sequences and transposons (Vincent et.al., 2010).

Aquatic systems can be highly impacted by anthrapogenic activities, receiving contaminants and bacteria from different sources and thus encouraging the loose exchange and mixture of genes and genetic platforms(Prabhat Kumar et.al., 2013). In the Kerala scenario, such studies have not been reported so far. So an effort confronting the present drug resistance and pollution is of immense significance. Sasthamcotta Fresh Water Lake is the largest of its kind in Kerala, serving as potable water source for half a million people of the Kollam district of Kerala. It has been pronounced as a Ramsar site since 2002 owing to its wetland importance. This is the first report on multi antibiotic resistant (MAR) *E. coli* from this lake and the first report on ESBL producing *E.coli* isolates from a lake system in Kerala.

## MATERIALS AND METHODS

The chemicals, Mueller Hinton agar, EMB agar, lactose broth and nutrient broth employed for the antibacterial activity studies were purchased from Himedia, India.

Unless otherwise specified, all the other reagents were of analytical reagent grade.

Water samples were collected aseptically in sterile bottles from nine geographical positions at the Sasthamcottah lake in May 2014. The samples were transported to the Antibacterials and Microbial Technology Lab, Pushpagiri Research Centre, Pushpagiri Institute of Medical Sciences and Research Centre, Thiruvalla, Kerala, India within 1 to 2 hours maintaining a temperature of $4^0$C. Coliform count was evaluated by multiple tube fermentation tests leading to most probable number (MPN). All the water samples showed a coliform count > 2500 indicating very high faecal pollution in the lake.

Bacteriological identification was done by techniques such as staining, colony morphology, biochemical test IMViC based on Bergey's Manual of Determinative Bacteriology. Green metallic sheen on EMB agar was taken. All the cultures were maintained on nutrient agar slants at $4^0$C. All the incubations were done at $37^o$C for 24 hours.

**Antimicrobial susceptibility testing**

The identified *E. coli* isolates were cultured on separate nutrient agar plates and incubated at 37°C for 48 hrs and checked for the appearance of colonies. A loopful of isolated colonies was inoculated into 4 ml of peptone water, incubated at 37°C for 4 h. This actively growing bacterial suspension was then adjusted with peptone water so as to obtain a turbidity visually comparable to that of 0.5 McFarland standard prepared by mixing 0.5 ml of 1.75% (w/v) barium chloride dihydrate ($BaCl_2 . 2H_2O$) with 99.5 ml of 1% (v/v) sulphuric acid ($H_2SO_4$). This turbidity is equivalent to approximately $1–2 \times 10^8$ colony forming units per ml (CFU/ml).

Disc diffusion method was employed to evaluate the antimicrobial susceptibility. The bacterial culture was swabbed on Mueller Hinton agar and discs of various antibiotics of known potencies were placed. After incubation at $37^o$C for 24 hrs, diameter of zone of inhibition was measured and consequently antibacterial activity was assessed. The average value of diameter of zone of inhibition exhibited by sensitive isolates to antibiotics was recorded. All the experiments were conducted in triplicates and an average value was taken. .

***Confirmation of ESBL in ceftazidime resistant isolate:*** Presence of ESBL in this isolate was evaluated using β-lactam (ceftazidime)-β-lactamase inhibitor [(ceftazidime-clavulanic acid (CAZ/CAC)] disks according to phenotypic confirmatory test (PCT). An increase in zone diameter by ≥5 mm around disks with CAZ/CAC versus disks with CAZ alone was interpreted as positive as per Clinical and Laboratory Standard shown in Institute Guidelines (CLSI, 2011; Bush and Jacoby, 2010)

**RESULTS AND DISCUSSION**

The bacterial colony obtained on EMB agar was given in Fig. 1. Of the nine water samples collected from the lake, only eight yielded *E. coli* isolates. Seven of these isolates were ampicillin resistant. Only one isolate showed resistance to gentamicin and ceftazidime.

**Fig. 1**
**Green metallic sheath on EB agar indicating E. coli isolates.**

The antibiotic resistant profile chart of *E. coli* isolates from this fresh water lake is given in Fig.2.

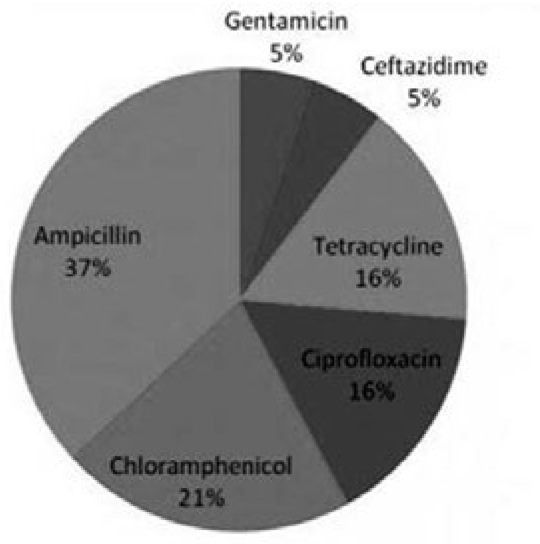


**Fig. 2**
**Percentage antibiotic resistance showed by E. coli isolates from Sasthamcottah lake**

The drug sensitivity pattern of this isolate is shown in Fig. 3. ESBL plays a vital role in hydrolyzing the extended spectrum cephalosporins (Bush and Jacoby, 2010). Ceftazidime is a third generation cephalosporin. The result of the ESBL test is included as Fig. 4.

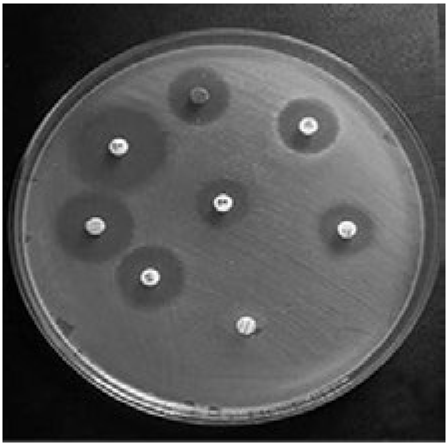

**Fig. 3**
**Antibiotic sensitivity of E. coli isolated**

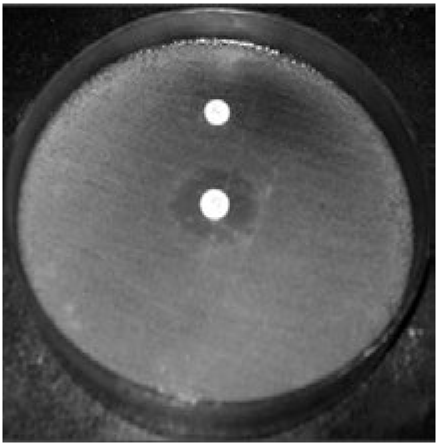

**Fig. 4**
**Result of the ESBL test**

The increase in the zone diameter by ≥5 mm around disks with CAZ/CAC rather than disks with CAZ alone indicated the presence of ESBL in this isolate. The presence of ampicillin resistant and ESBL producing isolates underline the occurrence of *β*-lactamase gene pool among the isolates and points to the hidden disaster of dissemination of drug resistance, within and across the species by genetic recombination.

## CONCLUSION

The incidence of MAR *E. coli* isolates in the water body of this Ramsar site is alarming. Periodic analysis of water sample and maintenance of proper standards to reduce the fecal contamination in this area. coupled with skilled awareness could bring in a control for the present scenario. Evaluation of antibiotic resistance by *E. coli* isolates of the lake water should be included in the surveillance programme as it is associated with enteric disease outbreak.

**ACKNOWLEDGEMENT**

The author, PGP wishes to acknowledge the partial financial assistance by Prof. R. Gangaprasad Foundation (Reg. No.54/12/IV), Sasthamcottah, Kollam.

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# Industrial Symbiosis Relationship between Cement Kiln Dust and Wastewater Treatment Plant in Sugar Industry

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## INTRODUCTION

Industrial symbiosis is the sharing of services, utility, and by-product resources among industries in order to add value, reduce costs and improve the environment. Industrial symbiosis is a subset of industrial ecology, with a particular focus on material and energy exchange (Hassan et. al., 2005).

A cooperative approach to business-environment issues is a key aspect of sustainable development. Resource sharing among firms offers the potential to increase stability of operations, especially in supply-constrained areas, by ensuring access to critical inputs such as water, energy, and raw materials. Industrial symbiosis (IS), a sub-field of industrial ecology, is principally concerned with the cyclical flow of resources through networks of businesses as a means of cooperatively approaching ecologically sustainable industrial activity. Industrial symbiosis has the potential to redefine industrial organization by pushing firms to think beyond their boundaries. IS neither advocates nor eschews process level changes – rather, given the inputs and outputs of a process, IS intends to match input needs with outputs available, following the principle that one company's by-product can become another company's feedstock, thus reducing resource use at the system level (Hassan et. al., 2005).

There are three primary opportunities for resource exchange:

1) By-product reuse - the exchange of firm-specific materials between two or more parties for use as substitutes for commercial products or raw materials. The materials exchange component has also been referred to as a by-product exchange, by-product syne, or waste exchange and may also be referred to as an industrial recycling network.
2) Utility/infrastructure sharing - the pooled use and management of commonly used resources such as energy, water, and wastewater.
3) Joint provision of services - meeting common needs across firms for ancillary activities such as fire suppression, transportation, and food provision

The major benefits of industrial symbiosis are:

- Reduce raw material and waste disposal costs.
- Earn new revenue from residues and byproducts.
- Divert waste from landfill and reduce carbon emissions.
- Open up new business opportunities.

As in the natural world, this type of industrial synergy brings advantages to both parties, and is usually done for both commercial and environmental reasons (Hassan et. al., 2005).

The economic benefits are:

- Turns a disposal cost into an income stream.
- Can reduce the cost of raw materials.
- Maximizes use of under-utilized resources and facilities.
- Spreads costs of new infrastructure.

The present study is about the sharing of by-products from the cement and sugar industry and indicates the symbiosis relationship between the industries. The efficiency of cement industry wastes, Cement kiln dust (CKD) in the wastewater treatment plant of sugar industry is studied.

**Cement Kiln Dust**

Cement kiln dust (CKD) in is a by-product material of cement manufacturing industry. It is a fine powdery material similar in appearance to Portland cement. The principal constituents of CKD are compounds of lime, silica, and alumina, and iron. The physical and chemical characteristics of CKD depend on the raw materials used and the method of its collection employed at a particular cement plant. Free lime is found in CKD. The concentration of free lime is generally highest in the coarser particles of CKD captured closest to the kiln. Finer particles of CKD contain higher concentrations of sulfates and alkalis. The primary value of cement kiln dust is its cementitious property. Depending on the concentration of lime (CaO), CKD can be highly cementitious. Therefore, CKD can be used as a replacement for other cementitious materials such as Portland cement, blast furnace slag cement, Portlandpozzolan cement, blended cements, and the like. Due to the generally higher amounts of alkalies present, the most common beneficial use of CKD is as a stabilizing agent for wastes, for example municipal sludge, red mud, mining tailings, dredged materials, and other similar materials, where its absorptive capacity and alkaline properties reduce the moisture content, increase the bearing capacity, and provide an alkaline environment for such materials (Abd El-Aleem et. al., 2005).

***Physical Characteristics:*** Although the relative constituent concentrations in CKD can vary significantly, CKD has certain physical characteristics that are relatively consistent. When stored fresh, CKD is a fine, dry, alkaline dust that readily absorbs water. When managed on site in a waste pile, CKD can retain these characteristics within the pile while developing an externally weathered crust, due to absorption of moisture and subsequent cementation of dust particles on the surface of the pile. The ability of CKD to absorb water stems from its chemically dehydrated nature, which results from the thermal treatment it receives in the kiln system. The action of absorbing water (rehydrating) releases a significant amount of heat from non-weathered dust, a phenomenon that can be exploited in beneficially using CKD. For example, CKD can be used to dewater municipal sewage sludge, while the heat of hydration can be used to sterilize the blended material (Abd El-Aleem et. al., 2005).

***Chemical Characteristics:*** Bulk constituents are defined herein as those that exceed 0.05 percent by weight in the CKD.

Bulk constituents are primarily those found in clinker, though they also may be present at levels in CKD that are unacceptable in the cement product. Although the types of bulk constituents found in CKD do not vary significantly among samples from different plants and over time, the relative proportions of these constituents vary widely. As an additional measure of chemical characteristics, that CKD is inherently alkaline. This characteristic is a clear function of the large quantity of CaO and other alkaline compounds, such as $K_2O$, NaOH, $Na_2CO_3$, and $Na_2SO_4$ that comprise CKD. Again, however, conclusions based on process differences are tenuous using the available data. In general, the pH of CKD leachates (using standard EPA leachate procedures) falls between 11 and 13 pH (Abd El-Aleem et. al., 2005).

***CKD Land Disposal Onsite:*** Waste CKD is most commonly land-disposed in on-site WMUs.(waste management unit) Respondents to the 1991 PCA Survey (representing usable data from 79 plants and 145 kilns) reported that they land disposed an average of about 33,000 metric tons of CKD per plant in 1990. Of this aggregated average, wet process facilities disposed of 41,735 metric tons per plant and dry process facilities disposed of 27,419 metric tons per plant. Extrapolating these averages for wet and dry kilns to the entire industry, an estimated 4.2 million metric tons of CKD were land disposed (land fills, piles and ponds) nationwide in 1990 (Abd El-Aleem et. al., 2005).

**Sugar Industry Waste Water**

India is one of the largest producers and consumers of 22 million tonnes of sugar per annum in the world and about 1000L of wastewater is produced for every ton of cane crushed. Because of high BOD content, sugar industry wastewater lead to the depletion of dissolved oxygen content in the water bodies resulting if discharged untreated, rendering the water bodies unfit for both aquatic and human uses. If untreated wastewater is discharged on land, decaying organic solids present in the wastewater clog the soil pores. Rapid urbanization, industrialization and population growth have led to the severe contamination of most of the fresh water resources with untreated industrial and municipal wastes. Treatment and reuse of wastewaters have become absolute necessity to avoid pollution of fresh water bodies. Hence purification of sugar industry wastewater is a challenging task due to the stringent discharge standards for the protection of environment.

***Characteristics of sugar industry waste water:*** The sugar industries wastewater is characterized by its color, low pH, ash and dissolved organic and inorganic matter of 50% as reducing sugar. In addition to sugar mill waste water carry the constituents such as Biological oxygen demand, chemical oxygen demand, oil and grease (Kolhe et. al., 2009).

## MATERIALS AND METHODS

The CKD is collected from the Cement Factory of Tamil Nadu Newsprint and Papers Limited (TNPL) at Kagithapuram in Karur. Effluent samples were collected from aeration tanks of E.I.D. Parry sugar industry in Karur. Samples were collected in one litre double cap acid washed polythene bottles. pH of sample is to be measured initially on site. The sampling and storage is done as prescribed in IS 3025 (Part 1)1986. According to IS No.3025 (Part 1)1986 Method of sampling and testing (physical and chemical) of wastewater is done. The CKD collected at different concentrations (1.5, 2.0, 2.5, 3.0, 3.5 gm/L) were mixed with the effluent samples taken from the sugar industry.

The chemically assisted sedimentation by cement dust kiln of doses (1.5, 2.0, 2.5, 3.0, 3.5 gm/L) were investigated using a standard bench-scale (jar test) apparatus. Then the samples have been drawn and then analysis proceeded. The parameters such as pH, BOD, COD, TSS and SVI were taken for analysis and measured as suggested by American Public Health Association (APHA, 1998).The analytical results of all the wastewater samples were thus evaluated in accordance with the norms prescribed under Bureau of Indian Standards and World Health Organization (WHO).

Total Suspended Solids were determined by the difference between the residue left after evaporation of unfiltered sample and of that of filtered sample (Metcalf and Eddy, 2003).

## RESULTS AND DISCUSSION

The Jar Test Results for Raw wastewater and Chemically Assisted Sedimentation of Dose (1.5, 2.0, 2.5, 3.0, 3.5gm Cement Dust/L) are shown in Fig. 1.

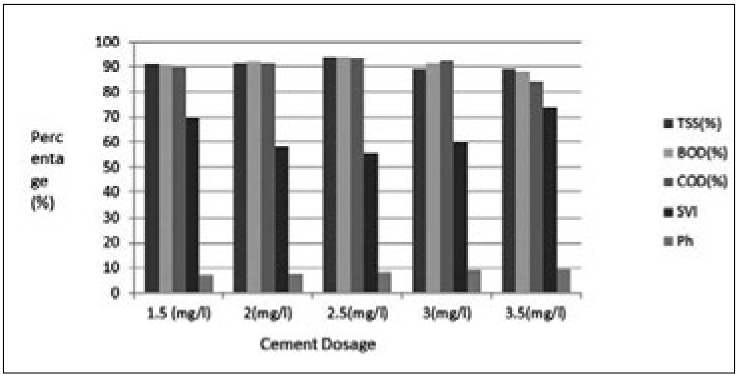


**Fig. 1**
**Cement dosage against removal efficiency in percentage**

The high removal efficiencies of 94.2 (BOD), 93.6 (COD) and 94.1 (TSS) was noticed for Cement Kiln Dust dosage of 2.5 gm/l and decreased gradually on increasing concentration. Increase in value of pH and SVI indicates that CKD enhances the settling properties of sludge and reduces the parameters of wastewater within the permissible limits for discharge.

The result indicates that the optimum dose of Cement Kiln Dust for waste water management is 2.5gm/l.

## CONCLUSIONS

Disposal of untreated wastewater from sugarcane mills is the major environmental problem in the industry. About 200 million gallons of raw liquid wastes from sugar mills are discharged daily into land and streams during the crane grinding season (Kolhe et. al., 2009). Although a number of plants recycle all gross CKD back to the kiln system, most plants remove a significant quantity of CKD from the a system and is a major water polluting material in cement factory concentrated areas. Industrial symbiosis between these two factory will result in reduction of water pollution

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# Column Mode Biosorption: A New Approach for Heavy Metal Remediation of Water

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## INTRODUCTION

Increasing aquatic environmental pollution due to industrial discharge, particularly in developing countries, is a matter of grave concern due to its adverse effects on human and environment (Volesky & Holan, 1995). Chromium is a widely used heavy metal used in manufacturing of inks, industrial dyes, paint and pigments, in chrome tanning, aluminum anodizing and other metal cleaning, plating and electroplating operations in addition to auto-mobile manufacturers (Aksu, 1998).Various methods used for removal of Cr (VI) ions include chemical reduction and precipitation, filtration, electrochemical treatment. But all these methods suffer from severe constraints, such as incomplete metal removal, high reagent or energy requirements, expensive equipment and monitoring system, generation of toxic sludge or other waste products that require safe disposal. Some of the treatment methods involve high operating and maintenance cost (Liping et. al., 2009). Conventional treatment technologies become less effective and more expensive when metal concentrations are in the range of 10-100 mg/L (Desbaumes & Ramaciotti, 1968). Therefore, there is a need for some alternate technique, which is efficient and cost-effective. The search for alternative and innovative treatment techniques has focused attention on use of biological materials such as algae, fungi, yeast, and bacteria for removal and recovery technologies for heavy metals (Kratochvil & Volesky, 1998; Tewaria et.al., 2005). Heavy metal ions have an affinity towards functional groups like carboxyl, sulfhydryl, amino, etc. These functional groups can sequester heavy metal ions present in the medium (Tewaria et.al., 2005; Ranjith et.al., 2011). The cell walls of the microbial biomass are mainly composed of polysaccharides, proteins, and lipids, which contain functional groups such as carboxylate, hydroxyl, sulfate, phosphate, and amino groups that bind to heavy metals (Parka et.al, 2005). Various types of biomass, including bacteria (Trivedi & Patel , 2007), yeast (Seki et.al., 2005), fungi (Pal et.al., 2006) and algae (Hansen et.al., 2006; Ranjith et.al., 2011) have been evaluated with the aim of identifying highly efficient metal removal adsorbents. In view of above, there is an emphasis on detailed studies on adsorption of heavy metals in column mode (Low & Lee, 1991). For continuous operation with biopolymers and immobilized biomass, the most convenient configuration is that of a packed column. Continuous packed bed adsorption has a number of process engineering advantages including high yield operations and relatively easy scaling up from a laboratory scale procedure. The separation of treated water from biomass is easy. A big volume of wastewater can be continuously treated using a known quantity of immobilized cells in the column (Volesky, 2001). Algae as biosoebent have several economical and effective roles since low nutrient requirement, autotrophic nature and unlike other biomass and microbes they generally do not produce toxic substances (Freire-nordi et. al., 2005). In order to increase efficiency, the matrix of the column should have high loading capacity, and should have a loose structure for overcoming diffusion limitations. The important matrices used in adsorbent immobilization include polysulfone, polyacrylamide, polyurethane and sodium alginate (Aksu & Gonen, 2004).

This study aimed to develop a column bed filtration unit for the removal of Cr (VI) by physical entrapment of adsorbents of algal origin viz., alginic acid, calcium alginate, agar-agar, *Spirulina platensis* dry biomass and conventional adsorbents such as zeolite and activated charcoal in a polyurethane matrix. It involved the designing and preparation of a column-bed reactor with adsorbents of algal origin entrapped in polyurethane blocks. An assessment of column performance on the basis of adsorption capacity and removal efficiency was carried out for developing a low cost column based water filtration unit.

## MATERIAL AND METHODS

### Column bed preparation

Locally marketed polyurethane foam of 73 × 30 × 2 inches was purchased for the preparation of polyurethane foam discs of 6 inches diameter. These discs were packed in column (Diameter: 6 inches and number of discs packed: Four) as shown in Fig.1. The algal compounds (alginic acid and calcium alginate), *S. platensis* biomass and conventional adsorbents were entrapped in polyurethane foam disc by

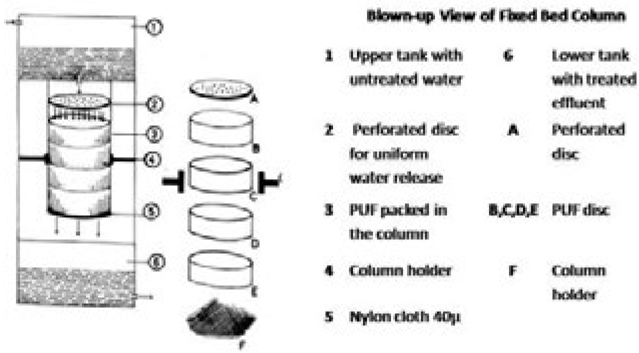


**Fig. 1**
**Schematic representation of the designed water filtration un**

soaking various adsorbents of known concentrations on the discs. The adsorption study was carried out for 3 hour and water samples were collected in triplicates in polypropylene bottles at every 15 minutes after passing the chromium solution through the column. The flow rate was fixed at the rate of 90 ± 2 ml per minute.

**Estimation of Cr (VI)**

The effluent coming out of the column was collected in 100 ml polypropylene bottles and filtered through 0.45$\mu$ filter paper and directly aspirated to the Atomic Absorption Spectrophotometer (AAnalyst 800, Perkin Elmer, USA) using flame atomization. The instrument was calibrated using Chromium standard (1000 mg/L) procured from Merck, Germany and the working standard having a concentration of 5 mg/L was prepared freshly for every analysis. The analytical conditions used Chromium estimation by flame atomization were: 357.9 nm wavelength; 0.7 nm slit width; hollow cathode lamp; air- acetylene for flame; burner head temperature: 2400 $^{O}$C; lamp current setting 25 mA; Lamp energy: 81; and results were expressed as mg/L.

**Removal efficiency**

The removal efficiency and adsorption capacity at various time interval of different column bed was calculated using the following equation (Urrutia et. al., 1995; Amin et.al, 2006).

$$\textbf{Removal efficiency (\%)} = \frac{Co - Ce}{Co} \times 100$$

Where, Co and Ce are the concentrations of metal before and after treatment.

**Adsorption capacity (AC)**

The adsorptioncapacity (Zhang & Banks, 2006) of the biomass combination was calculated by dividing the metal sequestered in the column (mb) by the mass of biomass in the column (M). This can be calculated as follow

**Adsorption capacity(AC)(mg/g) = Mb / M**

Where, mb is calculated by the following equation

$$mb = \Sigma\, [(C0 - Ci)\, Vi\, ]$$

Where, $C_0$ is the initial metal concentration, $C_i$ is the metal concentration of the ith fraction and $V_i$ is the volume of ith fraction.

**Breakthrough point**

The ratio of effluent concentration (Ce) and influent concentration (Co) was used for determining the breakthrough point. The ratio of 1.0 to 1.05 denoted the breakthrough point.

**Statistical analysis**

Statistical analysis has been done using ANOVA in SPSS 16.0

## RESULTS AND DISCUSSION

A column study was conducted for various concentrations such as 10, 20 30 40 and 50 mg/L initial concentrations of Cr (VI). Column reached equilibrium within the first 75 min. for 50 mg/L initial concentration, while the lower concentrations reached the breakthrough point still slowly than that of highest concentration (Fig.2). The percentage removal exhibited (Table 1) a gradual decline for higher concentration such as 30, 40 and 50 mg/L. After 15 minutes treatment time the higher removal obtained in the case of 10 mg/L, around 75.13%, while 50 mg/L initial Cr(VI) showed least adsorption (57.85%), this observation is similar to the findings of the investigation by (Gupta et.al., 2001). The break through point for each concentration was different, 50 mg/L reached equilibrium with in 75minutes. After 90 minutes the percentage removal at 30 and 40 mg/L was negligible, while 10 mg/L exhibited continuous removal up to 120 minutes.

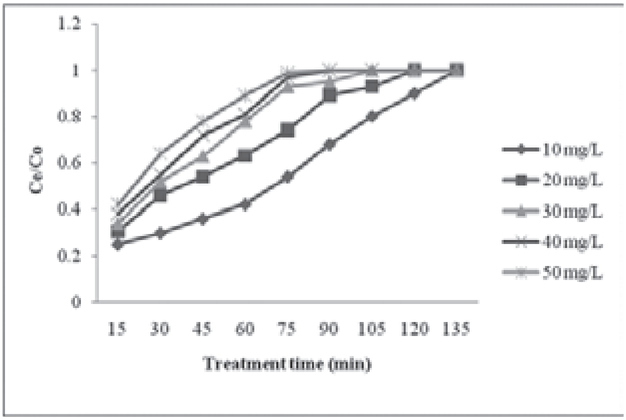


**Fig 2**
**Breakthrough curve for various initial Cr (VI) concentrations (10-50 mg/L) after filtration through column bed combinations of various adsorbents (Temp: 28 ± 2oC, pH: 6, Adsorbent quantity: 28g, Flow rate: 90 ml/min)**

After 30 minutes of treatment time, except for 10 mg/L, all other higher concentrations removed less than 50% Cr (VI). The bioadsorption capacity (AC) of the adsorbents was also evaluated (Table 2). There was a considerable extent of Cr (VI) removal in the concentration ranges 2-10 and 10-50 mg/L up to 60 minutes. The maximum removal was exhibited at 50 mg/L (1.76 mg/g) after 30 minute treatment time. The AC increased with increase in initial concentration, 0.68 to 1.76 mg/g when the concentration increased from 10 to 50 mg/L. Similar result was recorded (Saroj et.al., 2006), using saw dust, but this batch experiment was conducted at lower (pH 3.5), and the volume used was 50 ml only. Moreover, higher initial adsorbate concentration provided higher driving force to overcome all mass transfer resistances of the metal ions from the aqueous to the solid phase resulting in higher probability of collision between Cr (VI) ions and the active sites on the adsorbate surface. Further, it was

**Table 1**

**Effect of initial concentrations (10 to 50 mg/L) of Cr(Vi) on removal efficiency after filtration through column bed combinations of various adsorbents**

**(Temp: 29±2oC, pH: 6, Adsorbent quantity: 28g, Flow rate: 90 ml/min)**

| Initial Conc (mg/L) | Removal efficiency (%) (Co-C e)/Co x 100 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 15 min | 30 min | 45 min | 60min | 75 min | 90 min | 105min | 120min |
| **10** | $\mathbf{75.13\pm0.03^{eG}}$ | $70.50\pm1.08^{eF}$ | $67.53\pm0.24^{eE}$ | $55.37\pm1.45^{eD}$ | $31.88\pm0.04^{eC}$ | $31.59\pm0.23^{cC}$ | $19.87\pm0.20^{aB}$ | $0.33\pm0.32^{aA}$ |
| **20** | $69.85\pm0.18^{dF}$ | $58.54\pm0.48^{dE}$ | $49.50\pm0.26^{dD}$ | $39.48\pm0.02^{dD}$ | $24.98\pm0.02^{dC}$ | $9.83\pm0.16^{bB}$ | $0.08\pm0.08^{aA}$ | $0.00\pm0.00^{aA}$ |
| **30** | $66.30\pm0.02^{cF}$ | $48.54\pm0.29^{cE}$ | $36.60\pm0.14^{cD}$ | $19.92\pm0.06^{cC}$ | $6.76\pm0.09^{cB-}$ | $0.27\pm0.20^{aA}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ |
| **40** | $62.00\pm0.01^{bE}$ | $44.98\pm0.16^{bD}$ | $27.51\pm0.28^{bD}$ | $18.25\pm0.01^{bcC}$ | $2.96\pm0.04^{bB}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ |
| **50** | $57.85\pm0.08^{aD}$ | $36.47\pm0.78^{aC}$ | $21.43\pm0.57^{aC}$ | $9.91\pm0.07^{aB}$ | $0.14\pm0.13^{aA}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ |

Different superscripts in the same column signify statistical differences, ($p < 0.05$), mean ± SE, n = 3)

$^{A-G}$ Indicates the difference among mean value of different treatment time (in respective row)

$^{a-e}$ Indicates the difference among mean value of different initial concentrations of Cr(VI) (in respective column)

**Table 2**

**Effect of initial concentrations (10 to 50 mg/L) of Chromium(VI) on biosorption capacity after filtration through column bed combinations of various adsorbents (Temp: 29±2oC, pH: 6, Adsorbent quantity: 28g, Flow rate: 90 ml/min)**

| Initial conc. mg/L | Biosorption capacity( mg/g ) ∑[(Co-Ci) x Vi] / M | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 15min | 30min | 45min | 60min | 75min | 90min | 105min | 120min |
| **10** | $0.36\pm0.00^{eB}$ | $0.68\pm0.01^{dC}$ | $0.98\pm0.00^{cF}$ | $\mathbf{1.07\pm0.03^{bG}}$ | $0.77\pm0.00^{dD}$ | $0.91\pm0.01^{cE}$ | $0.91\pm0.01^{cC}$ | $0.01\pm0.01^{aA}$ |
| **20** | $0.67\pm0.00^{dC}$ | $1.13\pm0.01^{dD}$ | $1.43\pm0.01^{cF}$ | $\mathbf{1.52\pm0.00^{eG}}$ | $1.20\pm0.00^{eE}$ | $0.57\pm0.01^{bB}$ | $0.57\pm0.01^{bA}$ | $0.00\pm0.00^{aA}$ |
| **30** | $0.96\pm0.00^{cF}$ | $1.40\pm0.01^{cE}$ | $\mathbf{1.59\pm0.01^{cD}}$ | $1.15\pm0.00^{cC}$ | $0.49\pm0.01^{cB}$ | $0.02\pm0.02^{aA}$ | $0.02\pm0.02^{aA}$ | 0.00v0.00$^{aA}$ |
| **40** | $1.20\pm0.00^{bC}$ | $\mathbf{1.73\pm0.01^{bF}}$ | $1.59\pm0.02^{bE}$ | $1.41\pm0.00^{dD}$ | $0.29\pm0.00^{bB}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ |
| **50** | $1.39\pm0.00^{aC}$ | $\mathbf{1.76\pm0.04^{aE}}$ | $1.55\pm0.04^{aD}$ | $0.96\pm0.01^{aB}$ | $0.02\pm0.02^{aA}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ | $0.00\pm0.00^{aA}$ |

Different superscripts in the same column signify statistical differences. ($p< 0.05$), mean ± SE, n = 3)

$^{A-F}$ Indicates the difference among mean value of different treatment time (in respective row)

$^{a-e}$ Indicates the difference among mean value of different initial concentrations of Cr(VI) (in respective column also reported (Christian et.al., 2005) that high metal concentration may saturate the biomass more quickly, thereby, decreasing the breakthrough time (75 and 120 minutes for 50 and 10 mg/L). The Cr (VI) adsorption was in the range of 83.55% by *Sargassum* biomass (Akbar & Samira, 2012), similarly the immobilized biomass of *Nostoc linckia* in alginate beads could remove 80-90% chromium from solutions with initial metal concentration of 10-55 mg/L, but the process made use of batch mode of adsorption, where the volume treated might be comparatively less and further recovery of the beads are cumbersome (Sharma et.al., 2011). The potential of *Sargassum wightii* (brown algae) and *Caulerpa recemosa* (green algae) to biosorbCr(VI) was assessed by using 5-40 g/L of biomass to remove 100 mg/L metal in batch mode (Tamilselven et.al., 2012). At 25 g/L of adsorbent quantity, the removal of metal was around 78%, but the volume treated (25 ml) was very little compared to the present study (1350 ml for 15 minutes).

**ACKNOWLEDGEMENT**

The authors gratefully acknowledges Dr W. S. Lakra, Director & Vice chancellor of Central Institute of Fisheries Education, Mumbai and Indian Council of Agricultural Research (ICAR) for providing all the facilities needed for the completion of the work.

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# An Investigation on Heavy Metal Pollution in the Water and Fish Species '*Mystus Gulio*' in Vattakkayal, A Part of Ashtamudi Lake in South India

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## INTRODUCTION

Water is one of the most valuable natural resources. The quality of water is of vital concern for the mankind since it is directly linked with human welfare (Kumar, 2004). A major environmental concern due to dispersal of industrial and urban wastes generated by human activities is the contamination of water. Controlled and uncontrolled disposal of wastes, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to agricultural soils are responsible for transferring of contaminants into non-contaminated sites as dust or leachate, and contribute towards contamination of our ecosystem (Ghosh and Singh, 2005). A wide range of inorganic and organic compounds cause contamination, includes heavy metals, combustible and putrescible substances, hazardous wastes, explosives and petroleum products, phenol and textile dyes. Major component of inorganic contaminates are heavy metals. They have some different problems than organic contaminants (Gabr and Gab-Alla, 2008; Ghosh and Singh, 2005; Jadhav *et al.,* 2010).

The biological and toxic roles of metals have been studied extensively in recent years. If the water polluted with toxicants, e.g. heavy metals, fish growth may be inhibited. Inhibition of growth is one of the most distinct symptoms of toxication of metals on fish larvae. When larger animals feed on these contaminated organisms, the toxins are taken into their bodies, moving up the food chain with increasing concentrations in a process known as *biomagnification* (Begum *et al*., 2009).

Heavy metals in water are particularly dangerous for fish juveniles and may considerably reduce the size of fish populations or even cause extinction of entire fish population in polluted reservoirs. The studies by Stomińska and Jezierska (2000) indicate that heavy metals reduce survival and growth of fish larvae. They also cause behavioral anomalies (such as impaired locomotors performance resulting in increased susceptibility to predators) or structural damages. A major concern for environmental contamination is the extent to which pollutants concentrate from water into aquatic organisms such as fish. The extent of such concentration, termed the bioconcentration factor (BCF), is given by the ratio of the pollutant concentration in fish to that in the water (Arnot, 2006).

The major objective of the present work is to investigate the pollutants levels including the accumulation of some heavy metals (iron, copper, chromium, cadmium and lead) in the water, and fish organs of *Mystus gulio* in Vattakkayal, a part of Ashtamudi lake in South India.

## MATERIALS AND METHODS

### Study area

Vattakkayal, a part of Ashtamudi lake in Kollam district is selected as the study area. Vattakkayal is located at 8°55'3" North latitude and 76°32'57" East longitude, and is about 9 kms away from Kollam Railway Station and located in the Sakthikulangara panchayat. Vattakayal occupies more or less a central position of Kollam with respect to Neendakkara, Kavanadu and Maruthady area. Almost at the centre of this area there is a lake and it is known as Vattakkayal due to its shape. The Vattakkayal occupies an area of about 37 acres. The existing land use of the area consists of water bodies surrounded by marshy vacant land. Previously this low lying vacant land was used for paddy cultivation and the water body is enriched with fish and aquatic life in abundance. At present this kayal is with weeds like water hyacinth as the water body receives domestic wastes, domestic drainages, wastes from nearby factories etc. and is also subjected to many ecological problems. The Vattakkayal also indirectly receives waste water through Kattakkal kayal because it receives waste water discharged from neighboring fish processing unit, ice plants and freezing plants.

### Sample collection

Water and fish samples were collected from the Vattakkayal in the pre monsoon, monsoon and post monsoon seasons during the period February 2013 to January 2014 for estimating the heavy metals residues. Water Samples were collected from five selected sites during pre monsoon, monsoon, and post monsoon seasons in cleaned and dried plastic bottles for the analysis of various heavy metals. Heavy metals in water samples were extracted with conc. HCl and preserved in a refrigerator till analysis for Fe, Cr, Cu, Cd and Pb (Parker, 1972). The fish species, *Mystus gulio* of uniform length were also collected from the selected sites of Vattakkayal and were transported in ice box to the laboratory, where samples of different tissue/organs taken were sorted.

### Methodology

The concentrations of heavy metals in water samples were determined using an Atomic Absorption Spectrophotometer (Thermo Electron Corporation, S. Series AA Spectrometer with Gravities furnace, UK,) instrument was used to detect the heavy metals. The concentrations of heavy metals were expressed as mg/l for water samples.

The fish tissue (muscle) were weighed and heated in a hot air oven at 110$^{o}$C for 24 hours. Then powdered and subjected to diacid (2 Nitric acid : 1 Perchloric acid) digestion. The sample was dissolved in distilled water and made up to a known volume. The concentration of the heavy metals were determined using an Atomic Absorption Spectrophotometer. The concentration of heavy metals were expressed as mg/g wet tissue.

***Bioconcentration Factor:***

Bioconcentration Factor (BCF) was calculated using the formula,

BCF = CB/CW,

Where, CB = Chemical concentration in organism; CW = Chemical concentration in water (mass of chemical/L), CB usually expressed in units of mass of chemical per kg of organism.

## RESULTS AND DISCUSSION

### Heavy metal content in water

Heavy metal concentrations in water samples of Vattakkayal are illustrated in Tables 1, 2 and 3.

**Table 1**
**Descriptive statistics showing heavy metal concentration in Vattakkayal during pre monsoon season**

| Heavy metal | Range | Minimum | Maximum | Mean | | Std. Deviation | Variance |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic | Statistic |
| Fe | 7.79 | 6.05 | 13.84 | 9.9450 | 3.89500 | 5.50836 | 30.342 |
| Pb | 0.04 | 0.42 | 0.46 | 0.4428 | 0.02130 | 0.03012 | 0.001 |
| Cr | 0.06 | 0.06 | 0.12 | 0.0888 | 0.02835 | 0.04009 | 0.002 |
| Cu | 0.03 | 0.01 | 0.04 | 0.0257 | 0.01295 | 0.01831 | 0.000 |
| Cd | 0.08 | 0.02 | 0.10 | 0.0618 | 0.03860 | 0.05459 | 0.003 |

**Table 2**
**Descriptive statistics showing heavy metal concentration in Vattakkayal during monsoon season**

| Heavy metal | Range | Minimum | Maximum | Mean | | Std. Deviation | Variance |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic | Statistic |
| Fe | 2.19 | 1.17 | 3.37 | 2.2700 | 1.09700 | 1.55139 | 2.407 |
| Pb | 0.02 | 0.01 | 0.03 | 0.0185 | 0.00920 | 0.01301 | 0.000 |
| Cr | 0.00 | 0.00 | 0.01 | 0.0039 | 0.00155 | 0.00219 | 0.000 |
| Cu | 0.02 | 0.01 | 0.03 | 0.0189 | 0.01090 | 0.01541 | 0.000 |
| Cd | 0.00 | 0.02 | 0.03 | 0.0245 | 0.00245 | 0.00346 | 0.000 |

**Table 3**
**Descriptive statistics showing heavy metal concentration in Vattakkayal during post monsoon season**

| Heavy metal | Range | Minimum | Maximum | Mean | | Std. Deviation | Variance |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Std. Error | Statistic | Statistic |
| Fe | 6.14 | 2.72 | 8.86 | 5.790 5 | 3.06950 | 4.34093 | 18.844 |
| Pb | 0.32 | 0.00 | 0.32 | 0.1619 | 0.16085 | 0.22748 | 0.052 |
| Cr | 0.06 | 0.05 | 0.11 | 0.0753 | 0.02995 | 0.04236 | 0.002 |
| Cu | 0.03 | 0.01 | 0.05 | 0.0285 | 0.01655 | 0.02341 | 0.001 |
| Cd | 0.06 | 0.05 | 0.11 | 0.0828 | 0.02960 | 0.04186 | 0.002 |

The concentration of lead in the water samples collected from Vattakkayal ranged from 0.42 - 0.46 mg/l during pre monsoon, 0.01-0.03 mg/l during monsoon and 0 - 0. 32 mg/l during post monsoon season (Fig.1). The lead enters the lake from industrial effluents, different wastes and household sewage. The maximum permissible concentration of lead in drinking water is 0.1 ppm according to WHO and ICMR. The value of lead content in all water samples is higher than the maximum permissible level according to WHO (1996) standards. Toxic level of lead in human body is 500 ppm beyond which it causes anemia, brain damage and vomiting. Severe or prolonged exposure to lead may also cause chronic nephropathy, hypertension and reproductive impairment. Pb inhibits enzymes, alters cellular calcium metabolism and slows nerve conduction (Locketch, 1993).

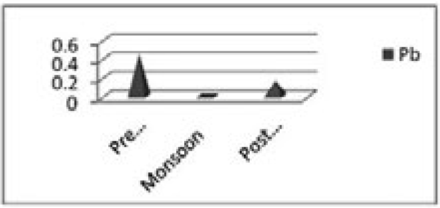


**Fig.1**
**Pb content in water**

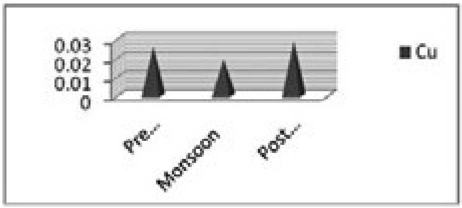


**Fig.2**
**Cu content in water**

The concentration of copper ranged from 0.01- 0.04 mg/l in pre monsoon, 0.01-.03 mg/l in monsoon and 0.01-.05 mg/l in post monsoon season (Fig.2). The maximum permissible concentration of copper in drinking water is 1.0 ppm according to WHO standards (1996). The value of copper content in all water samples were lower than maximum permissible level according to WHO (1996). Copper accumulates in liver and brain. Copper toxicity is a fundamental cause of Wilson's disease.

Concentration of iron in the water samples collected from Vattakkayal ranged from 6.05- 13.84 mg/l in pre monsoon, 1.17-3.37 mg/l in monsoon, 2.72-8.86 mg/l in post monsoon season (Fig.3). Iron is present as $Fe^{2+}$ or $Fe^{3+}$ in suspended form. It causes staining in clothes and imparts a bitter taste. It comes into water from natural geological sources, industrial wastes, domestic discharge and also from byproducts.

Excess amount of iron causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness. The maximum allowed concentration of iron in drinking water is 1.0 mg/L according to WHO report. It was found that the value of iron in all water samples are higher than maximum permissible limits according to WHO (1996) standards.

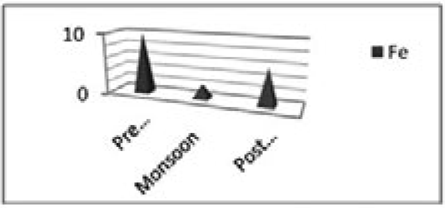


**Fig.3**
**Fe content in water**

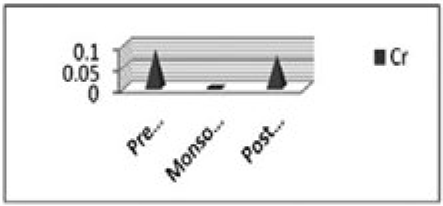


**Fig.4**
**Cr content in water**

Concentration of chromium in the water samples collected from Vattakkayal ranged from 0.06-0.12 mg/l in pre monsoon, 0 - 0.01 mg/l in monsoon, and 0.05- 0.11 mg/l in post monsoon season (Fig.4) The limit of chromium in drinking water is 0.01 ppm according to WHO standards (1996). The values of chromium content in all water samples were higher than maximum permissible levels of WHO standards. Chromium is also essential for organism as a micronutrient in traces from fat and carbohydrate metabolism. Chromium is also more harmful in its lower oxidation state. Chromium and chromates are potential carcinogens.

Concentration of cadmium ranges from 0.02 -0.10 mg/l in pre monsoon, 0.02 - 0.03 mg/l in monsoon, 0.05 - 0.11 mg/l in post monsoon seasons (Fig.5). The values of cadmium content in all water samples were higher than maximum permissible level (0.005 mg/l)) according to WHO (1996) standards. Cadmium is a very toxic metal. Cadmium has many uses, including batteries, pigments, metal coatings, and plastics. It is used extensively in electroplating. Cadmium and cadmium compounds are known human carcinogens. Ingesting very high levels severely irritates the stomach, leading to vomiting and diarrhea, Long-term exposure to lower levels leads to a buildup in the kidneys and possible kidney disease, lung damage, and fragile bones.

Heavy metal concentrations in the water samples of Vattakayal were detected in the following order: Fe > Pb > Cr > Cd > Cu in pre monsoon, while Fe > Cd >Cu >

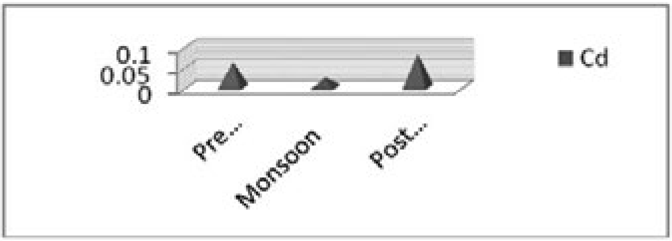


**Fig.5**
**Cd content in water**

Pb > Cr in monsoon and Post monsoon seasons. The heavy metals can exert adverse toxicological effects, when present in high concentrations in water (Pelgrom *et al.*, 1995). In fact, it is potentially toxic when the internal available concentration exceeds the capacity of physiological detoxification processes. On the other hand, organs of aquatic animals may accumulate copper when exposed to toxic concentrations (Mazon *et al.,* 2002), which can lead to redox reactions generating free radicals and, therefore, may cause biochemical and morphological alterations (Monteero *et al*., 2005).

Seasonal changes in the concentrations of metals - iron, lead, chromium, copper and cadmium in water were found in the following order: pre monsoon > post monsoon > monsoon season (Fig. 6). The lower concentration of metals in the Vattakayal was recorded during monsoon and may be due to heavy rainfall. Heavy Metal pollution and its effects on aquatic ecosystems and humans are very extensive. Industrial wastes in aquaculture cause toxic effects in aquatic organisms specially in fishes. Aquatic organisms absorb the pollutants directly from water and indirectly from food chains. Some of the toxic effects of heavy metals on fishes and aquatic invertebrates are; reduction of the developmental growth, increase of developmental anomalies, reduction of fishes survival- especially at the beginning of exogenous feeding or even cause extinction of entire fishes population in polluted reservoirs.

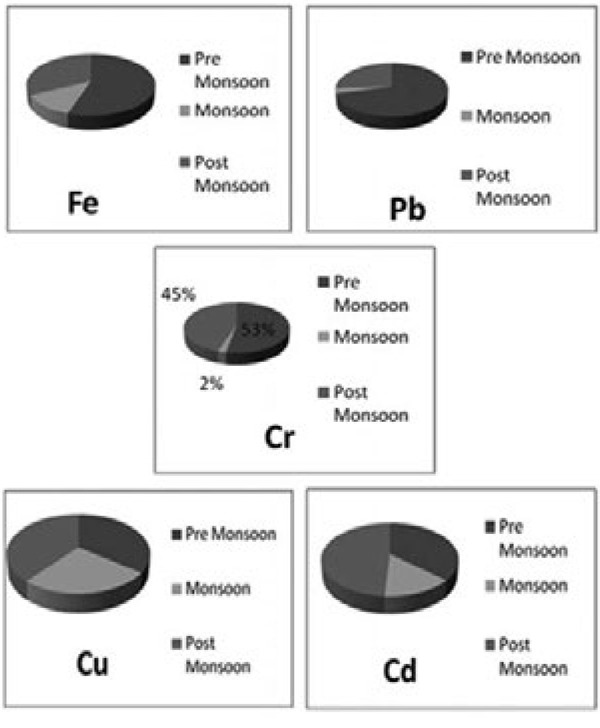


**Fig.6**
**Seasonal changes in Heavy metal concentration in the water samples of Vattakkayal**

These consequences can affect on geological, hydrological and finally on biological cycles also.

**Heavy metal content in fishes**

The concentration of heavy metals estimated in fish muscle is shown in Fig. 7-12. In this study, it is noted that Fe has the highest concentration (11.664 mg/g), while Cd has the lowest concentration (0.03521 mg/g) of all measured metals in fish organs. Iron concentration in Vattakkayal ranges from 2.605 mg/g to 11.664 mg/g with higher value in pre monsoon. The lead was found maximum (0.8903 mg/g) in post monsoon period and minimum (0.1352 mg/g) in pre monsoon season. The chromium value ranged from 0.3112 mg/g to 0.02 mg/g in pre monsoon and monsoon season respectively. Highest copper value was noted in pre monsoon (0.2288 mg/g) and the lowest in monsoon (0.0435 mg/g). The cadmium concentration ranged from 0.0215 mg/g to 0.0576 mg/g and was highest in pre monsoon and lowest in monsoon seasons. The recommended daily intake for an adult is 48.0, 3.0, and 0.214 mg/day wet weight for Fe, Cu, and Pb respectively according to FAO/WHO (1999). While, the permissible daily intake of Cd is 0.1 $\mu$g/g wet weight, where as the maximunm permissible limit of Cr is 1ppm. However, the muscle tissue of fish collected from the study area may pose health risk to consumer, as the concentrations of Cd and Pb exceeded compared to that of the international limits.

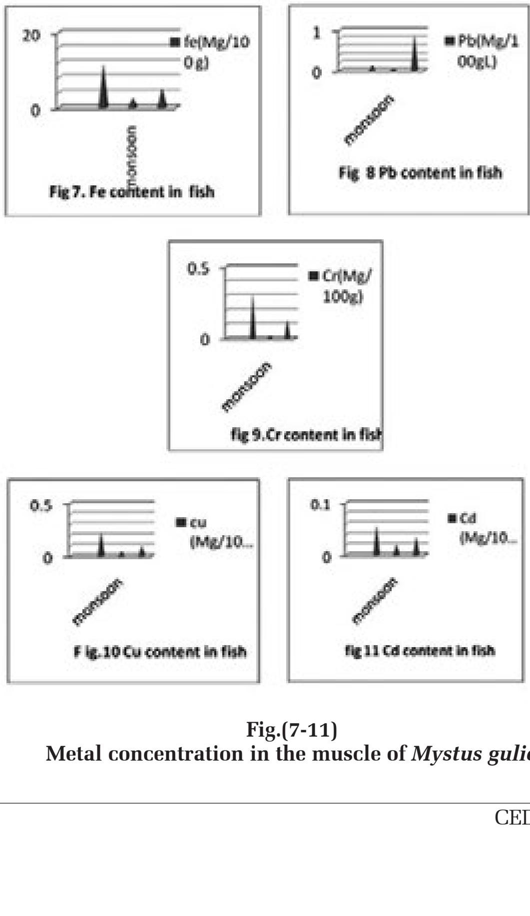


Fig 7. Fe content in fish

Fig 8 Pb content in fish

fig 9.Cr content in fish

F ig.10 Cu content in fish

fig 11 Cd content in fish

**Fig.(7-11)**
**Metal concentration in the muscle of *Mystus gulio***

In different seasons, the concentration of metals in fish muscles were detected in the following order: Fe > Cr> Cu > Pb >Cd in pre monsoon, Fe > Pb > Cu >Cd>Cr in monsoon and Fe > Pb >Cr > Cu >Cd in post monsoon. The present study show that the metal concentrations in fish organ (muscle) of *Mystus gulio* are closely associated with metal content in the water of Vattakkayal. A remarkable relationship between heavy metals concentrations in aquatic organisms and water were observed by Ibrahim *et al*. (2000) and Ibrahim and El-Naggar (2006). Similar observations were reported in the studies carried out with various fish species (Guerrin *et al.,* 1990; Saeed and Sakr, 2008).

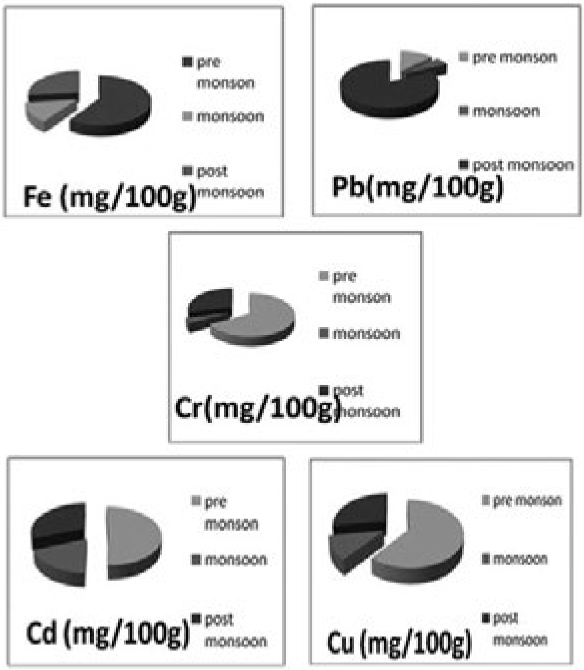


**Fig. 12**
**Seasonal changes in heavy metal concentration in the Fish sample of Vattakkayal**

## Bioconcentration Factor

Bioconcentration Factor (BCF) refers to the uptake of metals from water *via* respiratory surface and/or skin. The accumulation pattern of heavy metals in water, and fish organs were determined based on the Bioconcentration Factor and the BCF values determined are shown in Table 4. The results obtained showed that, the metals Cr, Pb, and Cu were accumulated in fish at high concentration than those those accumulated in water. The metals Cd and Fe recorded low values. BCF is controlled only by hydrophobicity of chemical and lipid content of organism (Gobas and Morrison, 2000). From the values of BCF in fishes, it is clear that, copper showed the highest bioconcentration in muscle tissue followed by zinc, while lead showed the lowest bioconcentration. This could be explained by the fact that, iron, zinc and copper are essential elements in the bodies of living organisms and has an important role in different physiological processes. As a whole the (BCF) of fish organs increased in pre monsoon followed by post monsoon and monsoon seasons. The bioaccumulation might be attributed to the different uptake, metabolism and detoxification of metals in fish. Similar observation was also recorded by Pelgrom *et al.* (1995).

**Table 4**
**Bioconcentration Factor (BCF) of Heavy metals in Mystus gulio**

| Heavy metal | pre monsoon | monsoon | post monsoon |
|---|---|---|---|
| Fe | 1172.851 | 1147.577093 | 907.6936361 |
| Pb | 305.32972 | 3162.162162 | 5499.073502 |
| Cr | 3504.504505 | 5128.205128 | 1782.337317 |
| Cu | 8902.723735 | 2301.587302 | 3582.45614 |
| Cd | 932.038835 | 877.5510204 | 425.2415459 |

## CONCLUSION

The concentration of heavy metals in the water samples of Vattakkayal exceeds the W.H.O maximum standard permissible limits. The presence of increased amounts of heavy metals may have a direct impact on the health of humans as well as aquatic animals. If the water contains toxic heavy metals it will enter into the aquatic organisms including fishes and thereby human beings through food chain, and accumulate in human organs through the process of bioaccumulation. It will create severe health hazards to human beings. The fish species, *Mystus Gulio* are highly delicious, and have great demand in the market. The main consumers of these fishes are the local residents of this region. If this lake is not protected from this hazardous situation, the lake as well as the dependent living organisms will be heavily affected. Hence necessary legislative measures should be implemented from the authorities to conserve Vattakayal, the part of the Ashtamudi lake, one of the Ramsar sites.

## ACKNOWLEDGEMENT

Authors are grateful to Kerala State Council for Science Technology and Environment (KSCSTE), Sastra Bhavan, Thiruvananthapuram for the financial support extended to this study.

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# Biogas Producton Potential of Whey-
# A Byproduct of Dairy Industry

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## INTRODUCTION

Energy is one of the most important factors to global prosperity. The overdependence on fossil fuels as primary energy source has led to global climate change, environmental pollution and degradation, thus leading to human health problems. Rapid dwindling of fossil fuel reserves has presented a scenario, which sues for alternative energy sources to be renewable, sustainable, efficient, cost-effective, convenient and safe. Fossil fuels are limited resources, concentrated in few geographical areas of our planet. The production and utilization of biogas from anaerobic digestion provides environmental and socioeconomic benefits to the society as a whole as well as for the involved stakeholders .The issue of finding an effective disposal of whey which is a byproduct of cheese (paneer) industry and reduction of pollution is a problem for dairy industries. Goyal, and Gandhi, (2009) suggested that, The main components of paneer whey were: lactose ( $4.5\pm0.89\%$) , protein ($0.41\pm0.07\%$ ), fat ($0.01\pm0\%$) and Total solids ($5.8\pm0.13\%$). The high concentration of organic material and nutrients in such wastewater makes unsatisfactory condition during waste treatment. Bovine whey was not only a cheap raw material, but also causes severe disposal problems because of the large amounts generated and its high organic matter content with a high biochemical oxygen demand (Mrwata and Kennedy, 1988; Mawson, 1994). During cheese production, whey accrues in almost equal volumes to the processed milk. The high organic load and biochemical oxygen demand are favuorable for anaerobic process (biogas production) Preparation of value added products from Whey is not cost effective. The generation of biogas from whey could be used to reduce the consumption of traditional fuels (Malaspina et al. 1996). Hence the present study was conducted to assess the biogas production potential of whey and physicochemical properties of whey and digesta.

## MATERIALS AND METHODS

Paneer Whey was collected during manufacture of buffalo milk paneer from University dairy Plant, College of Veterinary and Animal Sciences, Mannuthy, Thrissur. A portable biogas unit (0.75m$^3$ capacity) after initial charging of cow dung as per the recommendation kept at Technology Incubation Unit of Department of Livestock Production Management, College of Veterinary and Animal Sciences was used for the study. Five liters of heated whey (35ºC) was charged daily morning at 10 AM to the biogas plant for 30 days. After a period of 10 days adaptation, the observations were recorded. Volume of biogas was assessed from the dome height. Percentage of methane production was analyzed using methane analyzer developed in Central Instrumentation Laboratory, College of Veterinary and Animal Sciences. The heat generation capacity was assessed by taking the time taken to boil the measured quantity of water under standard pressure. The p$^H$,total solids and temperature of whey used as input and also that of digesta were recorded.

## RESULTS AND DISCSSION

The biogas production potential and physico-chemical parameters of whey and digesta as per the results obtained from the study are furnished in Table 1.

**Table 1**
**The biogas production potential and physico-chemical parameters of whey and digester**

| Parameter | Mean±SE |
|---|---|
| Quantity of gas production day/ litre of whey (cm$^3$) | 59032±1845.034 |
| Methane Content of gas (%) | 57.09±0.332 |
| Room temperature(ºC) | 28±0.240 |
| Digester temperature(ºC) | 28.8±0.247 |
| pH of whey | 3.88±1.0521 |
| pH of digesta | 6.404±0.2711 |
| Total solid content of whey (%) | 6.67±0.33 |
| Total solid content of digesta (%) | 5.5±0.255 |
| Heat generation capacity of biogas (J/ cm$^3$) | 4.79 |
| Biogas production potential of whey based on the total solid content (cm$^3$/g T.S) | 885.037 |

From the table it can be seen that the biogas potential of whey under specified condition is 59032±1845.034 day/ liter of whey daily. This has a heat potential at the rate of 4.79J/cm3. The methane content was found to be 57.09±0.332%. The pH of whey and digesta were found to be 3.88±1.0521 and 6.404±0.2711 respectively with trend for acidic p$^H$. The biogas production potential of total solid of whey was found to be 885.037cm$^3$/g whey. The overall reading indicates that whey is an efficient input for biogas digester, alleviating environmental pollution.

## CONCLUSION

Whey has a biogas production potential 59032±1845.034 day/ liter of whey on liquid basis and 885.037cm$^3$/g solid basis. Utilization of whey as input for biogas is an effective tool to utilize in is an ecofriendly manner. Whey can be used economically which in turn will beneficially contribute be for the solution for energy deficiency

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# *Open Forum*

# Introduction to Water and Energy Literacy and Learning (WELL) Program

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Water and Energy availability is the pillar for social and economic progress in a society. These two resources hold the key to development and remain fundamental throughout human life. It can be said that civilization and the level of development are largely influenced by the availability of these resources.

Water and energy are closely interlinked and interdependent. Therefore, the interlinkages between water and energy should be given adequate attention in the development agenda. One of the major global issues challenging the administrators and the scientific community is the management of water and energy resources, which on the one hand become more and more scarce and on the other hand generate new problems and challenges while put to new applications. The relevant questions are (i) effective management of the available resources (ii) reducing of the adverse impacts inherent to the use of these resources, and (iii) identifying and promoting non-conventional approaches.

There are global initiatives launched by many international agencies in water and energy sector. For example, the UN initiatives like 'Decade of Sustainable Energy for All' (2014-2024), 'Sustainable Energy for All Initiative' (2011), 'UN-Energy' (2004), 'The Water-Food-Energy Nexus' at FAO (2014), the World Banks's 'Thirsty Energy Initiative''Water and Sanitation Program (WSP)' the ADB's 'Thinking about Water Differently: Managing the Water–Food–Energy Nexus' (2013) all have focus on solving the water and energy crisis. There are other national and local initiatives of governments and non-governmental agencies initiated at massive scale or at small scale.

It is a fact that, the water and energy sectors face crisis and every player, whether large or small, has his own role to play. A local initiative intended for recharging a well or saving power in a household or in a small business unit has its own positive impact. At the same time, massive initiatives are also needed so that, the benefits could acquire universal pervasion. Any effort contributing towards water and energy security is welcome and is the need of the time.

We could identify and apply a number of options that offer strong opportunities to address the water and energy related issues. For example, one of the easiest solutions is also the most cost-effective: using less electricity or transportation fuel by making appliances, buildings, and vehicles more efficient.

Using renewable energy technologies and installation of power saving devices, when attempted on wider scale, also could help to reduce energy crisis. The choices we make about how we use energy will determine the extent to which we mitigate the worst impacts of energy inadequacy. Smart choices now will mean lower risks, greater energy security and strong environmental and economic benefits.

In the case of water, avoiding transmission loss and reducing wastage at user end will have remarkable effects as the saving, thus achieved, is equal to that quantity of water produced, but without any extra cost. Other relevant areas in the water sector are local adoption of sustainable management practices, and an increased commitment to water efficiency as well as partnerships and technical assistance to enhance the abilities of utilities to plan for, prevent, detect, and respond to sustainability problems and threats.

CED, an organization that believes in developing solutions for real time issues, had these two crisis areas in mind for some time and was prompted to enter into this area in a different way.CED conducted an energy audit in its office and laboratory in Thiruvananthapuram and implemented the suggestions came out of this, which helped us to drastically reduce the energy consumption.CED also implemented programs to reduce water use and also to recycle used water at CED. Fascinated by the benefits of the study and implementation of water and energy audit, CED decided to move slightly in a larger way so that the impacts could reach all over the country. Accordingly the ***"Water and Energy Literacy and Learning (WELL) Program"*** is evolved. This is a simple but high voltage program to train and develop capacity of people enabling and encouraging them for attempting water and energy saving and conservation practices. Though the program is simple, it is capable of producing major impacts. The major objectives of the program are:

- Create mass awareness on the importance of water and energy security
- Promote participatory and local initiatives in water and energy conservation and management
- Promote non-conventional methods that could facilitate water and energy conservation and management
- Contribute to a policy dialogue that focuses on the broad range of issues related to the nexus of water and energy
- Identify capacity development needs
- Demonstrate, through case studies and, if possible, through pilot applications, to decision makers that innovative approaches and solutions to water-energy issues can achieve greater economic and social impacts

The WELL Program has conceived 4 types of activities to achieve water and energy efficiency in the long run. These are:

(i) Mass awareness and sensitization programs to various groups in the society to bring in a change in attitude, behaviour and mind-set towards conservation, optimizing use, reducing consumption, reducing loss and wastage, recycling and reuse options, etc. of water and energy. The following major activities can be envisaged:

- High voltage campaigns has to be organised targeting general public, academic community (students and teachers), residents associations or similar CBOs, major water and energy user groups, generating and distributing agencies etc. Various types of programs has to be designed according to the target group.
- One major target group will be the children, since the message we inculcate in the early stage will be carried over in their life.CED had conducted many Information, Education and Communication (IEC) programs on Health and Sanitation for school children in Kerala with the participation of the Education Department and teachers and everybody involved in the program was convinced about the effectiveness of the program. The same strategy can be adopted here to make the children aware of the importance of Water and Energy Conservation and Management aspects. This will help not only to make the children aware about these things but through children it will reach to their parents and the society. The process will empower the teachers also.
- The various institutions, industries, governmental and non-governmental organisations, etc., has a major role to play by implementing the water and energy conservation and management activities. Various programs will be formulated for this purpose in consultation with these organisations.
- Media –both print media and electronic media can play a major role in this program. The Media people also has to be made aware about the importance of Water and Energy Security. Programs have to be formulated to empower the Media also to enable them to take up the message to the community. Both print and electronic media may initiate regular features and clippings, box news, etc to spread the message. Empowering Media to take up such activities and also providing information regularly to media people are also very important. CED plans to initiate a Science-Media Resource Centre(SMRC) to support this process.
- Involvement and support of the Policy-Decision makers is very important for achieving Water and Energy Security.CED plans to organise programs to sensitize these groups in the importance of water and energy security and also support them with necessary information on such matters

(ii) There needs to be lot of Research and Development activities required to find out solutions to some grey areas , to develop methods for optimization of use and leading to conservation and scientific management of water and energy. Research programs will be generally for identifying various methods to reduce consumption of these two resources, ensuring the quality aspects, reuse and recycle options especially in the case of water, developing energy efficient equipments and machineries, green offices and buildings, virtual water,etc

(iii) Technology development and technology transfer to help application of new tools and techniques, introducing equipment and devices to facilitate reduction in consumption. Application of prevailing and innovative technologies for optimization of water consumption. Since wastewater reuse (to the extent possible) could contribute towards reducing fresh water consumption, there will be efforts to promote wastewater recycle and reuse. The main task will be introducing the technologies to the concerned target groups and encouraging application of these technologies in real life situations and also promoting invention of new solutions.

Water and Energy Auditing should be made compulsory for all kinds of institutions and if possible to big residential complexes and houses.This process will help to identify the areas and method through which the water and energy use reduction and conservation can be effectively implemented.

(iv) Training and capacity building of engineers, technicians and others involved in supply and management related activities, auditing, construction activities, mechanical operations, etc., use of tools and equipment etc., fixing of different water supply and electrical appliances and also in various non-conventional practices.Officers of Water Boards/Public Health Engineering Department, Electricity departments, representatives of residents associations, civil and electrical engineering students, electricians and wiremen licensed by local governments, etc may be given orientation training .

There are three approaches to address the problems such as (i)There are a number of things which will help to reduce the consumption of water and energy without spending any money but through the change in the pattern of use and informed decision making (ii)There are some other activities to be carried out by spending minimum resources through which we can achieve a lot in this sector(iii) There are other things that can be achieved which requires additional investments such as changing the home appliances, equipments and machineries to more water and energy saving mode.

The first approach can be adopted without spending any money but by the change in mindset attitude and behaviour of the people. It will help to save lot of money and also such savings in water and energy resources will help to provide resources to more people.

The second approach can be implemented by investing minimum money which in the long run will be beneficial to the society, both financial benefit to the concerned individual/organisation and saving of resources which can be provided to more number of people. For example, by spending little money, one can implement grey water recycle program in households/institutions and then the recycled water can be utilised for irrigating your garden or washing your car, etc. The T-8 tubelights can be replaced by T-5 or LED lights with little spending which will help to reduce the energy consumption and savings in energy cost.

Replacing equipments, machineries, appliances,etc which require good investment is the third approach, but in the long run, this will also yield good results in terms of reduction in use and savings in cost.

Ensuring Water and Energy Security is very important for the survival and sustainable development of the country which can be achieved to a certain extent through the change in culture, attitude and behaviour of the people.CED plans to take up the task of organising various programs which will contribute to ensure Water and Energy Security of the Country.

# Water and Energy Security and Role of Media

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We are living in an era which is witnessing a fast depletion of resources. Resource use and its management cannot match the rise in population and changes in developmental demands. With the advent of climate change related livelihood issues the problem is going to affect the poorest sections of the society.

Water and energy security is linked to paradigm shifts in sustainable resource use and the creation of a relevant governance system. Change can be made possible only through life style changes and required policy initiatives. Media has a major role to play in initiating both these changes. Role of the media can be defined based on the identification of critical gaps in awareness creation and resultant action. As clearly articulated in the WELL programme of CED one major concern is that of mass education in regard to the optimization of resource use: "Mass awareness and sensitization programs to various groups in the society to bring in a change in attitude, behavior and mindset towards conservation of water and energy, optimization of their use, to bring in reduction of water and energy use , reducing loss and wastage etc". Along with this it is required to address policy initiatives as well.

Present solutions are mostly based on supply side enhancement. But it may lack in providing a sustainability quotient. Hence the policy on governance should also address demand management initiatives as well. Is the corporate controlled media able to address this multiple task?

24/7 media and incessant streaming of debates have a direct impact on governance and policy making in our country. With the emergence of umpteen number of satellite channels there is a profusion of stories on livelihood issues and related debates. But given its intrinsic commercial character media fails to provide long reaching policy guidelines.

In the post liberalization era there is a perceptible change in defining the role of the state in providing basic amenities to the general public. In the conventional state led policy in resource governance command and control vested with state run institutions. Limitations of this mode in terms of environmental and social externalities have triggered alternatives which emphasized on decentralization, participation and local management.

There are also debates on the role of civil society organizations and nongovernmental organizations which play a major role in policy formulation. With the change in role of CSOs and NGOs media is also expected to play a major role in supplementing civil society initiatives.

Considering both these roles the following broad guideline is being suggested to evolve a media strategy in supporting water and energy security initiatives:

1. All media spaces should have regular columns on water, energy and other resource security concerns.
2. Government can take the initiative in making use of existing slots in both the government and private media to strengthen awareness.
3. Target group specific programmes especially among school students.
4. More effective use of FM radio and community radio.
5. Participatory programmes in coordination with the NGOs which are working in this area.
6. Production of small quickies which can be repeatedly aired in the electronic media
7. Production of documentaries and training films
8. Campaign mode with intensive communication strategies which will span for a specified time span.

It is also important to conduct a media audit as well. We can look at the time and content that is being spent on such resource based livelihood issues. We can also impart media education to viewers to understand the politics of livelihood reporting.

**FUTURE ACTION PLAN**

It is in this background that a tentative action plan is being formulated:

1. A massive awareness programme which will run for an year and will use all available means of communication.
2. Preparation of communication materials which can be used by print, electronic and web media.
3. Massive participation of students who are our primary targets in the awareness campaign.
4. Preparation of documentaries and training materials for regular targeted workshops.

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**KERALA STATE COUNCIL FOR SCIENCE, TECHNOLOGY AND ENVIRONMENT**

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*Kerala State Council for Science, Technology and Environment (KSCSTE) is an organization committed towards the promotion of Science, Education, Research and Scientific temper.*

*Sharing Kerala's constant endeavourers in supporting developmental Schemes the Science & Technology Programme of KSCSTE is in the process of various creative Schemes in the Science sector. KSCSTE is now looking at the future by providing world class research and implementing globally accepted quality parameters pertaining to the State's overall development.*

**RESEARCH AVENUES, FELLOWSHIPS & SCHOLARSHIPS**

- *Emeritus Scientist Scheme for senior Scientists*
- *Doctoral & Post-Doctoral Fellowships*
- *Fellowships in Science writing & Science Communication*
- *Prathibha Scholarships for Students opting Science learning*

**FINANCIAL SUPPORT FOR PROJECTS**

- *Grant for Research Projects in emerging areas of Science (SRS Scheme), Technology (ETP Scheme) & Environment (E&E Scheme)*
- *Project for School and College Students*
- *Individual and collaborative projects in Engineering & Environment areas*
- *Industry linked biotechnology Schemes*
- *Intensive programmes for Innovators of Rural Technology(RTP Programme) and Biotechnology*
- *SARD Scheme focusing activity specific areas*
- *Innovation & Technology Development(TDAP)and Patent Information Centre*

**PROMOTIONAL PROGRAMMES**

- *Kerala Shastra Puraskaram for eminent scientists*
- *Science Literature Award*
- *Back to Lab Programme for Women*
- *Vocational skill oriented reinstated training [VSORT]*
- *Tech Fest, Green Corps, Eco Clubs*
- *Sasthra Poshini & Sasthra Bhodhini*

**POPULARISATION PROGRAMMES**

- *Science Popularization Programme*
- *Support for Seminar, Symposia and Workshop*
- *National Science Day, National Technology Day, World Environmental Day, Ozone Day etc.*

**KSCSTE IS ALSO SPREADING THE ACTIVITIES TO THE FOLLOWING AREAS:**

- *Technology Transfer*
- *Science City*
- *Scientific Management Training*
- *Innovation Warehouse & River Rejuvenation Projects*
- *Video Production on Science Awareness*

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