Towards Sustainable Water Resources Management for Auroville and the Bioregion

Proceedings of UNESCO-endorsed international seminar, 13th to 15th September 2004 at Auroville

Auroville Centre for Scientific Research (CSR)
Auroville Water Harvest

Auroshilpam
Auroville 605101
Tamil Nadu
India
csr@auroville.org.in
www.auroville.org
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Claudine Vignes, Auroville 605101.

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Luc Gastmans, Cynergy, Auroville 605101.
Raindrops falling on the earth, what a blessing, what a necessity, but more recently we can also observe a destructive dimension. What happens when rain infiltrates in the soil or runs off towards lower lying areas? How does it flow underground, how is it stored, how are reserves replenished? How do you safeguard the water reserves, what happens in case of pollution, what happens when the water table is over pumped? What dynamics take place in such scenarios, are there disasters in the making or are remedial actions possible?

During a three day seminar, “Towards a Sustainable Water Resources Management for Auroville and the Bioregion”, held at Auroville from 13th to 15th September 2004, 21 scientific papers were presented. The idea was to collect as much scientific data as possible for a coastal bioregion covering 1400 km² with a population of nearly 2 million. The seminar not only received a gracious encouragement letter from the President of India, Dr A.P.J. Abdul Kalam, but was also endorsed by UNESCO-HELP Basin program, which aims at supporting improvements in water management, science, policy and law.

Coastal regions have complex hydro-geological compositions and not much scientific research and data is readily available for such places. The Kaliveli-Pondicherry bioregion is no exception to this phenomenon. During the last two decades, this coastal region has shown an on-going environmental degradation. While salt-water infiltration has been the most talked about problem, causing permanent damage to the coastal fresh water resources, it certainly is not the only problem.

If the multifaceted socio-economic issues along the coasts are also considered, now highlighted after the tsunami disaster, then one has to conclude that the coastal bioregions are under continuous and increased pressure from many different directions.

This scientific monograph is only one step in a continuing effort to gather and compile a comprehensive scientific data-bank that can foster future environment-friendly, socially-acceptable and economically-viable interventions in the coastal region.

It is expected that Auroville will play a nodal role in initiating further scientific research and assessment studies. With its experience in afforestation, appropriate building technologies, renewable energy and waste water treatment systems one can foresee a further expansion of all these technologies within the wider bioregion. This can involve further afforestation, implementing and following up on proper sanitation programs, irrigation powered by solar power instead of diesel pumps, small desalination plants powered by renewable energy sources rather than conventional grid-supplied electricity and Pondicherry sewage effluent treated by decentralized methods and reused for infiltration and irrigation instead of being regarded as a waste product. The possibilities are numerous, one just has to start. It looks like this is happening, at last.
Organizing such an event and making sure that the flame of expectation results in a continuing process of implementation was guaranteed by Gilles Boulicot, Carel Thieme, Harini Sampathkumar, Walter Wagner, Michael Bonke and Claude Arpi. Without this first line of solid support the seminar would never have materialised.

There was also the transcription team Paula and Marijke, the crew from CSR-Auroville Building Centre with Ramu, the Auroville Water Harvest group, the Tibetan Pavilion team, Luc for the layout work and Claudine for the cover design. Valuable support and input came from all colleagues who are part of the Auroville Water group.

The seminar received an input from 24 presenters, all equally passionate about their specialization and eager to see a continuation of the further scientific data-gathering in order to be able to draw conclusions leading to successful remedial interventions.

Special thanks to Sophie Violette, Israel Gev, Jeen Kootstra and Shri Vasanthakumar Reddy, and to Shri Gopalswami who has tried to ensure that we do not doze off during the long journey of making the Kaliveli-Pondicherry bioregion a worthwhile model, a beacon of hope.

Tency Baetens
Auroville Centre for Scientific Research
Auroshilpam
Auroville 605101
India.
Towards a Sustainable Water Resources Management for Auroville and the Bioregion

Issues, Concerns and Achievements

The bioregion

The area of interest is located in the State of Tamil Nadu and is to some extent overlapping the northern part of the Union Territory of Pondicherry. It constitutes the coastal watershed of Kaliveli and is located between Marakanam, Tindivanam and Pondicherry towns, in the Tindivanam and Vanur blocks. It lies between 11°55' and 12°10' North and 79°35' and 79°55' East. This unique watershed of 764 km² is flowing to the Kaliveli swamp, with a single outlet to the sea, near Marakanam. It borders the sea on a 35 km stretch on the Bay of Bengal between Marakanam and Pondicherry. The main geological features are:

- in the coastal area, a track, 15 km broad, running parallel to coast composed mainly of sedimentary materials, where the main storage of ground water takes place;
- inland, a primary basement of charnockite is present, with a poorly exploitable ground water.

The soils in the watershed area are mostly black and red soils. Alluvial soils are also found in the eastern side, all along the coast. Black soils with clayey texture are confined to low grounds in select pockets of Vanur taluk.

The watershed is mostly flat although it has some hillocks in the central and northern part. The higher altitude of 50 m above mean sea level (msl) is seen in the northwest part of the watershed and it gently slopes towards the coast. Gullies and ravines intersect the watershed widely through which run-off monsoon rain water drains into the Kaliveli swamp, which ultimately flows into the sea. Coastal areas have older and younger flood plains and also beach landforms at some places.

Surface water storage structures like irrigation tanks and ponds are the major watershed water resources. There are 196 interconnected irrigation tanks, having a total of 34,500 acres of command area. In spite of some rain-fed rivers there is no perennial river.

There are 162 villages and three town panchayats in this area, besides Auroville. The total population of the area is 355,000 inhabitants. The main economic activity is agriculture; industrial activity is developed in the scattered areas belonging to Pondicherry Territory.

The Kaliveli swamp (72 km²) is one of the last unpolluted water bodies of South India and a wintering place for migrating water birds (more than 100 different species). The local population makes diverse use of the swamp in traditional activities including:

- Catching fresh and brackish water fish and prawns for consumption
- Reed and grass harvesting for building purposes, firewood and fodder
- Salt manufacture
- Cultivation of crops (mainly paddy) in the drier parts
- Harvesting many plant species for healing.
Auroville

Auroville sits on a plateau 50 m above sea level. At the centre is the Matrimandir area, which is the highest part. From this centre, the land slopes gently down on both sides, towards the east and the west. There is a ridge running along the north-east/south-west direction through this area.

Auroville today looks quite different from its inception in 1968. At that time the land was denuded of all vegetation, frequent wind and monsoon storms eroded all of its topsoil, carving ravines or canyons as rain water poured down from the plateau into the sea. Local people were involved in marginal farming and had a subsistence living standard. It was clear to the early Aurovilians that water held the key to this landscape. Land restoration work was undertaken with bunds and tree planting. Over the years, the early efforts transformed themselves into an interest into bringing back the original forest type and preserving the traditional knowledge of the region.

**Issues**

**Depletion of groundwater**
Aquifers in coastal regions all over India are reported to turn saline and groundwater levels are fast declining. Auroville has a reputation for its successful reforestation work, for rainwater harvesting, for the construction of check-dams, and for programs of tank rehabilitation. Despite all these measures, the groundwater table of Auroville and surrounding region is continuing to fall, and salinity increase is recorded. While several helpful projects do retard and sometimes reverse the situation, the trend is alarming.

*Keywords: Hydrogeology / Over extraction / salinity increase*

**Surface water management**
While regular repair and maintenance of the tanks was once an annual feature followed by the ancestors, we observe that today most of the irrigation tanks are in a neglected condition and are heavily silted up, having lost their original storage capacity. Additionally, the surrounding lands have been deforested, leading to heavy erosion, loss of arable soil, reduced yielding capacity, vanishing biodiversity and finally poor groundwater recharge from rain water.

*Keywords: Hydrology / Water management practice / Irrigation / Agriculture*

**Ground water pollution**
While solid waste management is now slowly being recognized as an issue to be addressed in the urban setting, this awareness is only gradually extending to the rural areas. The surroundings of Auroville, for example, are suffering from uncontrolled dumping of mixed solid wastes, and areas with high groundwater tables are threatened to get contaminated both chemically as well as microbiologically.

*Keywords: Solid waste management / Chemical disposal / Pesticide / hazardous waste disposal, sanitary landfill*
Sanitation
Though proper sanitation is generally acknowledged as a prime concern of public healthcare, proper functioning public sanitation systems are slow to manifest. In the Auroville area, a major part of the wastewater is neither collected nor appropriately treated. There are also good reasons to reconsider the appropriateness of conventional centralized sewage treatment systems, as they are capital intensive and handle water resources wastefully. Decentralised ecological approaches to sanitation need to be developed which fulfill the requirements of both urban and rural areas, and deal with the end products in a responsible manner.

Keywords: Sanitation practice / Valorization of resources / Decentralised wastewater treatment systems (Dewats) / Ecological Sanitation (Ecosan)

Storm water management and urban runoff
Water resource management in a tropical urban context cannot be realized without appropriate rainwater harvesting systems and storm water management. Proper solutions need to be developed.

Keywords: Best storm water management / Rainwater harvesting and storage / Integrated urban water management

Desalination
Of late, an increasing interest in desalination is observed in Tamil Nadu and Pondicherry states. This technology is making rapid advances and offers indeed possibilities for remedies of some acute problems of the “Thirsty Planet”. Its suitability in the context of Auroville needs to be explored, including its environmental sustainability (e.g. the environmental problems of brine) and the accessibility of purified water to the population of Auroville and the surrounding villages.

Keywords: Desalination / Renewable energy / Environmental implications (brine)

The Matrimandir Lake
The founder of Auroville, The Mother, envisioned a lake around the Matrimandir, the centre of Auroville. The water source needs to be identified and studied. The question as to whether the lake can make a positive component within the region’s water resource management has to be explored.

Keywords: Planning / Implementing / Functions / Water source identification

Future regional expansion plans
Environmental Impact Assessment (EIA) is becoming an important management tool for ensuring optimal use of natural resources for sustainable development. EIA has now been made mandatory under the Environmental Protection Act, 1986 for 29 categories of developmental activities.

Development projects in the bioregional context include expansion of the Pondicherry Airport, new roads, new railway track, and projected water ways. Though it appears that
EIA's are not required for these projected developments, the stakeholders may want to be informed about these new developments. Presently, very few water management rules or laws have been enacted upon and are being applied.

Keywords: Regional development plan / Bioregion / Environmental impact assessment / Protection of water resources

Collaboration between stakeholders

The seminar is being organized to present the available research data on water and related topics within the wider bioregion, in order to shed light on the issues and challenges, to place the development of Auroville within the context of the bioregion, and to initiate a constructive dialogue amongst the stakeholders of the region aiming at a joint and constructive development of strategies and solutions for a sustainable future.

Keywords: Regional / Urban-Rural / Macro and Micro level / Participatory Approach

Areas of concern

The areas of concern within the bioregion are briefly summarized below:

Need of appropriate institutional tools: Local government and administration have an extremely difficult task in the implementation of laws for safeguarding the environment. The present institutional setup is unable to concentrate on the problem areas with sufficient impact in order to offer sustainable solutions.

Lack of appropriate watershed management: The concerned area lacks a coordinated development and this is leading to serious environmental problems that may affect tens of thousands of people by ultimately depriving them of the supply of safe drinking water. In the absence of proper planning, huge amounts of water are extracted from the ground and natural resources are being abused.

Need for relevant database: Information about the status of the development of the area is collected by the Village Administrative Officer’s (VAO) and other department local officers. They are compiled at the taluk level and at the district level. The data give a general impression about the situation, their level of accuracy is not satisfactory, and even sometimes in contradiction with ground reality. Key information such as number and characteristics of tube wells are non-existent. Most of the information about the tanks (such as tank capacity) is often unavailable. Tank memoirs have not been prepared for this area. Maps are difficult to acquire, and their accuracy does not allow using them in computer modeling of the watershed. Topographic maps are inaccessible, being classified.

Need for in-depth ground water research: The concerned area, being classified as a backward area, has attracted very little interest from the concerned departments to explore the groundwater parameters in detail. Only two areas are known: the south-east area, where Auroville is situated, where two studies have been conducted by the Central Ground Water
Board (CGWB) - one in 1976 and the other one in 1984. These studies give broad knowledge about the behavior and the condition of the main aquifers. In the north-west part, DANIDA has conducted some drinking water schemes with TWAD (Tamil Nadu Water and Drainage Board). More elaborate and in-depth studies are available for Pondicherry territory, and Tindivanam district, but do not always address the central problem faced today. An in-depth geological investigation has been carried by Oil and Gas Corporation (ONGC) in this area, but the study is difficult to access.

Lack of scientific publication data: There is a lack of adequate knowledge about the functioning of this particular kind of coastal water system, the availability and the adequacy of the resources. The multiple coastal aquifer geology, which exists in the area, is not well researched or understood.

Non-availability of water: The diminishing availability of water could affect more than one hundred thousands people living in the coastal area, and deprive them of the supply of safe drinking water. It could also affect interior situated towns that are sourcing their drinking water from the affected aquifer. This lack of safe drinking water is both quantitative and qualitative.

Over-exploitation of ground water: The quantitative problem of available water is mainly due to over-exploitation of ground water and poor storage of surface water. The ground water has been so over-exploited that the free water table of the sedimentary portion is below mean sea level (msl) and seawater has started to intrude in many sectors up to 8 km inland, threatening the main source of drinking water for the entire region. Recent new developments (such as rotary drilling rigs, submersible pumps, etc.), have enabled the farmers to draw water from deeper aquifers. Further, farmers are being supplied with free electricity by the Tamil Nadu Electricity Board (TNEB) and are pumping without restriction round-the-clock thus extracting massive amounts of groundwater. Farming activity could be severely affected in the absence of suitable irrigation water to meet their requirements.

Pollution of ground water: The massive use of fertilizers and pesticides is spoiling the quality of the groundwater. Recent analyses have shown a serious increase of pesticide load in the water. The salt intrusion that has started in the south of the Kaliveli swamp is today affecting the quality of the ground water of the region.

Excessive irrigation: In the areas where paddy, sugarcane or coconut trees are grown, it is common to observe irrigation up to 10 times the water demand of the crop.

Poor storage of surface water: Most of the tanks are heavily silted up; they cannot hold the rainwater which consequently runs off to the sea. Encroachment is ongoing in nearly all the tanks of the watershed.
Local polluters: Local industrial development is not always following the Central Pollution
guidelines and consequently contributing towards local water and soil pollution.

Inadequate public awareness: There is an urgent need for the stakeholders in this area
to become aware and be informed about the necessity of water management, particularly
ground water, about the implementation of remedial measures. Traditional methods of
water management are slowly eroding, with stakeholders being unaware about the natural
resources degradation within the bioregion. Kaliveli wetland is facing since a few years
an expanded growth of unauthorized shrimp farming posing a serious pollution hazard for
the whole water body. The connection between rain, tanks, groundwater, bore wells, crops,
trees, erosion, pollution, sea, saltwater intrusion, etc is not yet fully understood.

Areas of achievement

Auroville’s many faceted environmental works have a significant impact both on land
owned by Auroville and on the surrounding region.

If Auroville wants to grow into a sustainable urban settlement, translated into the field
of water management this will have to include:

- **Utmost use of rainwater harvesting, water conservation, water recycling and**
  **such other practices that shall ensure minimum impact on the natural water**
  **quality and quantity regimes in the area and shall particularly not affect in any**
  **adverse manner the use, quality and availability of water to neighboring and**
  **adjacent communities. In fact it should enrich the regional water resources.**

- **Minimum use of fossil fuel based or conventional energy sources, for lifting**
  **and / or conveyance of water.**

- **It is expected that the initiatives shall contribute with the upgrading of the**
  **overall environment and aesthetic quality of the region in general and Auroville**
  **in particular.**

- **It is expected that such initiatives shall also provide enough scope for**
  **variations and diversity, enabling in-depth research and development on**
  **various management practices.**

Important environmentally appropriate initiatives undertaken by the Auroville community are:

Erosion control

Started in the early years and aimed at minimizing water run-off so that the water can
percolate down into the aquifers which Auroville and the surrounding bioregion depend
on.

Afforestation

Much of the land in the Auroville area was eroded and minimally productive. An integrated
soil and water conservation programme and the planting of 3 million trees has transformed
the landscape and created the substantial beginning of a “Green Belt”, an afforested zone
which will eventually surround the city area. Over recent years there has been an emphasis upon recreating the indigenous Tropical Dry Evergreen Forest which formerly covered much of the region.

Organisations working to promote afforestation, revitalizing traditional medicinal plant knowledge, developing of a shared forest management plan, regeneration of degraded and marginal land activities are Auroville Herbarium at Shakti, the Pitchandikulam Bio-Resource Centre, the Botanical Garden in the Green Belt, Palmyra Centre of Ecological Land Use and Rural Development.

**Water conservation and Rainwater harvesting**

Water conservation is an essential component of sustainable environmental practices. Diverse water conservation measures have been adopted.

Auroville green workers have built an extensive network of bunds (raised earth embankments) on Auroville and village land to prevent water run-off. Other conservation measures include the construction of check-dams, particularly in canyons, the use of drought-resistant tree species and plants to minimize irrigation, combined with the use of drip irrigation and sprinklers.

Rainwater harvesting techniques are being practiced around every building, the simplest form is to direct the rainwater into a swale or an infiltration well, more elaborate is to use cisterns, storage tanks near or under the buildings and use the collected rainwater during the dry period.

**Waste water treatment**

More than 50 decentralized waste water treatment systems are in use in Auroville. Research and development shifted from root zone treatment systems to more efficient pre-treatment systems like the baffled tank reactor, resulting in reducing the size and the cost of the overall system. The treated water can be safely used for irrigation purposes.

Several systems have been implemented outside; the largest among them is the treatment plant of Aravind Eye Hospital, Pondicherry, a 1600-bed hospital.

**Ecological agriculture**

From the beginning, Auroville has practiced organic farming, to heal and nourish back the depleted earth. Farms cover approximately 400 acres of cultivated land. All of them work with a combination of fruit trees, field crops, vegetable gardening and animal husbandry.

Several food processing units have been established and produce a range of products.

**Renewable Energy**

In an attempt to be self-sufficient in its energy needs and to cause minimal atmospheric pollution, Auroville has a policy of experimenting with and implementing renewable and non-polluting energy and appropriate building technologies.

Today, Auroville represents the biggest concentration of alternative and appropriate systems in India. Major forms of renewable energy utilized are
• Solar - at present there are around 250 KW of electricity generating solar photovoltaic (PV) panel, the Matrimandir solar power plant of 37 KW, the solar bowl at the Solar Kitchen generating steam for preparing community meals.
• 1025 solar PV pumps have been installed in several Indian states.
• Wind, wind pumps of which there are 30 installed within the community and more than 100 in nearby states.
• Manufacturing of pre-fabricated ferrocement biogas plants which are regularly shipped to the Andaman and Nicobar Islands.
• Research for developing an indigenous small scale wind generator of 5 and 10 KW. Experiments for generating energy from biomass and oil seeds.

Appropriate building technologies
Designing and constructing buildings while using processes and tools that are appropriate to the climate, to the socio-economic conditions, taking into account the natural resources of the area and simultaneously incorporating an aesthetical element are longtime endeavors of the Auroville community. Expertise and skill have been acquired in several technologies. Notable examples are the Visitors Centre, the Solar Kitchen and several settlements.

Data gathering and GIS analysis
The necessity of gathering regular, consistent and accurate data related to the different projects is of utmost importance. With regard to water Auroville Water Harvest keeps all essential data and initiates new research projects in order to elaborate a more complete picture of the water cycle and other linked topics within the region. The use of GIS analysis and satellite images are essential components for producing scientific documents. ISRO and the Auroville GIS unit are contributors to that process.
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I am delighted to learn that the Auroville Centre for Scientific Research is organising an international seminar on sustainable water resource management for Auroville and its bio-region, from Cuddalore to Kaluvely Tank, and from Villupuram to the Coromandel Coast. I am happy to see that UNESCO has endorsed the Seminar as an event of international significance and scientists from India and many countries participating.

The critical problem our planet will encounter in the next few decades is the shortage of water and energy. It is essential that we must have a water management plan that unfurls our vision for the next two decades. Integrating interlinking of rivers, desalination of sea water coupled with solar energy generation would form the centre-stage of our planning. Also international initiatives and cooperation are essential in this energy and water sector.

I am aware that Auroville is one of India’s spiritual gifts to the whole world which in cooperation with other organisations will be able to find a lasting solution to the water problem of the region.

My best wishes.

(A.P.J. Abdul Kalam)

New Delhi
September 6, 2004
Re: Endorsement of the 3-day seminar on Sustainable Water Management

Dear Mr. Baetens,

UNESCO-HELP is pleased to endorse the three-day seminar on Sustainable Water Management and related topics which will take place in Auroville on September 13-16, 2004. We are happy that the seminar will be a focus for experts from India and abroad to share experiences with the main stakeholders, policy makers and acting bodies of your area and propose solutions how to remediate, develop and sustain water management with a common vision and approach.

This seminar falls within the ambit of UNESCO's HELP program which aims at supporting specific improvements in water management, science, policy or law. We'll therefore also publish this seminar on the HELP website and circulate an e-mail to all the HELP network.

Yours sincerely,

Mike Bonell
Chief of Section Hydrological Processes and Climate
Division of Water Sciences UNESCO
Global coordinator of the FRIEND and HELP programmes

To: Mr. Tency Baetens
Chief Executive, Auroville Centre for Scientific Research
Aurosilpham, Auroville 605101
Tamil Nadu, India
Towards a sustainable water resources management for the bio-region

An Overview

Carel Thieme

Carel Thieme, born in 1950, is from the Netherlands where he worked as corporate lawyer for a multinational company before joining Auroville. He served as Chairman of Auroville International, as member of various Working Committees, as Chairman of the Funds and Assets Management Committee and as Chairman of the Auroville Planning and Development Council. He is also publisher and editor of the monthly magazine Auroville Today.

Samasti, Auroville, - 605 101
Tamil Nadu, India.
Phone: 413-2622208
Email: carel@auroville.org.in

The Auroville Centre for Scientific Research (CSR) together with Auroville’s unit Water Harvest organized a three-day seminar on sustainable water resource management from 13 to 15 September 2004. The seminar, held in the Pavilion of Tibetan Culture, was not only endorsed by UNESCO under its HELP (Hydrology for Environment, Life and Policy) programme, but also received an inspiring message from the President of India who referred to Auroville as ‘one of India’s spiritual gifts to the whole world’ and expressed his confidence that Auroville, in cooperation with other organizations, will be able to find a lasting solution to the water problems of the region. This region, often egocentrically referred to as ‘the Auroville bio-region’, had been defined by the organizers as ranging from the city of Villupuram west of Pondicherry to the Coromandel coast and from the city of Cuddalore south of Pondicherry to the Kaliveli tank, a brackish water body of 72 km² near the village of Marakanam north of Pondicherry. Government representatives, stakeholders, scientists, technical and legal experts from India, France, Germany, The Netherlands and Israel came together to share experiences and proposals about how to remedy, develop and sustain water management practices with a common vision and approach. Over three days, a total of 27 scientific papers were presented. The seminar concluded with an attempt to find a common ground for future cooperation between the stakeholders of the area.

Depletion of groundwater

Groundwater levels all over India are fast declining and aquifers in coastal regions are turning saline. Mr. R.Chakrapaani, Regional Director Central Ground Water Board, Tamil Nadu, sketched the dire state of affairs in Tamil Nadu. The available surface water resources have almost completely been harvested. Ground water is now the major source for domestic, industrial and irrigation requirements. As shallow wells have become defunct in many areas due to declining water levels and low yields, tube wells that reach into the deep aquifers have become the most common means of water extraction. However, water
tables are dropping at such an alarming pace that the status of the ground water resources in Tamil Nadu’s 385 administrative blocks has become a cause of concern. Eight blocks have turned saline, more than 100 blocks are over-exploited, around 200 blocks are listed as critical or semi-critical and less than 70 blocks are considered safe. As for the main causes for the present state affairs, Chakrappaani mentioned the population explosion and the consequent environmental impacts; industrial, urban and agricultural pollution; destruction of traditional water harvesting systems like tanks and ponds; and the free power which is being supplied for agricultural purposes. Water scarcity has led to loss of livelihood, irreversible socio-economic changes and population migration to urban areas. Tamil Nadu is now taking measures on all levels - government, industry, NGO’s and self-help groups – to stem the tide. Amongst the most affected cities is the Chennai metropolis, home to more than 6 million people. It now imports water from the groundwater rich Neyveli basin, an area of approximately 3000 km² located 200 km south of Chennai in the Cuddalore district. Chennai is also planning a big desalination plant.

The status of the groundwater situation in Pondicherry is not better than in Tamil Nadu. Mr. V. Radhakrishnan of Pondicherry’s Department of Agriculture explained that this small Union Territory has an estimated 35 million m³ of surface water and 150 million m³ of groundwater. However, the requirement exceeds the availability by more than 20%. Pondicherry’s observation wells have shown that the groundwater level has dropped in coastal areas up to 12 m, inland up to 55 m. Radhakrishnan listed lack of surface water irrigation, mismanagement of surface water bodies and neglect of runoff as the main causes for this state of affairs. “Pondicherry has become almost completely dependent on groundwater and this is being over-extracted. Intrusion of seawater into the groundwater has been observed up to 4 km inland in the southern parts of the state, 2 km inland in the city and 1 km in the northern side.”

**Groundwater pollution**

The depletion of groundwater resources and the state of disrepair of surface water bodies are not the only concerns of the Tamil Nadu and Pondicherry water boards. Pollution of groundwater resources comes a close third. While some of these pollutants have a natural origin, such as salinity in some aquifers and the presence of fluoride and iron in others, other pollutants are man-made. They come from industrial effluents, such as from tanneries and chemical industries, from bad solid waste management which contaminates groundwater both chemically and microbiologically, and from agricultural activities through the large usage of fertilizers and pesticides.

Mr. Gurunadha Rao of National Geophysical Research Institute, Hyderabad, presented a study on the impact of industrial effluents in Pondicherry’s groundwater. The chemical, metal and paper industries of the Mettupalayam Industrial Estate, established during 1979 on the fringe of Pondicherry, have generated effluents that have found their way into the groundwater. These effluents came from badly constructed drains, from waste dumps and, in a few outrageous cases, were deliberately injected by the industry into the ground. This polluted groundwater is now, at an average velocity of about 30 m a year, migrating to the
Muttarapalayam well field which houses the main wells for Pondicherry’s drinking water supply. To deal with the issue, water quality monitoring is now continuous and proposals have been made to drill a few wells for extraction and treatment of the contaminated groundwater.

Auroville’s problems

Auroville is renowned for its successful reforestation work, for rainwater harvesting, for the construction of check-dams, and for programmes of tank rehabilitation in the Auroville bioregion. Is Auroville, as a consequence, better off with its water resources? Gilles Boulicot, the Executive of Water Harvest was quick to dispel that idea. “The efforts conducted so far have not altered the trend of groundwater degradation. Auroville depends on the bioregion for its water management and a large part of this area is under immediate risk of a major environmental crisis. Around Auroville, most of the runoff still flows into the sea, the area is subject to rampant pollution and the general environmental degradation is heavy. The response of the local population is lacklustre, and there is no appropriate legal structure or regional body to dam the tide.” Boulicot particularly stressed the dangers of increasing groundwater salinity by seawater intrusion due to indiscriminate over-extraction. “The possibilities of further seawater intrusion are very likely and if left unattended could endanger the entire southern part of the Kalivelvi watershed, including the Auroville area. The consequences of such intrusion would be difficult to imagine, as water for irrigation and drinking purposes would become scarce.”

In partnership with Harvest, the hydro-geological situation of the Kalivelvi area is being studied by Dr. Sophie Violette and a team of French scientists of the University of Paris under the HELP programme of UNESCO. “The study has shown that the main exploitable aquifer of the area is being over-extracted by about 20 times the recharge per year. In this context, it came as no surprise that the aquifer is increasingly turning saline, not from seawater intrusion but from underground salt transfer. We expect that seawater intrusion may happen anytime in the near future,” said Dr. Violette.

Other studies in the area are being made by the Foundation for Ecological Research Advocacy and Learning (FERAL) who gave a presentation on their ongoing study of the physico-chemical characteristics of ground water from 65 hamlets in the Kalivelvi watershed.

But Auroville is not only facing problems related to the bioregional management. It must also ensure a coherent, progressive, sustainable and integrated water management for the emerging city. Is it possible to develop a city which will not affect negatively the water resources, and even improve it? And does the future Matrimandir Lake have a role to fulfil in Auroville’s water supply system? Two of the speakers, geo-ecologist J. Köhler and geologist C. Schillinger from the German institute LGA, Nürnberg spoke about aspects of the lake’s management and possible storage systems to supply the lake with water during the dry season, but did not integrate the lake into a wider water supply system of Auroville.
Remedial solutions

Measures to remedy the groundwater depletion and battle groundwater salinity were offered by a number of speakers. To remedy over-extraction Pondicherry has issued executive orders regulating the construction of tube wells and the extraction of ground water; banned construction of tube wells within 6 km from the sea coast; and now issues ground water clearances only to non water based industries. Farmers are encouraged, by means of subsidies, to switch to drip-irrigation techniques and renovate unused shallow wells for harvesting rainwater. Also the construction of roof top rainwater harvesting structures in private and industrial buildings is eligible for subsidy.

In contrast, the treatment and recycling of waste water for re-use in agriculture and industry has not yet taken off, notwithstanding its tremendous potential.

Also Tamil Nadu has made rainwater harvesting mandatory for all government buildings. In various locations in Tamil Nadu experiments are being done with forceful injection of rainwater through injection wells. But by far the most interesting of the remedial measurements is the renovation of the water storage tanks and their feeder channels in Tamil Nadu and Pondicherry. Most of these tanks were constructed by the Pallava Kings during 500-900 CE. For example, the Bahour Lake, the second largest tank in Pondicherry, was in existence before the Chola Period. (850-1150 CE), and the Usteri lake, the largest lake, was built by the Vijayanagar rulers around 1110 CE.

Auroville’s involvement in tank renovation programmes in the bio-region is extensive. Funded by national and international organisations, Auroville’s units Palmyra and Water Harvest have renovated many irrigation tanks.

Mr. Anandane, Project Director, gave a presentation on Pondicherry’s Tank Rehabilitation Project. He explained how the system of surface water management, which depended on irrigation tanks and their feeder canals from rivers, became obsolete when borewell technology became available, together with a government subsidy on electricity and the Green Revolution which stimulated ground water exploitation. “While in 1930 an area of 8,500 ha was under irrigation by tanks, it had been reduced to 6,500 ha in 1962 and became almost negligible in 1988.”

In 1999, the Government of India concluded a bilateral agreement with the European Commission to rehabilitate all the 84 remaining tanks and feeder systems in the Pondicherry area. The main objective of the 38.5 crore (US $ 8,3 million) project – for 80% funded by the EC – was to diminish the reliance on groundwater resources. A secondary aim was to empower communities to own and manage their tank system and stimulate surface water usage. This social mobilisation is done by several NGOs who have experienced that women’s participation has proven to be essential. Anandane considered the project a success, though a few villages continue to expect the government to solve their problems.

Innovative concepts

The seminar also discussed a few more far-reaching solutions to stem the tide. Boulicot suggested that a feasibility study be made of turning part of the 72 km² swamp of Kaliveli north of Auroville into a major fresh water resource area. Closing the swamp’s outlet to the
sea would affect the interests of part of the local population, such as those involved in salt extraction or shrimp farming. "But a large freshwater body would benefit all people in the area," says Boulicot. "With the involvement of the major stakeholders, the rejuvenation of the irrigation tanks and related drains and a concerted and long-term planned water management, this region could be transformed into a model sustainable area."

Another solution offered is seawater desalination. Messrs. Gopalaaswami and Kumaravel, connected to the Suryal desalination system designed in the UK, made a passionate plea for Auroville to enter into this area of research. As desalination is highly energy-intensive, they advocated that Auroville use alternative energy sources, preferably a combination of solar and biomass. "Then Auroville could truly be a global model for environmentally friendly living and a bridge between the past of global water depletion and the future of perennial supply of sweet water from the ocean using renewable energy." It is however understood that desalinisation of seawater cannot at present be considered an option for agricultural activities, but only for drinking water supply.

But as the main problems of the bio-region are over-extraction and lack of regulation, the need for an integrated water resource management for Auroville and the bio-region became the focal point of the seminar's conclusions. The Dutch engineer Jeen Koostra has developed such a management system for the Ambaji-Danta Region in Gujarat, a 600 km² area with a population of 140,000 people living in 193 villages together with tribal communities. "Though there are certainly limits to such a management system, it has proven to work and there is no reason why it could not work for the Auroville bio-region," said Kootstra. His ideas were supported by senior hydrologist Dr. Israel Gev of the Water Authority of Israel, who proposed that a Master Plan for Water Resources be developed for the entire Auroville bioregion with active participation of the governments of Tamil Nadu and Pondicherry. By evaluating accurately the water demand and the various water resources, including recycled sources (wastewater, desalinised sea water) and the future trends, it should be possible to develop a scalable development plan that includes the socio-economic factors.

Given the encouragement of the President of India such a plan may not be a distant dream.
Traditional Water Harvesting Systems and its Relevance for Today

Anupam Mishra

A Gandhian and an environmental activist, Anupam Mishra is among the most knowledgeable persons in India on traditional water harvesting systems. He has travelled to various part of the country, especially Rajasthan, Madhya Pradesh, Maharashtra and Uttar Pradesh, visiting various water harvesting systems managed by people. He has also interacted with grassroot-level water harvesters, inspired and supported them and helped them in their traditional water harvesting systems campaign. He has written two books on traditional tank management in India and various traditional water harvesting systems in Rajasthan titled Aaj bhi khare hai talab and Rajasthan ki rajat boonde. Mishra continues to travel to different parts of the country, while keeping in touch with grassroot-level water harvesters and NGOs and inspiring them. The mission of the Gandhi Peace Foundation is to promote the environmental activities of rural development agencies; to prepare survey reports on distressed areas and place them before concerned authorities; to disseminate environmental information through the publication of up-to-date reports on environmental issues; to organise workshops and seminars for environmental experts, policy makers, individuals and organisations engaged in environmental issues.

Secretary
Gandhi Peace Foundation
221 - 223, Deendayal Upadhyaya Marg
New Delhi 110 002, India.
Phone: 11-23237481 / 23237493

I have nothing new to tell: Tradition according to me means a society’s past, present and future; if these three elements are de-linked, then it becomes history. We will see a few slides on the desert area of India. We are seeing only the desert area of this country, which has 5 lakh villages. Who are the GOs and NGOs who are taking care of all the resources – water, forests? According to me, the society is the largest NGO; if the society is healthy, it can take care of its problems – but we have to put faith and confidence and prestige in that society; but sometimes we derail ourselves from that path.

This area on the slide is one, where clouds seldom come; average rainfall is 3-9 inch (16 cm) – but the society didn’t calculate this rainfall in cm or inches, but in terms of millions drops of rain; we will see some of the techniques for harvesting water during this presentation.

The first one is called kueen (small kuan or well) – not to draw ground water, but a very complicated type of rain water harvesting. In the desert, nature has provided a very unique system – a very special type of impervious belt running from the ground level to 50, 60, 80 ft below. The gypsum/impervious belt in a sandy surface is about 40 ft deep and the water from the clouds will be deposited in this area as moisture; below this belt there is abundant water but saline; the people had devised this complicated system 2000 years ago, and even experts from NGRI will tell that if you keep the map of these structures in the villages (not all the villages have such impervious belts), whenever you find this structure you will find the impervious belt below that area only. This struc-
ture gives 50-100 l of sweet water – trapped in
the sand as moisture. Squeezing the moisture
and turned into drops and this water is drawn
only once during the day; this structure needs a
kind of recharge for 24 hours – then the sand-
moisture will deposit into the depression zone
and it will be converted into pure sweet water.
Any modern device like tubewells, borewells,
etc., will give you only saline water in this area
and only this structure in this area will deliver
sweet water.

The second method is called kund or tan-
kas; there are a number of such structures in
villages, houses, buildings. They design a false
catchment and we see a slope from all sides –
coming to the central dome which is 40 ft deep
– and it will collect rain water – the structure
is done in the desert and they have very good
skills to halt the seepage loss. In such struc-
tures even small rainfalls produce 1,00,000 l of
sweet water; looking closely at this same area
and you will notice some filters on the periph-
ery of the structure so that water will flow from
the floor. There are social traditions to clean
this floor before the monsoons and do all kinds
of social vigilance to keep the water as pure as
possible.

A cement structure from Barmer – people
knew from their own wisdom that the whole
area is saline. Now if we cannot have faith
in their wisdom, we have satellite pictures to
show that most of Barmer is saline – but some-
how our planners decided to make a kind of
tubewell grid to supply water to these villages
– the villagers told them that this would be sa-
line and not usable – but they were constructed
nevertheless, hoping that the water quality will
improve over time. Slowly and slowly salini-
ity started increasing and this had to be aban-
donned; also traditional water harvesting tech-
niques were discontinued when these tubewells
came into existence. Now after the failure of
these tubewells, people went back into their old
systems of tankas. Salinity of water is obvious
when earthen pots storing salty water develop
perforations and people plug these holes with
cement and there is a belief that to break ear-
then pots is inauspicious – this happens only
when someone dies.

After introduction and failure of tubewells
involving crores of rupees, people went back to
their old system and newly constructed tankas.
The farmer also needs fresh water while
working in the fields, and he builds a ‘stup’ a
very spiritual kind of structure to collect rain
water – collect every drop and give honor to
that drop – don’t waste it - in any agricultural
field, you wash your hands, face and agricul-
tural equipment in that same pit and use the re-
maining for watering the plants.

The beautiful houses decorated with ran-
goli (patterns of color) on the border of Pa-
akistan in Jaisalmer – population density is
the lowest in the area - 5 persons/km², with
very low rainfall 3-9 inch; How do they meet
water needs? Every house has one water
body—a raised platform but goes 15 ft deep
and can store 20,000 l of rainwater falling
on the roof. Every house has this unwritten
social law and there is no house constructed
without this.

A big tanka – the capacity is 1,00,000 l per
monsoon and people utilize it for the whole
year; draw water from the bucket and pour it
into a pot; whatever gets spilled can be collect-
ed in a smaller one-brick level tank for birds/animals – a society that cares for man, animals
and birds.

Mr Laduram worked for Indian Railways
and he has retired from work – he is not paid
for doing any water conservation work, he is a
gateman – he constructed the water tanka struc-
ture – for helping passengers with water.

Bikaner, that has piped water supply since
25 years – some houses have not done away
with the traditional system, of collecting rain
water from the roof; 70,000 l is being collected in this manner, care is taken to keep the collection spaces/roofs clean – we have silt traps, the collection chamber is below 2 ventilators.

Roof of a school in a semi-desert area collects 50,000 l of sweet water, any handpump in that area gives only saline water.

Jaisalmer, oldest township in the desert – 800 years ago the ‘town planning department’ of this country had clearly indicated all rainwater collection from all the roofs.

In Amrasagar built 500 years ago, another technical feat, where there are 7 step wells in the tank bed, when the tank is dry these step wells have good water.

How to measure water levels? The people are the architects, builders, all illiterate. Rajinder Singh will tell you more how they are involved.

A deep well built 500 years ago, still exists and functions and the depth of this well is 400 ft.

Step wells have survived 800 years in the desert.

Q/A

Has analysis about water so collected been done and what does it show?
Yes, analysis has been done and in some cases there have been problems encountered, but the problems were only insofar as the methods of collection were not strict – strong social rules and norms have helped in collecting water as it is – without much bacteria due to incorrect handling; quality has not suffered much. The quality of this water is much better than the municipal water supply.

Have efforts been made to use these designs, and study them and make this technology available to all people?
Society was and is only doing/building these structures and not talking about how to do it. It is up to people like us to take this information and publish this. One of the books we have done is a translation from Hindi to French; from French to English.

Population increase – how has the community dealt with this?
It was a chaos in the beginning – modern development tried to destroy these structures – but when these failed, then people rely back on the old systems and starting building these structures.

Silt traps – where are they?
They are built into the system. They get cleaned every 3rd generation – if one generation makes the structure, sometimes the next doesn’t need to bother, but the third one will go down and clean it.
No society can exist on its own without regard for the environment. It has to create systems that help in adapting in the availability of resources, such as water, forest and land. In doing this, a society has to rise above mere technological systems and mould socio-cultural mechanisms that also find a place in its religion. Only after this can the system become strong enough to sustain the innumerable members of the society, thousands of villages and townships. Only then the society can tackle the problems of conservation of its land, water and forests. The society cannot restrict these life-supporting systems and techniques in the hands of ‘technicians’ and ‘foresters’. These techniques, so essential for the prosperity of the society, were handed over to the common people. The society incorporated these techniques into the cultural lives of the people characterized by the joys and the rhythms of the everyday life - where technique becomes culture.

And when this is done, the systems become edifices that go beyond space and time - self-sustaining and the livelihood of social institutions. These dynamic institutions do not have - and do not need - any headquarters, annual budgets or projects. They are absorbed in the collective memory of the society.

When a society organizes itself for work of such magnitude, its planning is not restricted like that of a five-year plan or a decade-long program that most of our governments and NGOs follow. Over such long periods of time, the technologies are not bound by textbooks. They assimilate in the lives of each and every member of the society, cutting through the barriers of caste, class and gender. Every member contributes to these socio-cultural mechanisms according to his/her capacity.

There is a lot of difference between culture and technology. All government organizations and NGOs in every one of their projects involving watershed development rely on elaborate surveys, A-frames, dumpy levels and other pits and trenches with names that are difficult to remember. On one side of this ‘technological divide’ are donor agencies, on the other are beneficiaries, at the very best, if not the laborers, cornered in their own land by an alien language of the ‘missionaries of parity’ I believe that such ‘green’ technological development projects, even when carried out with the best of intentions and honesty, leave a barren gap between the agencies and the beneficiaries. Even if the project is successful, it breaks the society’s spirit of independence and self-confidence.

All governments, institutions and agencies are facing budget cutbacks these days. The subsidies on which such projects bank are too much, even for large organizations like the World Bank. Then where will the initiative to undertake work of such importance come from? It will only come about by restoring the confidence in our own social institutions; by recognizing their strengths and the depth of their rich experience. Instead of looking down upon large sections of the society as illiterate, poor and weak, we need to reinstate their self-respect and their sense of identity that they have lost.
It will make these submissions clearer through the arid and the semi-arid regions of Rajasthan in India’s Thar desert.

The geography of Rajasthan is challenging, to put it lightly. Firstly, it has been understood as the land where the sun hardly ever seems to go down. Geography books describe the region as hot and arid.

Temperatures touch 50°C in summers. Water appears to be a rare commodity. Adding to this gloomy picture is the general remark that groundwater is also scarce, being usually available at depths of more than 300-400 ft. That too is largely saline.

Rajasthan is indeed a blessed land, for its people have nurtured and sustained rich and varied institutions and traditions of rain-water harvesting and water management to meet all their needs. So much so that the divine boon became synonymous with the resourcefulness, ability and skill of the people who did not allow even a drop of water to go waste!

Today there are 515 villages in the Jaisalmer district, out of which 462 are populated and 53 lie deserted. Except for one, all the other 514 villages have evidences of water availability. According to a state report, 99.78% of Jaisalmer’s villages had their own water resources like wells, baories, tankas, kunds, talabs, and kuinyas.

In contrast to this basic requirement and its fulfillment are other contemporary indicators of social and economic growth whose figures are far from satisfactory. The same government report says that out of 515 villages, only 19% are connected by modern roads; post and telegraph services cover just 30% while medical services run low at only 9% and electricity even lower at 4.5%.

Yet 99.78% of the villages had adequate water resources, all of which had been designed financed and maintained by the society - neither by the government nor by NGOs. The society in this arid zone also designed very comprehensive forest conservation institutions. These are called orans. This name is derived from the Sanskrit word aranya, which means a forest. It is interesting to note that the oran institution was the strongest in areas where it was needed the most - in the arid zone.

These sacred forests are attached to the village temple and are managed by the priests, not the foresters. They are not protected by barbed wire fencing, walls or ditches. Sometimes spread over hundreds of hectares, these, forests are protected by social fencing by the villagers, devotees of the temple who follow strict rules of conservation. These were treated as reserve forests, no one was allowed to take out even the twigs and leaves during the normal period. Only at the time of severe drought the priest would perform a special pooja (prayer and worship) and would declare the forest open for the & people who would take shelter with their cattle. It is interesting to note that even today we find that good track of oran where the state forest cannot show a single blade of grass.

All these institutions have been the lifelines of the life and the prosperity of the desert. They have withstood the test of time and change to become symbolic of the philosophy that not only links the past to the present but also harbours the potential to make the future like the past.
Arvari, the River
A People's Movement

Rajendra Singh

Born on 6th August, 1956 at Daola village in Meerut, Rajendra Singh did his post graduation in Hindi Literature and also obtained graduation in Ayurvedic Medicine and Surgery. During his student days, he was associated with the "Sampurna Kranti", movement led by J.P. Narayan, from year 1974 to 1982. After finishing his studies he joined as a National Service Volunteer at Jaipur under the youth education programme of the Ministry of Education, Govt. of India, between 1982 to 1984. In 1982 he became a member of Tarun Bharat Sangh (TBS), a Jaipur based voluntary organization. During the next few years he worked with nomadic tribes and tried to understand issues in natural resource management in rural areas.

Rajendra Singh is dedicated to mother earth and Tarun Bharat Sangh has been one such voluntary organization engaged in Rural Development with environment care and protection for the 15 years. Through his determination, vision, hard work and dedication, he has transformed the life of people in 750 villages of Aravali hills. He has turned the arid land cultivable, densely afforested large tracts making a wild life sanctuary by water management, made the dry rivers flow throughout year. Aquatic life and bird sanctuaries have flourished. Animal life has become lively, with desert land beaming with life all around.

For all his pioneering work in water-harvesting through Tarun Bharat Sangh, which has been instrumental in reviving dried-up rivers in Alwar district and organizing Jal Biradaris across India to discuss water issues, he was awarded the Ramon Magsaysay Award in 2001; he has traveled across India organizing public hearings and ‘water communities’ while laying out his vision for how to manage our water resources sustainably.

What is the spirituality of water in India? What is the spirituality of civil society or community living in the villages? What is the way of life and system of water management in India in arid and semi-arid zones? Where rainfall is 400 mm at the maximum, comes for a few days and falls within a few hours. What are the civil engineering, water harvesting methods?

Looking at this semi-arid zone in Rajasthan – this area Arvari river is about 250 km from Delhi – the spots in the river, are the water harvesting structures called johads or pond or talavas. Before Independence they conserved every drop of rain water, through water harvesting structures of johads, nalla bunds, etc., trees; so many designs and engineering – near the Independence – a big change in the ownership of common natural resource – whole forests were notified as national forest area- here started the destruction of these resources; then people who were dependent on forests turned to agriculture practices; they needed water and started extract-
ing from aquifers which became empty; all the river is dry (in the desert area no big river is perennial) – within 60 years this river Arvari became dry.

This river had disappeared in 1940s, and was revived in 1997. The 2 pictures show the contrast of the river from 1993 to 2003 and on the bottom you see, the scenario before 1985 - degraded and barren land in the catchment areas of Arvari river & extended drought which had forced people to migrate out of their villages.

TARUN BHARAT SANGH (TBS), is a non government organization and started to bring people together on the issues of management of forests and water resources.

10 years of change of green cover and this has been due to self discipline of society of preventing themselves, i.e. preventing grazing of cattle, cutting of trees, indiscriminate uses of water; the river has become alive now, when we started this work, migration to cities was rampant, all younger able-bodied people had left and we were left with older people with not much energy to work.

Water doesn’t belong to anybody – it belongs to everybody – the panch maha booths (5 elements of nature) – water, fire, earth, air and akash, all these 5 elements are intertwined and they create the rhythm of life – the most important element is water, related directly to life and has to be treated as divine. We had to fight against the vested interests – mining, commercial interests – animals in the forest sanctuary were also suffering and we had to fight against poachers also and the mining mafia – first the realization has to come to society that the resource is theirs and then the management aspect comes automatically. Poaching was an activity that used the society people also; when the water work started, the community-driven decentralized forest management took over and poachers who used to wait with their guns couldn’t get the local people to help them and hence poaching came to a halt. Social consciousness starts with the realization of ownership over the resource and then society took the responsibility of control of the use of the resource. Village councils were constituted with the specific purpose of rejuvenating Arvari river and protection of forests, using historical and traditional practices.

**WOMEN AND WATER**

Women had to go 9 km away to fetch water and hence girls never went to school, because
they were tending to the cattle. All this changed when water became available - reduced the drudgery and girls started to go to school. Once they started work in their villages, they could even force the sadus/sanyasis who were seated idle during the daytime to do work - people's life-style started changing - girls of 12-13 years of age became responsible for building the atmosphere for development, motivation and inspiration for people from the neighbouring villages to take action.

Hence women were mobilised to actively participate in such efforts. Their self confidence and several initiatives helped in reaching consensus when decisions on major issues were needed.

When rules regarding water are not imposed and observed then the river cannot be alive; the Government wanted to intervene once water was there and take it over- e.g. fisheries, other groups and get money out if it; but the village people became extremely conscious of their own rights.

Another part of the consciousness change of the people was to change the cropping pattern. Now it was possible for sugar-cane, wheat, chilies - all this they couldn’t have imagined in such an area of Rajasthan before this period!!

Cultural patterns of women and men sitting separately and other such habits, was changed through a process of social revolution and gender communication barriers were broken - Arvari padan was formed and the entire community was involved in decision making together; their issues were concerns and decisions regarding the future and appropriate land/water use. Village resources were mapped regarding all the topography and climate by the villagers completely (not the educated people from the cities) as they know best their area;

Wheat production has increased to at least double in 5 out of the 6 villages in this area and in these 6 villages total area of wasteland brought under cultivation due to the availability of water is 245 acres.

35 km away in another village, when water became available, they were advised to grow cash crops; farmers from neighbouring western Uttar Pradesh came to teach these villagers how to grow vegetables and the villagers in turn would teach the Uttar Pradesh farmers how to grow things in dry areas. By exchanging knowledge, new methodologies of agriculture developed and they have grown vegetables worth Rs. 3 crore last year and sent to Delhi, and the quality is so good that these vegetables fetch a price of Rs. 2/kg more than vegetables coming from elsewhere.

Tarun Bharat Sangh triggered off the process by building one johad (a pond-like water structure).

Johads serve to recharge ground water and as drinking water for the wildlife and cattle of the area. Success of the first johad inspired people to take up the building of more such structures - the connection between water and forests was made and this also led to the revival of traditional rules. In the past, forest ownership had been taken over by the Forest Department, leading to alienation of the people and loss of traditions of conservation - making it difficult to bring people together again.

Different johads (8600 village ponds have been made) made in different areas and villages are of different designs depending on the purpose of that johad – where you want water for cattle, where you want recharge, structures become different – depending on ground realities. Diversity is such an important aspect that has to addressed – the magnitude of change (of soil and water) between every 10-15 km has to be reckoned with – yet the common denominator of the spiritual aspect of water throughout the country has to be re-emphasised.
**BENEFITS OF JOHADS**

- Water is made available to cattle and wildlife
- More harvests per season
- Reduced migration
- Social issues of women and education get more attention

- Increased awareness about the use of forest resource

**POST-MANAGEMENT ASPECT**

On certain occasions like the special *amavasiiya* (new moon) people eat together there and discuss issues regarding the pond and repairs, etc. While eating the community gets together harmoniously to take important decisions.

Awareness campaigns were run in the villages with the help of children. Religious traditions were used as a unifying factor.

**SAVINGS**

Increasing investment on small water conservation works brings increasing economic returns.

An investment of Rs.100 per capita on *Johad* raises the economic production in the village by as much as Rs. 400 per capita per annum.

Also money is saved by people who don't go to places like Haridwar / Ganges to make the offerings to the dead relatives, but they

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**AWARENESS IN THE COMMUNITY**

- Awareness of various aspects of water management
- Respect for culture, traditions and historical practices
- Will to work together for community’s common interest

**WORKING STRATEGY**

- Constitution of Village Councils – Monthly meetings of all grown ups
- Maximum possible use of traditional technology with advice from engineers if needed
- All decisions including technical (siting, materials, design etc.) by Gram Sabha
- All decisions by consensus, and not majority
- Role of women in helping reach consensus
- Min. 30% of total cost contribution by community – rest from support agencies thru TBS
- No involvement or interference from government

**OPERATION AND MAINTENANCE**

- Total responsibility assumed by the community

**WATER – ABSTRACTION AND USE MANAGEMENT**

- River Parliament (Arvari Sansad) with all 72 villages of Arvari Basin represented
- Responsible for planning & enforcing sustainable use of water, particularly in agriculture
could do it here itself on the banks of the river. People are also offering prayers to the river, a tradition meant to treat the rivers and sources of water as sacred and have installed the statue of the Goddess of Arvari.

5. Inclusion of more systems of water management and inputs from the experiences and wisdom of other communities.

<table>
<thead>
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<th>No.</th>
<th>Total depth of well (in feet) 1988</th>
<th>Water level before Johad</th>
<th>Water level of well after Johad, 1994 (in feet)</th>
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<td>81</td>
<td>Dry completely</td>
<td>44.5</td>
</tr>
<tr>
<td>2.</td>
<td>73</td>
<td>Dry completely</td>
<td>37</td>
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<td>3.</td>
<td>67</td>
<td>3 feet</td>
<td>40.5</td>
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<td>4.</td>
<td>55½</td>
<td>4 feet (dry most of the time)</td>
<td>27</td>
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<td>81</td>
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<td>20 feet</td>
<td>50</td>
</tr>
<tr>
<td>7.</td>
<td>43</td>
<td>15 feet</td>
<td>35</td>
</tr>
<tr>
<td>8.</td>
<td>63</td>
<td>20 feet</td>
<td>58</td>
</tr>
<tr>
<td>9.</td>
<td>804</td>
<td>19 feet</td>
<td>55</td>
</tr>
<tr>
<td>10.</td>
<td>66½</td>
<td>Dry completely</td>
<td>25</td>
</tr>
</tbody>
</table>

CONCLUSIONS

This is not my technology – this is not a scientific or technological feat – the river doesn’t flow outside but in the heart of the society – it is a technology that society has been using for ages, but it has been revived now.

1. Lessons learnt from Arvari are being applied to the larger region and across the country.
2. Regeneration of rivers across India have started.
3. In wildlife sanctuaries, Forest Protection Committees are being formed in partnership between the forest department, people and TBS.
Q/A

There are dead rivers in this area of Chennai/Pondicherry which nobody takes care – how did you manage to do that there?
When water work started with the ponds, river revival was not a priority – 10-15 years later it became an issue consequentially when people realized that this river is also our responsibility and to make it alive. Community driven decentralized management – social audit and ecological governance started from there – the issue became one of balancing recharge and extraction – to give back to the earth what has been taken out.

What is your opinion about interlinking rivers?
I’m opposing this for this country – neither flood nor drought control is possible by doing this – this should be discouraged – it is against nature’s design and ecology and diversity - Alwar people have been able to do this locally (newspaper article).

What is the reaction of the local Government? Any resistance because it curtails some economic activities – all these social controls?
With 400 Jhodas along a stretch of 45 km, water situation in the region improved considerably.
An immediate issue faced: Who owns the river and the reservoirs? As per an old, colonial law, all waterways are owned by the State... which promptly gave a contract on Arvari river to private fishing contractors! The villagers successfully fought this; and this triggered the forming of the Arvari Parliament; 72 villages situated along Arvari river are represented. Rules are framed about issues of water conservation and utilization, and forest conservation.

1. Framing of rules regarding direct irrigation from the Arvari river and the wells.
2. Framing of rules regarding crops and cattle feed.
3. Rules to first fulfill local needs with crop production.
4. No sale of water and conservation of fishes in the river.
5. Restriction on the sale of land and the efforts to reduce the need to sell land.
6. Making the whole river area green, ban mining and restrict extended grazing by nomadic grazers.
7. Restrictions on hunting of animals and illegal cutting of trees.
8. Revive traditional methods of water and forest conservation.
9. Prevent over exploitation of water and promote water conservation work.
10. Establish an active system of the management of the river.
11. Define and redefine the role of the Arvari Parliament and village communities

Water parliaments are established by people who farm more than 500 hectares of land; they make the rules and 162 persons all over the area are such members. Earlier there were disputes between up and down-stream people. These parliaments work for the common cause – they make the local rules and laws and this is part of the self governance.
CHALLENGES STILL FACED:

- Contracts are given by the government to private fishing contractors and mining contractors.
- Government’s order to pull down the office being built by the water Parliament – Lack of encouragement from the government.
- Conflicts arising between policies of the forest department and village laws. For example, total ban on extraction of wood from forested land.

PERSPECTIVES

ARvari, the River — A People’s Movement
Drought-proof is also flood-proof

In August large parts of India were under drought and at least one-tenth was under floodwater. The landscape of the country is being etched either with drought or floods. Our political leaders are busy announcing gigantic projects like interlinking of rivers and inter-basin water transfers as the remedy to these critical problems. But such solutions will only help politicians, contractors and officials make money and lead to problems like the recent imbroglio over the Sutlej-Yamuna link canal in Punjab. About 150,000 villages have no water source while thousands of others are declared flood-prone. Since independence, an astronomical sum of money has been spent by the government drought relief. Yet the impact of drought relief works on drought prevention is negligible. Drought and floods are, in fact, two sides of the same coin. If taken up judiciously, both problems can be addressed with the same intervention. In 1995-96, Alwar in Rajasthan received more than twice its average annual rainfall. In places where water conservation measures were in place, the surplus water was trapped and it seeped into the earth. But in areas where there were no water harvesting structures, the same amount of rainfall caused floods. Consequently, the government had to spend Rs. 150 crore on flood relief there. The excess rainfall of 1995-96 was conserved in our area. The water percolated into the earth and the Arvari river began to flow perennially after a long long time. Since the past six years rainfall has been deficient. The same excess water, trapped in 1995-96 is sustaining all of us despite receiving less than half of normal rainfall, agriculture has done all right. There is enough fodder, grain and water available in our area. Even in the past, drought was frequent, but the village community had its own methods of coping. Rainwater was religiously collected in bawadis and jhalre. These structures also served as temples. Not just physical labour but social and cultural efforts were made to cope with drought and famine. Even marriage decisions were influenced by the prevailing drought situation. Drought-affected families used to migrate with their cattle to their relatives in areas that had received their normal share of rain. An ethos of tolerance and humanity in our society made it much easier to cope with drought and famine. But things have become lopsided today. There is growing tension between migrants and inhabitants leading to strained relationships. As a result, the impact of drought on people has become much more severe. A particular section of society is citing this adverse impact as an excuse to loot drought relief funds. Drought relief work is executed in such a way that no
one is held accountable for the loot. Whenever we ask a sarpanch carrying out drought relief work about the expenditure details, the stock answer one gets is that drought relief is meant to provide only succour and no work is expected. This morality, which is withdrawn from the government’s treasuries on the basis of thumb impressions, finds its way into the pockets of a particular section of society. The government’s drought relief work is affecting the people in two ways: first they witness rampant corruption and a decline in public morality and secondly they confront the stark reality of deprivation. If the money currently spent on drought relief is given directly to villages, they can undertake water conservation and even help other areas become drought-proof. Work carried out in this manner will be sustainable and its impact more visible. The village community will appreciate its own responsibility and devote itself to water conservation. Collective effort is required for water conservation. For achieving results everybody has to work as a team, keeping in mind local knowledge. That is the only way to save our nation from the fury of floods and drought. The role of the government in drought prevention is primarily of providing support. Their task is to motivate people, help them plan and support projects based on people’s priorities. The work should be carried out by the people, not by the government. The need of the hour is to recognise the capabilities of the people and their knowledge systems. People have performed miracles in water conservation, whenever trust was reposed in them. Based on this pattern, 750 villages in an area of 6,500 km² in Alwar have achieved great results after working for over 15 years. Their region was once a dark zone in government records (an over-exploited ground-water region). Even drinking water was insufficient. Today the same area has been designated a “white zone”. There is adequate water in wells and enough available for agriculture and drinking purposes. Barren lands have become fertile. The people launched a campaign to save fish and eventually took over the management of river bodies. This is the only region in India where the people themselves have set up a unique river basin organization, called the arvari sansad. This sansad has direct representation from 70 villages and it has devised norms for members on water resource management. The honourable former President of India K. R. Narayanan visited Hamirpur on 28th March 2000, to meet and honour the people who are the true architects of this transformation. But the government remains unimpressed. This area of 6,500 km², which has received less than half its normal rainfall in the last three years, is unaffected by drought. There is no need for any drought relief work here. There is a lot of talk about this success but the government and its bureaucracy remain insensitive and unwilling to learn. But civil society wants to learn from village communities in Alwar. Wherever there is a drought, people affected by it are keen to invite these villagers so that they can undertake similar works. For the same reason people are visiting this area to see things for themselves, to understand the transformation and to replicate. Such invitations have come from people in Gujarat, Andhra Pradesh, Maharashtra and other regions of Rajasthan, Kutch, Saurashtra, Sirohi, Barmer, Bikaner, Pali, Manosoda, Khandwa, Jhabua, Mandal, Bhadra, Ravatmal, Medhals... these are some of the regions where people want to learn. Villagers from these regions would like to take up water and forest conservation but the government is creating hurdles for them. Despite obstacles, small efforts by these people back in their villages are a beacon of hope for the future. Instead of supporting community initiatives, water-related policies and
laws stymie people initiatives. That’s what is presently happening in our country. Top leaders talk about self-reliance and gram swaraj for the village and on the other hand the executives of the government hamper the growth of such efforts. Our experience tells us that the only way to deal with drought is complete preparedness. Society must contribute. And government support should reach the people in rural and urban areas, honestly, directly and easily.
Toward a Sustainable Water Resources Management for Auroville & the Bioregion

Gilles Boulicot

Gilles Boulicot, the director of Auroville Water Service – Harvest, Center for Water Resources Management, is coordinating a range of efforts to understand the water situation and trend of evolution in the area and to develop remedial measures by rehabilitation of water structures, social mobilization, ground investigations, and organic farming. He is a specialist on water resource management.

He had been working in a large engineering company for 10 years, where he was involved in many projects, mainly in coordination engineering, infrastructure and overall project management. His interest has been in the area of renewable energy, organic farming and community living. While joining Auroville in January 1995, he started working on projects on renewable energy, appropriate technology, decentralized wastewater treatment, and rainwater harvesting. Today he is involved in the overall study of water supply of Auroville, as an advisor and expert for Auroville planning’s authority, and is developing various programs on sustainable water management (urban and rural). He is also a resource person on decentralized wastewater treatment in India, Co-responsible of the program ‘Kaliveli & Pondicherry sedimentary coastal basin, Tamil Nadu India’ (HELP-UNESCO.04/05), with Sophie Violette.

By looking at the situation described by the previous speakers, we are in quite a different context when we speak of water here. First because the quantity we speak about is different and it may be changing the way people feel about the resources. If you just compare the rainfall quantity, we really have plenty of water available. But that is not enough to catch the situation. I will try to develop a sound picture of how this area is in terms of water resources and what we can do with it accordingly.

In terms of administrative setup, Auroville is just on the edge of 2 different territories, Pondicherry Territory but chiefly Tamil Nadu State. This is one important aspect as far as how to deal with water resources is concerned, because when we want to develop something we have to address the proper governmental issues and the trans-boundary aspect as well.

Then in terms of surface water, you can see that we are also located in quite a complex area. There are plenty of water bodies, which is as such very helpful as they hold rainwater but also complex because of their interaction. They are largely interconnected and flowing chiefly toward this large water body on north, the swamp of Kaliveli which is 70 km². But due to the topography an important part is also going towards southwest near Pondicherry territory and toward east, the sea. The Gingee River is also present on south, but it is a seasonal river: the water is flowing only 10 - 15 days per year on the average due to the concentrated rainfall event we usually get. So, surface water is playing an essential role but as such it is not acting
50 m above mean sea level (msl) and centered 5 km inland. Around the Auroville plateau is a plain which is nearly flat with, a bit further west, upper lands of similar altitude of the Auroville plateau. What is happening is that naturally the rainwater flows out of Auroville and will finally go to the sea if we don’t do anything to intercept it. This was well understood centuries ago when ancient rulers decided to develop irrigation tanks. In fact, a lot of effort has been made by Auroville to catch the rainwater and consecutive runoff. We can today confirm that there is very little water leaving Auroville plateau towards the sea due to the very firm efforts conducted on water and soil conservation. Nevertheless that is still not enough to keep appropriate water resources as we will see in a moment. In the figure above, the light blue lines are the water bodies interconnecting channels, the canyons and the drains. Auroville is situated chiefly on a sub-watershed directly connected to Kaliveli swamp, while another part is flowing to the sea or towards the south. Hence, in terms of hydrology, we are naturally sharing the resources with our neighborhood, which is as a continuous source of water for the area. Surface water is flowing following natural boundaries hence supplying various specific areas.

But basically we can say that we are all working and living on the same resources. Administrative boundaries don’t make sense if you want to talk about sustainability and sharing of resources. Water has no frontiers other than natural ones!

Auroville is located on a hillock which is about

Watershed total area: 754.69 Sq.km
Number of tanks within watershed: 196
Area covered by swamp: 70.47 Sq.km
Area covered by tanks: 57 Sq.km
well and good. But it must not become a waste to our neighborhood: when we want to create appropriate management of surface water, we have to tackle this issue, and at various levels.

I will speak a bit on geology, just to give the general picture. Most of the area visible here, is sitting on an alluvial formation — it is even every where in Pondicherry Territory. Auroville itself is situated on a multilayered sedimentary formation which is acting in quite a different way. On the west, a rocky formation known as Charnockites is outcropping. The green area, the Cuddalore formation is very large and can be observed (outcropping or under other layers) down to the extreme south of India, creating hence a geological link on a very large scale. If we now look at the geological section map, we can observe that many layers are built one above the other, each one of a particular geological nature, and the full lot in contact with the sea. So, we are sitting on a complex geological system which is indicating also a complicate groundwater behavior.

I will explain a bit more about it, starting with the Cuddalore formation so that you can understand the problem we have here. Auroville chiefley sits on this formation and there is very successful work that has been done in terms of water conservation and runoff control. There is hardly any water which is allowed to run
Electroconductivity as an indicator of salinity in Vanur aquifer in January 2002

Water electroconductivity limit for drinking purpose: 1000 microsiemens per cm / World Health Organization
Water electroconductivity limit for irrigation purpose: 2500 microsiemens per cm

Electroconductivity Microsiemens per cm
500 - 750
751 - 1,000
1,001 - 1,500
1,501 - 2,000
2,001 - 2,500
2,501 - 3,000
3,001 - 3,500
3,501 - 4,000

Electroconductivity as an indicator of salinity in Vanur aquifer in January 2003

Water electroconductivity limit for drinking purpose: 1000 microsiemens per cm / World Health Organization
Water electroconductivity limit for irrigation purpose: 2500 microsiemens per cm

Electroconductivity Microsiemens per cm
500 - 750
751 - 1,000
1,001 - 1,500
1,501 - 2,000
2,001 - 2,500
2,501 - 3,000
3,001 - 3,500
3,501 - 4,000
away. So, this water should recharge the aquifer and hence we should have a lot of water available, and therefore we should be able to supply whatever is coming on the plateau or below in a successful way. Moreover, as it is locally shallow and not present further west, little over-extraction impact should be expected from the surrounding. But it is not like that. Referring to the contour maps generated, in June 1998, at the centre of Auroville, the water level is 38 m above msl and near the coast, water level is 2 m; in January 2004, the centre of Auroville is 22 m above msl and near the coast it is 0 m; in June 2004, it becomes 22 m and −2 m respectively. Consequently, there is no water in the most important part of Auroville plateau: the Cuddalore formation there is empty (there is still a lot of water closer to the shore). It means that today when we want to extract water we have to dig deeper and deeper because of this situation.

The efforts conducted so far do not change the groundwater trend of degradation!
Most of the runoff still get lost to the sea
The area is under rampant pollution impact
The local population response is far from satisfactory

The second formation is Manaveli. It is a clayey formation. At first glance, we may consider because of the particular texture of this formation that it might act as a natural barrier and hence create appropriate conditions for the Cuddalore formation to act as a reservoir. Why then is it empty? But in fact Manaveli clay (as per the NGRI study) is not acting as a water barrier; it is more a kind of a slow speed sieve. In this formation we observe some windows and weaknesses, and in fact there is no Manaveli at all in certain areas of Auroville. In other areas the thickness and quality of the clay is such that it cannot hold the water. Therefore when the water is passing through Cuddalore formation, you can expect it to percolate slowly through Manaveli and further down. If the underlying aquifers are not saturated the water will continue to go down and down! It means that the extraction scenario of the larger area is impacting on the very local resources.

Now we come automatically to a larger area: you can see on the geological map that the following formations are not any more limited to Auroville. We now speak about the Vanur formation, because it is the most promising aquifer of the surrounding area of Auroville. As per an earlier report from CGWB (1984) the water level was well above mean sea level (msl). In January 1999, we monitored a water level at 16
m below msl. In June 2004, 5 years later, we monitored in the central part of the Vanur formation a water level 40 m below msl. It means between 1999 and 2004, there was a water level fall of more than 20 m! That is the present situation. Now looking at the level of salinity for the same formation we can observe a strongly increasing salinity (areas in the figure that get darker shades). The values indicate that today a large portion of this aquifer is unsuitable for drinking water and sometime even for irrigation.

Why did we reach such a problem in such a short time? There must be some reasons that suddenly the water level dropped in such a short period of time! By conducting a detailed survey on an area of 264 km² we totalized 6000 wells. We then find that the extraction is 20 times the recharge for the Vanur formation.

The trend of development of extraction is absolutely unbearable.

This is obviously a very alarming situation. I will go quickly through the situation and you can observe several things. The most problematic source in this problem is due to agricultural practice. The people are over-irrigating. Many crops are irrigated with up to 10 times the water requirement. It is very clear that it is coming from the lack of policy on electricity. There are hardly any electricity charges to pay while running pumps for irrigation. The result is that farmers do not value water, switch on their pumps continuously and most of the time without rationale. The practical consequence is this monitored fast depletion of the aquifer and related salinity increase, and this is generating a very serious risk of sea water intrusion. On the other hand, the tanks and interconnecting canals described previously are not maintained any more because of this easily available water from the ground. The collection of rainwater is reduced, the time necessary for rainwater to percolate shrinks (which means that less groundwater recharge occurs), erosion develops with consecutive lost of soil fertility... Altogether we can observe a cumulative negative impact jeopardizing badly the area and putting its survival at risk.

Kaliveli, this huge wetland on the north, is collecting the major part of the runoff. It may act as a reservoir of fresh water because it is the natural outlet of a 750 km² area. So there is a potentially huge amount of water that can be stored there. This swamp is connected to the sea through a gullet ending in another naturally salty water body. But
the shutter that is in the gullet to stop the high tide from contaminating the water is destroyed. What happens is then that either the runoff goes straight to the sea or the freshwater is constantly contaminated with seawater. Practically, it means that a very large volume of freshwater is spoiled and lost!

But that is not the end of the story. The green areas in the figure below are the tanks rehabilitated by the Government or NGOs schemes. There has been more than 10 years of constant effort to try to improve the water situation in terms of surface water management and groundwater recharge. There has been sincere work done to understand water behaviour and help develop appropriate solutions with the population. Several efforts are being done through:

- Social mobilisation of involving the farmers on water resources management through active participation;
- Awareness campaigns using street theatre, and monitoring resources;
- Organic farming programmes that attempt to convert the polluted soil into living soil to stabilise the water cycle and protect groundwater over-exploitation by regulating the irrigation. e.g. cost analysis (paddy) is done to demonstrate to the farmer the effects of organic vs chemical farming.
- Aquaculture in village ponds (rain water storages) help to prolong water storages for more recharge and to involve women in water harvesting practices; and also to create an opportunity among women to make additional income to the family.
- Afforestation efforts to restore the tropical dry evergreen forests and protect ecologically sensitive sanctuaries.

However, whatever is there it is not enough as we can continue to observe that the groundwater situation is getting worse and worse.

We can also observe major surface and then groundwater pollution risks linked to heavy chemical fertilizers and fertilizers, but also some chemical wild disposal in some areas. Looking at the Kaliveli area, with this damaged shutter, there has been very fast growth of (illegal) shrimp farms which is directly contributing to the worsening water scenario of this region and pollution risk.

All together, the lack of appropriate legal structure and regional water authority is flagrant. Due to the growing labor demand of Pondicherry the possibility to mobilise the local population is reducing. Without official support at an appropriate scale, it is hardly possible to change the situation.

With these natural and human made water structures, there is tremendous scope to protect and to maintain the water resources. With the existing NGOs and the support of the governmental structures, which offer a very good potential for implementation and regulation, it is still possible to tackle this frightening problem a head and to maintain and revive the resources if we act together in a proper and coherent manner and in a short period.

**Conclusion**

- The groundwater resources for Auroville’s bioregion growth cannot be secured in the actual context;
- Auroville is largely depending on the bioregional water management for its own growth;
- A large part of the area is under immediate risk of major environmental blow;
• While many efforts are made in the last years to restore the situation in the bioregion, the main problem of securing appropriate water resources in the future is far to be met yet;
• Some legal and organizational frames are immediately necessary to address the intricacy of the problem.

Its not happening here alone
• Similar conditions prevail on most of coastal India;
• A large part of the world population is facing water scarcity;
• Appropriate quality & quantity of water supply is at stake.

Q/A

Water consumption you have mentioned is 500 million l/day – is that the consumption for the entire bio-region?
No this is for the area of our study which is 264 km², which is around 25% of the entire area, which includes irrigation and drinking water.

What do you mean that “tomorrow there will be no water”?
In terms of quality, we will face scarcity very soon - not have any drinking quality water, but in terms of quantity, the way we extract water may be that in a short time we will not have water. Sophie Violette will give more details about this in her presentation.
Comprehensive View of the Hydrologic Cycle of the Kaliveli-Pondicherry Sedimentary Basin Tamil Nadu, India

Sophie Violette
Aude Vincent
Noémi d’Ozouville
Ghislain de Marsily
Nathalie Gassama
Aïna Dia
Nathalie Jendrzejewski
Groundwater, GIS & GPS teams, Auroville Water Harvest

Dr. Sophie Violette who is a doctor in Hydrogeology, from the University of Paris, is an expert in hydrogeology for the Committee of orientation and follow up of the underground research laboratory, "Laboratoire de Géologie Appliquée, UMR-Sisyphé"- Université Pierre et Marie CURIE; she is a member of A.I.H./I.A.H., International Association of Hydrogeologists.

She has been responsible for the program: ‘Paris basin modeling’ (PNRH.89/95 & 01/44 & ECLIPSE II.04) as well as co-responsible for the following programs: ‘Kaliveli & Pondicherry sedimentary coastal basin, Tamil Nadu India’ (HELP-UNESCO.04/05), with G. Boulicot, ‘Study of freshwater resources in the Galápagos Islands’, (NEB. FF. ESA/ESRIN 03/05), with N. D’Ozouville & G. de Marsily; ‘Origin of salt in coastal aquifer, Kaliveli watershed, Tamil Nadu India’ (ACI-Eau.00/02), with N. Gassama; as well as responsible for the thematic 3 team "Modelling of aquifer system at whatever scale" of the UMR-Sisyphé since January 2001.

Dr Violette has been in 2003-2004 in the CNRS (France) delegation as a full time Researcher at the “Centre d’Informatique Géologique” (School of Mine – France); between 1995-2003, she served as an Assistant Professor with a HDR graduation at the “Université Pierre et Marie CURIE” (UPMC – Paris 6 – France), prior to which in 1993-1995 she was a temporary Assistant Professor at the “Université Pierre et Marie CURIE” (UPMC – Paris 6 – France).

Her scientific activities aim at studying the groundwater flow at regional scale using flow, heat and solute transport modeling, mechanical and basin modeling and natural tracers. Fluids flow through sedimentary basin in Paris and South-East basins of France; hydrogeologic study of vulnerable systems under anthropogenic exploitation and/or arid climate; in volcanic areas (Réunion Island, Galapagos Islands), crystalline basement (South of Madagascar) or coastal aquifers (Togo basin, Kaliveli-Pondicherry watershed, India). Her teaching activities include: general and quantitative hydrogeology; hydrogeology modelling seminars; hydrology, hydrogeology and hydrochemistry field training.

She has published several articles, papers and technical reports at national and international and 2 of these publications pertain to the Kaliveli area.

"Laboratoire de Géologie Appliquée, UMR-Sisyphé"- Université Pierre et Marie CURIE, Paris, France T.56-55, E.4, case 123, 4 place Jussieu, 75252 Paris cedex 05, France.
Phone: 33-1-4427-6130; Fax: 33-1-4427-5125
Email: Sophie.Violette@crj.jussieu.fr

This work started in January 1999, with Tom Gablier’s initiative when he was in charge of Harvest. This is the combined work of other hydrogeologists, geophysicists and geochemists from France. There is support for this work from many sides, many agencies. Support:
CNRS “ACI-EAU” (00/01) – NEB – UMR-Sisyphé – GéEAC Tours – HARVEST (AWS) Health, Environment, Life and Policy UNESCO Program (04/05).

Problem
- Piezometric drawdown (up to 35 m below) together with an increase in salinity (>3500 µS/cm) in the main aquifer (Vanur sandstone)
- Consequences on agriculture (soil salination, decrease of the crop rate)
- Lack of overall hydrological study

Aims
- Comprehensive view of the hydrological cycle
- Origin of salination and its dynamics
- Future investigations needed to better constrain uncertainty

The Kalveli – Pondicherry Sedimentary Basin
The entire sedimentary coastal basin area is 1400 km²; the Kalveli watershed area is 754 km² (the main area involved by Harvest and this study), with a swamp area of 70 km².

Meteorology Network
- Climatic station (monthly):
  Aurodam 1972-1983
- Climatic station (30 min):
  Vanur 2002–...
- Rain gauges (daily):
  Pondy 1968-1999,
  Sugar Mills 1984-2002,
  Harvest 1996–..., Harvest network (14)
- Rain gauges (monthly):
  Pondy-Hindu 1911–..., Pondy-PWD 1940-1997,
  Vanur 1951-1995,
  Cuddalore 1990-2002
  Villupuram 1997-1998

Meteorology – Rainfall
Tropical semi-arid climate with 1200 mm/year. This high average value means nothing because sometimes we have plenty and sometimes very dry years.

Meteorology – Water Balance

<table>
<thead>
<tr>
<th>Year</th>
<th>Input mm/yr</th>
<th>Output mm/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-1981</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 years</td>
<td>1,216</td>
<td></td>
</tr>
</tbody>
</table>

Real Evapotrans.:
With 50 mm of field capacity 810
Effective rainfall 407

There is only 3 months of effective rainfall – October, November and December.

If we look at the water balance to see what is the effective rainfall, we find this to be one third of the total rainfall i.e. 400 mm/year, occurring in October-December.

Main unknown variables are runoff and infiltration.

From literature infiltration estimation of 15% infiltration, for Vanur we get a recharge of 5 million m³/year and for Cuddalore we get a recharge of 9 million m³/year.

Hydrology
There are no perennial rivers; there is drainage of surface water by inter-connected tanks; there are 4 main outlets (Kalveli swamp, Ponmaiyar, Gingee, Malatar rivers).

North-West AV watershed:
- Complete GPS study, Malika 2001
- Area: 90 km²
- 22 tanks
- Tank capacity ranges from 0.09 to 0.61 million m³
  ⇔ total full storage more than 6 million m³ in this watershed.

Water balance has been calculated for 9-20 November 2003 to be 103 mm and extrapolated for the year 2003 to be 376 mm.
**Geology**

- Lithology:
  - 273 wells (CGWB, PWD, TWAD)
- Aquifers:
  - dune
  - alluvium
  - Cuddalore
  - Kaddaperikuppam
  - Vanur
  - Ramanathapuram
- Aquitards:
  - Manavalli clay
  - Ottai clay

Out of the main aquifers listed above: only Cuddalore and Vanur aquifers can be used for water resources (light green and dark green)

**Hydrogeology: Cuddalore and Vanur Aquifers Observation Wells**

We have made observations in some wells of the Cuddalore and Vanur aquifers, this has been done every month and we have selected those wells that use water only from one aquifer.


Vanur water level was 7 m above sea level in 1975, now we are 30 m below sea level – so drawdown of 37 m. While that of Katterikuppa the drawdown is 35 m between 1977-2003.

Looking at consumption figures we find that there has been an exponential increase in
consumption through bore wells between 1951 to 2003. The consumption was 2 times the natural recharge in the 1980s, and this has become 8 times in the 1990s and by extrapolation we estimate that it will become 20 times in 2001-2010. We have used the natural recharge estimation of: 5 million m³/year or 50 million m³/10 years.

**HYDROGEOLOGY — MODELLING OF THE SALINE INTRUSION IN VANUR AQUIFER**

Due to over exploitation we could have sea water intrusion and so I did a simple modeling of the fresh water-sea water interface motion due to pumping with 1D code (NEWVAR-School of Mine, Paris)

- we added a NE-SW cross section of 18 km long
- we assumed that there was no flow connection with down and upward aquifers — a very strong condition

- initial fresh water-sea water interface was at coast line position
- steady state: I tried with the calibration of recharge & K value to reproduce initial i
- I tested different recharge values:
  - 110, 165 & 235 mm.y⁻¹
  - a Best fit for K = 1.4 10⁻² m.s⁻¹ & recharge = 110 mm.y⁻¹
- transient state: I calculated the temporal evolution of the interface according with pumping rate evaluation and test different porosity values: 0.15% & 0.30% & initial boundary conditions.

**HYDROGEOLOGY: CONCLUSION ABOUT MODELLING OF THE SALINE INTRUSION**

- With a porosity of 15%:
  - in 2000 the deeper part of the Vanur aquifer should be saline
  => this implies that Auroville area is contaminated!
- in 2010 only one-third of the aquifer is still fresh water
- in 2050 the whole aquifer is saline

- With a porosity of 30%:
- in 2000/03 the situation remains ok
- in 2010 the deeper part of the Vanur aquifer should be saline => Auroville area contaminated!
- in 2020 only one-third of the aquifer is still fresh water

⇒ From a hydrodynamic point of view the situation is dramatic and may evolve rapidly.

Using 2 different value for porosity, we see with 15% porosity, in 2010, the Vanur aquifer has only one-third fresh water, and in 2050, everything will be salty – however if we use 30% porosity, in 2010 we may have salt water and in
2020 only one third of aquifer is still fresh and in 2050 there is no fresh water.

**Geochemistry: Possible Origin of Salination**

From the map of electro conductivity of Vanur aquifer in May 2004, we see the whole aquifer area has values which are beyond the limits specified for drinking or irrigation purposes (1000 microsiemens/cm).

Reasons may be:

(i) direct paleo or present seawater intrusion or through brackish water from the swamp;
(ii) downward transfer of salty evaporated irrigation water;
(iii) upward leakage of highly mineralized water from below aquifer caused by head differences due to the pumping.

Method 1

- Characterization of the geochemical water bodies
- Use of hydrodynamic, geochemical and isotopic tools

Method 2 - Monitoring a hydrological year Oct.00/Jan.01/July 01/Sept.01

- Aquifers sampled
  - Cuddalore sandstone (10)
  - Vanur sanstone (16)
  - Chamockite (8)
  - some intermediate ones (5)
- Choice of borewells according to aquifer and to x, y positions
- Surface waters
  - eris (7) & swamp (2)
- Physico-chemical parameters
  - T, pH, E.C.
- Analyses
  - Ca, Mg, K, Na, Cl, HCO₃, NO₃, SPO₄, SO₄, H₄SiO₄, Fe, Mn, Li, F, Sr
  - 18O, 2H, 87/86 Sr

To check whether there is mixing of sea and fresh water, from the figures we see that there must be another source for salinity other than just simple mixing.

Looking at the impact of evaporation, we see that by comparing with the mean local meteoric line obtained from rain waters of Sri Lanka, the results of all our samples, we find that there is an evidence for evaporation impact after putting in the same graph the ratio 2H versus 18O of the water; this evaporation takes place during infiltration and before infiltration of surface water.

To check the water-rock interaction, we see a linear relationship between chloride and electro conductivity, and if we draw a graph of sulphate as a function of electro-conductivity, we notice high sulphate content with high conductivity, which implies there is mixing with sulphate-rich water.

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Facies</th>
<th>Saturation index (mean)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuddalore</td>
<td>CaHCO₃</td>
<td>calcite: -2.82</td>
<td>rapid circulation</td>
</tr>
<tr>
<td>100 to 500 μS/cm</td>
<td>chalcedony: saturated</td>
<td>low water-rock interaction</td>
<td></td>
</tr>
<tr>
<td>Vanur</td>
<td>CaHCO₃ to CaCl</td>
<td>calcite: -0.27</td>
<td>marked evolution</td>
</tr>
<tr>
<td>600 to 1,800 μS/cm</td>
<td>chalcedony: saturated</td>
<td>from unconfined zone to confined zone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fluorite: -0.66</td>
<td></td>
<td>water-rock interaction</td>
</tr>
<tr>
<td>Chamockite</td>
<td>CaHCO₃ to NaCl</td>
<td>calcite: -0.16</td>
<td>discontinuous aquifer</td>
</tr>
<tr>
<td>500 to 2,200 μS/cm</td>
<td>chalcedony: saturated</td>
<td>2 distinct facies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fluorite: -0.95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conclusions:**

- Evaporation impact cannot be neglected
- Surface-sea water mixing - Not assessed yet (2000)
- Water-rock interaction - Water-rock interaction + mixing with sulphate-rich waters (Ramanathapuram aquifer)
GEOCHEMISTRY AND HYDRODYNAMIC DISCREPANCIES

Limitation of modelling & hypotheses
- no flow connection with down and upward aquifers
* salt water intrusion compensated inland by downward aquifer leakage
- initial fresh water-sea water interface position on coast line
* stock of fresh water far-east from the coast line
* homogeneous aquifer properties
* lithologic barrier or a fault effect

Hypotheses need to be tested with a better constraint modeling; which means the need of new data to be collected.

PERSPECTIVES

COMPREHENSIVE VIEW OF THE HYDROLOGIC CYCLE OF THE KALIVELI – PONDICHERRY SEDIMENTARY BASIN TAMIL NADU, INDIA

Future investigation needed to limit uncertainties
- Hydrodynamic monitoring of Anpakkam watershed
  * acquisition of water budget parameters (Rain, ETP & ETR, Runoff & Inf.)
- Monitoring of piezometres network of the main aquifers and their extension towards the South
  * collaborative work with Tamil Nadu and Pondicherry water management organisations through HELP program
- Pumping tests
  * acquisition of hydrodynamic parameters (T, K, S, w) for main aquifers
- Identification or not of a barrier close to the beach coast
* new borewells (?) from Cuddalore to Vanur aquifers
- Identification of geometry between Kaliveli swamp and Vanur
* Geophysical investigation such as TDEM
- Interpretation of satellite imagery
  * acquisition of morpho-physical parameters and their evolution along time (morphology, land cover…)
- Hydrodynamic modelling of the multilayer aquifer system constraint by geochemical and isotopic tracers, taking into account fresh water-salt water intrusion motion
* estimation of resources and long time quality evolution
If because of our efforts to change the environment for the better, will it have an impact on the disaster? It may help in storing fresh water that can be used for irrigation – it may help Vanur aquifer to recover; what we have to do is to increase the storage of freshwater in the region and Kaliveli is a natural refreshment that can help and the second is to preserve ground water and to stop indiscriminate use of water.

Either one has to decrease demand or increase supply – supply is limited by rainfall over the last 100 years – assuming rainwater is to be replenished for the next 15 years; and we are not able to decrease demand due to socio-economic factors, is there any way other than rainwater to give unlimited supply of fresh water to the aquifer so that there is a favorable balance of demand and supply for this bioregion? In fact how much will such supply of fresh water mean in terms of quantity? It is possible to study this and get the help of experts in water management.

Your model will not be accurate in a multilayered aquifer system where the assumption is that no leakage takes place of the above and below aquifer. True, at the time of this modeling we didn’t have the data, but since then we have the data, and we can use it to get a real picture. Our modelling is just a simple preliminary investigation, a tool to help to understand water cycle.
Carrying Capacity & Assimilation Capacity of Auroville Bio Region, Tamil Nadu: Assessment through Geo-Environmental Studies

V.V.S. Gurunadha Rao

Deputy Director, Head
Environmental Hydrology Group
National Geophysical Research Institute (NGRI)
Postbag 724, Hyderabad – 500 007, India.
Phone: 40-2343835
Email: gurunadherao@ngri.res.in

Thank you for allowing me to share the experiences of studies in the Neyveli basin and Mettupalayam Industrial Development Area and Auroville and its environs. We have carried out the studies for understanding the hydrodynamics of Neyveli basin during in 1986. With the sponsorship from Agriculture Department, Pondicherry, NGRI had completed a study entitled assessment of the impact of Mettupalayam Industrial Area on the drinking water supply of Muttarapalayam well field in Pondicherry in 1999-2001. Also we made a small attempt to understand what Dr. Sophie has presented-what will be the likely saline water intrusion that is likely to come up in the Auroville region based on the CGWB work of 1984 (Jaykumar and others) - we have used in the model the projected demands and which aquifer is likely to be exploited more – the results I will be presenting under 3 themes:

1. Mettupalayam Industrial Estate
2. Saline water intrusion study along a cross-section between Alankuppam, Matrimandir and Pillaichavadi;
3. Neyveli basin – all our understanding comes from here and I have studied Neyveli figures of 1956, 1986, 1996- 3 scenarios;

For Mr. Rajendra Singh and Mr. Anupam Mishra, I will show how we arrived at figures for a nalla bund – what is the real impact and how we have elongated the ground water flow of water.

Presently we are interested in what is the carrying capacity and assimilation capacity of Auroville region. This is our objective.

Why carrying capacity? So far we have exploited the ground water aquifer just like that - now after over-exploitation we could realize the problem. When we leave a lot of waste (both liquid and solid waste), how far can the aquifer assimilate that waste? We have started a project for such studies in the Vishakapatnam Industrial Area on the carrying capacity of the existing industries.

The carrying and assimilation capacity of this region depend on environmental impact by anthropogenic activities. By this, we mean what are the present lakes/reservoirs, ground-water resources, saline water intrusion in coastal aquifers and finally the remedial measures of how to augment water resources.

What is assimilation capacity - we produce waste water and we have common effluent treatment plants, industrial waste water, solid waste and municipal waste, pesticide residue contamination in agriculture and all of them will show an impact on our ground water resources.

There are different approaches to assess present status of groundwater potential & contamination, if any, in each watershed through:
• Hydro-geological & Hydrological
• Geophysical
• Water Quality Analyses (like that of what Dr. Sophie Violette carried out) of major ions; trace elements and pesticide residues
• Groundwater Flow and Mass Transport modeling Studies
Tasks to be carried out to achieve the above objectives:

Characterization of lithological units (how many layers are present in an aquifer) & their disposition in the watershed through geophysical investigations & detection of contaminants; hydro-geological investigations for water level configuration (this is a must in all areas – when you dig a well you know at what depth water is occurring) and aquifer characteristics; detailed water quality analyses of waste water, surface water as well as groundwater.

**Mettupalayam Industrial Estate**

Now I will present how we have followed the above 3 approaches in Mettupalayam Industrial Estate (MIE) study – this study was commissioned by the Agriculture Department, Pondicherry, and carried out in 1999-2000 – the Mettupalayam well-field which is the lifeline of Pondicherry – with 27 wells supplying since 1862; now you can see 175 HP pumps continuously pumping – Neyveli and Pondicherry are the only 2 places where ground water pumping is controlled completely by the Government/Lignite Corporation. On looking at the industries within the industrial area we see the sulphates and dissolved salts discharges are at elevated levels – some of the wells act as sinks for ground water contamination.

We have monitored ground water and surface effluents water quality- we have examined the TDS levels and sulphate levels in the surface level effluents of industries like GEM Eng, GEE PEE Eng, Saradha Electricals, Veda Chemicals; but now looking at the ground water scenario to see how they get affected, due to the presence of the Cuddalore sandstone which is highly permeable – we find alarming levels of TDS and sulphates in all the wells inside the MIE; this is more evident if the industry is a chemical industry (Magna or Guru Papers), where sulphate levels are very high. Knowledgeably or unknowingly people are spreading these effluents on high permeability ground and they are acting as artificial recharging sources to the aquifers with these effluents.

The study area is covering 6 km out of the 24 km² area; where the permeability of Cuddalore sandstone is 25 m/day (horizontal is 25, vertical is 2.5); Manaveli clay is 1 m/day and Kadaiperikuppam limestone is 2.5 m/day; the reason
for comparing these figures is to highlight the point that most of the pollution takes place in the top-most aquifer (Cuddalore), which is the most permeable.

The Muttarapalayam well field which gives all the water to Pondicherry city, pumps at the rate of 1600 m³/day, while the MIE well pumping rate is only 800 m³/day. We have computed the ground water head distribution using these parameters of hydraulic stresses- in Muttarapalayam well field the water level is -18 m in June 1999; the ground water velocity directions are from the coast side; looking at particles released in the ground water tables in MIE, we find that some of the wells in the MIE act as sinks and do not allow this contamination to reach the Muttarapalayam well fields, and thereby contained in the MIE area and saving the situation!

Hence Pondicherry water supply will not be affected; studying the well fields of the MIE regarding sulphate migration, in 1979 the MIE was started and in 1989, 1999 and 2019 we have figures and projections and we see that this migration doesn’t spill over to the Muttarapalayam well field areas, because clay acts as a good barrier.

SALT WATER INTRUSION IN THE LINE OF ALANKUPPAN, MATRIMANDIR, PILLAICHAVADI

The next theme is the Alankuppam, Matrimandir, Pillaichavadi lines, to understand the sea water intrusion based on the information from CGWB 20 years ago in 1984; they have projected that by 2004, the scenario will be such that the Cuddalore sandstone is exhausted and no further pumping will be available for Auroville region; if you take a cross-sectional
view of the Auroville region: the Kadaperikuppam sandstone is the one earmarked for drinking water supply with a pumping rate of 5 million m³/year of drinking water supply from this layer in 2004 and for irrigation purpose the VGNur sandstone can be used. When we commissioned some pumps accordingly near Auroville, I studied them without pumping for ascertaining the natural condition; the natural condition of saline water intrusion is just at 1.2 km inside the sea. If one starts pumping water at a rate of 5 million m³ for drinking water supply...
and 10 million m$^3$ for irrigation over a period of 20 years, the saline water will migrate – it will travel about 500 m from the coast line in the Kadaperikuppam formations, and in the Vanur they will come in 2 km inside. This is the scenario projected based on the CGWB report – the projections are still valid; we haven’t exceeded the pumping limits that they have projected because Auroville hasn’t grown as per its original plan.

Water requirements of Auroville Township spread over 42 km$^2$, in Tamil Nadu are solely dependent on groundwater resources. Earlier geo-hydrological investigations were carried out by Central Groundwater Board to study the nature aquifers and its proposed impact (Krupanidhi et al, 1979, Jayakumar et al, 1984). The Auroville township near Pondicherry is located about 5 km inland from the Bay of Bengal with initially steep gradient and later gentle gradient eastward slope. Cuddalore sandstones containing sandstones, clays, pebbles and gravels comprise the shallow aquifer thickening from west to east. The Manaveli clay and Kadaperikuppam limestone formations underlie the Cuddalore formations with fine to medium grained sandstone and limestones. Below them lay Cretaceous sediments of calcareous sandstones, carbonaceous clays, limestones and fined grained sandstones of Vanur and Ramanathapuram series (Jayakumar et al, 1984). Archean crystalline basement consisting of Charnokite and granitic gneisses. The disposition of lithological units with vertical dispositions covering 10 km includes 3.25 offshore extension (Fig. 1). As regards groundwater exploitation Kadaperikuppam formation is meant for drinking water and Vanur and Ramanathapuram formation is for irrigation. Flow and solute transport model for the vertical section has been simulated using SUTRA software (Gurunadharao and Gupta, 1989). It is assumed that the horizontal to vertical permeability is 10:1 in the potential aquifer zones whereas in the aquitards permeability is mainly same in both directions. The model has been tested for
natural condition without pumping and also for probable input/output stresses for next 20 years. It is envisaged about 15 million m³/year of groundwater will be exploited from Kadeparkuppam and Vanur formations in the ratio of 1:2 respectively during next 20 years. The solute transport model predicted that the saltwater and freshwater interface will move about 0.75 km in the Kadeparkuppam formation and about 2.5 km in the Vanur formation during next 20 years (Fig. 2). Periodical monitoring of groundwater quality has become imperative for safe exploitation of groundwater resources for supplying hazard free drinking water in the Auroville township in view of the above findings.

REFERENCES


STUDIES OF NEYVELI BASIN

Neyveli aquifer is an artesian aquifer in former South Arcot District, Tamilnadu and has very large lignite deposits. Mining of lignite has posed the problem due to huge hydrostatic pressure of about 100 tonnes/m² exerted by the artesian aquifer below the lignite seam. The artesian conditions have developed due to confinement of lignite seams and clay lenses. It has become imperative to depressurize the confined aquifer for safe mining of lignite by bringing the water level just below the lignite seam. For this purpose the Neyveli Lignite Corporation has resorted to continuous pumping of 6800 m³/hr since 1961 starting with the first mine. The pumping rate was gradually increased with expansion of mining operations with opening of a second mine and had reached about 20000 m³/hr during 1986. The withdrawal of water for mining operations has resulted in regional water level decline, resulted in stoppage of artesian wells use for irrigation to the tune of 52 million m³/year. Starting from 1986 NGRI has carried out prognostic studies in the Neyveli aquifer. Recently an update of the information the Neyveli aquifer has been revisited and in the presentation visualization of artesian conditions of 1956 and condition of 1996 has been presented through visual MODFLOW groundwater flow model. It suggests that how the groundwater divide has shifted towards Gadilam river from centre of the basin. The locale of that area is having mainly cashew as their crop and since this is not a water-intensive crop, the NLC has been able to safely use water for its mining activities without much objection from the people.

IN ANSWER TO THE QUERY OF RAJENDRA SINGH AND ANUPAM MISHRA

The Auroville region is a high permeability formation – the augmentation structures will help improving the ground water recharge. The Matrimandir lake will not have water staying, because of high recharge rate/seepage losses from the bed of the lake; hence in-spite of good rains, water levels will not rise much in the lake.

A partnership in 1992-1994 between Marathwada Agriculture University, Parbhani, Maharashtra demonstrate the case of impact of water harvesting structures on ground water regime – they have constructed 2 nalla bunds and 2 cement plugs in the Wagarwadi watershed covering 545 hectares in basaltic terrain
- ground water monitoring study was carried out by Prof Gore of Agriculture University for his Phd. This is a very low permeability formation compared to other regions. Here artificial recharge will work better. We have computed the catchment area of nalla bund 1 – 41 ha, nalla bund 2 – 59 ha; cement plug – 4.4 ha.

They have also measured the stage readings of water level in the nalla bunds and computed the water storage in them – we have constructed a ground water flow model with 28 observation wells; the results of the study indicate that 60% of water stored in the nalla bunds or johads will definitely contribute to the ground water system.
The Union Territory of Pondicherry comprises of 4 non-contiguous regions with an area of 492 km².
- Pondicherry 293 km²
- Karaikal 160 km²
- Yanam 30 km²
All the above are located on East Coromandel Coast and
- Mahe 9 km²
Located on the West Malabar Coast

**Topography**

a) Monotonous plain with an average elevation of about 15 m above mean sea level (msl)
b) Prominent high grounds varying from 30-45 m above msl towards interior NW & NE parts of the region

**Physiographic Units**

*Coastal Plain*—Narrow Stretch of 4 to 600 m width on the eastern part of region along the coast

*Alluvial Plain*—Formed by 2 major rivers Gingee and Ponnaiyar and occupies a major portion of Pondicherry. This is a monotonous plain with slope ranging from 1 to 3%

*Uplands*—High grounds with elevation of about 30-40 m above msl. (intersected by gullies and ravines)

**Rainfall**

Average annual Rainfall: 1205 mm
- 63% occurs during NE Monsoon (Oct-Dec)
- 27% occurs during SW Monsoon (June-Sep)

**Geology of Pondicherry**

- Sedimentary rock type
- Formations are unconsolidated to semi consolidated in nature
- Deposited in a basin
- Formations dipping towards east.
- The flow direction of ground water is towards east. Presently the direction is reversed along the coastal tract.

**Resource Utilisation**

**Land Resources**

1. Net area available for cultivation: 15,298 ha
2. The extent is expected to be reduced to 14,000 ha by 2005 due to urbanization and industrialization
3. Total Cropped area has also reduced from 28,575 ha in 1966-67 to 27,441 ha in 1996-97

* The Net area sown has declined from 18,331 ha to 15,298 ha over the same period
WATER RESOURCES
GROUND AND SURFACE WATER
STATUS OF PONDICHERRY

Sources of water:
Surface water: 35 million m$^3$ (mcm) and the sources are 84 system and non-system tanks plus 500 small ponds in the villages
Ground water : 150 mcm
Total : 185 mcm (A)

Requirements
Agriculture : 174.40 mcm (81%)
Domestic : 35.35 mcm (16%)
Industries : 7.02 mcm (3%)
Total : 216.77 mcm (B)
Deficit (B-A) : 31.70 mcm

SURFACE WATER
There are no perennial river sources in Pondicherry. Two elements that contribute to surface water are:

I) Seasonal river flows in the rivers originating in Tamil Nadu passing through Pondicherry
II) Direct Run-off from the areas lying wholly in this region
   • Gingee river traverses the region diagonally from NW to SW
   • Ponnaiyar forms the Southern border of the region
   • A branch of Ponnaiyar river called as Malattar flows through the region and joins the Bay of Bengal
   • Two diversion structures built across the Gingee river at Suthukeni and Pillayarkuppam and one diversion structure across Ponnaiyar at Somavur
   • These dams divert river water into feeder channels which feed the Usteri and Bahour major irrigation tanks (of the 84 tanks)
   • During Monsoon, heavy run-off has been observed

• As per assessment of WAPCOS made in 1987, the annual utilizable runoff is 49.51 mcm
• 84 irrigation tanks are available in Pondicherry region with a total water holding capacity of 46 mcm
• In 1930, an area of 8500 ha was under irrigation by tank
• After introduction of multiple cropping programmes, groundwater was utilized in conjunction with surface water
• In 1962, the area under tank irrigation was 6500 ha and it became almost negligible level in 1988
• Area under tubewell irrigation in 1962 was 7500 ha and it has increased to 13500 ha in 1996
• After transfer of management of Tank irrigation system from the Syndicate Agricole system to Commune Panchayat in 1974 the management of tank system has gone into disuse and entire need of irrigation is met from ground water resources.
• In the early 1960’s there were only 1000 shallow tubewells in existence operated with ordinary centrifugal pumps which commanded an area of 7500 ha. Gradually, due to lack of surface water irrigation, the tubewell population increased to around 6000 at present and the total area commanded by tubewells is around 13500 ha and the surface water irrigation has become negligible (depth of tubewells earlier was 30-40 m only, now this has increased to 100-200 m)
GROUND WATER

- Main source of irrigation, drinking and industrial needs
- Three major aquifer systems namely Alluvium (which cover almost 90% of Pondicherry), Cuddalore sandstone and Vanur-Ramanathapuram Sandstone constitute ground water
- Besides, Ottai granular Zones and Kadaperikuppam limestone constitute ground water to some extent
- The utilizable ground water resources at 85% of the gross recharge potential is assessed at 150 mcm
- Presently ground water requirement to meet the needs of all the sectors is in the order of 169 mcm, which reveals that the maximum limits of utilization of ground water exceeds the total resources
- Monitoring: The behaviour of ground water / aquifers together with their quality are monitored with the help of 100 observation wells tapping various aquifers. Additionally sea water intrusion is also monitored with a series of coastal battery keywells

GROUND WATER DEPLETION
Lowering of water levels in Pondicherry
In Coastal areas - 5 to 12 m
In Western parts - 15 to 55 m
- As of 1985, flow was in normal gradient (towards east). Piezometric head was above the mean sea level (in all aquifers)
- As of 1998, piezometric head showed a reversal of hydraulic gradient in the tertiary formation. The piezometric head in tertiary & cretaceous aquifers is far below the msl
- On comparison of water levels in the alluvial aquifers between the years 1983 and 2003, it has been observed that:
  a) there is a drop in water level from 4 to 12 m
  b) a max. drop is observed at Central and NW part. The present water level here is 38 m
- Likewise in the tertiary aquifer a drop of 9 m to 14 m is observed during the same period of 20 years. The max. drop is observed on the SW parts of Pondicherry. The present water level here is 25 m
- Similarly, a drastic depletion is observed in the cretaceous aquifer. The water level difference is 7m to 39 m during the 20 year period. Max. drop is observed at NW portion of Pondicherry. The max. water level is 60 m. Max. thickness of aquifer here is 150-160 m, presently standing water level is 60-65 m while pumping water level goes to 100-110 m and rest of the column is only 30-40 m

REASONS FOR DEPLETION
- Lack of surface water irrigation (after 1987 all needs are met by ground water)
- Mismanagement of surface water bodies and neglect of runoff
- Failure of monsoons
- Cultivation of high water consuming crops (in Pondicherry - sugar cane is a main crop and max depletion is near sugar mills e.g. Ariyur)
- Almost a complete dependence on ground water and overdrawal for all purposes
- Increasing population
- Development of certain water-based industries in some pockets
  A graphical representation of rainfall with water levels over periods of 20-30 years in different locations (coast, interior) shows a decrease in water level inspite of good rainfalls – this is more acute wherever sugarcane or paddy is being cropped (Madukarai, Abhishekapakkam, Sorapet)

**GROUND WATER QUALITY**
- In general, quality of ground water is good in Pondicherry with TDS ranging from 400 to 1000 mg/l
- Even along the coastal we have 170mg/l
- In some cases ground water in cretaceous aquifer is highly mineralised with TDS ranging from 1000 to 1500 mg/l (NW of Pondicherry due to over exploitation, the minerals in the Ramanathapuram formations)
- Degradation of ground water quality due to salt water ingress is noticed along the coast. Ground water in alluvial & upper Cuddalore sandstone formations is found to be saline along the coastal regions, which is due to over extraction of ground water – upto 1985 there was no such problem, as long as surface water was being used for irrigation.
- Increase in sulphate content is noticed in the north western part of Pondicherry due to the upward movement of the said constituent from the bottommost Ramanathapuram Sandstone aquifer

**SEA WATER INTRUSION NOTICED**
- 3 to 4 km inland in the southern parts
- 2 km inland in the city
- 1 km inland in the northern side (near Auroville, Kalapet)

An interesting observation is that sea water intrusion is more wherever there is mining of sand from rivers (Ponnaiyar area) – all shallow aquifer holes in this area are totally saline. There is a clay-seal in the Cuddalore sandstone - that acts as a barrier and prevents the downward percolation of sea water.

**REMEDIAL MEASURES TAKEN**
- Executive orders regulating the construction of new tubewells and extraction of ground water are in force since 1980 – existing ones continue to be used.
- Construction of new tubewells within 6 km from sea coast has been banned, but for drinking water purpose and rejuvenation of existing tubewells, there is permission given.
- Ground water clearances are issued only to non water based industries and the drawal of water by the industries is being monitored
- The Ground water (Control and Regulation)Act 2002 has been enacted

**MEASURES OF CONSERVATION AND RECHARGE**
- Subsidy assistance for laying of underground pipelines for conveying irrigation and for installation of drip/sprinkler irrigation systems and for construction of roof top rainwater harvesting structures in private buildings and in industrial buildings.
- 100% subsidy assistance is extended for installation of drip irrigation for sugarcane cultivation – for 1 acre
- Existing ponds are desilted and recharge tubewells are constructed in them.
• Subsidy assistance is extended to renovate the unused dug wells for harvesting rainwater (because farmers now use only their newly bored tube wells)
• Recharge shafts are constructed in the river/water courses
• Apart from the above the PWD is undertaking to desilt the 84 tanks through the EC program at an estimated cost of Rs. 40 crores – 50% tanks have been finished desilting and holding capacity increases from 46 mcm to 76 mcm – the maintenance of this is being brought under the control of farmers through the Syndicate Agricole. The work of 84 tanks will be finished before December 2004 and the Government will take it over (assessment, monitoring)
• World Bank project – Hydrology Project 2 at an estimated cost of Rs. 13.7 crores – under this program all information will be collected (surface water, ground water, hydrological) - all under one roof.

Q/A

**What is assessment for 10 years from now – regarding water demand and water resources in Pondicherry?**

Today we have 35 mcm deficit – this will increase in future and we are fighting this by recharge programs, desilting tanks, it will help.

**Any pesticide monitoring is done?**

Bio-technology program – schemes are being done and bio-fertilizers are being encouraged.

**What measures are taken to stop sand mining?**

Sand mining is one of the reasons for sea water intrusion; we are controlling the sand mining through government regulations and Government has taken up the leasing of sand mines; we are making check dams across the river.

**To restore the original surface water irrigation, how much should be spent?**

Rs. 39.40 crores

**Why sea water intrusion hasn’t taken place near our coastal communities of Auroville?**

These are uplands – they don’t get sea water intrusion.
Ground Water Management in the Neyveli Region

K.P. Agrawal

K.P. Agrawal, currently General Manager/Geology, Neyveli Lignite Corporation Limited, did his M.Tech. in Applied Geology from University of Roorkee (now IIT, Roorkee) in 1969 and joined Hindustan Zinc Limited. From HZL, he shifted to Geological Survey of India in early 1971 from where he had gone to Mineral Exploration Corporation Limited (MECL) in January-1976. Till March 2003 he continued in MECL, where as General Manager/Exploration serviced mineral exploration activity spread over throughout the country after which he joined NLC as General Manager.

He has acquired a diploma in Poly-metallic Ore deposits under UNDP programme in USSR in 1981. As a Technical Member of an Inter-Ministerial Group, studied thin seam lignite mining in Austria, Greece and Yugoslavia. Further, trends of Tin mining, beneficiation etc., were studied in United Kingdom and China. He has been closely associated with sub-groups on finalization of 9th and 10th plan approach for survey and mineral exploration constituted by Ministry of Mines. While in Mineral Exploration Corporation Limited, he led the campaign for search operations for lignite deposits with significant results. In recognition of his contribution, Government of India conferred upon him the Prestigious National Mineral Award for 1986. Further, Government of Rajasthan under the aegis of Department of Mines and Geology during the 50th year of Independence, has honoured Agrawal for his outstanding contribution in the development of mineral industry in the state. He is associated with more than 200 mineral exploration reports and 70 scientific and technical papers during his three and half decades of professional career.

General Manager - Geology
Neyveli Lignite Corporation Ltd.
F-39 Block-25, JN Salai, Neyveli - 607 801, TN, India.
Phone: 4142-252537

PREAMBLE

Neyveli Lignite Corporation (NLC), a premier public sector enterprise, was established in the year 1956, and is 48 years old. It is the largest lignite mining cum power company in India. Lignite is the younger off-spring of the coal family. It is fossil fuel belonging to Miocene age (25 million years) popularly known as "Brown Coal", lignite is tan brown in colour, light to handle and brittle in nature with high moisture, and makes transporting very difficult. This fuel is born from vegetable matter having undergone bio-chemical decay to the stage of peat and then metamorphosed to lignite under the pressure over millions of years. Normally lignite is used for power production and NLC is now operating 3 lignite mines and put together has a production capacity of 24 million tonnes /annum. This is linked with power generation to the tune of 3000 MW.

The country has 36 billion tonnes of lignite resources of which 90% are concentrated in Tamilnadu, 9.9% in Gujarat and Rajasthan and 1% in Jammu/Kashmir and Kerala. The lignite mined at Neyveli varies in colour from brown to dark brown and has a non-bonded granular structure. Microscopic studies of this section prepared from bulk samples of lignite indicate that the fuel is composed of a wide variety of plant ingredients, mainly of coniferous nature. Lignite contains 65-70% of carbon, 20-25% of oxygen, about 5% of hydrogen and small
amounts of nitrogen and sulphur. The average caloric value of lignite is 2400 K.Cal/Kg. About 4500 tonnes of lignite resources are available in Neyveli region of which at present it is looking for 1500 million tonnes of lignite to be exploited considering the difficulty in transportation unlike coal which can be imported and exported to longer distances. The company also has the responsibility of an effective ground water management during its mining and power generation operations.

**GROUND WATER**

Common man chants the Sanskrit sloka in his daily prayer “Aapo Hishtava Mayo BhuvaTan Aarje Dadhatana” meaning “Oh water! You are verily capable of conferring bliss; may you give us energy and nourishment”. This represents cultural or scientific spirit with which society should face the water problem in India. Water is a difficult thing to assess precisely, but we can study, foretell, simulate but lot of it is still unpredictable. Our country has 3.3 million km² land area representing rock formations varying in age from 100,000 years to 4500 million years. Water movement in each of these formations behave differently.

Galileoo said—“I can fortell the way celestial bodies move, but can say nothing of the movement of a small drop of water”. Such is the intricacy of the path taken by the water, and man being the most prolific consumer of this natural commodity needs to propagate water literacy—the need of the hour.
NEYVELI GROUND WATER BASIN

Ground water basin in the Neyveli region is spread over 3000 km² falling between latitude 110° 05’ N to 110° 45’ N and longitude 790° 10’ E to 790° 45’ E. While the river Gadilam constitutes the Northern boundary, the Southern boundary is limited by the Coleroon river. The Neyveli ground water basin, is in the form of a tilted basin with maximum thickness of 400 m of water bearing sand in the central portion which thins out to 50 m in the West. It is about 50 km wide in the West- East direction from the Tertiary-Cretaceous border to the Bay of Bengal and in the North- South direction, it extends to about 60 km between the Gadilam and the Coleroon rivers.

Physiography: The area can be broadly classified under four Physiographic divisions:

1. North-West high land
2. Central high grounds
3. Gadilam Ponnaiyarr alluvial plains
4. Vellar-Manimuthar alluvial plains

The north western of the area is high ground with steep slopes. The elevation gradually lowers in the northern and central parts. More or less a flat topography exists in southern and southeastern zones.

Drainage: The drainage in this area is controlled by Gadilam & Vellar Rivers and its tributaries. The rivers are mostly monsoon fed and flows during summer months are very lean. Veeranam eri, Walaja & Perumal eri are the three major lakes in alluvial plains of the Vellar river.

Geology: The geological formations in the area ranges in age from the Archaean to the Recent. The Archaean formation consists of blackish grey granitoid gneisses and Charnokites intruded at places by the pegmatites and dolerite dykes. These are found in the western most part of the region. The Cretaceous formations comprise calcareous sandstones, siliceous limestone, fossiliferous limestone etc. overlying the crystalline basement. The most important Tertiary formations consists of the Cudalore sandstones of the upper Miocene age (25 million years) containing fluvial to brackish marine deposits of clay, sands, gravel, pebbles and lignite. These sandstones from potential aquifers having semi-confined and confined nature.

Soils, Alluvium, Loam, Laterite and Kankar constitute the recent Quarternary formations.

Climate: The climate of this area is “tropical humid” characterized by long and severe summer, moderate monsoon and mild winter. March to May are summer months. This is followed by the southwest monsoon (June to August). However, the area is influenced by the Northeast monsoon during September to December followed by winter months January & February. The climate is largely influenced by the conditions of Bay of Bengal which is 30 km away on the eastern side. Maximum temperature recorded during summer is around 40° C and during winter months the temperature ranges between 18° C to 21° C.

Rain Fall: As stated above the Neyveli region receives to distinct monsoons i.e. 37% from South-West Monsoon, 58% from North East monsoon. Remaining 5% is received during other months. The average annual rainfall of this area is around 1200 mm based on 50 years average.

HYDRO-GEOLGY OF THE AREA

The hydrology of this area is extremely complex. According to the classification the aquifer system in the lignite field comprise of (a) Un-confined aquifer (water table aquifer), (b) Semi-confined aquifer above the lignite seam and (c) confined aquifer below lignite seam. It appears to be an inclined basin like structure. However in the region aquifer is considered as a seven layer system.
Aquifer Layer Configuration

The aquifer is considered as a seven layer system with water table as the first layer, followed by silty clay, semi confined aquifer, lignite seam, upper confined aquifer, clay layer and lower confined aquifer as the seventh layer.

NLC does not use the first layer for its ground water depressurization while mining lignite, but if there is leakage from this layer it is drained into the mine pits and it is pumped back to the natural drains for irrigating around 25,000 hectares of land, free of cost. The second layer has good porosity but high permeability. The semi confined aquifer above lignite varies in thickness from 5 to 10 m and there is no considerable ground water pressure. The upper confined aquifer 5th layer is generally 30 to 40 m thickness which has a good potential of ground water exerting a upward pressure makes the mining lignite difficult. NLC after in-depth study has selected suitable pumping strategy to depressurize locally the upper continued aquifer. The 6th layer is a thin clay layer followed by a thick layer of 300 m called the lower confined aquifer which has an upward pressure of 6 to 8 kg/cm².

Input to Ground Water Basin in the Neyveli Region:
The total area of recharge connected to the confined aquifer has been delineated as 420 km². 17.5% of the precipitation in the recharge area is calculated as recharge to the aquifer system. Recharge from other sources such as feed/leakage from phreatic aquifer, rivers, lakes etc.; inflow from South-West region of Neyveli.
OUTPUT FROM GROUND WATER BASIN IN THE NEYVELI REGION

<table>
<thead>
<tr>
<th>Activity</th>
<th>Aquifers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumping by industries along the coast</td>
<td>All aquifers</td>
</tr>
<tr>
<td>Rural water supply</td>
<td>All Aquifers</td>
</tr>
<tr>
<td>Irrigation pumping</td>
<td>All Aquifers</td>
</tr>
<tr>
<td>Chennai Metro Water Supply</td>
<td>Upper &amp; lower confined aquifers</td>
</tr>
<tr>
<td>Pumping by NLC</td>
<td>Upper confined aquifer which is fully utilized in captive power generation</td>
</tr>
</tbody>
</table>

A field study has been made to know the drawal of ground water from different aquifers in this region by different agencies like agriculturalist, industrialist and drinking water supply. Recently 45 pumping wells were sunk by Chennai metro department to carry around 75 million litres per day (mld) of water through 200 km Veeranam pipe lines. It can be summed up that the ground water pumped by NLC is fully utilized for power production and 30 to 35% of the total cost of the lignite mining is attributed to pumping of water from powerful artesian aquifer as wells as storm water collected in pit area.

ROLE OF NEYVELI LIGNITE CORPORATION IN MAINTAINING THE REGIONAL GROUND WATER BALANCE

Even though all the aquifers of the region are being exploited by the various sectors, NLC’s development of the aquifer is restricted to the local mining area only; that too the upper confined aquifer only. It has taken the onerous task of monitoring the ground water activities in a vast area of 3000 km² being a responsible Central Public Sector Company.

SCIENTIFIC MEASURES TAKEN /PROPOSED BY NLC TOWARDS GROUND WATER MANAGEMENT

- Continuous monitoring of the entire region periodically and systematically.
- The pumping in Mines has been optimized to the minimum (keep +ve pressure and wells brought nearer to deep cut).
- Water conservation in Power Station. All future Power Stations are planned to have dry ash disposal system.
- Waste water utilization - Ash water recycling in power station & effluent water treatment etc.,
- Utilization of storm water from Mines after treatment in Township water supply.
- Utilization of storm water from Mines after treatment and use in Industrial Units.
- Enhancement of ground water resources through artificial recharge.
- Updating the scientific know how in the field of hydro geology.

REGIONAL GROUND WATER MONITORING

In NLC a Separate Cell was created in 1988 (Regional Geology Division) for arial extent covered for monitoring of ground water is around 3000 km², which is divided into 16 sectors. Around 105 number of dug wells and 80 number of tube wells (confined aquifer) are periodically monitored for quantity and quality. For water balance studies data collection is being made from 14 rainfall stations and 2 meteorological centers in this region. In addition, ground water data from state ground water departments and central ground water departments are also collected.

From the monitoring efforts and measuring water levels it is observed that over a 14 year period 1990-2004, there is not much of an impact on the shallow aquifer of the basin by the pumping of water from the upper confined aquifer.

Mining as an activity in Neyveli requires the pumping of water from the upper confined aquifer to control the artesian pressure. The safe
and economic mining of Neyveli lignite deposit, it was beset with a danger of mine floor burst due to pressure head condition prevalent in the thick confined aquifers underlying the lignite seam, a problem unparalleled in the history of mining. Hydro-geological studies have established the feasibility of mining lignite by maintaining a constant cone of depression (pressure relief) around that aquifers below the mine cuts with continuous pumping through pre-planned network of wells.

**Studies on Artificial Recharge**
Experiments are being undertaken on artificial recharging through infiltration wells, percolation ponds, check dams etc. to enhance the recharge potential in the recharge area in two villages Maligampattu and Nadiyappattu located North and North-West of Neyveli area.

**Future Plans on Artificial Recharge**
Further NLC plans to undertake detailed study on recharging of confined aquifer through in-
jection wells for which it has invited consultants globally so that state of art knowledge can be acquired in this sector. The purpose of both artificial recharge techniques is to arm with latest technology and implementation of the same if need arises to achieve the larger objective of maintaining a ground water balance in the region.

Reclamation and Afforestation
Mined out area is being reclaimed and afforested from the spoil bank side progressively to give back to the mother earth the rehabilitated land to enable the utilization of the land to its virgin position.

NLC's Greener Pasture
Wide spectrum of industrial activities in Neyveli has led NLC to manage the environment from the stages of lignite mining, its utilization to final disposal of waste by
- land reclamation in Mines spoil with and without top soil
- orchard development
- reclamation of ash pond
- fly ash utilization of disposal
- massive afforestation in Mines and industrial township
- rehabilitation and resettlement
- formation of artificial lakes, ponds and picnic spots

Afforestation in NLC
Ecological balance is being maintained by launching massive afforestation programme not only in and around mines, Power plants but also in Industrial township. So far 17 million trees of various species are planted in 2750 ha.

Slope Stabilization: Species like grass: Brachia, Mutia, Cyanasin, Dactylin and small seed legumes, alfeira, annual lupin, health hen, fodder plants are planted along the slopes of the spoil bank for soil stability.

Close belt trees for dusi and Noise barriers: Trees like Eucaluptus SP, Acacia Qurculformis, silver oak, Casurina, subabul are planted to prevent for dust /noise pollution.

Replenishment of Ground Water Sources in the De-coaled Area
- NLC has initiated numerous measures to reclaim the mines spoil by using the Na, P, K and bio-fertilizers in the area to enrich soil.
- These measures contribute to create many conduits in the de-coaled area thereby leading to replenishment of shallow water tables during monsoon seasons.
- The massive afforestation and vegetation further enhance the replenishment of ground water sources in the mined out areas as well as in the outside mine spoil dumping yard.
- It helps in maintaining the ecological balance.

Conclusion
NLC has developed an effective ground water management system for the region by adopting the latest techniques in this field. NLC has also proposed to take further scientific studies to maintain and cope up with the state of art on the artificial recharge to suit the changes with reference to development of new techniques from time to time. This will help to update/refine the ground water management system.

Acknowledgement:
The author is grateful to NLC management with whose permission the above paper was presented in the seminar organized by Auroville Centre for Scientific Research.
Q/A

How much are your spending for the above regeneration/environment rejuvenation activities?
After tax, our profits are Rs. 1100-1200 crore every year; we are spending annually Rs. 10 crore on these type of activities—we are studying the ecosystem today in a very systematic and scientific manner.
50% of lignite mining is water-12 million tonnes of water is every year released into the atmosphere and improving rain condition.

How much lignite is there? For how many years you can mine?
4500 million tonnes is available in Neyveli region and we are planning mining of 25 million tonnes; if we increase number of mines to produce 100 million tonnes, life-time will be lesser.

What do you charge Chennai water supply for the water they take from Neyveli?
We don’t charge—the aquifer is state government property—they drill the aquifer and they take water and as I understand from newspaper it cost them Rs. 600-700 crore.

Is it possible for you to make a second pipeline and give us this water free?
It can be done but over-pumping will lead to ingress of sea water. We fully use the water we pump in our cooling work and in the power generation-100% utilization. The leakage water (storm water) is being pumped to the villages for irrigation.
Trends in Water Quality in the Kaliveli Watershed

Benjamin Laroquette

Benjamin Laroquette, with an MSc in Environment and Development, 2003 University of East Anglia, U.K., is the Assistant Managing Director and Consultant of FERAL (Foundation for Ecological Research Advocacy and Learning), India which coordinates project implementation and monitoring in agriculture, irrigation, education and sanitation, improving the lives of more than 20,000 people. This includes 94 women self-help groups engaging in both micro-credit and the rehabilitation of 32 irrigation reservoirs improving irrigation to more than 30,000 hectares. He has established an integrated planning, monitoring and evaluation system, which included participatory appraisals and self-assessments and implemented training programs in participatory techniques and Geographical Information Systems for the Indian Council for Agricultural Research. Planned and monitored the pullout of the ‘Kaliveli Watershed Minor Irrigation Tanks Rehabilitation Project’ in Tamil Nadu. He is also involved in the general management of 18 staff, including the organization of action plans and budgets of $40,000 per year.

Foundation for Ecological Research Advocacy and Learning (FERAL)
P.O. Box 28, Pondicherry – 605001, India.
Phone: 413–2678 602
Email: benlar75@yahoo.com

INTRODUCING FERAL
FERAL is the Foundation for Ecological Research Advocacy and Learning. We are a small organisation based in Pondicherry with a field office in Moratandi, a village on the Tindivanam highway behind Aurobrindavan. We are a non-profit non-governmental research organisation involved largely in ecology and resource management. We support National Resource Management (NRM) projects with local communities, train on ecological methods and tools, and advocate NRM and conservation through pilot projects and litigation where necessary.

THE STUDY AREA
This presentation deals with trends in water quality in the region North of the Auroville area in the Kaliveli Basin. This region is a centre of focus for a lot of FERAL’s ongoing work. The Kaliveli watershed comprises of a brackish wetland body of about 70 km². It has a catchment area of around 750 km² and linked to the sea by the Yediyanthittu estuary whereby the water body has a gradient of brackish to fresh water.

The present study is concerned with water quality in the Kaliveli basin. It is based on the analysis of a total of 356 water samples from various kinds of wells. These can be further divided into well water used for drinking (98), irrigation (244) or both (14) spread over 62 revenue villages. The location of the wells was marked using a Global Positioning System (Garmin 12-XL and Megellan ProMark-X).

OBSERVATIONS AND ANALYSIS
Laboratory analysis was carried out for 13 parameters based on standard methods prescribed by APHA which is an American Standard Association. Fluoride testing was carried out for drinking water. The results obtained were analysed based on standards prescribed by the Indian Standards Institute (ISI).

So, for drinking water, out of 13 parameters, 7 violate (exceed permissible limits) the ISI
TABLE 1: Descriptive samples of drinking water samples

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ISI Std</th>
<th>n</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>Std.Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH</td>
<td>6.5-8.5</td>
<td>108</td>
<td>7.41</td>
<td>3.9</td>
<td>8.4</td>
<td>0.546</td>
</tr>
<tr>
<td>Electric Cond. (dSm)</td>
<td>0.5</td>
<td>106</td>
<td>1.18</td>
<td>0.04</td>
<td>6.9</td>
<td>1.185</td>
</tr>
<tr>
<td>Total Dissolved Solids (mg/l)</td>
<td>500</td>
<td>105</td>
<td>770.47</td>
<td>25.6</td>
<td>4416</td>
<td>763.096</td>
</tr>
<tr>
<td>Total Hardness (mg/l)</td>
<td>300</td>
<td>105</td>
<td>379.11</td>
<td>13</td>
<td>3500</td>
<td>440.715</td>
</tr>
<tr>
<td>Calcium (mg/l)</td>
<td>75</td>
<td>105</td>
<td>99.54</td>
<td>2.8</td>
<td>1120</td>
<td>122.257</td>
</tr>
<tr>
<td>Magnesium (mg/l)</td>
<td>30</td>
<td>99</td>
<td>30.54</td>
<td>0</td>
<td>2.45</td>
<td>35.134</td>
</tr>
<tr>
<td>Sulphate (mg/l)</td>
<td>150</td>
<td>108</td>
<td>72.72</td>
<td>0</td>
<td>1250</td>
<td>144.469</td>
</tr>
<tr>
<td>Chloride (mg/l)</td>
<td>260</td>
<td>108</td>
<td>146.56</td>
<td>6</td>
<td>2600</td>
<td>334.485</td>
</tr>
<tr>
<td>Nitrate (mg/l)</td>
<td>45</td>
<td>105</td>
<td>22.098</td>
<td>0</td>
<td>105</td>
<td>23.85</td>
</tr>
<tr>
<td>Phosphate (mg/l)</td>
<td>0.1</td>
<td>105</td>
<td>0.168</td>
<td>0</td>
<td>2.3</td>
<td>0.33</td>
</tr>
<tr>
<td>Fluoride (mg/l)</td>
<td>0.8-1.2</td>
<td>90</td>
<td>0.77</td>
<td>0</td>
<td>3.5</td>
<td>0.52</td>
</tr>
<tr>
<td>Sodium (mg/l)</td>
<td>200</td>
<td>85</td>
<td>104.56</td>
<td>5</td>
<td>775</td>
<td>148.31</td>
</tr>
<tr>
<td>Salinity (mg/l)</td>
<td>300</td>
<td>107</td>
<td>363.81</td>
<td>11</td>
<td>4773.5</td>
<td>616.17</td>
</tr>
</tbody>
</table>

 standards, which is quite high. The same table for irrigation water, shows that irrigation water in terms of violations is far better, with only 3 violations out of 12 parameters.

**RESULTS**

If we look at the number of samples violated for any given parameter with respect to drinking water, electric conductivity (81%) and fluoride (64%) show high percentage violation. Eighty percent of all irrigation water samples had < 5 parameters being violated. The maximum number of parameters violated for any given sample was 10 and was observed in only one sample. In the case of drinking water, only 68% of the samples had 5 or less parameters violated with respect to the prescribed standards. The main parameter violated is electrical conductivity for both irrigation and drinking water, and fluoride for drinking water.

**SPATIAL DISTRIBUTION OF VIOLATIONS**

The spatial distribution of violations shows that the number of violations (darker blue) increases towards the South of Kaliveli. This may be the impact of the lake itself as the region overlaps with a high potential recharge zone. The violations to the North West (Perumukkal region) of the figure can be explained by the high intensity of quarrying that takes place here.

**Fluoride and Salinity Pockets**

Fig. 2 shows pockets of high violation of fluoride and salinity. Additional analysis was undertaken on the incidence of fluoride for drinking water and salinity for irrigation. We found that fluoride pockets are found both to the south of Kaliveli but also in other areas.

Mapping of regions with high salinity was done specifically to test the hypothesis of whether there was any salt water intrusion. However there was no relationship between distance from the coast and incidence of salinity. A regression of distance from coast and salinity levels indicated that the distance from the coast had no bearing on the observed salinity levels (R-sq. = 0.0007, F-ratio 0.2099, alpha = 0.05, DF = 310). The furthest incident of salinity was about 25 km inland. We therefore surmise that the incidence of salinity is a
consequence of mineral deposition in the bedrock. This assumption is strengthened by the high incidence of salinity around Perumkkal.

**Second Round of Sampling**

A second round of sampling was run in order to capture temporal trends in water quality. Samples were collected both before and after monsoons to capture the impact, if any, of recharge of ground water on water quality. The second round of sampling also added the important parameter of Total Coliforms and E. Coli for the drinking water samples.

**Descriptive statistics for T.Coli, E. Coli and Fluoride in relation to well type**

In order to compare the contamination by E. Coli from various water sources, analysis of water from three kinds of wells was taken up. These were bore wells, hand pumps and open wells. Results (Table 3) showed that hand-pumps had the lowest contamination with the exception of a single outlier which could be explained by the puncturing of the concrete collar around the hand-pump.

**Trends in Irrigation Water**

Two irrigation water parameter trends varied significantly over season. These were pH (negatively) and sulphates which increased positively over a three year period.

**Trends according to Well Types**

Open well water is more alkaline; and total hardness is more for open wells; calcium and magnesium salts are higher in open wells, while sulphates, phosphates and sodium salts are more in bore wells.

In the case of drinking water, a regression of well depths against violations indicated no significant relation (R-sq. = 0.0089, F-ratio 1.6680, alpha = 0.05, DF = 186); wells with <14 m depth were omitted from the analysis (3% of the sample). Similar results (R-sq. = 0.0134, F-ratio 1.8718, alpha = 0.05, DF = 139) were obtained for irrigation wells with depths ranging between >12 m and <140 m, which constituted 97% of the samples.

**Conclusion**

The overall quality of drinking water is poorer than that of irrigation water with higher number of violations and fewer parameters within the prescribed standards.

In the case of drinking water, the non-conformity of most of the parameters does not have any particular health hazards except in terms of acceptability and palatability by the consumers. It is the high levels of fluoride that are of particular concern given the hazardous effects they could have on the health of individuals.

In the case of irrigation water the violations are seen mainly in the salinity and salinity related parameters. That is of serious concern because irrigation with saline water results in salinity of soils. Given the large scale variation in water quality, further analysis incorporating geology, pedology and land management practices needs to be taken up. The localised effects of the Kaliveli wetlands themselves also need to be investigated given that the largest pocket of violations is seen at its southern region.
Causal Effects on Water Quality in the Kaliveli Basin

R.S.Bhalla

Foundation for Ecological Research, Advocacy and Learning (FERAL)
P.O.Box 28, Pondicherry - 605 001, India.
Phone: 413-2678 602
Email: bhalla@feralindia.org
http://www.feralindia.org

This presentation tries to cover the present priorities of FERAL in terms of research in the Kaliveli basin and is split into four sections:

- Introduction to the application of GIS in Hydrology and Landscape Ecology. Given that there have already been presentations on GIS this will be skipped through.
- Introducing the Kaliveli Basin.
- Data requirements and constraints in using assessment tools and models for the Kaliveli basin.

Figure 1: Drainage patterns (from IRS data).

Figure 1: Drainage in the Kaliveli Basin.
• A brief look at the research priorities of FERAL in the Kalivelri basin.

APPLICATIONS OF GIS IN HYDROLOGY
Basically there are 2 kinds of tools which we are currently working with, simulation models and landscape assessment tools.
- Landscape assessment tools
These permit the identification of regions which contribute significantly to water quality in terms of nutrient, pesticide and sediment loads. These are used extensively to prioritise areas which need to be treated.

- Hydrological models
Simulation models essentially answer if then situations. For example if you do this to your catchment, this is what is going to happen to the quality of water. There are a range of models which allow prediction of nutrient, pesticide and sediment loads in runoff or contamination of aquifers or lakes. These utilise a range of climatic, topographic, meteorological and soil related information. There is also a family of network models which are based on inflow and outflow parameters.
Figure 4: A dry run of ATiILA.

**BACKGROUND: THE KALIVELI BASIN AND ITS CHARACTERISTICS.**

The Kaliveli basin covers an area of about 780 km². This is sub-divided into 3 sub-watersheds, about 50 mini and over 150 micro watersheds. These delineations are done on the basis of little elevation models. Over 200 minor irrigation tanks flow into the lake. Figure 1 shows the basic drainage in the Kaliveli basin.

**BASELINE DATA**

Both landscape assessment tools and simulation models require substantial inputs of data. Much of the challenge in getting these tools to work is to collect and organise this information. We are currently involved in this process which involves the following main activities:

- Digitising of secondary information, largely maps from the Institute of Remote Sensing, Anna University, Chennai;
  - Vegetation/cropping pattern, land-use and soil maps.
  - Elevation models using available maps and field surveys – this is one of the biggest constraints.
  - Soil and water tests are being carried out right now.

The tools being used are:

- ATiILA\(^1\) [2], which is an avenue script and utilises available information to prioritise areas on the basis of their contribution to nutrient or sediment loads in streams.
- SWAT\(^2\) [3], a collection of hydrological models which can be used to simulate a range of surface water quality parameters.

\(^1\) Analytical tools interface for landscape assessments.
\(^2\) Soil and Water Assessment Tool
The GRASS\textsuperscript{1} landscape ecology programmes [1], a collection of programmes for the quantitative analysis of landscape structure. Using the ATRILA tool (Figure 4), we are moving from what the status is to identify what is causing the problem. The darker areas are impacting more and here we are looking at phosphates and where are they coming from.

**CHALLENGES**

It is virtually impossible at this point to get a very reliable output from any of these models or tools due to unavailability of data and poor resolution of available data. Specific lacunae are:

- We need digital elevation models (DEM) with vertical resolutions to the tune of 2 m to simulate flows in this very flat terrain.
- High local variation in precipitation requires each micro-watershed has multiple data (rainfall and meteorological parameters) loggers – places 2 km away from each other will have very different levels of rainfall.
- A lot of the secondary data available from IRS is too coarse or lacks ground verification – we have to verify the data.
- Environmental stressors need to be calibrated for land use types in our conditions; land use classifications are very often not designed for Indian conditions; maybe they are based on parts of the USA and need to be reclassified.

In this DEM in Figure 5, we have only 2 bands – 20 m and 40 m from all the available data; hence you have to be able to go down to 2 m.

**WHERE WE ARE HEADED**

We are currently compiling a (spatial) database for the region which includes higher resolution imageries, including DEM from the web as

\textsuperscript{1} Geographical Resource Analysis Support System
well as additional bands of data (LANDSAT). We are also digitising all available maps from government sources as well as those available off the web.

We expect that within the next six months we should be able to complete a preliminary identification of major sources of nutrients and sediment.

**Conclusion**

We hope to be able to be in a position to provide base-line planning information for agencies interested in implementing projects in this region. While FERAL does take up implementation of projects, these are mostly on a pilot scale and we don’t see ourselves as a major implementation agency. Having collected substantial data about the status of water quality in the Kaliveli basin, we are now trying to identify causes and locations of problem areas. This will feed in directly to interventions, be they community based projects or policies to scientifically manage our resources.

**References**


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**Q&A**

**Participant’s comment:** The nutrients information is very important because of heavy fertilizer use and the pesticide information is also very important in view of high recharge rates prevailing in this area. I think what you are planning will help understand better what is the anthropogenic causes for the pollution. For the nutrients, we have experience in the Hyderabad lakes where we analysed the total phosphorous and total nitrogen – bimonthly sampling of lake waters and sedimentation rates by flow measurements.

“The period of your study was not precise, what years were the studies done?”

The first round was 1999 – 2000 and the second round was 2001-till now in the pre-, post-, monsoons (October, January).

**Could you tell the effect of prawn farming in this area?**

We haven’t looked into that area, and it is a cause for serious concerns – particularly the northern stretch of Kaliveli where there are huge conversions into salt pans and prawn farms; we haven’t looked into these aspects as yet.

**Do you have any information about the fluctuation of water levels in the reservoir, related to what is happening to the quality of water?**

No, we don’t have this data – and it is not easily available, because in Kaliveli, one area will be fresh water at one
time of the year and saline in another time of the year. Also regions around Kaliveli are contributing substantially to recharge.

Participant's comment: the data kept by your group FERAL and Sophie can make up the water budget of the groundwater flow model and one can infer what is the real contribution of Kaliveli swamp.

How does granite mining affect water quality? Does it cause salinity?
Maybe a cause for salinity. There is a hillock which gets broken down to make cement and crush it and that creates a lot of particles – the tamarind trees are all white covered by this particle dust. That goes into the soil, the rain comes in and seeps in and it might affect the salinity level of the water.

You have shown that fluorides are high in 2 places – how will you account for this, as this is not such an area? We don’t know why the fluorides are high; and in some places very high. Further probing is required.

Participant's comment: Your presentation was very good and the results match with that of ours and validates it more. Part of the area of your study is charckonite area which is a bedrock and this kind of bedrock is really not a deep aquifer, and is a discontinuous aquifer - which means the water is replenished in some measure, but it is not in the porous area but maybe only in the fractures and this may explain why in some areas it is saline and in some other area it is not saline. If it is saline, it most probably is because the water-rock interaction is very long and minerals give salt to the water; and hence there is no relation between salinity and sea coast and therefore it’s not easy to make measurements and interpolations of water levels.
Prevention and Remedies of the Ground Water Contaminations around the Coastal Areas of Pondicherry Region

V.N. Varma

Dr. V. Navaneetha Varma, the present Dy. Director of Agriculture, Pondicherry had joined the departmental service in 1973 when the Green Revolution was in full swing. He had a Bachelor degree in Science while he had joined in service. After that, he had done the post-graduation and the doctoral degree in Geology awarded by the Osmania University, Hyderabad.

He had participated in the Soil Survey work from 1985-88. Prior to that, he was the analyst during the work in the Agricultural Quality Control labs. From 1989-93, he had done thesis work in the National Geophysical Research institute, Hyderabad, India focusing on the Salinity source investigation affecting the multi-layer coastal aquifers in the coastal Cauvery basin. Water cut problems in the Nawagam Oil fields near Ahmedabad and the Isotope hydrological study in the Neyveli basin.

In the teaching line, he was invited to teach Physical Geology, Stratigraphy, Economic Geology, Remote Sensing in Geology and Hydrogeology for BSc Geology Main students in the Government Arts College, Tindivanam from 2000-02. He had also taught Soil Science to BSc Chemistry students in Pondicherry Women Arts College during 1994. Further the same subject on Soil Geology was taught to MSc (Ag) students, Agricultural College, Karaikal in 2001.

He has published 25 scientific papers, of which 4 are in the International reputed journals/seminars. He was awarded the Fellow of Institution of Chemists, Calcutta during 1989.

He was elected the Council member of the Indian Society of Coastal Agricultural Research, Canning Town, West Bengal from 1984-1992. He has given co-guidance to the members and the researchers of the Pondicherry/Annamalai University and the M.S. Swaminathan Research Foundation.

Deputy Director, Agriculture (Micronutrients)
Department of Agriculture, Thetanchavadi Agri Campus,
Pondicherry – 605 009, India.
Phone: 413-2241942
www.pondicherryagri.org

For the overall development of a country and for the basic amenities, fresh water plays a vital role. The groundwater use is estimated about 180 km$^3$ and by 2025 A.D, it crosses over 350 km$^3$. At one stage, the groundwater is considered to be safer than the surface water from the contaminants but the recent studies conducted have shown that the assumption is not correct (Handa, 1994). Fresh water scarcity is found in all the climatic regions. The lack of water is caused by the low water storage capacity, low infiltration, larger annual fluctuations of precipitation and high evaporation demand. Groundwater salinity, alkalinity and water-logging problems occur in the coastal areas affecting the soil health and spoilage of fresh water, as referred in the Table-1. The heavy discharge of industrial effluents also cause serious concerns over the soil and the water conditions. Water conservation and water management is essential to avert such problems.

Augmentation of the water resources is the prime necessity at this stage to meet the water requirements. In South Eastern coastal India, the groundwater potential is at variance levels. While focusing on the groundwater recharge condition, the dynamic and the static recharge zones are delineated with respect to geology, soil types, physiography, etc. In the dynamic groundwater recharge zone, the fresh water is
annually replenishing the groundwater storage whereas in the static recharge zone, the relic water stored is used. The geology and the coastal South Indian groundwater recharge dynamic zone classes are presented in Fig: 1 and Fig: 2.

I. Soil and Water Contaminants Problems to the Sustainable Water and Soil Resources in and around the Pondicherry Region.

The coastal area of Pondicherry lies in the active dynamic groundwater recharge zone, but the adjoining western parts of the Villupuram and the Cuddalore districts have the groundwater potential status to be semi critical. In the coastal region and around Pondicherry, groundwater salinity, acidity and alkalinity, soil salinity and alkalinity are observed. The surface sea water intrusions and the past sea water intrusions occur in the south eastern coastal belt including the Pondicherry and Karaikal regions. The old marine water salinity called the palaeosalinity is found to be scattered throughout this coastal line as shown in Figure 3 and is also adversely affecting the groundwater quality to a larger extent. This palaeosaline marine bed layer occurred in the Eocene and Pliocene formations is identified around Tavalakuppam (Pondicherry), Parangipetattai (Chidambaram) and throughout the tail end of Cauvery basin. Yet, this type of survey in the southern coastal end was not conducted for this identification. Our study area lies in between 11°30' to 12°10' latitudes to 79° to 80° longitudes.

The saline groundwater in Pondicherry and Tindivanam is of SO₄-Cl salt type, the well water around Panruti is of Na-HCO₃-Cl type. The tertiary lateritic formation groundwater around Auroville, near the coastal Pondicherry and in Neyveli mine show acidic due to excess free CO₂ formation as illustrated in Fig: 4. The identification of salinity source is to be exploited prior to modeling. The saline groundwater samples affected by the coastal sea water intrusions laterally or by upconing of the palaeosaline water vertically are determined for the organic analyses of the acid fractions. Specific organic biomarkers present in the groundwater samples represent the concerned solute saline sources. For example, the modern marine saline water namely, the sea water, estuaries, lagoons etc., have possessed the presence of Hopanoic (stearic) and Vaccum (mono unsaturated carboxylic) acids. The palaeomarine saline water has the characteristic biomarkers like Oleic and Palmitoleic acids. For identifying and calculating the concentrations of these discriminating biomarkers, the organic acid fractions of groundwater samples are passed through the Infra Red Spectrometer and the Mass Spectrometer analyses and outcome of the results will be the specific representative analytes of the particular geostatigraphic formation adversely affecting the groundwater, well indicated in the diagrams as in Fig: 5 and Fig: 6. HOP represents the hopanoic acid, VAC is for Vaccum acid, PAL is for the Palmitoleic acid and OL is for the Oleic acid. The representative organic biomarkers of modern marine layers, the palaeomarine formation and the coalfield formations are tabulated in Table-2. The conventional inorganic ionic ratio methods like Mg/Ca and CI/HCO₃ may sometimes lead to ambiguous results. The stable isotope and radioisotope tests may be encouraging for the confirming to the organic results outputs (Sukhija et al., 1996).

The alkalinity development in the groundwater is widely due to partial pressure of CO₂ modifications due to the temperature and the ionic potential activation The dilute water has pCO₂ = 5 x 10⁻² atm. Carbonate dissolution, sulfate reduction, cationic-clay modifications due to ions adsorption mechanism and drought develop alkalinity. All the tertiary aquifers exhibit the alkalinity in the western areas of Pondicherry around Panruti.
The sulfide gas emission from the tertiary groundwater in Tamilandu areas close by the North West fag end of Pondicherry region (namely, Vazudavur and Sorapet west) had contaminated the soil. Rice and sugarcane crops had collapsed at the earlier stage of planting. The sulfide ion concentrations detected by the iodimetric test method are in 0.2-1.5 ppm range. The high level of the gas posed purgative problems to human health. This kind of problem occurs in some selected areas, subsiding and regenerating.

A decade back, industrial pollution was writ largely in and around Pondicherry region. Inorganic and organic pollutants discharged from industries impoverished the water and soil resources. The acid effluents in Mettupalayam and the organic toxicants in Cuddalore South were the key problems concerned. Some of toxicants, namely, Nicotine, Urea, Malathion, Chlorpyrifos, Oxon, AMPA detected were found to be slightly higher than the tolerance limit. The organic compounds were detected by using the Ultra Violet-Visible Spectrophotometer and the High Performance Liquid Chromatograph. The toxic analytes concentrations are shown in Table-3. Further, the presence of halogenated and sulfated hydrocarbons toxicants are likely.

II. PREVENTION AND REMEDIATION TECHNIQUES

Water congestion is the main cause for building up the soil salinity. The sea water intrusion laterally and the ancient marine water contact with groundwater by upcoming process deteriorate the fresh water quality. As preventive measures, the water quality is periodically monitored by the chemical tests, the water table and piezometric level measurements and the water balance concept. The skimming technique is adopted for tapping the good groundwater underlying the salt water carefully without disturbing the latter provided, it has the vertical drainage system. The soil is protected by providing artificial drainage to remove excess water stagnating in the field to minimize the salinity. The Government of Pondicherry had launched to provide for free land drainage structures where the possibility of soil salinity occur.

Further, the water conservation structures and the recycling of waste water in the recent years have attracted the attention. The groundwater availability and category in the Tamilum and Pondicherry coastal areas is shown in Table-4 (Veerapan, PWD report, Tamilnadu). Except the Cuddalore and the Villupuram Districts, the other districts have surplus storage. Water harvesting in a broad sense is defined as the collection of run-off water for human use and for minor irrigation. As suggested by Mohan, 2003, the suitability of various types of artificial recharge structures in this area for a number of applications are as mentioned in Table-5. Periodical maintenance of artificial structures is important to avoid the reduction of the infiltration capacity as a result of silting, chemical precipitation and the accumulation of the organic matter. This recharge scheme developmental activities depend upon the community cooperation as the public participation.

Recycling of waste water is a value added technology adopted around Pondicherry, namely, in Neyveli, Pondicherry, Auroville, etc. The recycled water contain the nutrients for horticultural and also for washing purposes. The industrial pollutants are allowed to infiltrate below the ground so that they will pass away from the groundwater cone of depression. Some chemicals additives may immobilize the pollutants transport. The pollutant transport (Kashyap et al., 1994) can be done by modeling techniques. For the sulfide toxicity in groundwater and for the soil degradation, selected withstandable crops like banana, pulses, etc., are recommended. The sulfate chemicals, organic matter, etc., are avoided.
To sum up, the soil and water resources are often encountered with modified changes in the environment. To cope up for the sustainability of these natural resources from the environmental degradation, steps are further needed to conserve and manage them with suitable scientific and socio economic approaches.

III. REFERENCES

1. P. Handa, 1994; Special Guest lecture on the scenario of Groundwater Development in India, Alumini Association of Anna University, Chennai.


Fig: 1
Geology of the South East Indian Coast

Fig: 2
Dynamic GW recharge of this coastal belt

I - SCATTERED
II - UNFAVOURABLE
III - GOOD
IV - FAIRLY GOOD

Scale: 1 cm = 71 km

Fig: 3
Coastal Palaeosaline groundwater Occurrence- First Phase of Identification

Fig: 4
Water Quality Protracting Pondicherry Region

Scale: 1 cm = 20 km
**Fig: 5**

**MODERN MARINE FEATURE**

*MASS SPECTROMETRIC FRAGMENTATIONS*

Mass spectrum of Arasalaru estuarine sediment.

**HOP - Hopanoeic Acid : VAC - Vaccenic Acid**

Mass spectrum of Melkottucherry (deeper alluvium) groundwater sample to investigate vaccenic acid (pretreated with methanol–bromine).

Mass spectrum of Pondicherry groundwater (deeper alluvium) sample to investigate vaccenic acid (pretreated with methanol–bromine).
Fig: 5 (a)

PALAEOMARINE FEATURES
BY MASS SPECTRA

Mass spectrum of Pliocene sediment (from Vedaramyam).

OL - Oleic Acid; PAL - Palmitoleic Acid

Fig: 6

INFRA RED SPECTRA

IR spectrum of (a) marine bed sediments of Vedaramyam host formation and (b) Arasalu estuarine sediment, Kurnool.
## Annexures

### ANNEXURE: A

#### Waterlogged areas (ICAR report)

<table>
<thead>
<tr>
<th>No.</th>
<th>State</th>
<th>Estimate by M/O Agriculture for Waterlogged Areas (lakh ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>West Bengal</td>
<td>21.80</td>
</tr>
<tr>
<td>2</td>
<td>Uttar Pradesh</td>
<td>19.80</td>
</tr>
<tr>
<td>3</td>
<td>Punjab</td>
<td>10.90</td>
</tr>
<tr>
<td>4</td>
<td>Tamilnadu</td>
<td>9.60</td>
</tr>
<tr>
<td>5</td>
<td>Bihar</td>
<td>7.07</td>
</tr>
<tr>
<td>6</td>
<td>Andhra Pradesh</td>
<td>3.39</td>
</tr>
</tbody>
</table>

### ANNEXURE: B

#### Extent of coastal salinity (ICAR report)

<table>
<thead>
<tr>
<th>No.</th>
<th>State</th>
<th>Area (Thousand ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>West Bengal</td>
<td>820</td>
</tr>
<tr>
<td>2</td>
<td>Gujarat</td>
<td>714</td>
</tr>
<tr>
<td>3</td>
<td>Swamp Saline Forests</td>
<td>546</td>
</tr>
<tr>
<td>4</td>
<td>Orissa</td>
<td>400</td>
</tr>
<tr>
<td>5</td>
<td>Tamilnadu</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>Karnataka, Maharashtra &amp; Goa</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>Kerala</td>
<td>46</td>
</tr>
<tr>
<td>8</td>
<td>Andaman &amp; Nicobar</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>Pondicherry</td>
<td>1</td>
</tr>
</tbody>
</table>

### Groundwater Availability and Category

<table>
<thead>
<tr>
<th>No.</th>
<th>District</th>
<th>AnnGW recharge (MCM)</th>
<th>Net GW Rech. MCM</th>
<th>Gross GW draft (MCM)</th>
<th>Balance avl. (MCM)</th>
<th>category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kanchipuram</td>
<td>1401</td>
<td>1261</td>
<td>675</td>
<td>551</td>
<td>Safe</td>
</tr>
<tr>
<td>2</td>
<td>Cuddalore</td>
<td>1829</td>
<td>1488</td>
<td>885</td>
<td>433</td>
<td>Fair</td>
</tr>
<tr>
<td>3</td>
<td>Villupuram</td>
<td>2240</td>
<td>2015</td>
<td>1797</td>
<td>182</td>
<td>Critical</td>
</tr>
<tr>
<td>4</td>
<td>Pudukottai</td>
<td>1123</td>
<td>1010</td>
<td>180</td>
<td>806</td>
<td>Safe</td>
</tr>
<tr>
<td>5</td>
<td>Sivagangai</td>
<td>811</td>
<td>730</td>
<td>104</td>
<td>808</td>
<td>Safe</td>
</tr>
<tr>
<td>6</td>
<td>Ramnathapuram</td>
<td>309</td>
<td>217</td>
<td>35</td>
<td>222</td>
<td>Safe</td>
</tr>
<tr>
<td>7</td>
<td>Tuticorin</td>
<td>311</td>
<td>260</td>
<td>159</td>
<td>101</td>
<td>Safe</td>
</tr>
<tr>
<td>8</td>
<td>Kanyakumari</td>
<td>378</td>
<td>339</td>
<td>172</td>
<td>233</td>
<td>Safe</td>
</tr>
</tbody>
</table>
Table 1: Groundwater Contamination

<table>
<thead>
<tr>
<th>Factors</th>
<th>Climate</th>
<th>Natural phenomena</th>
<th>Man made</th>
<th>Anthropogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movements</td>
<td>Topography</td>
<td>Phase changes</td>
<td>Formations</td>
<td>Mixings</td>
</tr>
<tr>
<td>Type</td>
<td>Salinity</td>
<td>Alkalinity</td>
<td>Acidity</td>
<td>Organica</td>
</tr>
<tr>
<td>Coastal soil Problems</td>
<td>Water Logging</td>
<td>Soil Alkalinity</td>
<td>Soil Salinity</td>
<td>Soil Acidity</td>
</tr>
<tr>
<td>GW/Salinity-Coastal</td>
<td>Sea water intrusion</td>
<td>Palaeo marine</td>
<td>uprising Acid Sulphate</td>
<td>Pollutant toxicity</td>
</tr>
</tbody>
</table>

Table 2: Marine Bio markers to identify GW contamination

<table>
<thead>
<tr>
<th>No</th>
<th>Sediments</th>
<th>Associated Biomarkers</th>
<th>Organic compound Groups</th>
<th>Identified by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Modern marine</td>
<td>Hapnoneic &amp; Vaccenic acids</td>
<td>Stearic &amp; Monounsaturated acid</td>
<td>Mass Spectrometer</td>
</tr>
<tr>
<td>2</td>
<td>Palaeo marine salinity</td>
<td>Pamibleic &amp; Oleic acids</td>
<td>Monounsaturated fatty acids</td>
<td>Mass Spectrometer</td>
</tr>
<tr>
<td>3</td>
<td>Coalfield sediments</td>
<td>Cresols, Benzo fluorane, Fluorene</td>
<td>Aromatic Hydro Carbons</td>
<td>Chromatographs</td>
</tr>
</tbody>
</table>

Table 3: Organic toxicants in Cuddalore Industrial Belt

<table>
<thead>
<tr>
<th>No</th>
<th>Compounds</th>
<th>Detected by</th>
<th>Maximum Limit</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nicotine</td>
<td>Visible Spectrophotometer</td>
<td>10-15 mg</td>
<td>unsafe</td>
</tr>
<tr>
<td>2</td>
<td>Urea(Diuron)</td>
<td>Liquid Chromatograph</td>
<td>0.22 ppm</td>
<td>Safe</td>
</tr>
<tr>
<td>3</td>
<td>Oxon</td>
<td>Visible Spectrophotometer</td>
<td>0.11 ppm</td>
<td>Safe</td>
</tr>
<tr>
<td>4</td>
<td>Chlorpyrifos</td>
<td>Liquid Chromatograph</td>
<td>0.52 ppm</td>
<td>unsafe</td>
</tr>
<tr>
<td>5</td>
<td>AMPA</td>
<td>Liquid Chromatograph</td>
<td>0.45 ppm</td>
<td>unsafe</td>
</tr>
<tr>
<td>6</td>
<td>Carbaryl</td>
<td>Liquid Chromatograph</td>
<td>0.22 ppm</td>
<td>Safe</td>
</tr>
<tr>
<td>7</td>
<td>MBC</td>
<td>Visible Spectrophotometer</td>
<td>0.13 ppm</td>
<td>Unsafe</td>
</tr>
</tbody>
</table>

Table 4: Suitable structure for Artificial Recharge

<table>
<thead>
<tr>
<th>No</th>
<th>Lithology</th>
<th>Topography</th>
<th>Type of Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alluvial formation</td>
<td>Plain or gently undulating area</td>
<td>Spreading and percolation tanks, check dams, dike etc...</td>
</tr>
<tr>
<td>2</td>
<td>Hard Rock</td>
<td>Plateau region</td>
<td>Recharge ponds</td>
</tr>
<tr>
<td>3</td>
<td>Alluv. aquifer to 40 m</td>
<td>Plain or flood plain deposits</td>
<td>Injection well or connection well</td>
</tr>
<tr>
<td>4</td>
<td>Hard rock/Alluvial</td>
<td>Forested area</td>
<td>Subsurface dikes</td>
</tr>
</tbody>
</table>
Thirty years ago, after completing his professional Graduate course in the present Anna University, Anandane took up work as a Junior Engineer in Public works department planning, designing and managing water supply and allied fields. Directed by his inner urge to bring about a revolutionary change in the water usage pattern in Pondicherry he actively involved himself in the Kaliveli Project. Presently he is the Superintending Engineer, PWD giving special importance to Conservation, development and management of water resources, which is the key to food & livelihood security, ensuring healthy environment and social stability. Owing to his efficiency in prioritizing need based activities, grasping the ground realities, exploring the existing resources and tapping them to their maximum potential he has been appointed as the Project Director of the Tank Rehabilitation Project Pondicherry assisted by the European commission. His quick analysis, perseverance and innovativeness have assisted the tank rehabilitation project to be one of the model projects on water conservation paving way for much larger replication.

INTRODUCTION

Tank fed agriculture has been in practice in Pondicherry since some centuries. Historically irrigation tanks were established about 1000 years ago and there were well-established systems for maintenance of these irrigation tanks by the communities themselves called the “Kudimaramathu”. But over the years the community’s collective involvement and responsibility waned. The reasons for this were: the non-dependence of tank water for the increased water demand (larger than the supply from the tanks) consequent to the green revolution, taking away the role of the community in maintenance of tanks subsidies for alternate water withdrawal technologies, neglect of tank maintenance by the government and associated encroachment on tank water spread area and feeder channels.

All the above led to an increased dependence on deep bore wells. This consequent over-exploitation of groundwater resulted in groundwater depletion and saltwater intrusion into the aquifers. The use of saline water for irrigation resulted in diminishing crop yields.

Looking into the history of the tanks show that most of the tanks in Tamilnadu and Pondicherry were constructed by the Pallava Kings.
during 500-900 A.D. Bahour Lake, the second largest tank in Pondicherry was in existence before the Chola Period. Usteri, the largest lake in Pondicherry was built by the Vijayanagar rulers around 1110 A.D. The French have connected these tanks with feeder canals and constructed offtake structures in rivers.

**Need for the Project**

With new scientific inventions, modernization, and change in attitude of the people, farmers started to shift from ground water irrigation to surface water irrigation. Increase in population increased the demand for food production and the need for more water supply. Failure of proper maintenance of tanks assisted the trend of tank irrigation shifting to well irrigation, then sub surface irrigation through oil engines and now through deep borewell using submersible engines. The major reason for the downfall of surface water irrigation are

- Main reason is the bore wells:
  - Attitudinal change among farmers – they want to go for cash crops like sugar cane; plus they want to do 3 full crops every year of paddy – earlier it was one paddy crop, maybe another one of shorter variety.
  - Government subsidy on electricity which means a 24 hour pumping takes place.
  - Inconsistent policies/ rules & regulations, when the tanks were handed over the commune panchayats who couldn’t handle it
  - Less community participation – over-reliance on the government for everything – they didn’t know how to manage water, how to receive it, store it – they were just cultivating, thinking water is an eternal material available forever.
- Green revolution through ground water exploitation
- Lack of management and maintenance of tank
- Inadequate local institutions – because no awareness creation was attempted at
- Communal conflicts

Statistics show that 70% of the water consumed in Pondicherry is used for agriculture. Thus shifting to ground water utilization for irrigation had a great impact on the ground water level.

**Tank Rehabilitation Project Pondicherry (TRPP)**

Recognizing the importance and potential of the 86 valuable tank irrigation systems both for irrigation and for recharging groundwater, the government of Pondicherry and European Union took up a project to rehabilitate the tanks in Pondicherry. The essential component of this project was to organize the communities for ensuring the sustainability of these structures. By organizing the communities and empowering them to take up rehabilitation of the tanks, their participation and commitment could be
ensured. Since community control had been in practice for hundreds of years, reviving this time-tested approach was considered possible and desirable.

Further the problems of over-exploitation of groundwater coupled with neglect of tanks is not unique to Pondicherry. In most Deccan plateau regions a similar situations exists. This project thus becomes a pilot programme for a much larger replication.

**INTEGRATED ADMINISTRATIVE SET-UP**
The Tank Rehabilitation Project was commenced from 1999 and is being undertaken by the Public Works Department, Pondicherry with the assistance of Agriculture department. In order to ensure cooperation among the various departments and coordinate the project a Steering committee was formed with officials from the Public Work Department, Agriculture department, Revenue Department & Local Area Development Department. The Development Commissioner of the Government of Pondicherry is the chair-person of the committee.

**SHARING OF PROJECT COST**
Total project cost is Rs. 38.59 crore. Participatory approach has been adopted by sharing the project cost. Rs. 31.26 crore which is 81% of the project cost is shared by the European union, Rs. 4.89 crore which is 13% of the Project cost is given by the Government of Pondicherry and Rs. 2.44 crore which is 6% of the project cost is extended by the beneficiaries. By the way of collecting work cost from the shareholders, the ownership of people on the tank resources is ensured and a sense of responsibility is created. People are not forced to give money; instead they are made to willing come forward to commit for the social cause.

**APPROACHES ADOPTED**
It is essential that the community has to be seen as active partner of the project (in contrast to being merely beneficiaries of participants). This requires creation of a local institutional structure where the heterogeneous community with different stakeholders having different, at times having conflicting perspective, will learn to act together.

1. **NGOs as an active partner**
To empower the local community with the knowledge and confidence to participate effectively in the programme in all stages called for participation of NGOs as an active partners. As the work required mobilization and organization of the community 4 reputed NGOs have been involved at present in the project. Community organizers are deputed through the NGO to work with the people to achieve sustainable water management in the villages.

2. **Awareness creation to involve people**
The village people and the leaders were explained about the need and importance of water conservation.

**TRPP - its objective and benefits.**
- Pamphlets were distributed
- Street plays were staged
- Village meetings were conducted
- Ayacut farmers meeting were held
- Village leaders meeting were mobilized
- Exposure visit to rehabilitated tanks

This paved way for establishing rapport with the people, to find their willingness as well as to identify the interest groups, individuals and key persons to mobilize the tank rehabilitation work and community organisation in the villages.
3. Evaluation of existing condition
PRA is an approach, which combines a number of participation enhancing methods in order to initiate and support a process of self analysis, planning and implementation. The techniques are helpful for capturing and analyzing information of relevance to action in a participatory process. It is a relatively short exercise consisting of a few meetings that help to understand the village system, its social dynamics, and politics by using various techniques. They often produced interesting and varied information of the village when conducted with various stakeholder groups. The process of understanding the social and physical structure was successful with the total involvement of the village people concerned. Some of the PRA Tools adopted were:
- Village profile map: resources and social mapping
- Seasonality of agricultural crops, labour availability
- Timeline/trend analysis
- Tank profile
- Matrix ranking
- Venn diagram
Beside door to door house-hold survey has also been conducted in most of the target villages except a few 4th batch tanks.

4. Building of Local Institutional Structure
   - Tank association
     - General body
A man and a woman from each household are combined to form the general body of the tank association. Unlike other tank rehabilitation projects in Tamil Nadu and Andhra, the weaker sections and stake holders have been given representation. (The project has taken into consideration not only the land holders but also the other dependents of the tank like collection of twigs for firewood, grazing of cattle, etc.). It is not merely resuscitation of the old village collective but a sense of collective ownership on newly negotiated term. The membership fees is decided as per the convenience of the people, mostly Rs. 5/- per member.
- Executive Committee
  The General Body elects its office bears who form the Executive Committee. The Executive Committee comprises of the President, Vice-president, Secretary, Joint Secretary, Treasurer and Honorary President. The Executive Committee will look into the day to day affair of the committee and shall act on behalf of the committee.
- Registration of committee
  Formation and registration of tank association (TA) is an important milestone in the process of sustainable water management through people’s participation. The tank associations are registered under the societies act. So far 83 tank associations have been registered.

5. Strengthening of Local Institutional Structure
In order to strengthen the institutions organized the following activities have been undertaken:
- Training and exposure visits
Numerous trainings are extended to staff, officials, community workers and Tank Association members
  1. Operation and maintenance
  2. Capacity building of TAs
  3. Hydrological training
  4. Leadership training
  5. Computer training
  6. Training on water management
     The members are taken for many exposure visits to increase their awareness level
- Agriculture Extension Programmes

Field Schools: The main objectives of the field schools are to train the farmers and other stake holders to grow profitable, healthy crops and increase productivity using water in an opti-
mum way, and to create awareness among the farmers on judicious use of water use in Pondicherry, using tank and bore well water in conjunction. The field schools are held twice a year with focus on the crop water management in paddy cultivation in Samba and Navarai. About 11 field schools are conducted during each batch in the tank areas. Each field school is conducted by two or three Agricultural Officers for a period of 12 weeks.

Demonstration plots: Around 35 to 40 one-acre demonstrations are laid in the field school areas, for the benefit of the farming community.

- Income Generating activities
  a) Animal Husbandry: assistance is given through the project for goats, calves and rabbit rearing
  b) Self-help groups: power tillers, tractors and harvesters at 50% subsidy for income generation
  c) Mini-Enterprise: tank shop, soap making food processing
  d) Alternate cropping system: flower cultivation, vegetable cultivation, fodder cultivation, medicinal plants cultivation and horticulture
  e) Other: fish cultivation, vermi-compost production
  f) On-farm activities: Promoting a rice intensification system called the SRI method or System of Rice Intensification Methodology with
     - Less water consumption (40% water saving)
     - Less seeds (3 kg per acre)
     - More yield (25 – 40%)
     - Drudgery reduction (women friendly- cono weeder)
     - Promoted in 10 villages (150 acres)
     - Expected in 2004 samba – 250 to 350 acres

Motivation towards alternate crops like marigold
- Less investment (Rs. 6,000/- per acre)
- Less water consumption (550 to 600 mm)
- More employment generation for the women
- Average yield per acre (8 tonnes)
- High profit (Rs. 20,000/- per acre)
- Tree Plantation and Usufruct

Planting of saplings in the bunds of the tanks has been undertaken in order to strengthen the bunds, act as an income generation activity for the tank association and to protect infrastructure. Usufruct right have been transferred to the TA of pilot, first and second batch tank associations.

- Gender Sensitization
  - Awareness formation on gender
  - Formation and training for gender committee
  - Preparation of gender equity promotion materials
  - Training of local resource person
  - Cluster and Federation formation

In order to sustain TAs they are being further organized into hydrological units (12 clusters of TA) and a federation as an apex body. Formation of these bodies is expected to be completed in the near future.

Technical Impacts

The physical works undertaken by the project has increased the dead storage – 3.5 million m³. The activities undertaken are
1. Tanks have been desilted
2. Sluices constructed/renovated
3. Feeder channels and irrigation channels restored

and all these work were undertaken by the tank association themselves.
IMPACT OF PEOPLE PARTICIPATION
IN WATER MANAGEMENT

1) Actual need of the people has been
realized and fulfilled
2) People have realized the importance of
water management
3) A sense of ownership has been created
4) Managerial capacity has been
developed
5) Efficient work implementation - a
better link between the government
and the public, has reduces chances
for bribe and other illegal activities,
 improv ing the quality of work
6) More productivity - tank water is more
fertile than ground water and the
productivity in the field is found to
increase by a minimum of 10%
7) Sharing of available water - due
to participatory approach water
distribution schedule is prepared

which facilitated equal distribution of
water till the tail end.
8) Improvement in the quality of
water - as the tanks are maintained
by the people, it is found that over
exploitation of ground water has been
reduced and lowering of ground water
table has been prevented. Owing to
good rainfall the ground water table
has also increased. Various places,
especially near Bahour tank show a
notable change in the quality of water.
9) Women Empowerment – initially
though it was difficult to attract
their attention the project has been
successful to such a extent that women
have been appointed treasurers for
some of the 4th batch tank associations
10) Increase in dead storage to around 3.5
million m³ will help in reducing over
exploitation of ground water
CHALLENGES AHEAD

We have a few challenges to meet because a few of our villages still:

- expect the government to resolve their problems
- mistrust leaders and hence conflicts within the villages
- lack transparency
- collection of genuine community contributions is not possible
- have a lot of political interference
- have difficulty in removing encroachments
- have difficulty in involving women.

CONCLUSION

Need for water conservation and optimum usage and neglect of tanks are not unique problems faced by the union territory Pondicherry alone. It is a global problem. This project thus becomes a pilot programme for a much larger replication.

Among the important appointments he held were Chairman of the Board and Managing Director, and earlier Technical Director of Bharat Dynamics Ltd, Hyderabad; and earlier on, as an officer-on-special-duty, he was a Technical Adviser to the Scientific Adviser to the Defence Minister. He was twice recipient (1976 & 1987) of Awards from the President of India for distinguished services of exceptional order to the Nation for research and development. He was recipient of the Indira Gandhi and Rajiv Gandhi Awards (in 1990 and 1992) for excellence in Industrial Management. He received the National Unity Award (1993), and Award (in 1995) from the Astronautical Society of India for Space Systems Management. He was Chairman of India's first Working Group on fully reusable aerospace vehicles. His contributions to the evolution of aerobic space plane designs "Hyperplane" and "Avatar", and their applications for Space Solar Power Stations have been published in national and international scientific literature.

He is well known in India as an expert in strategic planning, systems analysis and engineering design of complex interdisciplinary technologies, management of technology and organization development; he has presented and published many technical papers in national and international seminars in these areas.

53 Vayupuri
Secunderabad - 500 094, India.
Phone: 9392465486 (cell)
Email: gopalavatar@123india.com

Dr. M. Kumaravel joined Central Electronics Centre (CEC), of IIT Madras in the year 1971, after a brief service of three years in National Aerospace Laboratory, Bangalore. After holding several technical/scientific positions in CEC, he is now heading this Centre. He took his Ph.D from IIT Madras in 1995. He has 32 years of experience in the area of Industrial Electronics and Instrumentation including 15 years in the area of Solar Photo Voltaics.

He has been running regular one year / two year CEC Training Programs from 1971 till date. In addition, he conducted many short term courses in Industrial Electronics and Instrumentation and conducted 12 weeks training programs for AMET (Academy of Maritime Education and Training). As Chief Project Coordinator, he conducted training programs in the area of Solar Photo Voltaics in collaboration with IREDA/ Siemens/World Bank and trained 855 candidates from all over the country. This is considered as the first major training program project at International level. Also, he conducted training programs at University of Malaysia.

His publications are in the area of Industrial Electronics and Instrumentation, Bio Medical Instrumentation and Solar Photo Voltaics. He has authored and co-authored several articles, technical papers and reports at national and international levels.

He served as member of different expert/ advisory committees and as resource person at National/ International level in the area of Solar Photo Voltaics. He is member of PV Task Analysis Committee, formed by Solar Energy Society of India for drawing guidelines for PV Accreditation and for drafting the Standards.
for PV Balance of Systems to suit Indian conditions. He is member of the International Committee of ISP (Institute of Sustainable Power), USA for PV accreditation activities, and also member of the World Renewable Energy Council.

Head, Central Electronics Centre
IIT – Madras
Chennai – 600 036, TN, India.
Phone: 44-22578426; Fax: 44-22570509 / 545
Email : mkum@iitm.ac.in

The aim of today’s presentation, we are advocating this renewable energy-based desalination as one the sustainable approaches to water management in Auroville and its bioregion.

We have so far advocated pluralistic approaches – people’s involvement, participation – it’s very very important; but now we will shift our focus to a more centralized industrial approach. It was Walter who brought to our team’s notice that as far back as 1965, the Mother had said that, there will likely be a water shortage and She envisioned that we will get a perennial supply of water from the ocean.

The integrating factor between the agricultural approach (people based) and the industrial approach (technology based) is the use the renewable energy.

WATER: AN IMPENDING GLOBAL CRISIS
We know that 70% of the earth’s surface is water, but only 1% of it is available as fresh drinking water.

In 2003, world population is 6 billion and 1 in 6 people are without access to safe drinking water; 1 in 3 without access to sanitation. 20,000 children dying every day due to drinking of polluted water - this is like facing a war everyday. This situation will not be improving and in 2025, world population is expected to be 8 billion; more than 5 in 8 people will live under moderate to high water scarcity; more than 2 in 8 will live in extreme water scarcity.

Water is a universal problem and we are happy that Auroville and the bio-region is taking a lead where an agrarian society (people-based) is looking at an industrial approach.

The drying of India is a fact and is felt by:
- Falling water tables all over the country; by 3 m per year in Gujarat
- Water supply to cities in Tamil Nadu & Andhra Pradesh is critical; about 70 l per day per person
- To provide 140 l per day in urban India requires Rs. 34,000 crore
- Today 65,000 villages have no safe water within 1.6 km, and ultimately it is all the women who have to walk all the way to fetch water (9 km was what our speaker from Rajasthan has said!)
- 80% of all India’s water spent on irrigation
- In Punjab, water from borewells is around 4000 years old
- Industries and coastal settlements dependent for survival on agricultural and ground water supply are highly vulnerable – the world’s coastal regions in another 20 years will have 70% of the world’s 6 billion, living in them
- Irrigation tanks heavily silted up; and hence original storage capacity lost
- Lands deforested, vanished biodiversity, heavy soil erosion, leading to poor ground water recharge from rain
• Ground water increasingly polluted chemically & microbiologically due to uncontrolled dumping of solid wastes.

There are only 4 ways to address the above issue:

Economize: Reduce the demand and save water; the agriculture sector is consuming 5 times more than what is to be consumed; water literacy is required and education is part of it.

Recycle is a domestic or local solution and not available on large scale.

Redistribute available water supplies
- Networking of Rivers
- Rain water harvesting

Create new sources
- Sea water desalination
- Polar Ice caps

India consumes 100 GW of power. 5% of this is from renewable energies and 95% is from oil, coal, gas. According to world energy council and GOI’s figures, 220 GW is required in 2012 – even if all the 100% renewable energy is harvested (biomass, wind, micro-hydrel, ocean), we will get 100 GW only; so what should we do the remaining 120 GW? Oil reserves are going to be 0 by 2010 – we will have to depend on outside (West Asia, Pakistan and others) for oil and natural gas; coal might last for another 100 years but this is non-renewable and we are continuing to make the same problems as others (depleting).

Now if we look at terrestrial solar power, if 1% of India’s land area is harvested in the day-time, almost 1840 GW of power is available. Then why isn’t this happening? Nuclear power is predicted to give some 20 GW, gas reserves are also depleting. Solar energy might be the only option for India; but do we have to wait till we are forced to see this? 200 GW power from coal will need 1100 million tonnes of coal. Now we have a production of 300 million tonnes; within the next 8 years could we triple our coal production? We need a large foreign direct investment of $25-30 billion which is not going to happen.

Energy technology options available for desalination are:

- Thermal Power
- Nuclear Power
- Renewable Energies
  - Terrestrial solar power
    1. solar photovoltaic
    2. solar thermal (HT/LT)
  - Bio-mass (solid)
  - Wind energy
  - Space Solar Power

But today’s presentation we will talk only about solar photovoltaic under Terrestrial Solar power under renewable energies.

Desalination: Global perspective

- World over in 1998 there were 12,433 desalination plants, with 60% installed capacity located in oil surplus, high oil income (West Asian) countries who are using oil/gas based thermal power for desalination.
- Desalination is highly energy intensive.
- Global trend for desalination using fossil fuels is not sustainable anywhere as global fossil fuel reserves are also depleting. This approach is also ecologically not globally acceptable hence India should not emulate.

The case for using Solar Energy

Solar energy in advocated globally because of

- Sustainability: it will be available so long as the sun exists i.e. billions of years.
- Abundance: one day of solar energy = 27 years of energy consumed today by 6 billion people.
- Environment friendly
- Safety

Solar energy is advocated for India because:
- All forms of renewable energy in India (wind, biomass, hydel, ocean, etc.)
together have a total potential of just
100 GW while India’s energy demand
in 2012 is 215 GW.
- 1% of India’s land area harvested for
solar energy will generate about 1000
Gigawatts i.e 100,000 MW of electric
power.
- With current fuel consumption rates,
India will be depleted of oil during
2010-2032, gas from 2023-2048,
coal from 2074. Fossil fuel era is
ending. Fossil fuels are therefore not
sustainable. Man must find other fuels
for survival.

The major deterrent in harnessing solar energy
is high initial cost. We will look into a strategy
of how the costs should come down.

GLOBAL SOLAR ENERGY COSTS ARE
RAPIDLY FALLING DUE TO:
- Advances in solar cell technology
yielding higher efficiencies – all these
concepts have come from the space
technology sector.
- Advances in cell production
  techniques and processes are reducing
  the costs.
- Further fall in capital cost when Very
  Large Scale Photovoltaic (VLS-
  Photovoltaic) solar power stations are
  set up e.g. solar energy for farmers. In
  Andhra Pradesh farmers are given free
  electricity – Rs. 1500 crore, if they set
  up two 100 MW solar power plants
  with the same capital, they can then
  afford to give electricity free - no fuel
cost.
- Country in greatest need for renewable
  energy is India hence is best placed to
take the global lead.

COST REDUCTION STRATEGY OPTION FOR INDIA IS:
- India is facing acute scarcity of fresh
  water and energy concurrently.
- Couple solar energy to large scale
  seawater desalination
- Sell sweet water as value added
  product and not electrical energy.
- Build solar cell manufacturing
capacity and reduce costs by using
  India’s compelling demand for fresh
  water as a starter.
- Major weakness in India - no
  Advanced Energy Technology
  R&D Institute established as yet. It
  is coming up in NOIDA, in NTPC
  a major Energy Technology R&D
  facility has been approved.
- 65 MW solar cell/panel production
capacity established in India. But
country still dependent on West/Japan
for solar technology and cell raw
material e.g. silicon.

CASE FOR SURYAJAL PROGRAMME FOR AUROVILLE
- Groundwater table of Auroville region
  continues to fall, salinity increasing,
despite many path-breaking
  conservation measures.
- Substantial quantities of sweet
  water are required by Auroville and
  surrounding villages on a sustainable
  basis.
- The only remaining source of water
  for Auroville is the ocean – with
  12,000 desalination plants in West
  Asia burning fuel, the Indian ocean is
  covered by haze and thereby affecting
  our atmosphere and also climate.
But desalination is highly energy intensive and India’s oil, gas and coal reserves are depleting rapidly, oil imports (now 73%) are escalating, fuel costs are soaring. There is need for India, and Auroville, to carefully conserve fossil fuels. Hence burning fossil fuels to produce fresh water from seawater cannot be a priority for Auroville. This is neither a sustainable nor an ecologically correct solution.

Auroville bio-region has close access to the ocean and pioneering initiatives in renewable energy, and environmental regeneration are important objectives of Auroville’s mission. Also solar energy & biomass sources are abundant in Auroville. If these 2 are linked the cost effectiveness is 4 times as compared to solar energy alone. This would be an enormous scope for employment generation in this bio-mass collection. Once the cycle starts then there will be breathing time for ground water to get recharged. We have to do a study to find out how much should the optimum capacity be, so that we can recharge the water for the agrarian sector with help from the industry.

Auroville is a global model for environmental friendly living and maybe it is a bridge between the past of global water depletion and the future of perennial supply of sweet water from the ocean using renewable energy?

“Suryajal” is wisely doing what nature is doing i.e. producing sweet water using solar energy in a safe, non-polluting, ecologically friendly manner. Biomass and biofuel energy can effectively supplement solar energy in Auroville.

Suryajal renewable energy based desalination programme for Auroville is a local initiative for transition from globally unsustainable, to a model sustainable solution by plant capacity & skills building in a gradual and carefully planned manner.

Hence Auroville’s policies for sustainable water resource management & investment may be directed with reference to principles of sustainability, abundance, environment friendliness and safety.

**Photovoltaic Technology**

Photovoltaic is sunlight-generated electricity – several types of Photovoltaic cells are available; the stages are: cell – module – panel – array- subarray – feed – plant and so on. Photovoltaic is the only technology that can produce power from 3 MilliWatt to 3 MegaWatt.

When the materials used are changed over the years, thereby changing the efficiency, we see that the costs also reduce from 80$ per watt in the 1980s to 3$ per watt in 2003 to 1$ per watt in 2020. If you spread the applications, the volume increases then due to large scale productions the costs come down.

**How clean is Solar Photovoltaic?**

1.0 MW (=1000 kWp) of Solar Photovoltaic helps to avoid:

- 1500 tonnes of CO₂ emission/year (CO₂ is one of the primary green house gases that contributes to global warming);
- 720 kg of sulphur oxide;
- 340 kg of harmful nitrogen oxide emission/year.

The above figures are roughly equivalent to air cleaning power of 183 acres of trees – this means that to clean the environment from the above levels of toxicity using fossil fuels (of CO₂, NO₂, sulphur oxide), you need 183 acres of trees.

Emission avoided by 1000 kWp of Photovoltaic plant is equivalent: to that emitted by driving 3,000,000 km in an average car (= going around the equator 75 times!)

Looking at the different plant capacities we see that (from 1 KW to 500 MW plant), although different parameters have gone into calculation of area of Solar Photovoltaic array, (like cell,
module, interspacing details, angle at which the Photovoltaic module has been projected); area-wise we see that Solar Photovoltaic occupies only 50% of what solar thermal uses.

**Desalination Options**

Here there are only 2 methods: Thermal process and Membrane process:

- Thermal Process which requires heat energy (~1100 C) > 10 KWh/m³ – this has 3 times more energy requirement than the Membrane process and hence we advocate the latter.
  - Multi-Stage Flash Distillation
  - Multi-Effect Evaporation
  - Vapour Compression
- Membrane Process which requires pressure energy (40-100 bar) < 3 KWh/m³
  - Reverse Osmosis (RO)
  - Electro-Dialysis (ED)

**RO - Merits**

Lower energy consumption than thermal; more environmentally friendly than thermal; when linked to Photovoltaic source of energy, land requirements are 2.5 times lower than solar thermal-multiple effect evaporation schemes.

RO is modular and easier to scale up – this is very important for India where you don’t need very large scale plants at any one place and you can locate smaller plants at different places along the coast-line.

The principle of RO is similar to the principle of salinity ingress. If you have a beaker with a partition of permeable membrane in the centre with fresh water on one side and saline water on the other side – fresh water will permeate and push up the saline water – this natural process is called osmosis. If you put pressure on the sea water, then it pushes the water in the reverse direction through the semi-permeable membrane and you get fresh water –
this is reverse osmosis. This membrane will be like a fax-roll – you need a sea water well and send it under high pressure and you have fresh water coming out. The pressure drop is low and so you can use the return pressure to drive another set of pumps (this is the pressure exchanger technology that has come in for the last 5-7 years); another advantage of desalination is that you can have the quality of end water as per your requirement – pure drinking water or agriculture-quality or industrial-quality.

Suryajal, will convert seawater into fresh water @ 3 KW/m³ hydraulic. For a system that needs 1000 l per day, you need 12 m² of Solar Photovoltaic area and solar cell efficiency of 13-14%. If you need 1 m³/day of fresh water you need 3 m³/day of sea water – the 2 extra m³ of sea water concentrate (56,000 tds) goes back into the ocean. We have a mathematical model which is decision interactive, and it has a numerical simulation mode – with this we have done a whole range of scenarios.

**ECONOMICS**

The bigger the plant the lower the cost – this is from data we obtained from manufacturers. Similarly the Solar Photovoltaic which is Rs. 30 crore per MegaWatt, will be reduced to Rs. 5-6 crore per MegaWatt when you talk about 100 MegaWatt capacities.

Hence larger the water production capacity, lower will be the specific cost of the plant, and larger the plant capacity lower will be fresh water cost. When we talk about river water sharing we talk about costs of 2-3 paise per litre – this costs can be matched to the desalination costs of plant sizes of 100 mld (million litres per day).

**IMPACT OF INTEGRATING SOLAR PHOTOVOLTAIC TO BIOMASS ENERGY SOURCES**

1. The advantage of biomass energy is that when there is not enough solar energy - “Booster” doses of electrical energy from biomass sources are available early morning and late evening when solar energy levels are very low enhances the yield of the Photovoltaic-RO system, the plant can run on bio-mass energy.

2. Capacity utilization of the RO system designed only for Photovoltaic energy source is greatly enhanced with biomass: 24-hour power supplies as against 8 hours with solar.

3. Capital costs of biomass energy plants significantly lower than solar Photovoltaic plants. Integrating solar Photovoltaic to biomass source brings down capital costs and water costs substantially.

4. The hybrid renewable energy system delivers about 1.5 times the fresh water output at about half the cost i.e. about three times more cost effective than pure solar system: provided adequate bio-mass resources are made available in a sustainable manner.

5. Local economy and employment will be greatly stimulated and enhanced prosperity follows.

**ENVIRONMENTAL IMPACT OF DESALINATION PLANTS**

- 12,000 desalination plants operational some for about 50 years – no serious issues of marine environment degradation reported so far.

- Brine disposal can be effectively managed – reference California State Task Force Report on Desalination, October 2003.

- Location of desalination plant and brine disposal system design is very site specific – requires expert decisions and independent review.
Downstream industries from desalination

- Diluted brine used for selected crops and marine aquaculture.
- Sequential extraction of dissolved salts
  - sodium chloride
  - gypsum
  - calcium chloride
  - calcium carbonate
  - sodium sulphate
  - etc.

Strategy for sustainable water management in Auroville

Factors which might be kept in mind while goal setting:

- India’s fossil fuel reserves are depleting rapidly.
- Global greenhouse effect & changing global weather patterns creating drought conditions in India.
- Complexity, costs, limitations and diminishing returns of more widespread efforts to conserve & redistribute existing water resources in Auroville bioregion.
- Desalination with renewable energy is an implementable & sustainable solution. Long term use will help restore ground water levels and bring in all round economic prosperity.
- “Suryajal” programme has thus the potential to fulfill the Mother’s vision for Auroville.
- The goal will be to create a value for Auroville through strategic partnership and collaboration with industry and academic institutions; and a constant progress through scientific and technological leadership in sustainable water resources management through seawater desalination using integrated system of renewable energy.

Suryajal Management Organization

First stage (planning and design)


**SECOND STAGE**

- Auroville Council
- "Suryajal" Programme Management Board
- Programme Office (Auroville)
- Energy Technology Project Board
- Desalination Technology Project Board

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**OBJECTIVES**

**Phase 1:** Pre-Feasibility Report Phase

**Phase 2:** Experimental & Capacity/Capability Build-up Phase of building a small 10 m³ per day experimental plant on the coastline near Auroville [Funded by Auroville Council]

**Phase 3:** Commercial phase - 5 mld “Suryajal” plant on the coastline near Auroville (Serves 50,000 people @ 100 litres/day) [Funded by Government/Industry/FDI]

**Cost of the Auroville programme for desalination with renewable energies:**

1. Pre-Feasibility Study Rs 10.00 Lakh
2. 10 m³/day Experimental Plant Rs 75 - Rs 100 Lakh
3. Capital Costs Commercially Viable Plants in Auroville
   - 1 mld Rs 25.5 cr
   - 5 mld Rs 116.5 cr
   - 10 mld Rs 226 cr
4. Fresh Water Costs: About 5 to 10 paise /litre
5. NOTE: Estimates are tentative need pre-feasibility study for validation

Both capital and water costs will fall by use of hybrid renewable energy technology

**ON INVESTMENTS**

There is nothing to gain for Auroville by deferring investment in renewable energy and everything to lose by postponing it further...

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**MOVING FORWARD**

- Auroville takes a decision to experiment on desalination using renewable energy (solar+biomass) as a sustainable solution.
- Auroville Council for Sustainable Water Resource Management set up to oversee this programme.
- The Approach: Plant Capacity & Skills - Building in a gradual and carefully planned manner.
- The Council decides to fund a Pre-Feasibility Study for the programme as a whole.
- Council sets up Working Group with industry and academic/design institutions.
- Pre-feasibility Report submitted by Working Group with sources of funding indicated for DEPR and project implementation.
- Collaboration approved by Auroville Council.
- Working Group prepares DEPR and MOU for strategic partnership.
- Planning & Implementing the “Suryajal” programme commences.
- Suryajal plant commissioned & operated at Auroville.
During desalination process what about the minerals you need in the water? Fresh water out of desalinations needs a post-treatment stage, where you add whatever minerals you need depending on the end use.

Can RO tackle polluted sea water -pollution from sewerage? The construction of the plant will be site specific and we have pre-treatment plants.

Radioactivity is also a pollution in sea-water from the natural reasons. Will this desalination technique remove this? I don’t know whether this membrane can remove radio-isotopes.

Participant’s comment: In Germany, using RO, they are treating all types of waste water, but there are specific specifications of what will be the end use of this treated water (drinking, irrigation, etc). We can reduce pollution factor a bit not by drawing direct open sea water from the surface but from bore-wells- this reduces salinity a bit and also pollution.

Will not the membrane get clogged if you don’t have a constant flow of water (if the plant will not be operational in the night)? This does not change the efficiency or maintenance cost of the membrane – this is shown from studies in existing plants.

Will desalination affect flora and fauna by throwing the brine back into the sea? If all the world’s water from snow, rainfall, rivers are met by desalination only and people are throwing back the brine into the sea, the salinity will increase by 0.12%. However it is a site specific issue as to how do I recycle back the brine. One has to do oceanographic studies. To the best of our knowledge there is no flora/fauna problems in any of 12,000 operating desalination plants.
Auroville GIS
an Overview
Current Status – Future Possibilities

Lata Iyer & Prashant Hedao

Lata Iyer, with a Masters in Regional Planning, Univ. of Pennsylvania, Philadelphia, U.S.A.; B.Arch., S.P.A, New Delhi, is a GIS Analyst, Regional Planner, Architect with experience in GIS application / product design, project management, biodiversity conservation, mapping, architecture, etc. Worked in ESRI, USA, in product design, project management, consulting for the last 4 + years (1999–2003). Worked in Conservation International, USA, an international organization devoted to biodiversity conservation as the Director of their Regional Conservation Analysis program which involved conservation assessments, priority-setting workshops, GIS lab management, etc. (1995–1998).

Coordinator,
Auroville GIS,
Auroville – 605 101, TN, India
Phone: 9443409201 (cell)
Email: lata@auroville.org.in


Coordinator,
Auroville GIS,
Auroville – 605 101, TN, India
Phone: 9443409201 (cell)
Email: prashant@auroville.org.in

BACKGROUND HISTORY

2000 – Visit by Dr. Kasturirangan, then Chairman Indian Space Research Organization (ISRO) followed by few visits by ISRO Scientists and talk about setting up a GIS / Remote Sensing Cell here in Auroville & Pondicherry

2001 – Support from ESRI Conservation Program (ECP) with a grant of GIS Software (ArcView & Extensions)

2001 – Support from the Society for Conservation GIS (SGGIS) for GIS training

MISSION

• To coordinate a systematic implementation of GIS, which will simplify data transfer between agencies, minimise data redundancy, and ensure suitable expertise is available to operate and manage the various components of the system

• To disseminate information and technology, with the sole objective of maintaining a healthy natural environment

Activities foreseen by ISRO in collaboration with Auroville:
• Use remote sensing inputs to derive various thematic layers
• Create a comprehensive GIS database for integrated decision support
• Develop standards, specifications and procedures for orderly collection, storage and retrieval of GIS data
• Create customised Query shells to cater to all applications
• Maintain integrated database for –
  Common data queries, open to all
  Restricted workspaces for research and analysis
• Provide technical support by –
  Developing standard interface utilities
  Setting up application oriented work groups
  Co-ordinating and hosting training programs
• Provide online access mechanism
• Maintain relationships with other GIS organisations

The list may seem a bit ambitious - the expectation was that everyone would start to use GIS, there would be collaboration between groups using GIS, and applications specific to certain work would be developed. All of the above didn’t happen and one of the key reasons is that we do not have enough GIS professionals; also the software is expensive, and there are institutional bottlenecks. Here, the activities that did happen have been highlighted.

**Current data holding**
The satellite imagery from ISRO was used to extract the following layers in 1999. Now we have more satellite imagery available.

**Bioregion**
• Transportation network (roads, railroad, etc.)
• Landuse
• Geology (surficial and sub surface)
• Hydrology (rivers, streams, lakes, irrigation tanks, etc.)
• Settlements (villages, blocks, panchayats, district, etc.)

The above data was extracted from Satellite Imagery (from ISRO, Liss-Pan merge; 23 m res.) and some obtained from Institute of Remote Sensing (IRS), Anna University, Chennai
• Also we have ASTER (15 m res.) & ETM (23 m res.) Satellite Imagery for various time periods from 1991 – 2003
• We have the latest 90 m resolution SRTM topography data – this is not useful in smaller areas but in larger watersheds like that of the Kaliveli, it is quite useful
• Census data for villages

AUROVILLE & IMMEDIATE SURROUNDINGS
• Information such as communities, built structures, roads, canyons / water channels, infrastructure, topography etc. from the Topographic Survey done in 2001 for the Auroville City area
• Digital Elevation Model (DEM) from the Topographic Survey
• Hydrology (streams, rivers, lakes, irrigation tanks, etc.)
• Roads (all categories)
• Cadastral data from village/Panchayat maps
• Pilot studies done for electrical, telephone service, water usage, environmental monitoring databases

This is a DEM from the topographic survey done and more precise than that derived from the global SRTM.

The map with roads, canyons, built areas are available from the topographic survey done and hence represent more reliable information than global SRTM topography maps. We have also been able to do a utilities map of the city area. The most exhaustive and up-dated one is the cadastral map, which shows all land ownership in and outside Auroville – this was the most important map for planning purposes.

In Auroville, Harvest is the most advanced GIS user – they have collected a lot of information that they have used for modeling purposes.

ONGOING WORK OF AUROVILLE-GIS
When we started with this Auroville GIS in February this year, we found that there were many copies of same data, and their sources were not documented. Also, although people had heard the word GIS, there was not much of an awareness about what it was or what it could do.

DATA ORGANIZATION AND METADATA CREATION
• For all current data holding

DATA CREATION AND UPDATING
• Farm Group data – to understand what our farms are like and what kind of cropping patterns we have; what kind of water requirements do we have currently.
• Land use in Green Belt and surrounding areas
• Cadastral data
• Surrounding village data

CAPACITY BUILDING & TRAINING
• Auroville GIS staff
• Staff of other Auroville groups such as Planning, Forestry, etc.
• GIS in local schools & universities (Engineering college has shown interest).

GIS ANALYSIS
• Town planning regarding roads
• Planning of Green corridors and Parks
CAPACITY

- Ecological planning and conservation using GIS
- Use of GIS as a decision making tool in the field of Health, Education, Environment, etc.
- Design and development of products and applications
- Building conservation GIS users networks

SUPPORT

- In-kind support from ECP
Connected with other user networks such as SCGIS and conservation GIS user networks in several countries

TRAINING AND CAPACITY BUILDING

- Trained field biologists in the use of GIS and converting their databases into spatial data
- Helped them setup the GIS systems and get them started on their projects
- Currently, in West Africa, Cameroon conservationists are one of the main GIS users

SOCIETY FOR THE CONSERVATION OF GEOGRAPHIC INFORMATION SYSTEMS
This is a network of professionals who use GIS for bio-diversity conservation.

- Officially started off in 1997, has currently over 600 members from around the world
- SCGIS works to assist conservationists worldwide in using GIS through communication, networking, annual conference, scholarships, and training
- Membership is open to any individual seeking assistance in the achievement of conservation goals
- Already we have helped set up local SCGIS in-country chapters in Russia, Madagascar and Chile
- http://www.SCGIS.org

FUTURE POSSIBILITIES

GIS USERS NETWORK

- Local as well as regional to bring the GIS users and planners together

FRAMEWORK FOR DATA BUILDING & SHARING

- For effective use of GIS that benefits all
- Create seamless datasets
- Avoid data duplication

COLLABORATE WITH TN & POIDICHERRY

- For effective Planning at Watershed/Regional level with Water, Forestry, Planning, Transportation departments.
Ground Water Scenario in Tamil Nadu and Scope for Development

R. Chakrapaani

R. Chakrapaani, after completing his post-graduation in Earth Sciences from Annamalai University, Tamil Nadu, joined the Ground Water Investigation Project in Thanjavur district under the United Nations Development Programme in 1967. During 1970 – 72, he was engaged in geological mapping and mineral exploration as an officer of the Geology Department, Govt. of Tamil Nadu. As an officer of the AR & DC Programme, he was engaged in the formulation of various minor irrigation schemes in Coimbatore and Nilgiri districts.

Chakrapaani joined the Central Ground Water Board in 1975 and has been involved in various activities of the Board including Systematic Hydrogeological Surveys, Ground Water Exploration, evaluation of ground water resources and design of well fields in Punjab, Haryana and Tamil Nadu.

He has undergone training on ‘Photo-interpretation and Remote Sensing under NNIRMS Programme at the Training Institute of the Geological Survey of India, Hyderabad and has also undergone ‘Advanced Training in Applied Ground Water Modelling’ at the Institute of Hydrological and Environmental Engineering at Delft, Netherlands. He has participated in several International and National Seminars and has a number of publications to his credit.

Regional Director
CGWB
SE Coastal Region wing, South Eastern Board,
Besant Nagar, Chennai - 600 090, India
Phone: 44 - 24914494

Central Ground Water Board is the apex body at national level involved in Ground Water surveys, exploratory drilling and assessment and management of ground water resources. CGWB has constructed a number of bore/tube wells to meet the drinking water demands in Tamil Nadu as well as Pondicherry and Karaikal regions and all the successful exploratory wells have been handed over to the concerned Government agencies, either to augment the rural/urban water supply or gainful utilisation.

Tamil Nadu - Background Information
- Geographical Area (km²) : 1,30,060
- No. of districts : 30
- No. of Blocks : 385
- Average Rainfall (mm) : 925
- Rainy Seasons
  - SW Monsoon - June to September
  - NE Monsoon - October to December (eastern part of Tamil Nadu)

These monsoons are the only source of natural recharge and if the NE monsoon fails, we see the state of affairs in Tamil Nadu and Pondicherry
- Geology : Archaean to Recent
  - About 73% of area underlain by crystalline (hard rock) formations, heterogeneous in nature and diverse hydrogeological conditions (Archaean Crystalline rocks like Charnockite, Gneisses, Granites etc.)
  - Remaining 27% is Sedimentary formations : Mesozoic, Tertiary & Quaternary – Sand, Clay, SSt, etc.
**GROUND WATER OCCURRENCE**
- Water table conditions in weathered zone in hard rocks & shallow sedimentary aquifers
- Semi-confined to confined conditions in deeper fracture systems and sedimentary formations
- Considerable heterogeneity in the occurrence and movement of ground water in aquifers.

**GROUND WATER DEVELOPMENT**
- Surface water resources available have already been harnessed almost completely
- Ground water is the major source now for domestic, industrial and irrigation requirements
- At present, tube/bore wells are the most common ground water abstraction structures now
- Development through dug wells from the weathered zone and through tube/bore wells from the deep-seated aquifers
- Dug wells have become defunct in many areas of the state due to low yields and declining water levels.

**GROUND WATER LEVELS**
- CGWB monitors about 900 observation wells 4 times a year to monitor status of ground water levels (Jan, May, Aug, Nov)
- Water samples collected during May every year to monitor water quality.

**GROUND WATER STATUS – MAY 2003**
(PRE MONSOON SCENARIO)
- Depth to water in observation wells ranged from 0.93 – 43.43 m.bgl (metres below ground level)

**GROUND WATER STATUS – JAN 2004**
(POST MONSOON SCENARIO)
- Depth to water in observation wells ranged from 0.37 – 44.40 m.bgl
- Water levels in the range of 5 – 10 m.bgl in the major part of the State
- Water levels in the range of 2 – 5 m.bgl observed mostly in the coastal areas
- Water levels >20 m.bgl observed in isolated pockets in Salem, Namakkal, Coimbatore and Erode districts.

**LONG-TERM CHANGES IN GROUND WATER LEVELS**
- Depth to water levels in observation wells during May 2003 and January 2004 compared with mean water levels of respective months for the previous decade
- Rise/ fall indicate the changes in water levels in response to recharge/discharge parameters.

**MAY 2003 – DECADAL MEAN**
- Decline in water levels observed in 79% of wells analyzed.
- About 42% wells show decline in excess of 2 m
- Rise in water levels observed mostly in the coastal tracts
- Decline is spread all over the State.
JAN 2004 - DECADAL MEAN

- Decline in water levels observed in 86% of wells analysed
- About 49% wells show decline in excess of 2 m.

GROUND WATER Resources Estimated as per Groundwater Estimation Committee GEC-1997 Norms

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage of Ground Water Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-exploited</td>
<td>&gt;100 (drawal is more than recharge)</td>
</tr>
<tr>
<td>Critical</td>
<td>90 – 100</td>
</tr>
<tr>
<td>Semi-Critical</td>
<td>70 – 90</td>
</tr>
<tr>
<td>Safe</td>
<td>&lt;70</td>
</tr>
</tbody>
</table>

TAMIL NADU Scenario in Jan 2003 as per the above Norms

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-exploited (here further development schemes shouldn't be allowed)</td>
<td>136</td>
</tr>
<tr>
<td>Critical (in another 5 years this will be become over-exploited)</td>
<td>37</td>
</tr>
<tr>
<td>Semi-Critical (Though scope exists for ground water development, it has to be taken up judiciously)</td>
<td>105</td>
</tr>
<tr>
<td>Safe</td>
<td>97</td>
</tr>
<tr>
<td>Saline Zones (Thiruvananthapuram, Tuticorin etc)</td>
<td>8</td>
</tr>
</tbody>
</table>

STATUS OF GROUND WATER QUALITY

- Ground water suitable for domestic, industrial and irrigation uses in general
- Major quality constraints include:
  1. Insitu salinity in Sedimentary aquifers – Ramanathapuram, Nagapattinam etc.
  2. Fluoride – Dharmapuri, Salem, Erode, Coimbatore, Trichy
  3. Iron
- Pollution due to
  1. Tanneries (major source of foreign exchange spread over Vellore, Tiruvananmalai, Trichy, Coimbatore); Dyeing & Bleaching (Karur, Trichy Coimbatore, Erode); Sago industry (Salem and Namakkal), Chemical industries (Coimbatore, Chennai), etc.

CAUSES FOR THE PRESENT STATE OF AFFAIRS

- Population explosion & consequent environmental impacts like urbanisation, deforestation etc.
- Alteration of river systems – droughts & floods
- Inefficient water management practices
- Improper cropping pattern
- Industrial, urban & agricultural pollution
- Destruction of traditional water harvesting systems like tanks, ponds etc.
- Large scale water marketing for meeting drinking water requirements
- Free power supply for agricultural purposes.

ENVIRONMENTAL IMPACTS

- Silting up of reservoirs
- Drying up of shallow wells
- Long-term decline of water levels
- Progressively deeper water levels resulting in increased power consumption for lifting water
- Quality deterioration
- Saline water ingress in coastal aquifers
- Loss of livelihood & irreversible socio-economic changes
- Population migration leading to more congestion in urban areas.
ROLE OF VARIOUS SECTORS IN GROUND WATER DEVELOPMENT:

Government
- Check population growth
- Building institutional capacity
- Creating competent administrative & legal structures
- Making institutions more responsive & effective
- Training senior water managers
- Co-ordinate activities of various agencies in water sector
- Building closer ties with Universities and research institutions
- Policy initiatives for providing incentives for adoption of water augmentation (RWH) / conservation measures.

Industries
- Promote environment-friendly technologies for minimizing pollution of water resources
- Steps for conservation, augmentation and quality improvement of water resources
- Sponsor research into use of alternative sources of water for industrial use – recycling & reuse of waste water, desalination in coastal areas
- Locate highly sensitive, polluting industries in saline blocks by developing saline water through suitable technologies like R.O. Plants
- Less water consuming industries to be located in select pockets in white and semi-critical blocks with adoption and implementation of rain water harvesting structures
- Water intensive industries only in earmarked areas with sustainable water sources and conducive eco-system
- Spare fragile fresh water systems for drinking purposes and exploit brackish/saline sources (97%) for industrial development in the future.

NGOs, VOs and Self-Help Groups
- Close interaction at community level
- Create mass awareness at grass root level
- Popularise low-cost alternatives for sustainable water management and conservation
- Popularise rain water harvesting techniques on scientific lines based on field conditions.

The Lay Man
- Understand the value of water and avoid wastage
- Minimise use of water & conserve it wherever possible
- Adopt rain water harvesting
- Spread the message of water conservation & protection in the neighborhood.
Dynamic Precipitation Runoff Model for the Matrimandir (MM) Area

Jochen Kohler

Jochen Kohler is an experienced geo-ecologist specialized in soil science, contaminated land and environmental impact assessments. Since 1994 he is working at LGA - Institute of Environmental Geology and Contaminated Land, in Germany as Project Manager. He carried out projects on different aspects: installation and controlling of a long-term research site for measuring water movement in the unsaturated zone; soil classification mapping of Northern Bavarian soils according to US-soil-taxonomy, FAO- and German classification systems; research on the influence of different suction-cup materials on PAH and Dissolved Organic Matter (DOM) in soil solutions; evaluation of expert reports for the Bavarian Environmental Protection Agency; reforestation project in the Hinterstein valley (German Alps); co-author of the guidebook "Controlled dismantling of (contaminated) buildings; remediation of groundwater damages with highly volatile organic carbons; design of remediation and rehabilitation of landfills; groundwater monitoring; development of ecological guidelines for evaluation/certification of golf courses (German golf association).

LGA Institut für Umweltgeologie und Altableten GmbH
Tillystraße 2
90431 Nürnberg, Germany
Phone: 49-911-655-5583; Fax: 49-911-655-5699

INTRODUCTION

Dynamic Precipitation Runoff Model is a system of calibration or modeling to get different results, using varying parameters. It is like a complex statistical tool package.

AIMS

- Reduce water consumption, especially for irrigation
- Implementation of rainwater harvesting systems
- Estimation of storage volumes

QUESTIONS TO ANSWER

- What yield can be earned by rainwater harvesting in a defined area on a long-term basis?
- How much storage volume is necessary or useful?
- How often do we have overflow events for a given volume?

<table>
<thead>
<tr>
<th>MM-Oval</th>
<th>Area [m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>sealed areas (paved, amphitheatre)</td>
<td>31,470</td>
</tr>
<tr>
<td>greens</td>
<td>7,045</td>
</tr>
<tr>
<td>gardens</td>
<td>50,658</td>
</tr>
<tr>
<td>Total</td>
<td>89,200</td>
</tr>
</tbody>
</table>

PRECIPITATION

From the data from Harvest we see:
- Minimum 660 mm (1974), Maximum 2,160 mm (1996). Calculation basis: average rainfall 1,280 mm. Daily data were transformed into two sections (4:00 - 10:00 a.m.; 4:00 - 10:00 p.m.) with 15 minute intervals.

EVAPOTRANSPIRATION

This is a very important parameter, but difficult to handle in principle; there are many methods to calculate this, we decided on the Thornthwaite-method which gives for Auroville 1,732 mm/year
Effective rainfall i.e. rainfall that creates runoff:

On sealed areas (which are simple to calculate): Extended threshold value method according to Paulsen.

<table>
<thead>
<tr>
<th>Wetting losses</th>
<th>Lw</th>
<th>0.75 mm/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollow losses</td>
<td>LH</td>
<td>3.0 mm/m²</td>
</tr>
<tr>
<td>Runoff coeff.start</td>
<td>Ψ₀</td>
<td>0.2</td>
</tr>
<tr>
<td>Runoff coeff.end</td>
<td>Ψₑ</td>
<td>1.0</td>
</tr>
</tbody>
</table>

On unsealed areas (which are complex to calculate and we have to combine methods): Combination of Paulsen and Horton’s infiltration model. Beside wetting and hollow losses one has to consider infiltration and interception losses and the calculation gets more complex. For example: term to calculate the potential
infiltration rate (rain-event after dry period)
 \[ f_t = f_0 + (f_0 - f_{i,t}) \cdot e^{-e^{D \cdot kD \cdot At}} \]

<table>
<thead>
<tr>
<th>Infiltration parameter (sandy loam)</th>
<th>Runoff parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>1 mm/min.</td>
</tr>
<tr>
<td>Lw</td>
<td>4 mm</td>
</tr>
<tr>
<td>f0</td>
<td>0.05 mm/min.</td>
</tr>
<tr>
<td>LH</td>
<td>3 mm</td>
</tr>
<tr>
<td>K</td>
<td>0.05 l/min.</td>
</tr>
<tr>
<td>( \Psi )</td>
<td>0.0</td>
</tr>
<tr>
<td>KD</td>
<td>0.0003 l/min.</td>
</tr>
<tr>
<td>( \Psi_e )</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**IRRIGATION**

Irrigation-demand on MM Oval = 300 m³/d. This demand is calculated as system output (daily). No output during rain events + 24 hours. There is no advanced irrigation technology in use.

**RESULTS**

What kind of information do you get from the simulation?

Most important information for sizing a storage facility are:
- Overflow frequency (how often is my system constant),
- ratio of efficiency and
- ratio of satisfaction of requirement.

A static model is not able to give this information. To estimate the storage capacity for water harvesting on MM oval, 13 long-time (1969 - 2003) simulations were calculated with different volumes for 10,000 m³ to 50,000 m³.

**OVERFLOW FREQUENCY**

This extreme-value statistic is only useful if overflow events are relatively rare - in this case with a storage volume \( \geq 37,500 \) m³

- A Storage volume of 50,000 m³ means an overflow every 12 years
- A Storage volume 10,000 m³ means 14 - 15 overflows per year

**RATIO OF EFFICIENCY AND SATISFACTION OF REQUIREMENT @ DEMAND=300 M³/DAY**

- ratio of efficiency = percentage of rainwater that reaches the storage facility e.g. if you 50,000 m³ storage capacity, you will have 100% of water reaching the storage system; if you have 30,000 m³, you will have 10% losses.
- ratio of satisfaction of requirement = percentage of demand that can be stored.

If you have a demand of 300 m³ per day for irrigation; if you have a storage capacity of 50,000 m³, you can only satisfy 50% of your demand (assuming you are storing every drop of runoff).

**RESULTS**

- Only 50% of the irrigation-demand could be stored by rainwater-harvesting on MM oval even with a storage volume \( \geq 50,000 \) m³.
- Between 30,000 m³ and 50,000 m³ will not be any significant increase in
producing stored water. To build larger storage volumes doesn’t help much.

- With the actual irrigation technique, up to 50% additional freshwater is necessary.

<table>
<thead>
<tr>
<th></th>
<th>Irrigation demand 300 m³/d</th>
<th>Irrigation demand 200 m³/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overflow events</td>
<td>3 – 4 year-1</td>
<td>~ 5 year-1</td>
</tr>
<tr>
<td>Ratio of efficiency</td>
<td>~ 93 %</td>
<td>~ 90 %</td>
</tr>
<tr>
<td>Ratio of satisfaction of requirement</td>
<td>~ 47 %</td>
<td>~ 66 %</td>
</tr>
</tbody>
</table>

If you build a storage volume of 30,000 m³, only for irrigation in MM oval, you need 53% additional fresh water if demand is 300 m³/day or you need 34% additional fresh water if demand is 200 m³/day.

**CONCLUSIONS**

A precipitation-runoff model is a useful tool to estimate storage capacities on a long-term scale (35 years).

- Parameters like overflow events, efficiency of usage and satisfaction of requirement can be calculated for different storage volumes.
- The model could be applied to all sizes of areas.
- Further aspects have to be considered to build storage capacity for rainwater-harvesting.
- Most important, appropriate financial situation as well as adequate local circumstances.

**To increase the satisfaction of requirement, water consumption for irrigation has to be reduced.**

**RATIO OF EFFICIENCY AND SATISFACTION OF REQUIREMENT @ DEMAND=200 m³/DAY**

We did another simulation of reduced demand of 200 m³ per day and we found: with decreased demand the outflow from the system is less.

- Maximum of storable demand is 76%, when the storage capacity is 80,000 m³
- Reduction of water consumption implies a slight increase in overflow events.
What more information do you need to consolidate your findings /model? We calculated with different levels of evapo-transpiration, to see how the system will react – however with different evapo-transpiration rates is not so big changes as we thought.

There is a structural dislocation or linear fault at a depth of 30 m beneath the Auroville surface, travelling 30 km from Marakanam to Muttarapalayam, the top portion is called Cuddalore sandstone where you are going to construct the lake which will store around 50,000 m³ of water – what will be the dynamic hydrostatic force on that fault – whether the structure of the entire 30 m will collapse? It depends on how you make your storage. If you change soil with water and water is less heavy, so there will be no effect on the pressure.

Participant’s comment: all fault zones are unable to store water.
Technical Aspects of Rainwater Storage Systems and Matrimandir Lake

Carlo Schillinger, LGA

Carlo Schillinger is an experienced geologist with a strong background in hydrogeology and geotechniques. His special profession is to evaluate the behaviour of different soil materials and geotechnical calculations. He planned and monitored the sanitation of many landfills (cover and bottom liner), always with the view to effectiveness and cost and implementing innovative techniques. He also developed and optimised modern technology for the taking of samples. Since 1990 Mr. Schillinger had organised and directed more than 40 training-colleges on sampling and assessment on contaminated sites and landfills. In 2003 he was appointed as a member of the examination committee for approval of experts acc. §18 BBodSchG (Federal Soil Protection Law). Since 1987, he has been working at LGA - Institute of Foundation Engineering and between 1988 - 1994 he has worked in investigation and sanitation of contaminated sites; in 1994, he has been responsible for the foundation of the LGA - "Institute for Environmental Geology and Contaminated Land "; and since 2002, he has been the head of LGA Institute of Environmental Geology and Contaminated Land GmbH

LGA Institut für Umweltgeologie und Abfallstrom GmbH
Tillystraße 2
90431 Nürnberg, Germany
Phone: 49-911-655-5583, 49-171-559-1875; Fax: 49-911-655-5699
Email: Carlo.Schillinger@LGA.de

We are scientists and we are consultants and we have the honesty to take care not to look at only one problem, but to look at the whole system (not compartmentalising into e.g. a geological problem alone, hydrology problem alone, etc).

**General situation in Auroville**

Water consumption exceeds available water resources. The upper aquifers are empty, lower ones show falling water levels and increasing salinity. An effective water management has to be installed and the aquifers have to be recharged. But we have to keep in mind that there is no unique solution for solving these problems – we have to look at the problem from all sides. If we want to find the best solution to the problem we have to first make a very simple analysis like that below.

<table>
<thead>
<tr>
<th>Water consumption</th>
<th>used</th>
<th>Resources</th>
<th>used</th>
</tr>
</thead>
<tbody>
<tr>
<td>drinking water</td>
<td></td>
<td>rainwater</td>
<td>10%</td>
</tr>
<tr>
<td>shower/bath</td>
<td>25%</td>
<td>storm water</td>
<td></td>
</tr>
<tr>
<td>kitchen/Washing</td>
<td></td>
<td>groundwater</td>
<td>90%</td>
</tr>
<tr>
<td>toilet flush</td>
<td></td>
<td>sea</td>
<td>0%</td>
</tr>
<tr>
<td>irrigation</td>
<td>75%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Matrix shows simply the relations between consumption and resources. Themes and values can be changed for analysis.

The best results here: changing of irrigation practice and reducing of groundwater consumption.

**Use of alternative water resources**

All over the world, water resources have to be managed sustainably. Effective management has two conditions, technical systems and consent of the community.
ALTERNATIVE RESOURCES

1. Rainwater and storm water management
2. Desalination of sea water
3. Reuse of domestic water (which is only a small percentage of the total demand).

USAGE OF RAINWATER AND STORM WATER

<table>
<thead>
<tr>
<th>System</th>
<th>Benefits (pros)</th>
<th>Risks (cons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment systems</td>
<td>• Renewable water resource</td>
<td>- No groundwater recharge</td>
</tr>
<tr>
<td></td>
<td>• Everywhere available</td>
<td>- Disadvantage for neighbours</td>
</tr>
<tr>
<td></td>
<td>• Easy to build</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Low costs (long time)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Can be built step by step</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Low maintenance cost</td>
<td></td>
</tr>
<tr>
<td>Storage reservoirs</td>
<td>• No water purification</td>
<td>- Evaporation (ponds)</td>
</tr>
<tr>
<td></td>
<td>• Irrigation water reservoir</td>
<td>- Biology (roots, germs)</td>
</tr>
<tr>
<td></td>
<td>• Low costs (long time)</td>
<td>- Swelling of soils and damage of rigid reservoirs</td>
</tr>
<tr>
<td></td>
<td>• Low pumping costs</td>
<td>- Sedimentation</td>
</tr>
<tr>
<td></td>
<td>• Low maintenance cost</td>
<td>- Drying of mineral sealings</td>
</tr>
<tr>
<td>Other methods</td>
<td>Not discussed</td>
<td></td>
</tr>
</tbody>
</table>

Desalination and reuse of water

<table>
<thead>
<tr>
<th>System</th>
<th>Benefits (pros)</th>
<th>Risks (cons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination</td>
<td>• Inexhaustible water resource</td>
<td>- High initial investment for the plant (+ site)</td>
</tr>
<tr>
<td></td>
<td>• Low cost for drinking water production (50 Rs/l)</td>
<td>- Maintenance costs</td>
</tr>
<tr>
<td></td>
<td>• Groundwater recharge</td>
<td>- Pipeline and distribution system needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Energy + chemicals needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Disadvantage for other alternatives</td>
</tr>
</tbody>
</table>

REUSE OF DOMESTIC WATER

<table>
<thead>
<tr>
<th>System</th>
<th>Benefits (pros)</th>
<th>Risks (cons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purification + reuse</td>
<td>• Using for toilet flush</td>
<td>- High biological risks by using for washing</td>
</tr>
<tr>
<td></td>
<td>• Groundwater recharge</td>
<td>- High costs for purification plant, maintenance and double installations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Small resource</td>
</tr>
</tbody>
</table>

FIRST RESULTS

- The installation of a desalination plant would be one way to give Auroville a sure drinking water resource (not irrigation water).
- The reuse of domestic waste water or the use for water harvesting can only meet a small part of the water demand. On the other hand it can be one useful place in the puzzle of water management.
- An increasing usage of rainwater and storm water can be realised soon and with less money.
- Local solutions for catchment and storage are to be created (decentralised system).
- The aim cannot be to catch and store every drop of rain (neighbours, groundwater).
- Storage reservoirs must be easy to build and must have a maximum durability.

Hence in my view, rainwater / storm water management has to be pushed forward and every person of the community must help to save water.
STORAGE SYSTEMS – CISTERNs

In the first day of this 3 day seminar we heard about traditional ways of storing water through cisterns and now we show you a very modern cistern.

ADVANTAGES OF CISTERNs
- No loss of water to evaporation
- Water is protected against exposure to sunlight
- Water stays clean for a long time

3 OPTIONS TO BUILD CISTERNs

<table>
<thead>
<tr>
<th>Bricks</th>
<th>Quality management is needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>High costs and often low durability; risk of fissuring and cracking (swelling soil, …) with following crack corrosion and root penetration</td>
</tr>
<tr>
<td>&quot;filled ditches or pits&quot;</td>
<td>A new chance for water storage under paths, roads, places, this shown below.</td>
</tr>
</tbody>
</table>

A schematic c-s looks like this:

The grid box is sealed and there is an extraction well next to it that extracts water; there is a hollow where rain/storm water flow in and reach the percolation pipe and flow into the grid box and fill it.

We constructed this cistern in Germany in winter. The grid boxes are in a plastic foil sealing; after closing the grid boxes, we have filled the gaps around the covered/ sealed grid box with sand and finally packed at least a metre of soil above the boxes. There are wells for extraction of water and also for cleaning and control.
MATRIMANDIR LAKE AS AN EXAMPLE FOR LAKE SEALING

Solutions possible are:

- Vacuum sealed clay (expensive)
- Mineral sealing with red laterite soil + bentonite
- Geomembranes (foil, bentonite-filled geotextile = BFG, as shown below – 2 layers of textiles in the top and bottom and bentonite filling in between and plastic strings that connect the textiles and hence you get a sandwich-structure).

We made in 2003 some test ponds in Matrimandir, to find out whether the local laterite is usable for making sealings.

We mixed some bentonite into the red laterite. Then we have moistened our mixture to compact it, but the sunlight here makes the mixture very dry very soon and so we had to moisten it several times.

This is what the Matrimandir actual lake would appear in cross-section. We have to consider that the sea level will go up and down – we have seen that laterite can be used as a sealant in our test pond and we have granite blocks with pebbles/gravel between the blocks. At the lower level, where the slope is very steep we can use the grid baskets/boxes, to protect the mineral sealing.

RESULTS

- storage water of cisterns and ponds can be used best for irrigation to reduce the enormous groundwater consumption
- it is possible to use the local laterite soil for sealings
- to construct mineral sealings requires better machines and working at night
- the use of geotextiles and geomembranes can facilitate constructing the sealings
- a test-section of the lake should be built to get experiences about best practice.

CONCLUSION

- Auroville and the region need water management with more storage systems to give aquifers a chance to regenerate
The before and after pictures show:

- The way to a sustainable water management for Auroville is still long. But if one wants to avoid "water wars", one has to start immediately and has to use every technique to reach this aim as soon as possible.
Auroville in the last 25 years has done a lot in bunding, and afforestation – to what extent is the drop in aquifer due to what Auroville uses or what is being used in the villages/bioregion – is Auroville extracting more than the recharge? Are we conserving water that can be used elsewhere? What is the economics of water balance in this area?

Auroville is not an island; by even doing everything to recharge ground water will not reverse the situation; but Auroville has a moral character and people will look here and will be an example.

What is the cost of this box?
Cost of this box – 45 euros per box; 90 euros per m³ – it is possible to produce in India to lower the cost and the life of this system is 100 years.

Participant’s comment: Water needed for irrigation of Matrimandir is enormous compared to the number of people in Auroville.

How to harvest rainwater in the Matrimandir area – structure, oval, amphitheatre? In the gardens it is not possible, because if the landscaping is done well you will have percolation and not run-off.

What is the performance of the test-clay of red laterite mixed with bentonite in the test pond?
Zero leakage; we compared the evaporation with an evapo-meter and put a barrel inside and measured the water temperature inside the barrel and outside and found it the same and the water level inside the barrel and pond was the same.

Participant’s comment: While demand is a crucial factor, management is a key factor – three quarters of the issue is the management and not the availability of water. Scarcity is not the issue, as much as effective usage is.

What is the purpose of the layer of gravel in the bottom level of the lake?
This is for the capillarity of the sealing layer – if it gets dry the humidity still remains below the gravel.

Participant’s comment: Using the same principle of sealing using bentonite with laterite, we made 2 waste water treatment plants and these work well and we have a tremendous saving of structural costs. Solar Kitchen is the bigger one and there is a smaller one.
Sustainable Water Resource Management in Sanitation an Overview

Lucas Dengel

Dr. Lucas Dengel, German by birth, first visit to Auroville in 1973, stayed in Auroville from 1975 – 79, worked in gardening, crafts units, and then at the Auroville Health Centre. Went into formal medical studies in Germany from 1979 – 85, returned to Auroville in 1988. Joined Auroville Health Centre, worked administratively and clinically, and developed, jointly with colleagues, a preventative and educational program in twenty villages, including provision of water supply facilities and public toilets. Motivated by clinical challenges, Lucas increasingly focused on environmental issues, and dropped clinical medicine in 1998. Coordinated setting up a decentralized wastewater treatment plant for Health Centre and Auroville-Aspiration, organized a composting project for Kulipalayam village to sort out solid waste management issues, collaborated with farmers on issues of composting and organic farming, and started a demonstration farm for organic cashew cultivation in 1988. In 2000 founded AuroAnnam, a company promoting organic farming, trading organic food, promoting EM (Effective Micro-organisms) technology, providing consultancy in organic farming, solid waste management and effluent treatment, and promoting decentralized wastewater treatment and ecological sanitation.

Grace, Auroville – 605 101,
Tamil Nadu, India.
Phone : 413-2622 044
e-mail: lucasdl@auroville.org.in

Abstract

Modern sanitation makes liberal use of water to achieve its goals, i.e. hygiene of living conditions and disposal of liquid and solid wastes including human excreta. It is recognized that conventional approaches to these issues, on the one hand, contribute to environmental stress, and, on the other hand, are wasteful in water use, and hence non-sustainable.

This presentation introduces concepts of sanitation, hygiene, and wastewater treatment that aim at conserving water resources and an ecologically responsible water use. This includes technologies which require little or no water, which do not burden the self-cleaning mechanisms of soil, groundwater or natural water bodies, and which recycle water maximally.

Ecological hygiene management dispenses with the use of biocides and disinfectants and thus reduces toxic pollutants in water and soil. It aims at creating a beneficial microbial environment which spontaneously controls pathogens and provides full hygienic and aesthetic benefits, while facilitating treatment of wastewater downstream.

At the upstream end of human waste disposal the eco-sanitation concept favors flush-free urinals, minimal-flush toilets or water-less composting toilets, separation of urine and feces for the retrieval of nutrients for farming and gardening and for recycling of liquid and solid wastes.

Conventional wastewater treatment systems favor a centralized approach with extensive sewerage lines, highly engineered treatment plants requiring chemical inputs, constant energy supply and high maintenance. Decentralized treatment systems decrease the need for sewers, maximally utilize natural slope for flow, operate without chemical inputs, and are low in energy and maintenance requirements.
(1) INTRODUCTION: A HISTORICAL PERSPECTIVE

HUMAN WASTE DISPOSAL AND DISEASE CONTROL

The historical period of the European Middle Age lasting from around 500 to 1,500 AD evokes, in regard to public hygiene and sanitation, pictures of filth and stink. The dark ages of bad sanitation lasted well into the 19th century, and technical progress initially did not at all counteract ill-health, but rather contributed to its spread. Cholera has always been an endemic of South East Asia, it has always been at home here. In 1817 an epidemic wave of cholera moved to the West, with pilgrims to Damascus, Mekka, Alexandria. From the Middle East northwards and westwards, in 1830 killed 4,500 people in Moscow, and went with the soldiers of the tsar to Prussia. In 1831/32 Hamburg and Berlin were badly affected, the disease reached Duesseldorf at the Rhine in 1832. The next epidemic wave of cholera hit Germany in 1848, Prussia counted 85,000 cases and Berlin 5,000 dead. While Hamburg and Munich suffered, Nuremberg which is not situated at a major river had had no contact with the disease. This changed when the railway track from Munich to Nuremberg got built in 1852. From now on a travel between these towns took less time than the average incubation time of cholera i.e. two days. Passengers entering the train infected in Munich manifested and spread the disease in Nuremberg.

The great bacteriologists of the 19th century, such as Virchow (1821-1902), Pasteur (1822-1895) and Koch (1843-1910), not only engaged in research and clinical medicine, but in public hygiene, policy, and in the engineering of sanitation facilities.

Amongst medical historians it is acknowledged that it was not the development of medicines that halted spread of diseases and epidemics, but improvements in sanitation including water toilets and sewerage systems, and improvements in nutrition made widely available. Vaccines, antituberculotics, antibiotics etc. were developed when infectious diseases were statistically already on the decline.

Nowadays the affluent West (or North) is proud of its living standard, its public hygiene and control of epidemics, and its civil engineering for transport and treatment of human wastes. It has not yet become a common realization that conventional sanitation systems regardless of their efficiency are always extremely wasteful, wasteful in material investments, in water use, and in energy use.

What is true for the disposal and treatment of human waste (and for the disposal and treatment of other liquid and solid wastes as well) – i.e. wasteful and non-ecological use of water and resources – is also true for hygiene management.

BREAKTHROUGH IN HYGIENE FOR SURGERY

Only when chemists and physicians discovered disinfectants (Semmelweis, Lister), surgery had a chance to develop. In 1850 a caring and conscientious physician was obliged to advise his patients not to undergo surgery as more patients died from surgery than from the diseases for which surgery was applied. With the discovery of biocides and the development of disinfectants surgery became safe and an actual treatment option. Modern surgery developed from about 1880 onwards and is definitely a post-Listerian affair.

Swabbing a patch of skin with a disinfectant to allow the surgeon to invade the body without causing an infection has been a breakthrough for surgical history and can obviously be a beneficial procedure for the individual patient. However, if applied to our bodies in general, to our households, to urban environment, and to the environment at large, the same procedure becomes completely nonsensical and positively harmful.

The use of antibiotics and disinfectants in hospitals has led to the development of the
most virulent pathogens against which medicine has no cure. The use of disinfectants and
detergents in households and human environment has led, or at least greatly contributed, to
the development of allergies and diseases that are difficult to treat. And, outside the realm of
sanitation and public hygiene, the use of biocidal chemicals in industrial processes and agri-
cultural practices has lead to a deadening of the soil and to pollution of groundwater. Not
only have we massively increased the pollution load that rivers and oceans are expected to take
care of, we have also to a large extent actively destroyed nature’s capacity to treat our wastes.

PRESENT SCENARIO - SUMMARY
Currently about 2.4 billion people lack access to basic sanitation, but actually most of humanity
is affected by a global sanitation crisis: 70% of the sewage systems in the world, serving about
1 billion people, are dysfunctional. Even of 540 European Union cities, only 79 have advanced
sewage treatment and 45% have either no or incomplete treatment. In 2002 the European
Commission took legal action against France, Greece, Germany, Ireland, Luxembourg, Bel-
gium, Spain and the United Kingdom for failure to implement various environmental laws for
water quality protection. The city of Brussels was one of the worst defaulters. In developing
countries 80% of all diseases and 25% of all deaths can be attributed to polluted water. The
need for hygiene and sanitation is indisputable and is being made focus of various interna-
tional and national campaigns and programs.

The present scenario of sanitation and hy-

giene is characterized by
- the use of biocidal hygiene
inputs which are a burden on the environment,
- wasteful use of water,
- unnecessary use of fresh drinking water,
- energy-intensive and expensive wastewater treatment,
- waste of plant nutrients and organic matter,
- due to capacity constraints of the operators, frequent breakdown of systems resulting in transfer of
pollution instead of elimination, and
- due to discharge of ill-treated sewage into rivers and water bodies, massive pollution down-stream by nutrients
(leading to eutrophication), organic matter, and hazardous substances.

This presentation introduces concepts and technologies that offer solutions to the above-de-
scribed problems, which need to be made part and parcel of a sustainable management of wa-
ter resources:
1) decentralized ecological wastewater treatment,
2) ecological sanitation, and
3) hygiene management with beneficial micro-organisms.

The presentation does not address the issue of industrial water pollution specifically.

(2) DEWATS - DECENTRALIZED WASTEWATER TREATMENT SYSTEMS

CENTRALIZED WASTEWATER TREATMENT - ITS DISADVANTAGES
In conventional water-borne disposal of hu-
man wastes and treatment of wastewater, large
amounts of clean water are used to flush and
transport human waste to distant sites for treat-
ment. The disadvantages of centralized large
sewage treatment plants and extensive sewer-
age are as follows:
- Investment costs are high, in particular in regard to sewerage which can cost up to five times more than the central
  sewage plant itself.
- Energy requirements are high, either for pumping sewage uphill in the
course of extensive sewer lines, or for
the operation of the treatment plant.
- Accordingly operation and
maintenance costs are high, not only
because of energy requirements, but
also because treatment systems depend
on a range of technical gadgets that
require attention and skilled labour.
- The longer the sewer lines, the
more chances for leakage, i.e. for
contamination of groundwater or piped
drinking water, and hence for the
spread of disease.
- Like water-borne sewage systems in
general, it depends on large volumes
of water, and mostly uses water of
drinking water quality for the flushing
of toilets: it wastes clean water.

FIRST CORRECTIVE MEASURE FOR WATER-BORNE
SEWAGE SYSTEMS: SEGREGATED SUPPLY SYSTEM
FOR WATER OF DIFFERENT QUALITIES

A first corrective measure to counteract waste
of high quality water is the installment of sepa-
rate plumbing for the supply of water that need
not be of drinking water quality, e.g. for floor
washing, toilet flushing, gardening. Theoretically
segregation may be into more than two
water qualities, in practice two are more easily
feasible and affordable.

Further corrective measures will be short-
ening of the sewer lines, and treatment of
wastewater with lowered investment costs,
lesser energy requirements, lesser operational
costs, and appropriate re-use of treated water.
If this is implemented by setting up a de-
centralized wastewater treatment plant, it will be
easy to re-use treated water on site and in the
households via segregated plumbing. Treated
wastewater can not only be used for garden-
ing, but, depending on treatment quality, also
for toilet flushing, general room hygiene,
laundry and bathing.

DECENTRALIZED WASTEWATER TREATMENT –
ADVANTAGES AND TECHNICAL COMPONENTS

Decentralized wastewater treatment offers a
range of technical and ecological advantages,
and additionally addresses the crucial factor of
decentralization of responsibility. While enor-
mos funds are being spent on setting up cen-
tral treatment plants, and the same plants often
become sources of pollution, and governance
systems are overwhelmed by their upkeep and
operation, dewats play a major role in passing
on the control over disposal of human waste to
groups and associations of citizens, in institu-
tions, hostels, hotels, residential blocks and ar-
eas, and villages.

- Decentralized wastewater treatment
  systems, short “dewats”, provide
treatment for wastewater flows from 1
to 500 m³ per day, from both domestic
and industrial sources.
- dewats are based on a set of treatment
  principles the selection of which has
been determined by their reliability,
longevity, tolerance towards inflow
fluctuation, and because they dispense
with the need for sophisticated control
and maintenance.
- dewats work without (or minimal)
technical energy, and cannot be
switched off intentionally. Thus they
guarantee permanent and continuous
operation. However, fluctuation in
effluent quality may occur temporarily.
- Most dewats modules require little
  space, are inexpensive in investment
and extremely cheap in operation and
maintenance.
- dewats facilitate re-use of treated
  water on site and are ideally combined
with segregated water supply.
- dewats can be well integrated into
  an aesthetic pleasing rural and urban
  landscaping.
- dewats are not everywhere the best solution. However, where skilled and responsible operation and maintenance cannot be guaranteed, they are the best choice available.

Technically, dewats involve four treatment steps and systems:
- Sedimentation (and primary treatment) in ponds, septic tanks, or Imhoff tanks.
- Secondary anaerobic treatment in fixed bed filters or baffled septic tanks (baffled reactors).
- Secondary or tertiary aerobic / anaerobic treatment in constructed wetlands (subsurface flow filters).
- Secondary and tertiary aerobic / anaerobic treatment in ponds.

Of these, constructed wetlands require the largest area (i.e. 1 m² per m³ daily flow), are the most expensive to construct, and may loose large amounts of water by transevaporation. Wherever space availability is a constraint or land prices so high that land use for wastewater treatment is regarded as prohibitively uneconomical, dewats modules of lesser space requirements should be considered.

There are other examples of a community dewats in Auroville, for 200 users and also a large dewats at Aravind Eye Hospital Pondicherry, for 310 m³ wastewater volume per day; segregated water supply plumbing installed.

Dewats for a single household in Auroville

(3) ECOSAN – ECOLOGICAL SANITATION

For many years the United States Census measure of progress was the number of flush toilets in the country. Any departure from this was looked at as a step backwards. Water-borne disposal of human waste depends on large volumes of water – 20 to 25 percent of indoor wastewater generation is from toilet use – and, as said above, in general water of drinking water quality is unwisely taken for toilet flushing and other uses which do not require this water quality. Conventional toilets use 15 to 20 l for one flush, i.e. to transport 200 gm of feces (average amount per capita per day). Presently available water-saving toilets use volumes in the range of 5 to 7 l.

Speaking of human wastes and toilet facilities, the issue is not only one of health and hygiene, and of environmental sustainability, but also one of human dignity. This presentation, however, deals with technical aspects mainly. It starts
from the assumptions that maximal benefits of hygiene, water conservation, and nutrient recycling, are to be matched, and that at every socio-economic level appropriate technical solutions can be developed.

ECOLOGICAL CHALLENGE

Additionally to the above-said disadvantages of water-borne sewer systems and centralized treatment plants, the conventional approach generally does not make use of the nutrients in human waste and thus contributes to the impoverishment of soils. Neither do conventional pit latrines – the “drop-and-store” type – rectify this deficiency. Pit latrines and seepage pits are also not appropriate in areas of high water tables and increasing population density. The approach of ecological sanitation – short “ecosan” – is an effort to replace a linear end-of-pipe technology aiming to get rid of waste with a system that closes material-flow cycles.

Handling of human feces poses health risks and hence requires thorough treatment. There are basically two options: Either it is used for generation of biogas from anaerobic digestion. Or it is dehydrated and/or composted and then, like other types of compost, is easy to handle, provides small amounts of nutrients, improves soil structure and increases water retention capacity.

Urine contains the highest proportion of nutrients in human excreta, directly available to plants and as effective as mineral fertilizers without having their disadvantages. It contains about 90% of the total nitrogen, 55% of the total phosphorus, and a similar portion of the potassium in human excreta. The urine produced by one person per year contains 4 kg N, 0.365 kg P and 1 kg K. As urine is a sterile product of the human kidney, there is, in contrast to feces, little need for its sanitization. Urine can be collected separately with the help of separation toilets or waterless urinals.

The nutrients in human waste per capita per year are sufficient to produce 250 kg of cereals. One person can provide enough nutrients for 200 to 400 m² agricultural production area.

Greywater from washing, rinsing, showers etc. is the largest fraction of the total wastewater flow. It has only a very low nutrient content and needs to be treated to a quality at which it can be used for irrigation or for groundwater recharge.

Ecosan remedies two unsustainable defaults of conventional wastewater treatment: waste of water, and waste of nutrients and organic matter.

ECOSAN – TECHNICAL OPTIONS

Waterless urinals operate without flushing and do not generate any unpleasant odor. They either are equipped with a trap filled with a sealing agent, or with a simple curtain-device of material closing against odors from the sewers. The first type is more expensive and difficult in maintenance, the latter type is practically free of maintenance and hence extremely cost-efficient. Cleaning of the urinals is being done in the usual way, as in the case of flushed urinals. (Naturally, it would be wise to combine the system with a more ecological hygiene input – see below.) Waterless urinals have been installed in many parts of the world, the curtain-seal model has been developed in South Africa and is in use in several hundreds of toilets, in universities, restaurants etc. without any complaints.

Separation toilets separate feces from urine in order to treat the two waste products separately. Feces may be composted, and urine, after minimal treatment, channeled to agricultural use. Rustic low-cost models of this type have been successfully set up in villages in Tamil Nadu, and the users enjoy odor-free toilets and green kitchen gardens, and demonstrate their appreciation of the benefits of hygiene and gar-
den productivity by maintaining their toilets clean.

Bringing urine to agricultural production sites requires transport. Considering the energy consumption for this transport compared to wastewater treatment and production of mineral fertilizers, it is still economical to transport urine 200 km.

Composting toilets can operate if fed with urine and feces (and small amounts of washwater), or they receive feces only and composting becomes a simple operation manageable by a willing user. Fully composted human feces can be handled like any other compost. Composting toilets make sense where compost is desired or welcome, or where collection of compost is feasible and makes economical sense. In South India there are several examples of composting toilets, at the level of individual households as well as of public facilities. (In Auroville we have a few composting toilets in individual households.)

Vacuum flush toilets are used in aeroplanes and on ships. (Vacuum flush system is a misnomer as it does not operate with a vacuum, but with suction from negative pressure.) They operate with minimal amounts of water (1 or 2 l per flush), but require energy supply. Actual energy requirements are minimal, and wherever energy supply is assured (for reasons different from flushing toilets), vacuum sewerage has great advantages: It needs small-diameter sewer piping only; and, as operation does not depend on gravity flow, in old buildings to be retrofitted or in conditions where continuous downward slope of sewers is not feasible, the technology is an ideal option.

Presently Scandinavian countries are leading in design and development of ecosan equipment, manufactured in porcelain (for the toilet bowls) and high-quality plastics (for composting chambers etc.), but similar equipment in simpler versions and cheaper materials has been developed in other parts of the world, including China and India. Indian sanitary ware manufacturers have expressed their readiness to go into serial production of ecosan toilets if and when informed about the demand of the market. Plastic manufacturers are also ready to enter the market.

**Examples in pictures**

*Separation toilet – porcelain sanitary ware in Europe*

*Composting toilet – model available in Europe and North America*

(4) **EcoLOGICAL HYGIENE – THE USE OF EFFECTIVE MICRO-ORGANISMS (EM)**

Medical science, in the course of the last decades, has realized that the wide-spread use of disinfectants and biocides in hospitals has provoked the evolution of the most virulent
and treatment-resistant pathogens imaginable. A pneumonia caught on the road might be well treatable with an antibiotic, a pneumonia caught in hospital is likely to be untreatable by any antibiotic and might kill the patient.

EM stands for Effective Micro-organisms. It is a product developed by Japanese agriculturist Prof. Teruo Higa in the seventies and eighties and presently used in over 150 countries. It is produced in about 50 countries including India. EM contains lactobacilli, yeasts, and photosynthetic bacteria. These organisms are sourced from food processing and nature, are safe to handle, harmless to human health if ingested, and beneficial to man and environment. The breakthrough of EM does not consist in finding or identifying particular microbes, but in the discovery that a symbiotic culture of these organisms attains new capacities beyond expectation, and in finding an appropriate culture medium that makes the product into a marketable product with several months of shelf life.

Originally EM was developed for agri- and horticulture, and then it was found to be effective also in animal husbandry, aquaculture, composting and solid waste management, sewage and effluent treatment, and environmental regeneration. The capacity of EM to control odors, in particular if generated by bio-degradable substances, fast and efficiently, and thus to eliminate or drastically decrease all nuisance and risks affiliated with putrefying organic debris, such as flies, cockroaches, rats, spread of pathogens etc. make EM an ideal agent for hygiene management.

We have observed that a sewerage inspection manhole – which usually is the ideal habitat for cockroaches – after two weeks of EM use in the kitchen drain was completely free of cockroaches. A household that used to call a pest control agency for spraying against cockroaches every three months has, after several weeks of EM use for floor hygiene, become cockroach-free while neighboring households left and right continue to engage chemical warfare against the same pest.

EM – and potentially similar products – could well replace the use of detergents, disinfectants, pesticides etc. in the hygiene management of toilets, bathrooms, tiled walls, shelves, cupboards, floors, floor mats and carpets. Its use would result in the desired hygiene benefits, be cheaper than conventional inputs, safer to handle – even beneficial to the skin of the handler –, and generate multiple benefits downstream: enhance sewage treatment, stimulate beneficial micro-organisms in soils, revive damaged en-
environment and stimulate biodiversity in water bodies.

Basic practical steps are as follows:

One volume part of stock solution (the product available from the manufacturer) is mixed with one volume part of molasses or jaggery and 20-30 parts of water. Fermentation for about one week under anaerobic conditions – and till a pH of 3.5 has been reached – makes activated EM solution ready for use. For practical application activated EM solution is diluted with water in the range of 1 into 100 for hygiene management, 1 into 1,000 for agriculture, and mixed into effluents at a dilution of 1 into several thousand for sewage and effluent treatment.

Naturally, EM technology is an ideal combination with dewats and ecosan technologies. Independent of this, EM can assist any sewage treatment and reduce COD, BOD, dissolved and suspended solids; it decreases sludge formation and the need for de-sludging; it may decrease the need for aeration and thus energy consumption; and it counteracts corrosion of sewer systems and thus decreases maintenance costs. EM has been used for sewage treatment from 1990 onwards and is successfully used in a growing number of treatment plants in India.

(5) Conclusion

Following the stream of human waste disposal from downstream to upstream, this presentation has introduced concepts and technologies that have great potential to transform the field of hygiene and sanitation into a more ecological and sustainable scenario. Some of these technologies are well developed, others are in development. Further development, implementation and utilization of these technologies require courageous collaboration of innovative players, architects, engineers, builders, municipal authorities and citizens. In an overall strategy for water resources management, they should be utilized as widely as possible.

Q/A

*By how much does the water treated from a dewats plant reduce the demand for fresh water in irrigation?*

In the big plant in Aravind Eye Hospital, all their irrigation needs are met by this water; in Auroville, by around 60% reduction – not only recycling of water, but the system making use of less water also.
Legal Aspects of Water Resource Management

Shobha Iyer

Citizens, Consumer and Civic Action Group (CAG)
8, 4th Street Venketeswara Nagar
Adyar, Chennai- 600 020, Tamil Nadu, India.
Phone: 44- 24460387
Email: cag@xlweb.com

ABOUT CAG

- CAG was founded on 7 October 1985
- Non-profit, non-religious, voluntary and professional citizens group based in Chennai, India
- Twice awarded GoI ‘National Award for Consumer Protection’:
  - 1989 (Second Prize)
  - 1992 (First Prize)

Activities

- Runs a free legal / consumer clinic
- Represent citizens in policy making agencies
- Participate in exercises aimed at empowering elected representatives, students, advocacy groups, NGOs and the general public
- Advocacy tools range from consumer education in schools to signature campaigns and public interest litigation

Policy Research, Advocacy

- CAG research and studies on policy have assisted in the development of citizen-friendly policy prescriptions in local and national fora
- Some recent interventions include:
  - Arguing against the demolition of the Queen Mary’s college as being part of Chennai’s heritage
  - Developing an improved health care waste management plan for Chennai city
  - Helping set service delivery standards in telecom, broadcasting and electricity sectors

INTRODUCTION

*Cujus est solum est usque ad coelum, et ad inferos* – this is a Latin Phrase which means – “he who owns the land, owns the air above and the ground beneath.”

This is the basis of land and water laws. Water laws have never been developed on its own – the reason being that they were always linked to the land. You would find more emphasis on land development, land laws than water laws; water laws have been developing off and on but the basic premise still remains today as ‘he who owns the land, owns the air above and the ground beneath’

DOCTRINE OF PUBLIC TRUST

- The ancient Roman Empire had a legal theory known as the ‘Doctrine of the Public Trust’

Primarily rests on the principle that certain resources like air, sea, waters and the forests have such a great importance to the people as a whole that it would be wholly unjustified to make them a subject of private ownership. All these resources are common to everyone.

Today we have a situation in India where certain landmark judgements in the Supreme Court brought to the fore, repeatedly these issues –
1 The Public Trust Doctrine – there is a trustee who is going to look after water
2 Inter Generation Equity – there should be enough for the next generation; hence we use what we need, and we save and conserve for the next generation
3 Precaution principle – we take care of our resources, we conserve them, develop them and see how we can leave more for the next generation.

Because of the legal judgements these three are called judiciously developed principles and this leads on to the next basic principle that:

- The right to water as a part of the right to life, is a fundamental right
- The right to clean water (Environmental Protection Act and Water Pollution Control Act) – we have reached a state where we have contaminated our water to such an extent that people have had to take recourse from courts demanding clean water. We have seen in the papers presented in the last 2 days, large-scale contamination of ground water and governments literally supplying this contaminated water to citizens, as there is no choice – because it is the only source.

**LEGAL ASPECTS**

- The Constitution defines – allocation of functions relating to water resource development between Central and State Governments separately. This line of divide becomes more and more difficult to define.
- Water has been designated on the State List – the controller/eminence domain is the State.
- Central intervention is prevalent only to regulate the development of Interstate Water Disputes: since many parts of India have had consistent drought for the last few years, sharing of water between rivers that cross 2-3 states, has become such a huge problem, that the centre has had to intervene; we have River Water Boards, Inter-State Water Disputes Act.

Tamil Nadu has a problem with Karnataka to share the Kaveri river water; and also with Kerala; so did Punjab and Haryana have a problem of sharing water. When the interstate problems get political mileage or coverage, then the Centre imposes its views – and hence today we have the issue of the Centre trying to bring in the concept of ‘river-water’ sharing under its concurrent list- concurrent list, means you amend the law and say that the State and Centre will have an equal say in the sharing of water. This complicates things more but unless they mandate a law it is going to be very difficult to resolve issues today.

**STATE POWERS**

- State has absolute powers over water and its absolute right to regulate its appropriation, use, and to change entitlements and rules of allocation at its discretion, except when the Centre intervenes for interstate river water issues.
- Legislated Irrigation Acts – acts that deal with surface water – empower the State to regulate the development and use of surface water in their territory (the State decides who is going to be given, how much, for what time, how will it be given) e.g. a river, duct, or a lake or body which is used for irrigation purposes, you would have to
map out the area and the people living around it would be registered as those entitled to this water; these people will get a particular share of water depending on what the Government decides i.e. backed by legislation and executive orders setting out the rules. Hence surface water irrigation completely depends on the state’s discretion to provide water.

- No formal law specifying the form and structures of organisations to manage individual surface systems – i.e. state can keep changing its rules depending on the pressure on it to provide to whom. This is also valid for individual surface systems.

- The government has assumed direct and full responsibility for planning, designing, construction and management of new surface water projects /large tanks and other old local works.

- The state is under no legal obligation to consult or involve those affected (even the beneficiaries).

- Land Acquisition Act empowers the government to acquire land for public purposes on payment of compensation e.g. case study of water-starved Chennai going to ground water ‘rich’ areas in the outskirts, and the land being acquired there by the Government so as to meet the drinking water needs of Chennai.

- Costs for irrigation works are taken from public funds – nowhere is anyone consulted The state develops, controls, regulates and administers – there is no public participation.

- Older smaller works are managed by institutions of the user communities based on their customary rules - this refers to small rivers, tanks, oorani (small ponds) which have for years given adequate water to the area around it –this old pond has some customary rules that it follows for years regarding how much water will each person get, what is the cess, what are the penalties, etc - here there is no state intervention, but yet the state owns that water body. Ooranis are used to provide water for drinking purposes.

**INDIVIDUAL OWNERSHIP**

- Indian Easements Act 1882- the right of extraction and use by a person who owns the piece of land without any limits subject only to the condition that such extraction must not adversely affect the availability to neighboring users.

- Recent regulations empower the State to control/regulate private exploitation.

**CENTRAL POWERS**

- The ISWD Act empowers the Central Government to set up Tribunals to adjudicate between two states.

- No such mechanism at the State level – if there is dispute between 2 districts there is no such tribunal set up – the state will decide by itself.

- Disputes keep increasing not only in inter-state but intrastate also.

**OTHER ASPECTS**

- International Treaties or agreements over rivers:
  1. Harmon Principle – which recognises the right of a region to use water, which flows through it
  2. Helsinki/Dublin Rules – optimum utilisation for common benefit
• National Coastal Regulation Zone Notification (CRZ) 1991 - we have state ownership of water, individual ownership of water, but we have one more law come in recently called CRZ Notification 1991 – this assumes a great importance to states having a coastal belt. Any industry or building which takes heavy drawal of ground water cannot do so without the permission of the state Government. This CRZ legislation came about because of shrimp farming – this was causing over-exploitation and salinity – the Supreme court decided to save the coastal belts from further environmental degradation and brought about this notification.

PROBLEMS
• States regulatory role has been totally abdicated; it does things on its own whims and fancies – constructing and operating systems which are blurred, totally evading responsibility
• Lack of clear defined framework of laws – arbitrary /opaque/ shortsighted
• Lack of clearly defined criteria of different claimants to common water resources; we have groups demanding for the appointing of a Regulator – whereby rules and laws will be clearly defined, where and who receives the water will be clearly mentioned
• Traditional users – courts recognise them as a valid basis
• Powerful interests/ political considerations
• No penal provisions are invoked
• Violations are often legitimised
• Commercialisation – this goes on even with Government support

• Privatisation – Aqua robbers in every state
• Aggrieved persons/groups can seek redress only in the courts.

NATIONAL WATER LAW
We need to have national law that will take over the powers of the state; how far will the states be willing to give up their powers? If we need uniformity we need a national law.
• Supreme Court directed the Union Government to constitute a Central Ground Water Board to legally regulate indiscriminate boring and withdrawal of water in the country.
• Draft Ground Water (Development and Protection) Rules - under the framework of the Environment Protection Act in 1998/2001- none of the States are interested in this and it is lying in the draft stage.

CONCLUSIONS
• Importance of water laws as an effective water management tool must be recognised in India – our conceptualization of water laws has been adhoc and based on short-term needs.
• Critical look at the gaps, weaknesses and inconsistencies in existing laws and regulations as well as their implementation.
• Multi stakeholder participation;
• Based on the principles of justice –serving the interests of efficient equitable and sustainable use of water.

ACTS GOVERNING WATER IN TAMIL NADU
• The Tamil Nadu Groundwater (Development and Management) Act 2003
• Chennai Metropolitan Area
groundwater (Regulation Act) 1987-
Amended in 2002
• Government felt it is necessary in the
public interest:
  – to regulate and control the
  extraction and use of ground
  water in any form and to conserve
  the ground water in the city of
  Chennai and certain revenue
  villages in Kancheepuram and
  Thiruvellore district.

Acts
• Permission to sink a well-open well
  / dug well / bore well / dug cum bore
  well / tube well.
• The authorities to maintain a register
  of existing wells, types of wells and
  purpose for which it is used.
• License – extraction or use of
  groundwater for commercial or any
  other purpose or for transporting
  ground water in a lorry.
• Prohibition of use of groundwater
  in certain areas – non potable use by
  industry when alternate sources are
  available from the authorised water
  supply agency.
• Extract water for use in swimming
  pool (except sports complexes with
  permission).
• Artificial recharge of the Arni
  Korataliyar (AK) basin and formation
  of a hydraulic barrier against sea water
  intrusion – by linking the AK basin at
  one or two points and building check
  dams to capture the excess flood water.
• Rain Water Harvesting.
Integration of Water Management into Planning Process

B.R. Balachandran, Sandeep Sethi & Rahul Sachdeva

Environmental Planning Collaborative (EPC)
701 Pratap, Usmanpura,
Ahmedabad – 380 013, Gujarat, India
Phone: 79 27553089
Email: bala@epoonnet.com

INTRODUCTION

- Environmental Planning Collaborative (EPC) is a not-for-profit organization, which seeks to improve planning processes through action research, advocacy and capacity building and working much with the government. We started with work through funding, but realized that such projects do not have sufficient impact and we started work hands-on with the government.
- EPC believes in continuously improving existing institutions and systems.
- This presentation explores systemic interventions for integrating water management into official/legally valid planning process at various scales viz. micro/urban level, city level and regional level.

CONTENTS

- Water management at micro/urban level
- Water management at city level
- Water management at regional level

MICRO/URBAN LEVEL

1. ISSUES

1. Deteriorating water bodies

The reasons for this are several and some of them are highlighted: within city or municipal areas water bodies were perceived as nuisance due to health and hygiene factors, gradually becoming dumpyards and breeding grounds for mosquitoes and flies, hence were deliberately filled up by the municipal bodies. There was no perception of water as a “Common Property Resource” and also there is no institutional framework to address the same. Another major issue was that the emotional connection between people and water bodies got lost when water was made available to the communities through pipelines inside their houses.

2. DEPLETING GROUND WATER – QUANTITY AND QUALITY

With rapid urbanization the demand of water is ever increasing. In absence of sufficient water bodies that can cater to the demand, the focus now has shifted to utilizing ground water. The increased dependence on ground water has led to its intense exploitation and water levels are receding at an alarming rate. Unplanned activities have resulted in deterioration of water bodies both in terms of its quality and availability.

3. STORM WATER

At present the tendency is to drain the rainwater out of the city/municipal limits as fast as possible. The current approach is a centralized system that channelizes storm water all the way to the nearest water body. Even for the present approach we don’t have sufficient information, as most of the contour maps are outdated and poor
in detail (micro level planning requires contour interval of half or one meter while the existing maps have 5 m interval). With development the topography of the city changes drastically – new roads, plots getting filled up, etc. These developments are not captured in topography maps and hence our drainage systems are not based on topographical changes resulting in water logging in low-lying areas.

4. Waste Water
Centralized systems are very expensive to build and hence new growth in internal and peripheral areas is deprived of any wastewater collection/treatment because of high capital and O&M costs. Wastewater is often released untreated thereby polluting either ground water or surface water bodies.

2. Interventions
We will see a few examples of types of interventions that were taken up to address the above mentioned issues.

1. Rejuvenation of Local Water Bodies
In an urban area if you want to protect or take care of a water body then you need to have publicly accessible developed open spaces (parks, gardens) around that water body, which will be used regularly and the deterioration will be ‘felt’ by the people. That is the only real way of protecting and conserving the body. In our planning process we try to ensure that development plans and micro-level plans would create such open spaces. The example shown in the picture is that of Vastrapur lake – this was surrounded by encroachments and the storm-water that drained into this lake was being blocked at different points due to developmental activities – AUDA (Ahmedabad Urban Dev Authority) gave better housing to all the people living in slums around that lake and also tried to clear up the drains leading into the lake – they tried this through trial and error without having accurate maps. Thus the water body was cleared from encroachments leading to its development and preventing from water being contaminated.

2. Conservation of Ground Water
The basic issues here are
a. Management of ground water withdrawal
b. Intercepting effluents contaminating water bodies
c. Replenishment of ground water – percolation wells at plot level/community level for aquifer recharge.

There has been a lot of effort on creating percolation wells for recharge of ground water but with mixed results. Sometimes these wells are not properly designed, therefore get choked
up and do not facilitate groundwater recharge. Due to this the investment goes waste without yielding desired results. Another major issue is misuse of percolation wells thereby posing risk of contaminating the ground water (in the early 1990’s there were cases of industries in south Gujarat boring deep percolation wells and putting in their effluents without proper treatment).

3. Rainwater Management
There has been a lot of discussion nowadays on tapping rainwater for augmenting ground water resources. In cities as well as rural areas rainwater can be effectively tapped by various methods as mentioned below:

a. Roof rainwater harvesting at building level
b. Percolation pit method
c. Borewell with settlement tank
d. Percolation pit with bore method
e. Channelize storm water into local water bodies.

4. Waste Water Management
Centralized wastewater treatment systems are capital intensive and high on O&M costs. The municipal authorities are not able to provide services to areas situated on the periphery and the waste water generated finds its way into nearest water body without treatment. Alternatively decentralized approach (DEWATS – Decentralized Wastewater Treatment Systems) can be adopted by such areas to treat wastewater near source and reusing treated wastewater for uses like landscaping, construction, etc.

3. Planning Tools
If one has the above ideas and want to put them in a planning process, one needs to identify an appropriate legal mechanism. In Gujarat urban planning takes place at two levels – Development Plan at the city level and Town Planning Schemes at the micro level.

Town Planning (TP) Schemes are land readjustment processes. An area, usually on the periphery of the city and coming under development pressure is delineated for planning. During the planning process, the entire land is vested in the agency which is preparing the TP scheme; and people continue to live and use that land, till the layout is finalized and “final plots” are given back to the people. The scheme is unique that you take a little bit of land from every person and give them back a more organized plot which is smaller and the land taken away is pooled and used for creating public infrastructure, including streets, open spaces, social infrastructure, etc.

Our effort at EPC has been to see how we can consolidate those open spaces and put it around existing/new water bodies. These public spaces can also be used for decentralized wastewater treatment and use that water for landscaping, etc. (e.g. a set of 5 TP schemes in south-eastern part of Ahmedabad, totaling to 5 km² of area – taking them together, we could consolidate the open space more effectively).

At the city level, we can put in specific proposals in the city’s Development Plan, to deal with micro-level problems e.g. – the Desalsar lake on the eastern side of Bhuj city, for which we had made the development plan – this shows how development plan proposes the redevelopment of recreational facilities (gardens/restaurants, etc.) around the lake. Including it in a plan doesn’t ensure that it gets done automatically. However, inclusion in the Development Plan provides a legal basis for anyone to act on it.

Another interesting project in Bhuj is restoring the traditional relationship between the urban community and water in the Hamirsar project. In the development plan we had pro-
posed the re-development of the space around the lake as a public recreational space. The proposal also included developing one side of the lake, which was originally meant for migratory birds – it was shallow enough for feeding and breeding. This project of rejuvenating the Hamirsar involved clearing channels leading to Hamirsar; treating wastewater flowing into the lake; developing lake edge; dredging and grading the lake and also creating islands for migratory birds.

**City Level**

1. Issues

1. Water Bodies and Storm Water Management

If we scale up the issues mentioned earlier, then most cities used to have a system of interconnected water bodies and courses to store and manage storm water. This over a period of time got deteriorated. City Development Plans don’t even recognize such systems and most of the cities do not have a management plan for their revival. The storm water drainage plans do not view the city as “catchments” and in fact the cities haven’t been re-surveyed after the British left, although the topography has changed a lot.

2. Ground Water

Monitoring or management of ground water is not mandatory for urban local bodies, and therefore the data regarding the same is very poor. Moreover, there is no legal framework at city level for regulating the exploitation of ground water resources.

3. Waste Water

As mentioned earlier the current approach of centralized treatment systems do not work because of inadequate networks, inefficient treatment plants and water intensive means of transporting waste to sewage treatment plants; plus the coverage being limited to city limits because of high capital and O&M costs.

4. Institutional Issues

Urban local bodies have limited capacity to address the problems that are emerging. Problems and their solutions often extend beyond city limits, particularly when dealing with flowing water. As the 73rd and 74th Constitutional Amendments have not been implemented fully, there is no institutional framework for conflict resolution at the city/regional scale (District Planning Committee, etc.).

2. Interventions

- Revive and maintain natural system of water bodies – for this there is need to carry out accurate topographical survey, map all catchments and turn them into projects to restore the natural system or create a new system.
- Conserve and manage ground water – this essentially means monitor ground water conditions and also regulate exploitation of ground water.
- Promote decentralized waste water treatment systems – we are trying to work with the DEWATS group in Bangalore and Auroville to figure out how to scale up the systems to be functional at city level i.e. define appropriate “units” for decentralization: spatial/community/administrative units and integrate these decentralized units within a city level system. This may involve balancing costs and charges i.e. if urban communities/institutions invest in water management, how it should reflect in the charges they pay the city. Moreover, we need to price the use of “treated” water very realistically.
to increase the incentive for local treatment.

3. Tools
It is important to include proposals in the City Development Plan, which is one of the legal documents prepared for the city as a whole. e.g.— the Bhuj Development Plan recognized the traditional system of water bodies and proposed its revival. The proposals were widely discussed in a consultative process, so that relevant stakeholders become a part of the planning process. Participatory interventions from Bhuj NGOs like Kutch Navnirman Abhiyan, Sahjeewan, have taken up a systematic exercise to revive the Hamirsar catchments as their initiative. The entire system was documented as it originally existed and how it changed with the city’s development.

REGULATORY INTERVENTIONS
The Development Control Regulations which contains the building by-laws, has in the case of Bhuj, introduced the compulsory requirement of seeking permission for ground water withdrawal, i.e. any person intending to withdraw ground water within the limits of Development Area shall make an application in writing. The regulations in Bhuj also specify that the quality of effluents that can be released into the ground/open; industrial effluents should follow Gujarat Pollution Control Board norms. However these regulations offer the challenge to find a system for monitoring ground and surface water conditions.

The other major tool is infrastructure planning – in Bhuj the detailed infrastructure plans were prepared by another agency – they have proposed a centralized system with a treatment plant at one end, but the DEWATS (decentralized) idea is picking up in Bhuj.

REGIONAL LEVEL
We started with 3 regional planning exercises one of which was in Kutch after the earthquake disaster, funded by the Royal Netherlands Embassy through the UNDP. The following shows our experience with Kutch.

1. Issues
Lack of holistic approach and perspective planning across space and time has resulted in increasing cross boundary conflicts amongst various users and sectors. At micro level the issue is more about providing safe drinking water, while at the regional level the issue is more between bigger players like industries and agriculture that account for most of the water consumption.

Sub-optimal use of surface water sources over the years due to advancement of techniques has shifted the reliance on to ground water and therefore resulting in over-exploitation. In addition to these there are many actors that play an important role in management of water resources but there is no synergy across various agencies.

2. Interventions
It is necessary to prepare basin-wide management plans that account for the entire hydrological cycle, looking at the balance between resource protection and resource utilization; balance between the economic growth and sustainability; stakeholder participation (involving the people is an absolutely essential activity) and integrated water management.

Within the Water Resources Action Plan, EPC used the concept of Water Balancing. For this the entire area was delineated into water basins and within each basin, we estimated what would be the demand and supply components.
Demand Components included
  - Domestic
    • Human, livestock population
  - Agriculture
    • Land-use
    • Seasonal crop pattern
    • Water demand projected based on crop water requirement
  - Industrial
    • Industrial Growth patterns
      • Type of industries and their water requirement
  • Supply Components included
    rainwater mainly being distributed into
  - Ground Water
    • Ground water recharge potential zones based upon sub-surface geological features
  - Surface Water
    • Medium and minor structures, check dams
  - Soil Moisture
    • Land use, soil associations
    • Water holding capacity of soil
  - Evapotranspiration losses
    • Vegetation coverage and losses from each type.

Doing this exercise for every basin – 78 in our case, we arrive at whether the basin is a water surplus basin or a deficit basin. In those basins where there is a surplus we see that the run-off has been mostly tapped, while the rest of the basins most of the run-off has not been tapped. Our assumption is that even if 50% of the un-augmented run-off can be tapped, then the deficit could be managed.

Another concept/exercise is the prioritization of water use across sectors – in the Kutch region it is known that approximately 85% of ground water extracted is used for agriculture, 10% for domestic use and rest 5% for industries. We have prioritized the water use across these sectors in all the basins and we find the priority as follows:

1. Domestic - firstly ground water for safety and then surface water
2. Agriculture - firstly utilizing runoff, surface water and then ground water
3. Industry - utilizing surface run-off, should avoid dependence on ground water as far as possible.

Another exercise is to identify/grade the whole area in terms of water recharge potential and on that basis plan what industries will come where – this requires a lot of hydrological, morphological and tectonic data. Based on this we can use the technology appropriate for water management – e.g. coastal areas will use technologies that will prevent salt water intrusion; soil conservation areas will use structures that will help that.

We have proposed a Decision Support System to simulate groundwater scenarios and support land use decisions (for a given quantum of rainfall within a region, what would be the likely scenario for different situations) – it will give assessment of basin-wide ground water recharge; 3D simulated model of the ground water aquifers of the region; trend analysis for ground water; a spatial ground water modeling system and based on this we can rationalize land use decision making for prioritization of water use across various sectors.

Right now we do not have regulation/policy on ground water extraction - we suggest that there should be regulatory (official) mechanisms and bodies (board) to manage ground water exploitation; regulate depth and density of bore wells to control the salinity ingress; electricity connection may be linked to the permission from the board.

Prioritization of drinking water supply interventions – by studying the mapping of delivery mechanisms (e.g.- breakdowns because of pipeline damages); mapping of efficiency;
mapping of vulnerability (to see areas that fall within a water supply scheme but still subject to water scarcity).

3. TOOLS
- Regional Plans
  - Some states have Regional Planning Acts, most don’t
- District Plans/ Metropolitan Area Plans
- District/ Metropolitan Area Planning Committee
  - Mandated by the 73rd and 74th Constitutional Amendments – not operational in most states
  - Watershed Management Plans of the DRDA
  - Various Government Schemes and Projects

CONCLUSIONS
Considerable experience and knowledge is available through numerous scattered initiatives on water management across the country. However, institutionalization through formal, statutory planning processes is crucial. Existing institutional frameworks are underdeveloped. To bring about significant change, we have to undertake systematically organized advocacy efforts with stakeholder participation at regional level.

Q&A

Any of the planned spaces around the water bodies have been implemented?
Yes, the space around the Hamirsar is being developed right now and one of the streams leading to the Hamirsar – there is a local NGO working in collaboration with the Govt – to create a ‘greenbelt’ on both sides of the stream right upto the lake.

The issue of encroachment is being tackled in Ahmedabad by the town planning authority who gave land specifically for housing to the weaker sections. - this is a legal provision in any town planning scheme that 10% of land needs to be set aside for creating housing.

Why do we need another Board to regulate and monitor the ground water extraction, when the CGWB already exists for this purpose?
CGWB is too far away from the reality of the locale. It has to be a local body.

Have you seen the issue of pricing of water?
The water supplied to communities is charged at Rs. 14 per year. But the collection mechanism was not in place owing to reasons like lack of staff, political pressure to waive off the charge and communities perception of water being a social right and therefore has to be supplied free of cost. Supplying Narmada water to Kutch will cost significant and therefore we have proposed metering of water supply and communities to pay for the quantum of water consumed.
A Master Plan is an essential tool to bring together all the data you have, and figure out what should be the alternatives for your future water management. I came to this conference with little information; in the last 3 days I have heard the presentations and learnt a lot regarding the data and the situation in Auroville and the bioregion. I am convinced you could start with Master Plan and figure out what solutions have to be taken in the future and for the sustainability of the society in Auroville.

Water management means managing the water resources and demand in such a way that the reliability of water supply is high, and by the same time preserving the water resources in the present and also for future. This is accordingly to a policy, and regulations.

I would like to give an example from the country of Israel - the place I came from. Israel is a small country, area of 25,000 km². Within a range of 200 km, rainfall drops from over 700 mm/year in the north to 100 mm/year in the south. Israel is situated at the edge of the desert, where the rainfall is 50-100 mm. Fluctuations in rainfall are very extreme. Series of drought years are common phenomena. 75% of rainfalls occur within a period of 3 months from December to February and are characterized by few (3 - 7) highly intensive rain storms. The summers are dry.

Floods are relatively short in time but highly intensive. There are 3 major ground water resources: the Sea of Galilee, the Coastal aquifer, and the Mountain Aquifer; the total average annual production of water is 1.555 million m³ (mem). This is the average amount of water available for supplying water. 90% of natural water resources are groundwater, and only 10% of natural water resources are surface water.

All water resources are surrounded by salty water bodies. The major water supply system comes from the Sea of Galilee to the central part of the country where most of the population lives. Since the natural ground water reservoirs has a different feature, we manage them together; in such way that distributions system are connected, and allows us to change in flexible way the pumping between the resources in drought and good-rain years.
Taking into account that the natural water resource is 1.5 mcm per year, and looking at consumption figures from 1998 to 2010, we see that the per capita consumption is increasing gradually from 100 m³ to 120 m³. The total domestic use in 2010 will be about 900 mcm/year; agriculture will be 1000 mcm/year (500 fresh water and 500 treated sewage); industrial and nature will be 100 mcm/year. Hence in 2010 the projected use will be more than the natural resources (1.5 mcm). We also should take into account supplying of water to Palestine, Jordan, and remaining storage for drought years. That is the reason we have to produce new water from two sources – sea (desalination) and sewage.

Laws of water and regulations are the tools that have been given to the water commissioner by the government in order to manage, and control the water resources and supply. In Israel

- All water resources are public property.
- There is no private or governmental ownership of water resources.
- Water resources are all types including sewage, brackish and even seawater for desalination.
- Each person has the right to a water allocation for recognized purposes (domestic, agriculture, etc., according to strict levels) - not an absolute right.
- Only centralized allocation of water can ensure an optimal use of the limited water resources.

The Water Law creates a balance between water scarcity and the needs to provide water for the most important sectors. Water resources are controlled by the State of Israel as the trustee for its residents, through the workings of the Water Commissioner and his staff. Every water use requires a license for well drilling, production, supplying, consumption or for subsurface recharging. The Water Commissioner has the right to take appropriate actions to prevent the pollution of water resources.

With this background, I have decided to put a challenge for you. Start with a Master Plan for Auroville. I will help you by giving, only, the main topics, as I see, how this Master Plan should be, and I hope you will continue.

1. DESCRIPTION OF THE BASIN
   
   You have very good GIS data and also a lot of data from Harvest.
   - Physiography and Administrative Units
   - Geology
   - Land Use
   - Soil Climate
   - Demographic and Social Characteristics
   - Economic Status.

2. PRESENT AND FUTURE WATER DEMANDS
   - A very important issue.

   Each of the below subjects is of utmost importance and has to be done: The data gives the base of how to manage the water resource with the available resources that you have. If you will find that you don’t have enough, then you have to look for solutions; and each solution or alternative involves different costs and environmental aspects. The subjects are:
   - Long term economic forecasts
   - Population projections
   - Domestic water demand
   - Irrigation water demand
   - Livestock water demand
   - Industrial water demand.

   From the figures supplied by Harvest, I found that there are 3 scales of water demand: domestic — the smallest of 1.2 mcm/yr for Auroville; agriculture in the bioregion — which is about 30 mcm/yr; and domestic and industrial use in Pondicherry (only related although it is not in the water shed of Auroville, but which may
have to be considered); hence Auroville is situated in an area which has high demands of water and has related to Auroville much.

Looking deeper into the Auroville figures we find that today domestic use of water is a smaller proportion of the total use, while most of it is public use. My focus is that in 2010 the population of Auroville will be around 3500-5000 people – water consumption per capita will be constant, but with a re-distribution into the various uses of water – public use goes down, domestic may increase. Also, we see that water available for re-use from domestic and industry will start only from 2010, and then we ask WHY this delay? One of the alternatives is to reduce the water for public use by changing the methods of irrigation to say – drip; also another possibility is to reuse treated sewage.

### 3. Hydrometeorological Characteristics
- Rainfall – more than 1000 mm/year.
- Climatic Characteristics

### 4. Surface Water Resources
- Since we have lot of rainfall there is a lot of runoff.
We should put the data together regarding the following:
- The Basin
- River system
- Discharge data
- Surface water potential
- Existing surface water supply systems
- Institutional setup of runoff management.

Looking at the basin map we see that the Kalliveli swamp has a 100 mcm/yr coming into it, and it is not used. Plus, the numerous tanks in the watershed which are silted and not in use, and should be made fully functional.

### 5. Ground Water Resources and Quality
- 80% of the 1.2 mcm/yr use in Auroville comes from ground water resources
- Aquifers occurrence – the two important aquifers are Cuddalore and Vanur – Vanur is over-exploited with very small natural recharge area; there are 6000 wells in the whole bioregion, whereas 250 wells are in the area of Auroville.
- Ground water flow regime and water level fluctuations – most of the extractions in the bioregion is from the Vanur aquifer, it is more than 25 mcm/yr, 5 times more than the natural recharge, and here in Auroville from the Cuddalore whereas the extraction is about 1.5 mcm/yr. The wells distribution are spread all the area and the pumping is without any control, thereby affecting:
  - Ground water quality
  - Water balance
  - Ground water Potential.

We need to very urgently have:
- Institutional setup of groundwater management

Looking at the piezometric level map of the Cuddalore aquifer in June 1998, it shows the water level ranges from 30 m in the centre area of Auroville to 0 m at the sea coast; but in 2004, this pattern has changed – the change from 30 m to (-2) m near the coast. This could be due to change in recharge amounts over these years and/or increasing the extraction in the eastern part (we see the water level declines in 2 wells of Auroville (Transformation and Auromodel) although the rainfall is the same). Increases of extraction so close to the sea mean that the in-
terface between the sea and, fresh water bodies move towards west; also, the storage of the Cuddalore aquifer (depended on the thickness of the saturation zone) is not homogenous. In the central part of Auroville the thickness is very small 20-30 m, compare to the eastern part, which is about 70 m; in the eastern part close to the shore the extraction of villages should be also taken into management considerations.

Looking at the piezometric level of the Varur aquifer in 1999 and 2004, we see it decline from (-14) m in the area of Auroville to (-30) m respectively; also the conductivity tests show that the water is not suitable for drinking. I do not recommend extracting water from this aquifer.

6. ENVIRONMENTAL ASPECTS
- Land use
- Groundwater
- Surface water
- Sewage
- Industrial pollution
- Forest
- Tourism spots

7. SIMULATION STUDIES FOR WATER PLANNING
The general idea is to put together all the water resources and demands quantities, in the present and in the future. Storage capacity of the system is also taken as essential parameter – and according to annual, and monthly simulation we could identify water shortage, and conclude what are the major problems.

8. PRESENT INSTITUTIONAL SETUP
- Water resources control
- Working group
- Water resources organization
- Need for better coordination - this is where Auroville should focus on.

9 (a). SUMMARY OF PROBLEMS (EXAMPLE)
- Groundwater conservation
- Industrial pollution
- Water deficiency and possible additional water resources – maybe the Kaliveli reservoir can be used, maybe desalination of sea water, or just better management of the available water resources
- Drought vulnerability
- Floods, and occurrence of floods.

9 (b). SUMMARY OF PROBLEMS
- Improving of tank irrigation performances
- Siltation
- Water charges
- Budgeting of development projects
- Policy and institutional issues
- Legal issues
- Physical planning of the area – distribution of water resources should be done by one authority/office.

10(a). POLICIES LEGISLATION AND INSTITUTIONAL BUILDUP
- Ground water management
- Drinking water supply regulation
- Drought management planning
- Flood management
- Public awareness to water resources management
- Water charge.

10(b). POLICIES LEGISLATION AND INSTITUTIONAL BUILDUP
- Budgeting and development plan
- Irrigation management
- Infrastructure development to supplement construction and rehabilitation of tank
- Environment protection and pollution prevention
- Land use planning
- Database management
- Research and development.

11. Development plan should be focused on
- Improve drinking water supply
- Improved management of ground water
- Desilting and reclamation of existing tanks
- Waste water reuse
- Water harvesting
- Soil conservation
- Desalination of salty or sea water.

12. Action plan
- Domains of required action
- Proposed action
- Economic analysis of water resources
- Financial requirements
- Prioritization
- Institutional measures
- Action plan.

Start working on these issues (on some in parallel). It will give you a broad look on your water problems, and hopefully will raise various ways of sustainable solutions for the water resources and environment.

Q/a

In Israel – is there a policy that you are not extracting more than your recharge? Is there a law in place that prevents taking out more than the recharge?

Twice a year, an “operation committee” decides in each of the aquifers what are the limits. Also the water commissioner has the right to enforce the agriculture to use even 50% of the water allocation. We manage to enforce this and those who don’t follow are penalized.

If the Kaliveli water is supposed to be used as you recommend, will it not damage the ecological balance? And this has to be considered in the action plan.

Without a doubt, that ecology has to be included into the environmental aspects. But this could be also mean a lot of water which runs into the sea, if you don’t use it.

The water law at the national level of Israel, in its enforcement are the communities involved directly at any level?

Yes, and also we have NGOs and also the strong political agriculture lobby; but all have the understanding that either they will not have water or they will be forced to follow these laws.

You had showed that 40% of the water consumption will come from manufactured water in 2010. How did you arrive at this figure?

We made simulations according to water demands and water resources.
Coherent Water Resources Management
Jeen Kootstra

Jeen Kootstra studied Mining Engineering – Engineering Geology and works as a consultant for Royal Haskoning; he worked on rural water supply in Africa, India, Vietnam; small to large scale groundwater and surface water projects; presently urban water management in the Netherlands. Occasionally he has been involved in projects abroad.

Weesenhof 6816
6536 BM Uyinegen, Holland.
Phone: 31-243441709
Email: jkootstra@royalhaskoning.com

- What is Coherent Water Resources management
- What is Integrated Water Resources Management (IWRM)
- More on IWRM
- Examples of IWRM
- The concept of IWRM applied to Auroville
- Steps yet to be taken
- What next is to be done.

Coherent Water Resources Management best mentioned as Integrated Water Resources Management (IWRM)
The management of surface and sub-surface water in qualitative, quantitative and environmental sense from a multi-disciplinary and participatory perspective and focussed on the needs and requirements of the society at large with regard to water now and in the future.

It concerns the following issues
- All water resources (spatial dimensions) – ground water, surface water, sea-water, rain water
- All social interests (social dimensions) – not only Auroville but the surrounding farmers
- All governmental sectors (multi-disciplinary) – irrigation, water supply, environment
- All administrative levels (multi-tier approach) – all Government levels
- All stakeholders (participatory approach) – farmers, users, NGOs
- All dimensions of sustainability – in all the resources, environment, energy.

Measures to be taken for IWRM:
- Integrated planning (policy, water rights, river basins, quality, infrastructure required)
- Demand management (creating awareness of people using the water; technical management measures to reduce water consumption – drip irrigation; there should be incentives/penalties to limit demand)
- Supply management (what are the sources, how are you going to do the operation and maintenance)
- Decentralisation (water should be managed at the appropriate level – not managed at a very high level)
- Commercialisation (income, investment, operation)
World Water Availability

1980

2000

2015 Estimate

Water Availability (1,000 m²/year per capita)
- More than 20 - very high
- 10 to 20 - high
- 5 to 10 - average
- 2 to 5 - low
- 1 to 2 - very low
- Less than 1 - catastrophically low
- No data

Source: Stockholm Environmental Institute, 1997. Comprehensive Assessment of the Freshwater Resources of the World
- Private sector participation (this might bring in the required capital through companies, through the construction of water system)

This World Bank map shows that India is moving towards very low per capita availability of water.

**Principles of IWRM applied in the Ambaji-Danta Regional Water Supply Scheme, in Banaskantha Dt of Gujarat**

Initially the Gujarat Water Supply and Sewerage Board (GWSSB) formulated this project in 1992 and this was reformulated in 1995 – 1996. The reasons for reformulation were as follows:

- Heavy dimensioned centralised scheme – there was a single reservoir in the Sabarmati river and from there water was pumped over several hills to the central storage facility and from there distributed again to the villages. Due to these technical measures, the capital costs were very high (50% more than other schemes).
- Difficult topography – rough edged small mountains, ravines, winding roads that makes laying of pipelines very difficult.
- Operational problems expected – very frequent electricity cuts, pressure of water in the pipelines.
- Sources available in the area itself – although the area doesn’t have much rainfall, some major rivers are originating in that area; several minor irrigation schemes.
- Study area is around 600 km².
- Population at present is 140,000. (1991) and the target is 300,000 (2026) in 193 villages.
- These are mainly tribal communities and the elevation is 150 – 850 m above sea level; this is a hardrock area with sharp contours (Ambaji is famous for its white marble).
- Small winding roads with steep gradients.

**Old scheme features**

Water from Dharoi reservoir (Sabarmati River) was pumped to a central storage and distributed to 193 villages and the cost per capita was Rs. 1513 at 1991 prices.

**New scheme features**

Water from variety of sources (ground and surface); minor irrigation schemes, we had discussions with irrigation panchayats whether we could use the seepage through dams and construct seepage wells downstream of larger dams and we proposed 10 locations for smaller dams and we put radial wells into river beds – the river beds were dry. By division into smaller schemes, the facilities could be much better manageable. and we could also get large involvement of villagers, which assures more sustainability in water supply schemes and the cost per capita reduced to Rs. 1039.

**Application of IWRM in the Dutch situation**

The ‘Dutch’ experience: see the inundation area, and the runoff that comes into Holland spilling into the valley of the Rhine. We have at the highest level water entering Holland at 18,000 m³/sec – Holland is a delta and we receive water from the major rivers of Belgium, Germany, France. This area was designed as a emergency inundation area – if the water in the river rises too high, the dykes cannot control it; then as a special designed system, river water is allowed to inundate this area; all the red spots are villages. The reason why we came to this type of solution is because nature cannot be forced eternally to the will of man; to prevent this we have to go on building higher and higher dykes and then greater will the risk when it
breaks; at a Government level we reached this conclusion, not to go beyond a certain height.

We had severe threat of flooding in 1995 – 1996 and 500,000 people were evacuated from low lying areas behind the dykes. On the edge of the Rhine we built walls with slots and with high rising water levels, we put wooden planks in the slots and put clay in between so that it becomes an almost impervious structure. By doing this the same river in almost the same location had hardly any water left and hence waterway transport stopped and our economy suffered quite a loss; power plants almost stopped because the backflow of the cooling water was so warm that the surface water got heated up too much and damaged the river system. We also got an initial salt water ingress – we had a choice of letting water levels go further and further lower thereby causing all dykes and water structures that retain the water to go dry – this would cause instability of the structures and so instead we allowed the salt water to purposely

ingress – the agricultural houses had to stop using this water; as a countermeasure some pipelines were laid and water was taken to the west part of Holland where the salt ingress was taking place (transfer of millions of m³ water).

As a result of all this for the past 10 years, in the Netherlands, we worked on:

Diverting rainwater from sewers to surface water – we have rainwater on roofs, flowing into the sewer system and excess of this water from the sewerage goes into the surface water, but now to divert it directly into the surface water, we have to create more open water in urban areas, create retention capacities near urban areas; designing river-widening measures – these are like parallel rivers of 400 m wide and 2 km long – houses will be removed to stop forcing them into narrow areas and create risks; sourcing narrow passages in river system and sourcing inundation areas – like in the picture; we are also cleaning the bottom of waterways - the sewerage that takes out the excess water into
the waterways makes them toxic and we are rejuvenating waterbodies – we are looking at how big, how much, how can we increase their self-cleaning capacity, their capacity against deterioration; we have introduced ‘grey’ water – for low grade purposes; we have created awareness amongst citizens and boats, isolated houses and rural areas are all connected to the sewer system.

Lessons we have learnt so far are not to force nature through making dykes higher; we revived an old situation of allowing controlled flooding to take place; tackling problems at source e.g. rainwater retention. We have taken notice of the climatic development and make a new design basis with respect to rainfall; the national budget will pay for these measures and hence the citizens will be taxed more for these measures; we have institutional measures to ensure that all these work: water boards are sitting with us as consultants and with municipalities at design stage; if municipalities do not follow this, town plans will not be approved and no development can take place.

**Concept of IWRM applied to Auroville**

The start pointing will be Demand Management, that means taking the inventory of demand:

- Purpose of supply (drinking, irrigation, hydropower, industry and others) and prioritise them
- Who should be supplied (Aurovilians, all habitants in region, or farmers also)
- What quality should be supplied (drinking, drinking and irrigation)?

**Demand management will cover the following areas:**

- Technical measures – to enforce drip irrigation or continue flood irrigation
- Awareness – of water as a precious commodity and what you can/cannot do with it
- Communication to the people
- Financial incentives/penalties – water billings and tariffs to be organised in such a way that as you consume beyond certain limits the tariffs will go up steeply.

**Supply Management – this means taking the inventory of available supply (sources)**

- Groundwater
- Rainwater
- Surface water
- Recycled (grey) water
- Salt water or brackish water via desalination

All these sources should be ranked – how expensive are they, what is the impact of each on the environment, etc, by doing so we can make a good evaluation of the different sources and compare them with each other.

**Organisation of Water Supply**

Management has to be done at appropriate level – who is doing operation and maintenance and how is it organised? Who will do the monitoring – is it Auroville, Harvest, any other authority?

Who gives the permission to construct any structure, license for drilling, operation of scheme, collection of fees, allocation of funds for replacement-maintenance-extension of scheme?

**Participation of stakeholders**

- Who are the stakeholders? they are water users, responsible government authorities (drinking water, ground water, irrigation), organising authority (Water Board, Harvest), relevant
NGOs. And they are involved / participating in Design, Building, Operation, Financial management and Monitoring.

- Cost recovery of O&M and capital through pricing of the water, collection of fees; who will sanction the structure
- Private sector participation is important in build-operate-transfer; build-operate-maintain construction systems.

Steps that have already been taken in Auroville:

- General assessment of demand
- Inventory of groundwater resources
- Introduced rainwater harvesting
- Rehabilitated several tanks
- General layout of the scheme
- Established organisation within Auroville
- Liaised with local authorities.

Steps yet to be taken

- Detailed assessment of demand (max/min) – we have to address these issues: Do we irrigate our gardens? Is it responsible where we have shortage of water? Irrigate our gardens vis-à-vis irrigate the crops of the villagers?
- Evaluation of sources available
- Decisions on what to supply and from where
- Decision on whom to supply
- Cost – benefit
- Comparison different scenarios.

Q/a

In India electricity is free for farmers and how do we control the over-exploitation of bore-wells?

I don’t have an answer, but somewhere we should register the bore-wells and free supply of electricity should be replaced by higher tariffs for irrigation than domestic. This might be the only way of forcing the farmer to use his water carefully. This is very difficult as it is such a big political lobby.

I believe the concept of consumption of water is not only a social problem but also a technological problem – e.g. river water dispute between states, gets referred to higher and higher authorities, but when the time is for water to be regulated there is no-one to control because there are no accurate measurements – many

proposals have been made to put - measurement stations and telemeters that data through satellite control stations so that you monitor the actual flow of water on a daily basis; is there any such measurement tool for bore-wells and make this data available, so that regulation can be done?

You could start with pumping capacity or the surface of irrigation area – because water metre installation for the bore-wells is very difficult.

Another method is the water induction metres which measure the influence of the water on the induced electromagnetic fields – this is a non-intrusive method (not having to cut already installed pipelines).

Is it possible to link our wells, storage and then supply under pressure
to all users. What is your opinion on this in terms of planning?

Very difficult method to implement, considerable transport distances and I doubt whether extraction levels might decrease because of this; whether investment will be worth it, I’m skeptical. Also quality differences are there in water and also losses.

The projected lake around the Matrimandir is believed to have an important function in the water supply concept. What is your opinion about it?

I do not believe that a lake around the Matrimandir can have an important function in the water supply for Auroville. It certainly should not be as large and deep as initially proposed. If water is desired around the Matrimandir, then one could make an artificial basin with controlled water quality, underground water buffer to prevent warming up of the water and high flow rates to prevent deterioration of the water quality.
Towards a Sustainable Water Resources Management in Auroville and the Bioregion

A Panel Discussion held on 15 September 2004
as part of the concluding session of the 3 day seminar

Tency Baetens:
After listening for 3 days to major topics in the water scenario in the bioregional context, we have all received information about hydrology, hydrogeology, moving over to the social aspect of participatory approaches, touching the area of economics, explored the ongoing developments in desalination; listening to the complexity of legal aspects dealing with issues of water, we moved towards solutions – how can we define accurately major aspects of water problems and how can we work towards solutions in this area? We are a tiny player in this bioregion; we have to deal with Tamil Nadu and Pondicherry state. Our bioregion includes Kaliyeli lake, Tindivanam and Villupuram towns and borders the Bay of Bengal. How can we make use of the creativity, the innovative qualities that are so in-built within the Auroville community? How can we share with the wider circle our quest for perfection and translate that into an action plan for the water situation in the bio-region?

For the final part of the seminar we have brought together a distinguished panel:

Shri. Vasanthakumar Reddy who is chief hydro-geologist of Pondicherry, Director of Agriculture, and now on deputation as Secretary to the Chief Minister of Pondicherry;

Shri. Gopalaswami who provided us with an interesting lecture on desalination and renewable energy;

Ms. Shobha Iyer from Chennai from CAG – Citizens, Consumer Civic Action Group
Dr. Sophie Violette from Paris University – a professor teaching hydro-geology and involved since many years with research projects in collaboration with Auroville Water Harvest.

Dr. Israel Gev, Senior Hydrogeologist, in charge of Water Resources Management, Water Commission of Israel.

Mr. Jeen Kootstra, from Royal Haskonings of the Netherlands, a water consultant.

Mr. Carel Thieme, who will be the anchor during the panel discussion.

We would like the participants to focus on the issue of:

1. An integrated water management program for the bioregion, how to interest and involve Pondicherry and Tamil Nadu, powerful stakeholders in the bioregion.

2. How to proceed and move forward with an integrated water plan for the community of Auroville. It is time that we coordinate and proceed on this aspect as we have been dragging our feet far too long.
Carel Thieme:
- In the first part, we would like to have the impressions of the speakers regarding the Integrated Water Plan - I would request each one of the speakers to give in 5 minutes their feelings and ideas regarding this.
- In the second part, we would to make the floor available to other questions/ contributions made from all of us here.

Integrated Water Plan:

Israel Gev:
We are looking for solutions to preserve the natural water balance of the bioregion and Auroville; but we didn’t identify exactly what is the total water balance we would like to be in the future, including consumption. This is one of the things we should think about - how much of water could we demand from the natural resources and how much will be available, in the bioregion and in Auroville itself? The next issue is how we make the water resources in the bio-region and in Auroville so that the water balance will be positive, looking at the priorities (domestic vs. agriculture); there is no one solution, we should look from all angles, and choose the best alternative, not just from cost-benefit aspects but also the one related to environment problems. It is obvious that you should improve the management of irrigation in Auroville, and in the bio region, it is a policy issue of how Pondicherry and Tamil Nadu Governments deal with it. A coordination between Auroville and the Governments must be established; one of most important element is the ability of Auroville to continue with research work for improving the water management concerning irrigation, sewage reclamation, desalination, and understanding better the ground water boundaries condition; in Auroville you could do all this research and evaluation; I have tried to give you the main guidelines in my presentation – you may have to modify it for your particular situation.

Sophie Violette:
Regarding the hydrogeology in the bioregion, I think the work that various people have done has to be completed, but also put together to have a really good understanding of the situation now and to be able to make some predictions for different scenarios regarding the consumption and the evolution of the consumption of the water and their use. The second important factor is that the situation of one of the main aquifers of this region (Vanur aquifer) is very very bad – if Auroville, Tamil Nadu and Pondicherry are not working together to find the solutions for replacing fresh water irrigation of farmers and also show ways to make the farmer use less water, I think the situation will be very bad – particularly when Auroville will be safe with fresh water and the surrounding area will not have fresh water any more. From our calculations, in a few years (maybe 10 years) they will not have fresh water!!! And the consequence for the whole population will be drastic – I don’t want to sound alarmist, but I think the time has come now when we have to take care and
try to work together; a good starting point will be the project we do with Harvest and the support of UNESCO, and I think this would be a good frame to work together – not only for Auroville but also for everyone in this area; and Auroville could be a good example of what we could do in India.

R. Gopalaswami:
Water is a subject where everybody has to work together. If you see the evolution of planning systems particularly in the developed countries – water is a subject that can’t be planned centrally, it has to be planned bottom upwards – this movement that takes place with Auroville and Pondicherry taking the lead, is a step in the right direction – it has been done a few places in India but this will be a great example and planning is the key and it has started on a war-footing – it is very difficult to go to war on a subject like water but the attitude that we are suggesting is very important – while one shouldn’t be an alarmist, I was chilled to see the creeping figures of salinity – this is like a terrorist movement – silent, underground, and irreversible – in the southern part of this region it has already come in 5 km; in Pondicherry it has come in 2 km; obviously it is a concern for Auroville, and there is a need for Pondicherry state Government and Tamil Nadu state Government to take these signals seriously – the very fact that we are gathered in this seminar to discuss this, means that we have to work together and get a good plan – to get a good plan is not so difficult with the guidelines in the presentations offered by Israel Gev and Jeen Kootstra – the elements in them are very clear. In India we are good in planning, but how do we implement these plans – the implementation has a diversified set of solutions to be found – although I am passionate about desalination, taking the example of Israel which says that in 2010, 40% of Israel’s water will be manufactured water; similarly we have to ascertain our target in say the next 20 years, as has been suggested by our President Dr. Abdul Kalam – in the next 20 years we should unfurl our water management plans; I would happy if we could estimate that in 2020, how much % of water is from natural resources and how much % of water is manufactured water. Auroville can team up with IITs in India and other institutes and come up with solutions for desalination using renewable energy and become trend-setters not only for India but also for the world. I hope and pray that Auroville comes forward with an excellent water management plan, unfurls its plan and shows what Mother has intended Auroville to be - a bridge between the past and future.

Shobha lyer:
I would like to mention that when you are talking about bio-region/bio-sphere, you have to look at the legal implications, this means that you look at the land classifications – after you pass on from the land classification, you look into the use of water – and although domestic and agricultural use does not always cause problems, the issue of commercial use and privatization, take on very strong connotations. To safe-guard ourselves from this, the whole community has to be brought together, unless they are involved in every stage of the planning they will not get a sense of ownership. Until the sense of ownership
comes, chances of de-fragmentation are aplenty; even if you are well within the legality, chances of things going wrong will be there when market forces take over – we see this in Chennai, where the city gets its water from 250 villages in the surrounding areas of Chennai – although they do not fall within the jurisdiction of metropolitan area and are actually under the Panchayat System. However these areas have been notified as ‘potential ground water sources’, because they have more groundwater than what they need. Now for villagers in some of these areas, depleted water sources are forcing them to look elsewhere for their own needs. Market forces have entered the picture where they have made contracts with the farmers – the person who supplies water to my house has paid Rs 3.5 lakh/year to a farmer for withdrawing any quantity of water. Where is the justice in this? We are now looking at the implications of such contracts where there is no quantification and this is a new issue for us also. Even the Government has entered into contracts with farmers for withdrawal of large quantities of water to supply the city of Chennai.

Jeen Kootstra:
You have to work on consumption on the one hand and the level of ground water extraction on the other hand – perhaps Auroville could take an initiative and discuss with the surrounding Government agencies that farmers may have to start compensating for the amount of water extracted – they have to take care and recharge – this might be difficult, but we have to then build facilities for infiltration and rain-water harvesting- this could be a way of slowing down the lowering of water levels and also work simultaneously on the limiting of water use.

Vasanthakumar Reddy:
You might have seen the Hydrogeological data of Pondicherry presented earlier by my colleagues. The Government is aware of the situation of ground water in the Pondicherry region and lot of initiatives have been introduced in Pondicherry, focusing on the 10th Plan with the tone and terror for conservation of water than exploitation. Many schemes like the Tank Rehabilitation Projects, Groundwater Recharge have been introduced in our Territory. The Government cannot take hard decisions on utilization of water for agriculture, as it is the largest enterprise involving farmers. To bring an awareness among the farmers, many participatory programmes involving farmers have been introduced. About 7000 old open wells are available in Pondicherry region, wherein, farmers have been given 75% subsidy for utilizing them as recharging structures to boost artificial recharge of the ground water. By far, people have realized that there is going to be shortage of ground water in future and more user education programmes are being implemented.

Added to all our problems we had 3 bad monsoons on a row. This had been a rare phenomenon looking at rainfall data for the past 30 years, culminating in drought-like situation for a prolonged period. Pondicherry’s water requirement for drinking, agriculture and industrial purposes are met out from the ground water and hence schemes for water harvesting, and utilization of surface water is being given priority. The Government
machinery is not sufficient alone to undertake the awareness programmes and it is heartening to note that the political will has enhanced towards the management of ground water in years to come. The Government of Pondicherry has introduced restriction on the usage of ground water especially, within 6 km from the coast for the past 20 years and effectively restricted number of tube-wells constructed for various purposes. After a long struggle to bring in a ‘legal arm’, the Pondicherry Ground Water Authority is being enacted for effective control of exploitation of ground water. The geographical area and sociological aspects are so complex, we (Pondicherry) have pockets in Tamil Nadu area in between places like Reddichavady, Kottakuppam, etc. Even though we have effectively controlled in utilization in our territory, no such controls are available in the adjoining Tamil Nadu areas which has resulted in farmers constructing tube-wells in Tamil Nadu area and utilizing the water to irrigate the lands in Pondicherry, which was the other way around 20 years ago! In the absence of such complexities inside Auroville, you need to have a perfect water management plan by Auroville by fixing priorities for various users. As the average rainfall is 1200 mm in this region, effective utilization of surface water for various needs and also for recharging be looked into on priority. There is a very thick clay layer of 3-8 m depth underneath the plateau of Auroville, so you need to plan proper recharge structures for boosting artificial re-charging, as most of the tubewells are tapping from tertiary aquifers of 30 m depth and weathered lime stones at 60 m depth. Proper re-charge programmes can benefit the above-said aquifers. Economic returns from agriculture is dwindling year by year. Agriculturists are mostly small and marginal farmers with one or two acres of land and hence multiple cropping programme is being followed everywhere. The Government is trying to reduce the area under paddy and increase crops with less water requirements to bring in proper management of groundwater and lot of subsidies are being extended for this purpose.

The involvement of NGOs is very much essential in bringing out proper management practices among the farming communities apart from the interference for change of cropping pattern and also looking at sustainable agriculture. Auroville has done marvelous work on afforestation and I hope they can do similar work in water management for neighbours to follow their experiences.

Q/A – Plenary Session

→ Lucas Dengel:

1. When we say that irrigation/agriculture consumes the major percentage of water, do we refer to the agriculture of one, half, less than 5 acre farmer or the large plantations of the corporates/industries?

Reddy: Plantations are also considered part of farming activity and compared to paddy and sugar cane – we are encouraging people to go for plantations/orchards as their water requirement is much lesser and we are giving incentives
to people who are converting their land.

2. Commercial use of water is one of my major concerns – bottling and selling of water – what can we do about it?

Reddy: I was responsible for starting Pondicherry Natural Mineral Water by PASIC as a business proposition with the basic idea to strengthen the resources of PASIC so that various other benefits could be extended to farmers. We realized that there is a potential danger from private enterprises to replicate commercial utilization of water, as quality of ground water is good in Pondicherry. The Government has introduced a ban on starting mineral water industries in Pondicherry. Now a couple of units have been set up in Tamil Nadu area especially around Auroville where water quality is good. To quote an example, there was so much pressure on our Government to start a Coca Cola bottling industry in Pondicherry. Fortunately the Government has not approved of any such water intensive industry especially, after seeing the experiences of a similar unit in Kerala which landed in controversy. The Honorable CM of Pondicherry has announced in very clear cut terms in the last budget session that no more water intensive, polluting and chemical industries are welcome in Pondicherry.

Gopalaswami: Industries could use desalination – you can get mineral quality water also and the ocean is an infinite source of water; and this is not causing any ecological damage; so industries who want to make bottled water or Coca Cola could have a small desalination plant in the coastline and use renewable energy like solar and biomass only and not gas/oil/coal/electricity.

Shobha: We cannot all the time keep looking at laws to control – we should look at self-regulation mechanisms – in this context if we use only ‘grey’ water for the gardens; that is one stage of conservation.

Then we have concept of polluter pays principle – so if someone has commercialized water in your area, in the long-term plan it could be that in future he pays something for conservation in your area, as he is drawing that much water and he should give back to the community what he is taking.

Rauf Ali:

Consumption is not the only reason for reducing water or increasing salinity; 15 years ago a break-water was built in Pondicherry town and today beaches upto 8 km north of this have eroded some quite badly and this might be contributing to the salinity seriously. The other industry that has occurred is the glass-bottle making plant for Coca Cola which uses beach sand and hence severe mining of this has caused a pocket of salinity in that
area. What can be done to mitigate the consequences of such projects?

Reddy: We are aware of this problem and we are in touch with IIT to address this problem. In 1974, when doing hydro-geological surveys in the Gingee river – the main river next to Pondicherry, the back waters was hardly 400 m; today it is more than 3 km! All the top alluvial aquifer adjoining the river-course have become saline; I’m not really aware of the cause of increased backwaters; new beaches are coming and old beaches have been washed away. It is alleged that a couple of groynes that were constructed for the new pier is responsible for eroding a part of the coast line near Kottakupam and we are asking IIT to investigate and give us a plan to restore and control all these salt water movements inland. As far as the Gingee river backwaters are concerned, we have suggested that an old east-coast bridge can be converted into a barrier and a scheme has been sanctioned for Rs. 3.5 crore where we plan to stop the backwater intrusion into the river and also that barrier will store fresh water from the upper reaches when there is rainfall and above that a couple of small barrages have been constructed and 2 more have been sanctioned. So definitely what you mention is also a problem that you have to consider when you are handling the east coast.

*Tom Gablier:*

From the model presented by Sophie, it is clear what we have ahead of us in 15-20 years in the Vanur sandstone - after all this is saline and 20 villages behind us will go waste with no more cultivation, trees. Palmyra and Harvest started working in the watershed 7 years ago and today some result is already there; but it is slow – and we need a very strong social movement, and a complete reversal of the political situation – reversal in the sense that the Government has to put a drastic decision in order to protect the 15 km from the sea coast. We may be very efficient in social development but the trend is so much set – the farmer is not going to happily change his crop pattern, skipping crops, these are strategies that require a lot of time – my question /concern is that we have very little time according to data – this is also corroborated by the overall picture, not only Tamil Nadu, Pondicherry, but the whole coastal belt of India – what are the suggestions you could make to help us to reach intensive strategies that could really give us the chance to protect the problem. We can go ‘soft’ up to a certain point but I’m afraid that if we go too slow the trend that is already set will catch us anyway. Is there a way to go rapidly, efficiently without harming the relationship with people and to reach some effective solutions?

*Israel:* Here the policy of Government of Tamil Nadu and Pondicherry should do direct intervention – as I saw we made a kind of simulation between demand
and water resources until 2020; we could manage the water balance in such a way by decreasing the agriculture demand – that is also the Government’s decision – not even to 50%, but 0% – which means no agriculture! It is also theoretically possible – you can’t do it in India because of the social force/aspect. However we don’t know exactly the data, the water balance for the future; but manufacture of new water resources could be a very good solution – a desalination plant may be the solution to this problem in the next 5 years for both Chennai and Pondicherry.

**Dirk Nagelschmidt:**

1. Pondicherry produces every day about 10 million m³ of waste water; these waste waters get pumped on wetlands and my idea is will a big treatment plant provide treated waste water to the farmers to reduce extraction of fresh ground water?

2. Soil management – there is a substance that when mixed in the soil will help save 50% of the water – 1 kg of this material mixed in the soil will hold 150 lts of water; in this direction we should also go and make a movement – this movement can be done only if the Governments of Tamil Nadu and Pondicherry are taking a step in this direction; what is your opinion?

**Reddy:** 1. Pondicherry has more waste water than you say. Collection of all this waste water (these programs were drawn 25 years ago) – 25% of waste water is being collected in these oxidation ponds; last year around Rs. 20 crore was sanctioned to connect the left-out areas of the city to the bring waste water to these ponds – which means you are going to get 100% more than what is there already in the ponds. But these oxidation ponds that are near the bio-region, even if you purify and want to reuse for agriculture, the agriculture operations are 6 km away from Pondicherry city and none close by; theoretically it is possible, but it is all economics we have to see when using Government money; the other option of using this water for recharge is being looked into. We have asked a consultant to do this study and tell us how best to use this water – whether for recharge or distribution for agriculture – although I think active supply to agriculture, looks as a bleak option to me, because paddy cultivation is far away.

2. The substance that you are talking about has been tried for potted plants and in green houses for orchids, etc. I am told that it cannot be used for paddy which is the main crop of Pondicherry. It can be done in mango, coconut plantations where there is drip irrigation.

**Carel Thieme:**

Can the treated waste water be used for Tamil Nadu farms, since they are
close by?

Reddy: There shouldn’t be any problem – you can discuss this with our people and I will create an environment where you can discuss with them – and how best you can use this water. I have also mentioned to Tency in an earlier session that we shouldn’t rely on the data given by the people on the discharge from the oxidation pond – it is not done that scientifically; so please check up with the ground realities of what exactly is the quality of water coming out of the ponds – I saw once that the BOD was very high – the issues can be definitely looked into and this water can be used in Tamil Nadu or even in Auroville!

♦ Gilles Boulicot:

We need to bring to the community of Auroville which may then act as a leading body in the larger area, at least in terms of demonstration - we need to have a practical water plan step by step on how we should implement the practical way to deal with water issues. I request the support and participation of this panel of experts for this task.

Gopalswami: How do we speed up the planning process so that by the time the plan is not completed the salinity is already crept in. We have the data to support this – the time taken for preparing the IWRM plan, which is what this seminar has been working for, helped by our colleagues from other countries – how long do you feel that it is reasonable because we have the full support and understanding of the Pondicherry state from this panel chairman, but there is no-one from Tamil Nadu – if you talk about integrated plan you must have someone from Tamil Nadu also and we can talk about the integration. In my opinion I think that Pondicherry state may have greater clout than Auroville on the Tamil Nadu Government and plus the President himself having mentioned clearly that we should unfurl a 20-year plan, perhaps Auroville working closely with Pondicherry Government could co-opt/request senior people from Planning Department of Tamil Nadu and form a planning group and fix a target that if the Pondicherry CM were to request that the whole job is to be completed in 6 months time!!! I understand your concern that the time for planning should be quick, maybe 2% of the time taken for salinity to reach this place.

Reddy: I dream that the developmental revolution will come from the villages – practically very little can be enforced by the Government – especially issues which are not palatable to the farmers. Unless they understand what is going to happen to them in another 10 years, it is not likely that the Government can enforce anything by just a rule of a letter/order (e.g. is the rainwater harvesting structure of Tamil Nadu – these structures have been forced, but so badly made
and how much water reaches ground water is a question) – Government orders have only relevance to Government offices – there should be a movement from the villages – how best we can accentuate that movement through NGOs, GOs or through whatever support is necessary will really solve the problem in the long run and we can’t have tough schedules because we have salt water coming today and we can’t have deadlines and say it will be done by this day – it is practically not possible – it only shows our eagerness to do something very quickly – anything related to water management, recharge will take very very long time.

_Shabha:_ It might be a good idea to take one area of Auroville as a pilot project to see and demonstrate. When you see this area – the community has worked towards it and is enjoying the fruits of it, it’s the success story that can carry a lot of weight. And replication is a completely feasible option because it is the same area (not any regional differences).

*Prashant Hedao:*

Recharge areas have to be protected so that we can channel overflow water into those areas and make sure that industrial pollution doesn’t take place; do you have a detailed map of these aquifer recharge areas in Pondicherry (and Tamil Nadu) so that we can take this information to the villages and make people aware of the need to protect them. We would like to have this information.

_Reddy:_ We do have information on aquifer recharge – if you look at the artesian, sub-artesian aquifers of Tertiary and Vanur, Ramanathapuram, we have data on where the material is getting exposed; but 85% of Pondicherry is covered by a thick alluvium which is highly heterogeneous – it could help recharge in this place and 500 m away it may not; there are definite indications that the tanks, the feeder canals, the supply canals have definite impact on improving your recharge; but if you look at Cuddalore aquifer which is the good aquifer for Pondicherry, all that area is in Tamil Nadu – Neyveli to Panruti – vast areas of exposed Cuddalore sandstone where there is good recharge; now if we look at the Mettupalayam Industrial Estate near JIPMER – with red laterite soils which is a good recharge area – in 1978 unfortunately it was declared as an industrial area with all chemical and polluting industries; pollution has already occurred – heavy amounts of sulphates, acids and fluorides have gone inside, and it is moving towards the coast. We requested NGRI to study this and tell us where is the movement and which areas will be affected – protecting these areas further, and action is being taken by Pondicherry Government for the last 3 years. The number of chemical, water-intensive industries that have come to Pondicherry for the past 3 years is negligible – the time period of
1981-95 was the period when all types of industries came into Pondicherry (even those refused permission by Tamil Nadu)- the damage is already done and the top 27 m of dry soil profile is fully charged with chemicals – on every good rainfall day, a particular amount of these chemicals are discharged into the water table.

- **Carel Thieme:**
  Between the Pondicherry-Tamil Nadu borders we have a couple of polluting industries like Chemfab – is there anything the Pondicherry Government can do about it?

- **Gilles Boulicot:**
  While doing our systematic study last year of all the borewells to be able to do a good evaluation and we passed through the Kalapet area where people complained about Chemfab and the odors from the factory; we took one single sample relatively far away from the factory and we analysed that the phenol content in the ground water is 20 times the permissible limit. I assume that not only are they pumping a large quantity of water but also dumping chemicals into the water table.

  *Reddy:* Chemfab is situated in Pondicherry area and 3 years ago they were served with a notice that they cannot pump any more ground water – they have to take their requirement from desalination plants – they have been putting together a desalination plant and are ready with it, but there are other issues also – the social issue of tackling the coastal community that is close to the factory, that is objecting to these operational arrangements and this is being sorted out. About 500 l of water that they have been pumping out will stop when they start their desalination plant; while I am unaware of this particular problem of polluting the water tables by Chemfab with phenol (it has taken place in other places – Mettupalayam Industrial Estate where a factory was directly pumping into an old tubewell, effluents of heavy sulphates, which resulted in the dramatic increase of sulphate in the whole area); I am only aware of the salinity that they have caused immediately in that pocket by heavy extraction of ground water; there are problems with the disposal of brine that is the product of de-salination – that was being worked out. There was a mention of brackish water (i.e. again salty ground water) – we are not for this idea as it means continuously pumping the ground water- the ground water here is 6000-7000 mg/l and if you use this water for desalination then maybe in 5 years what is 9000 mg/l will become 13000 mg/l!!! This effect will impair the nearby aquifer systems. Hence it has been clearly told to Chemfab that they have to use only sea water for desalination and discharge it back to the sea.
Gopalaswami: BHEL has already set up 11 desalination plants in Tamil Nadu (brackish water) – they working quite well – in Trichy, they have a very large facility which manufactures these plants; in Ramachandrapuram, BHEL has a very large desalination plant – here the desalinated water was up to the specifications, but the pipelines which they attached to take it to the villagers, were left unspecified and so the rust in these pipelines made the water coloured at the end use in the village. When you get into high technology, your knowledge of the technology has to be complete right from where a factory starts to where the water is used.

In the context of desalination, I would to point to you that I visited the National Thermal Power Station near Vizag – 1000 MW station and it is a Rs. 5000 crore project spread out over 7000 acres – the lifeline of this thermal station is a channel about 3 m wide, 1 m deep and 150 km long bringing agricultural water from the Godavari river. The farmers have been agitated that water meant for agriculture is being used by industry. I strongly believe that industrial water shouldn’t be the water meant for agriculture – the NTPC circulates 9000 tonne/hour of sea water which is about 215 million l per day, which is enough to supply a large city; they draw it from the sea 2 km away – all the technology is indigenous – Kirloskar pumps, deep sea wells done by our engineers including the jetty, etc. and when they circulate the sea water for cooling - putting in 4 inch pipeline; and generate the 14 million l of water that they need for the plant – they use their sweet water for their boilers, ash, fire-fighting, residential colony, etc. This awareness of using desalination as an option has already started in this country – however this will be a wrong priority if we start using coal, oil or gas to run these plants. We will have to develop our own technology and go for renewable energies.

♦ Gilles Guigan:

We can always keep saying that we need the Governments to enforce this or that; but the Governments are unable to impose this or that, because it can’t impose anything on the people; the key to this seems to be environmental education – we need to know more about successful education of the people and we need to know if Governments are funding NGOs to do environmental education. The key of introducing any new technique is not the technology itself but how to make people aware and convinced.

♦ Kalyan Paul:

It’s a big problem for all of us in India – I come from the hills of Uttranchal and Himachal Pradesh where I work for an organization called Grassroots.
I suppose we should get out of the syndrome of either technology-fix (desalination) or Government-fix – this either or situation; there are solid examples in the world today where people have had to face severe hardships with water scarcity and how they have had to resolve it is through adopting principles of integrated water resources management – that’s a multi-stake holder platform you have to create and its lot of hard work and you can’t do it over night – but that’s the real way to go about it – where you involve a whole range of people – the farmers, civil society, Government and in that you have to involve the scientists, the hydrologists – it’s a very very difficult work and will take 20-30 years, but that is the sustainable way shown from all over the world - from developed nations to the developing nations; everybody has to play a role in it, even the Government – when it is said that the Government can’t do anything about the farmers, I don’t agree with it – if you can ask the farmers not to grow opium, then you can ask them not to grow paddy 3 times a year. Its not a dead end that the Government can’t do anything about the farmers. It’s a question of the Government understanding a bit about the ecology – lets face it: we haven’t studied it, we never bothered about it, and most of us don’t know enough about it; firstly we should go on a learning curve ourselves and figure out how we should figure this whole problem. I don’t think there is any other short-cut to this that one or two men can together give us a solution. The technology-fix is the last option we should be considering for a situation and problem like this.

*Ingo Wey:*

During our seminar the technical topics were very well dealt with, but the other side of it is the consciousness side – and if we don’t resolve the consciousness problem all technical solutions don’t go far. I would be very interested to see that our next meeting would focus on creating water consciousness within the populations of Auroville, how to create the consciousness of all the technical problems that come up, but also how to create the consciousness of the next generation being in need of the same water that we are using now. What can Auroville do to increase this consciousness?

*Carel Thieme:*

The person who addressed this topic was Rajendra Singh from Rajasthan on the first day. But here we have Jeen Kootstra from his project experience in Gujarat who worked fully with people’s participation.

Jeen Kootstra: People’s participation is absolutely necessary, but it has to be clear for people that it pays off – either by using less energy or saving
on water; in Banaskantha, people didn’t participate so much in the direct construction. Women participated in income generation that allowed the water bills to be paid; this allowed the Gujarat Water Board to do the operation and maintenance of the schemes.

Sophie Violette: My comments on Gilles Guigan and Ingo Wey are – 5 years ago we had the feeling that the situation was not good and now we know better that the situation is not good; if this can be shown in an appropriate way to the population – it may help their awareness and consciousness; I think the next way could be to work with a farmer in a small area in the bioregion and from the results of this changes in the way of farming of this farmer, this could demonstrate to people; we have to spend some money and do this experiment and we have to do it right now.

Peter Clarence-Smith:
Necessity is the mother of invention – there are not enough people who feel this necessity and so we have to accelerate the perception of this necessity through environmental education, mobilisation, etc., so that enough people feel this necessity and then we can start inventing.

Gerard Jak:
In Rajasthan they started with a disaster and so there was an awareness. Here the situation is not like that – we have to fight the greed of people for immediate economic gains, when they don’t feel they should change their flood irrigation patterns to drip, or even I made check dams it was not appreciated because I asked for water to do the construction; even if there is education and consciousness we have to fight this greed. We have learn to deal with this and the Government is necessary for this, to impose certain things.

Lucas Dengel:
The best educator is catastrophe – now we would like to avoid the catastrophe – the next best educator is collaboration of those who should collaborate and how do you get the collaboration – they have to see/perceive benefits; not directly just financial benefits – so whatever we do educationally has to be done in a movement of collaboration for mutual benefit; otherwise education is counter-productive – we see it in our children and we see it in the general population.
Tency Baetens:

After listening to the concerns by seminar participants, especially in the area of environmental protection, let me try to summarize and offer some tentative insights towards the future. How to manifest a move forward, how to initiate a coherent and sustainable water plan.

Auroville has been an initiator bringing in creative ideas into this place and the surrounding bioregion. Looking back and comparing with what happened in the beginning stage of our community development in the area of afforestation, we witnessed that a rather small group of people ended up planting close to 3 million trees, all this with the help of the community and involving all stakeholders around us. This was a movement, not planned, that grew organically over several years and which continues to grow. While planting and maintaining the forest areas, other persons, institutes and agencies became interested and often helped us – to name just two out of the many, the Indian Space Research Organisation (ISRO) and the French Institute. Those organisations helped us on various fronts and often provided valuable scientific input. It is an astonishing fact that within less than 25 years an area which was absolutely barren and on the road to become a kind of a desert, evolved into a lush green oasis/forest- there are not too many places in India which have managed that feature. Why could this unique event of initiating and creating a forest, over a period of two decades, not be replicated in the area of water, rainwater harvesting, and its wider applications?

Looking at the different challenges involved in the search for a plentiful and a sustainable water supply, one can only visualize that it will take the effort and work of many individuals, groups, organisations, communities, administrations to combine energies, muster goodwill, use perseverance and excellence towards an aim which could evolve into a model that is affordable, tested and fine-tuned first within the surrounding area and later ready for replication in other places around the planet which encounter similar water shortages.

It is rather hopeful that the beginning has already started quite some time ago. If we look at the water conservation efforts of bunding and damming of the canyons, the collection and analysis of water levels for 3000 bore wells, collection of weather and rain data, using GIS and satellite images, rehabilitation of existing tanks in the bioregion, implementing of decentralized waste water treatment systems on a large scale, providing safe and healthy drinking water to surrounding villages who self-manage the machines, the continuing work in the area of micro organism, also called EM, the efforts of finding a way and a solution for reutilizing the Pondicherry sewage farm effluent, the planning and effort for setting up a desalinization plant, the fact that we have a functional environmental monitoring lab, the efforts for storing huge water reserves in an affordable manner, experiments with integrating rainwater storage and rain water percolation next to buildings by the architects, the bioregional self help groups of women and youth, the sanitation programs, efforts to introduce eco-sanitation and alternative means for providing hygienic conditions with EM, organizing village level solid waste management practices, and so on. If you actually start thinking about it, the initiatives are numerous.
There is a pattern in our progress; it ties our many small endeavors together in an ever wider and more complete design.

All these efforts will have to spread and be implemented towards a wider region and involving a larger population of stakeholders.

A growing Auroville will have to deal with a critical water situation, and we will need to combine efforts, creativity, goodwill and not forget the vision. How to start, how do we manage, how to plan, how to involve all the stakeholders.

Already part of the seminar presentations dealt with the issues. Let us continue the effort, the time is right and the energy is available.

I would like to thank the members of the panel for their valuable input in the seminar and the many participants for their presence.
Coastal regions have complex hydrogeological compositions. If the multifaceted socio-economic issues along the coasts are also considered, then one has to conclude that the coastal bioregions are under continuous and increased pressure from all sides.

The Auroville bioregion is no exception to this phenomenon. During the last two decades, this coastal region of 1400 km² with a population of nearly 2 million has shown an ongoing environmental degradation. While salt-water infiltration has been the most talked about problem, causing permanent damage to the coastal fresh water resources, it certainly is not the only problem.

The scientific monograph brings together 21 research documents dealing with water management in the wider context of complex socio-economic issues in the Auroville bioregion.

This document is only one step in a continuing effort to gather and compile a comprehensive scientific data-bank that can foster future environment-friendly, socially acceptable and economically-viable interventions in the coastal region.