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Review Article

A Collective Conscientiousness for Water Conservation & Safe Water: A Review

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ABSTRACT
There is no resource more precious than water. As our water supply is put under greater and greater stress, the abuse of this precious resource and its holding environment is increasingly being realized. Availability of safe drinking water, healthy and intact natural ecosystems and humanity's ability to feed itself are at threat as demand for water outstrips availability. Conserving water is the new gold. Investing efforts of this valuable resource will ensure our future security. Referred to as 'blue gold', the value of water is immense in all aspects of life – whether for household, industrial or agricultural need. It plays a critical role in the natural environment, in our economies, in production and in production and in politics. It even goes beyond national boundaries to create debate on its importance, scarcity as well as conservation. Water conservation is not new in South Asia. Rainwater harvesting structures are the oldest recorded hydrological activities used 8000 years ago in South Asia. India is known for its traditional rainwater harvesting structures - tanks and simple village ponds developed by Vijayangar Kings of South India in the 14th century. Some of these continue to support local production and domestic activities till today. Water is a part of larger ecological system. Realizing the importance and scarcity attached to the fresh water, it has to be treated as an essential environment for sustaining all forms of life.
Keywords: Groundwater; Hydrological system; Water audit; Pollution; RWH; Reverse osmosis; CEDI technology

INTRODUCTION

Even today in rural India we see hundreds of community managed water initiatives from very small ponds and wells to small reservoirs active in increasing water availability, recharging groundwater, and boosting local efficiency as well as productivity. Tarun Bharat Sangh an NGO in Rajasthan has succeeded in building more than 5,000 water harvesting structures (johads) in 1,058 villages with the help of villagers of Alwar district. The initiative it is claimed has made a marked difference by transforming a dark zone region into white zone. The Indian constitution is among the few in the world that contains provision for environmental protection, being explicitly stated in the 76th amendment stipulating the conservation, protection and improvement of the environment. Article 51 (a) (g) entitled fundamental duties – imposes responsibility on every citizen to protect and improve the natural environment including forests, rivers, lakes, tanks, wild life and to have compassion for living creatures.

With the onslaught of rapid and unchecked industrialization and urbanization this constitutional responsibility has long been breached. The exponential growth in water use and abuse, deforestation and change in land use patterns, has meant these water bodies are destroyed, affecting groundwater recharge and resulting in groundwater depletion and contamination. Historically, industries were extracting groundwater and using tankers to overcome the lack of water supply in cities. But now as groundwater slowly inches towards dangerous mark and industry demand continues to increase, effective and efficient use, management and governance of water is gaining greater and greater importance. Total groundwater use according to government estimation will be over 240 billion cubic meters (BCM) in 2012. The Central Ground Water Board (CGWB) has revealed that 30% of India is overusing groundwater resource. News of the groundwater table dropping from 30-40 feet just after independence is now even at 1,000ft (it is difficult to get water in some areas of Bangalore) is worrying news. Daily news of farmer suicide is a sign of concern of inadequate water supply in India to meet even the basic need of its citizens. On the other hand government's promise of water supply for 24/7 to industries smacks in the face of our belief in justice. Report 2006 concluded that "Scarcity of water at the heart of the global water crisis is rooted in power, poverty and inequality, not in physical availability". Also in accordance with the World Bank report in 2003 – This crisis is one of water governance, essentially caused by the ways in which we mismanage our water. Both reports articulate the need for an integrated management of water and its environment to ensure that there is more than enough water in the world for domestic, agriculture and industry needs.

In this article we look at the wider meaning of water conservation and the importance of industry to conserve, protect and be prudent in its use. We will also point out to some examples of where and how it can be accomplished. Water conservation encompasses a range of actions by individuals, community as well as legal requirements. It includes harvesting rainwater in small tanks for domestic use, constructing small dams and reservoirs for agriculture and industry use, as well as helping to recharge groundwater. It now increasingly includes using lower quality water whenever possible in order to save fresh water, reducing the demand for water and stopping wasteful uses. There also technological advancements and improved management techniques available for use in industry, agriculture and in homes all leading to efficient use of water, recycling and harvesting water. In short, water conservation means efficient water use through its protection, up keep, maintenance, management and preservation[1-3].

THE IMPORTANCE OF WATER CONSERVATION IN INDUSTRY

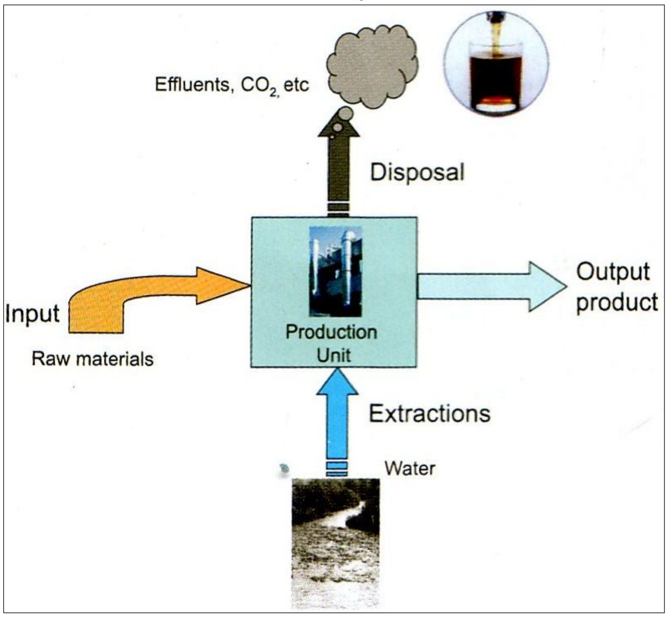
Although in India agriculture takes the lion's share of water, with industry currently using 4% of water, its use is projected to increase 500% by 2025 as urbanization and growth of manufacturing continues to increase. In 1990 globally, industry used and estimated 6% of the of the world's water, it now uses 4x that share – showing a trend of water redistribution from agriculture to non-agriculture. This average masks huge inequity in the use of water. Some industries consume more water than others due to a combination of factors including obsolete process technology, poor recycling and reuse practices and poor wastewater treatment. And there are some industries that have achieved optimal use of water and remain competitive in the market. Access to reliable supply of water is an absolute requisite for all the industries. In fact, industry would do well to take a page out of community led initiatives in conserving water or better still join community in their efforts to conserve water and protect the environment.

The question then is of practice, policy, politics, and partnership, economics, regulation as well as science and technological know-how. The solution lies in effective and integrated management of water resources and protection of the environment. An integrated approach involving prudence in water use, aiming for zero discharge, waste minimization as well as zero waste, effective effluent treatment, end of pipe and in-pipe (in process) solutions. In addition to managing industries, own immediate need for water, industry need to play key role in the collective conscientiousness for protecting the environment from which may draw the natural resource. This will require industry to see the value of water going beyond its economic value – valuing water as a public good with equity in sharing water and not as private property with unfair and indiscriminate practice of extraction and exploitation.

India has 16% of the world's population but only 4% of global water resources. Across India the hydrological cycle is predicted to become more intense, both with higher annual average rainfall as well as longer periods of drought 2 million people (14% population) are still without sustainable access to an improved water source. Water quality and water resources are under threat – Water pollution is a serious problem in India as almost 70% of its surface water resources and a growing number of its groundwater reserves are already contaminated by biological, toxic organic and inorganic pollutants. Although the industrial sector only accounts for 4% of the annual water withdrawals in India, its contribution to water pollution, particularly in urban areas, is considerable .Fertilizers and pesticides have entered the water supply through run-off and leaching to the groundwater table posing a hazard to human, animal and plant population – rendering water unsafe for not only human consumption but affecting irrigation and industrial needs and affecting the ecosystem

STRATEGIES FOR CONSERVING WATER – AN INTEGRATED APPROACH

An integrated approach means that the conservation efforts must take into account the whole environmental performance of the planet, covering extraction of natural resources, use of raw materials, energy efficiency, emissions to air, water and soil, generation of waste as well as responsibility for products after it leaves the factory gates and taking responsibility for protecting sources of water. The purpose of the integrated approach is to ensure a high level of protection of the environment taken as a whole. Below are some of the practical initiatives that industries can adopt as part of their business to ensure efficiency and water conservation.



Water Audit

A comprehensive water audit involving site survey, review of physical use and distribution of water would help to uncover inefficiency in the water use and distribution system that results in money literally pouring down the drain. The audit should also assess the impact of water use and discharge by industries on the local environment and community. Such an audit would help industry to reduce its water consumption often with significant cost savings. Industry should move to produce an integrated water resource management plan that will help the environment and ensure availability of clean water to all community members.

Treat Industrial Pollution and Manage Sludge

The Ministry of Environment and Forest (MoEF) estimates that industry contributes to more than one third of the total pollution in rivers and other water bodies. India currently generates over 110,000 million litres of wastewater a day, and over 12,000tonnes of hazardous waste. Untreated wastewater from municipalities, households, organic and inorganic toxic from industrial effluents dumped directly into local rivers and streams without prior treatment putting additional stress on availability of fresh water. There are many instances when industries have directly polluted the aquifers by using failed bore wells to discharge untreated effluents resulting in contamination of groundwater. All these illegal and irresponsible actions affect all directly and indirectly.

Conventional policy approaches towards pollution treatment focus on Common Effluent Treatment Plant (CETP) where industries are expected to send effluents with standardised characteristics. In practice, there is a huge difference in what is sent to the CETP and the actual effluents discharged by industry. Much of it is then released in the local water body. Given the increasing diversity in quality and quantity of effluent discharge there is a requirement for industry to pre-treat effluents on site. CETPs are under capacitated to deal with the variations in the biological and chemical compositions of incoming effluents. There is an increasing need for industry to consider "in process" treatment technologies. This way not only will it easier for CETP to treat the final effluent but also result in more efficient use of raw materials, energy and water. Clean technology or technology to ensure clean production, the ultimate aim is to reduce the generation of wastes and toxic emissions. Reducing input material cost, effluents and wastes become a money earner. The treatment process should be carefully designed, planned and controlled in order to meet the required discharged or lead to zero discharge. The various procedural steps currently available and used include:

Primary treatment: - a preliminary treatment removing large floating materials followed by primary clarifiers to separate suspended solids from primary effluent;

Secondary treatment: - to include aeration tanks and secondary clarifiers to consume organic materials;

Tertiary treatment: - uses membranes of varying pore sizes such as micro-filtration (MF), ultra-filtration (UF), and nano-filtration (NF) to separate suspended and dissolved inorganic and organic contaminants;
Polishing unit: - to ultra clean water for recycling. Reverse osmosis is an example of polishing unit – an advance membrane technology used to purify water for drinking purposes;
Sludge management: - is becoming increasingly important as they can be harmful to the ecology

and are difficult to dispose off through incineration or landfills.

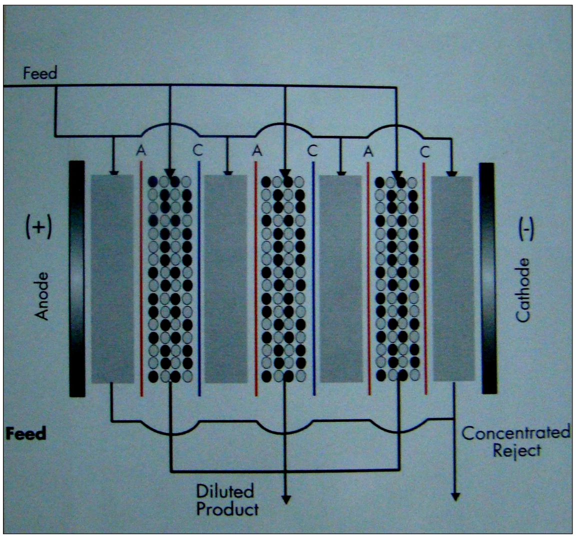
CONTINUOUS ELECTRODEIONIZATION TO PRODUCE ULTRAPURE WATER

A new generation of continuous elecrodeionization (CEDI) modules is capable of changing the way high-purity water is commercially produced. More than any other, the semiconductor industry has spurred its development, due to its stringent demands on water purity. Yet the benefits of this technology are also very applicable in power generation. This is not all as besides the benefits, the chemical waste creation in conventional ionexchange pre-treatment, is also eliminated with CEDI. The new breed of CEDI system offers a clean, environmentally superior alternative to chemically regenerated, mixed ionexchange plant, while matching it in performance.

In semiconductor manufacturing processes, the use of conventional bed deionization (DI) for the production of ultrapure water has its drawbacks, due to fluctuations in produced water quality. This is caused by exhaustion and regeneration of ion exchange beds. As CDEI, by definition, is free from this fluctuations and designers of this technology have focussed on making CDEI competitive with conventional mixed bed DI by improving module performance, increasing module reliability and lowering the overall cost of ownership of CDEI system. Product water specifications for CDEI technologies hitherto are typically in the range of 10-16 meghohm-cm with removal of weakly dissociated species such as silica and boron in the 90-98% range. This is sufficient for many industrial uses, such as water production in the pharmaceutical and power generation markets. However, this quality is not sufficient for use in the microelectronics industry where requirements are stringent – requiring greater than 18 meghohm-cm, with most species non-detectable. In this case, and in many power applications where there is a stringent silica requirement, CDEI is followed by ion exchange polishing.

While this approach can greatly extend the ion exchange service cycle and reduce operating costs, there were still issues such as regeneration and ionic breakthrough of the ion exchange resin that had to be addressed. The ideal solution was for the CEDI to produce water directly of a quality acceptable to the microelectronics manufacturing process, i.e. greater than 18 megohm-cm with acceptable levels of silica, boron and other dissolved species.

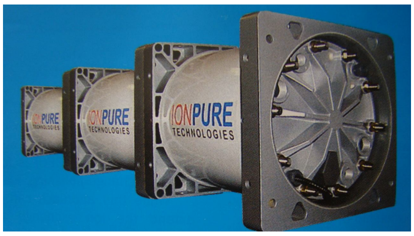
CEDI Technology: Continuous electrodeionization removes ionized substances from water using ion exchange membranes, electrically active media (typically ion exchange resin), and a DC electric potential. Most commercial CDEI devices have layers comprising cation and anion-permeable membranes with spaces in between, configured to create liquid flow compartments with inlets and outlets. The compartments bound by an anion membrane facing the negatively charged cathode are diluting compartments. The compartments bound by an anion membrane facing the cathode and a cation membrane facing the anode are

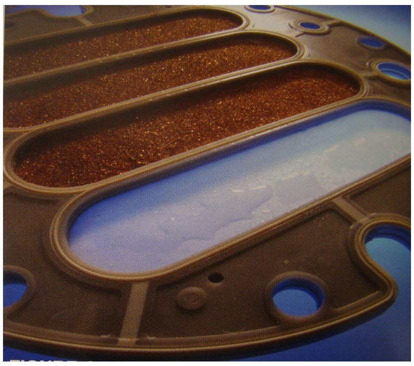


concentrating compartments. To facilitate ion transfer in low ionic strength solutions, the dilute compartments are filled with ion exchange resins. A transverse DC electrical field is applied by an external power source using electrodes at the boundaries of the membranes and compartments. When the electric field is applied, ions in the liquid are attracted to their respective counter-electrodes. The result is that the diluting compartments are depleted of ions and the concentrating compartments are concentrated with ions. (Figure 1)

IMPROVING PERFORMANCE

In CEDI technology, the goal of the individual layers is to remove their respective counter ions, i.e. the anion exchange resin layers remove anions and the cation resin layers remove cations. To maintain electroneutrality in a layer where cations are being transferred to the concentrate, water splitting must take place at the anion exchange membrane to provide the hydrogen ion (H^+). A similar process happens in the anion layer at the cation membrane providing the hydroxide ion (OH^-) to replace removed anions. In the layered bed, the acid or base created through water splitting regenerates some of the ion exchange resin. It can also change the bulk pH in the particular layer. This is critical to the removal of species that are very weakly ionized at neutral or slightly acidic conditions, typical of CEDI feed waters. Acids of silica and boron have pKa values between 9 to10. This means the pH must be increased to this range to achieve effective removal. Dissolved CO_2, the predominant species in most reverse osmosis (RO) permeates, is also effectively converted to the ionized forms in this range.





Just as the pH is elevated in the enhanced anion layer, the pH can be reduced or neutralized in an enhanced cation or mixed bed layer. So it is necessary to pass through different types of layers to produce high quality of water. The problem is that the electrical resistance of the different, potentially allowing preferential current flow. In addition, the resistance of each layer can change due to the form of the resin or the bulk pH. This issue was overcome in standard single pass modules by doping certain layers to equalize resistance.

BETTER RELIABILITY

The latest advance in CEDI module design improves reliability and reduces cost at both the module and the system level (Figure 2). The VNX module (from Ionpure Technologies) has a cylindrical housing, with integral mounting brackets at both the ends. The diameter of the cylinder is ~ 46cm and the length is 66cm. Internally, the module is of a thick-cell design. The dilute spacer is fabricated in a multi-step process and consists of two mirror-imaged [Figure 2] halves molded in glass-filled poly-propylene, which are then clamed together and over-moulded with thermoplastic elastomer (TPE) (Figure 3). The TPE thermally bonds the two halves together and forms integral)-

rings that seal the membranes to the spacers and the spacers to each other. The stack of spacers, end-blocks, and endplates are sealed inside a fibre-glass-reinforced plastic cylinder by O-rings on the periphery of the end-blocks (analogues to the end-caps in an RO vessel). The module is therefore guaranteed to be leak-free at an operating pressure of 7 bar. Higher pressure may be possible, since the operating pressure is limited only by the effectiveness of the end-block, O-rings and the pressure rating of the cylinder and the endplates. The new module combines the superior flow distribution of a plate-and-frame design with the benefits of a cylindrical housing.

CDI IN ACTION

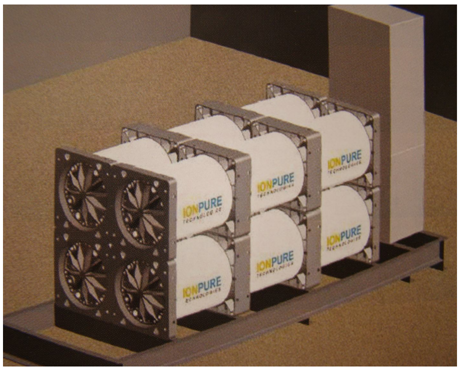
Ionpure Technologies (A Siemens Company) is the world leader in the CDEI technology and has significant contribution in the development of this for many industrial applications. The largest single installation of Ionpure modules in Asia to date is a series of five VNX-3 units in UP. One of the most interesting applications, however, is in the Netherlands. This involves a 1,288m^3/hr (5,667gallons/min) water pre-treatment system and a 170m^3/hr (750gpm) demineralization system at the Rijnmond Energy Centre, Rotterdam. Ionpure Technologies provided the CEDI modules for the US Filter demineralization system. Designed to produce high-purity water for boiler feed, the demineralization system includes two RO systems feeding two CDI-LX systems with a capacity of 85m^3/hr (375gpm).

The demineralization system treats brackish water from the Rotterdam harbour and performance has since been outstanding since it was commissioned. Feed water conductivity, which varies depending on the tides, has been measured at levels up to 10,000µS/cm. "Water quality from the RO/CDI system is exceptional, with conductivity averaging less than 0.07 µS/cm," says Todd Hook, PE, Director of Engineering and Project Management for US Filter's Engineered Products and Services Group. "In addition, the sodium concentration in the RO/CDI product water is about 1ppb and the silica concentration is below 3ppb."

The performance of the system significantly exceeds the water quality specifications, when require that the conductivity be less than 0.10µS/cm and the sodium and silica concentrations be less than 10ppb.

LOWER COST

Over the last few years there has been a shift towards thicker diluting cells, which reduce the amount of ion exchange membrane area necessary to treat a given amount of water, and modular system approaches, both of which have lowered capital costs. System assembly costs have been reduced via an innovative building block approach to system assembly, based on multiple modules connected in-line, much like RO elements. With VNX, mounting holes in the end brackets allow the modules to be bolted together end to end, side by side, or stacked vertically, thereby reducing the amount of framing and structural support necessary. Multiple modules can be connected in line using sections of pipes with O-rings at both ends, similar to the product interconnect tubes in RO vessels. This multiple-module building block approach provides the system designer with the flexibility of modular design without increasing the complexity of mechanical mounting, piping and electrical connections.



A basic system, consisting of modules arrayed on a skid (Figure 4), can form the basis for system integrators to construct systems for specific applications by adding the required piping, instrumentation, controls and power supply. Direct shipment of the basic system from the factory to site is possible, with final assembly on site [1].

Mitigation As Well As Adaptation – Reuse/ Recycle

There needs to be a paradigm shift in the production systems as well as on production lines taking responsibilities for inputs as well as outputs at all stages of production. Industries should design systems which reduce water consumption, waste as well as promote practices to reuse and recycle as much as possible within the plant processes thus reducing the extraction of further fresh water. There should be a move away from the linear model of resource use where resources are extracted for producing goods for consumers which are then discarded after use. In the process valuable fresh water resource is used and discharged indiscriminately. Industry need to design products that are environment friendly taking responsibility for extraction to disposal, producing safe products and products that has longer life line and are recyclable/ reusable (to move away disposal and harmful lines such as the throwaway plastic). To complete the cycle consumers should learn to repair and reuse items. As stated in the GreenBlue website "Business needs to take greater responsibility for the whole life of a product cradle to cradle". Here government should provide incentives to good businesses and penalise bad businesses that produce non-recyclable products.

RAINWATER HARVESTING

Rainwater harvesting is the new buzz phrase in India. Households, public buildings as well as corporate houses are investing in technology to collect rainwater either from rooftops or by surface run-off in tanks. Many states now have legislation or are in the process of passing legislation making rainwater harvesting mandatory on all new buildings with a specified roof surface area ranging from 250sqm in Indore (MP) to 1000sqm in Mumbai. The centre for Science and Environment (CSE) lists good models on its website. The site has an on-line run-off calculator which estimates annual rain water harvest from your roof top simply by entering your location and roof area. It lists 16 models of rainwater harvesting in urban Delhi detailing the system and monitoring impact on the depth of groundwater. A building in Bangalore with roof top area of 100sqm can harvest nearly 1lakh litres of rain annually.

BALANCING INFRASTRUCTURE PLANS WITH PROTECTION OF ENVIRONMENT

India is undergoing a huge investment in infrastructure building to support industrialization which is argued will enhance India's growth and development. Plans for infrastructure have to be balanced with the protection of environment and water resources. The industries need to make the environment Impact Assessment (EIA) more than just a paper exercise. They have to keep an eye on the people who will be directly affected by the plans and/ or plants. If the affected peoples concerns cannot be addressed adequately than plan and/ or plant must be abandoned. The longer term cost of environmental damage will be too huge for humanity to bear. Bangalore once famous for its lakes and tanks is now a city of flyovers and car parks. The slightest of heavy downpour, floods the city with huge damage to people, place and property.

DEVELOP A LOCAL SUSTAINABLE WATER MANAGEMENT STANDARD FOR SUSTAINABLE PRODUCT STANDARD

The objective of such a standard is to signal industries intention to recreate the way water and raw material is used in their production. The standard should include a framework for assessing, analyzing and auditing water use and abuse by industries. The information collated will help industry make informed decisions about the future of its manufacturing and enabling sustainable product to lead the way towards a more efficient, ethical and responsible industry – the next industrial revolution. An example heighted on the Green Blue website of The Sustainable Textile Standard (STS) offers an ambitious new concept for textile production, where a truly sustainable textile would meet or exceed all industry performance and cost requirement as well as gain the confidence and loyalty of the increasingly of the increasingly informed consumer on the need for environment protection. The standard set includes: Use of safe materials and processes for human and ecological health in all phases of the product life cycle;Ensuring that energy, material and process input all come from renewable sources; that materials are capable of returning safely to either natural (biological nutrient) or industrial (technical nutrient) systems; all stages in the product lifecycle actively support the reuse or recycling of these materials at the highest possible level of quality; all persons involved with the creation of textiles are treated fairly with respect to human rights and given training to increase their mastery of this craft.

Today's industry needs clear leadership in collective vision for collective action in protein our environment. There are numerous examples of local community coming together in India to protect their water resources taking direct responsibility in water shed management including in rejuvenating local water bodies and managing their supply and demand ensuring equitable distribution and sustainability. Clusters of industries in a particular area can act as a "community" with vested interest in its local environment taking responsibility for ensuring accountability of every industry in the zone for environment protection. A well designed decentralized industry regulatory framework for good environment governance, building on central and state environment compliance and enforced locally by an elected stakeholder committee, to stop over exploitation and abuse of water. The committee can be entrusted with the responsibility for recharge and rejuvenating activities. Such a system will not only ensure a fair level playing field where competition between companies is based on sound environmental practices prevent a good company being undercut by the bad and the bad by worse, but also ensure sustainability of efficient industries and local environment through guaranteed availability of water. Here the emphasis is not on competition but co-operation between public, private, researchers, environmentalist and community to: mobilize knowledge and power of science and innovation in new technologies; using market, social and cultural mechanisms to give incentives to change in the way companies operate; promote greater personal and social responsibility in all aspects of business operation.

EXTENDING THE GREEN COVER

Many communities are already are already involved in activities of reforestation and water shed management. Industries should support these initiatives and show leadership by increasing green cover on and around their plant. Plant tress such as Pongamian and Neem are excellent for maintaining the balance in the ecosystem for longer term benefits.

EXTEND RESPONSIBILITY TO BASIN PROTECTION

Indian rivers basins which are the sources for ensuring livelihoods and development of the nation are also rich in biodiversity and multiple ecosystems. These need to be protected. However, weaknesses in policy, environmental regulatory framework and its enforcement, is leading to its rapid deterioration. The result is socio-economic in equalities and environmental damage; culminating in farmers' suicide, excessive groundwater exploitation, distress mitigation, water conflicts, pollution and wide-spread social unrest. Industry can work with local stakeholders groups to share knowledge and expertise and support interventions and implementation of decentralized small scale efficient solutions to protect our river and its basins and increase local quality and quantity of water supply.

ADOPT CORPORATE RESPONSIBILITY FOR ENVIRONMENT AND DEVELOPMENT

Business excellence now should include corporate responsibility at the heart of what companies do. Companies can make a difference in the environment, employment and community life, as well as in success of their own business organizations and investing in local communities and its environment. The smart solution for business in modern world is where economic prosperity, social justice and environmental sustainability work together. But most of all companies need to make a cultural shift in the way they see water – treating water as public good not as a private property. The value of water the Indian society goes beyond the commercial value. Water has cultural importance as well as importance in the environment in maintaining the balance in ecosystems of our earth. Access must to water is a human right and priority must be given to ensuring safe drinking water for all.

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