CURRENT TRENDS IN WATER QUALITY AND RESOURCES MANAGEMENT

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Abstract

About 97% of the water on the Earth's surface is salty water, and only 3% is freshwater. Of the freshwater, 77% is stored as snow, polar ice caps and glaciers while 22% is store below ground, soil moisture and swamp water. The current world population of about 6 billion is expected to double in 100 years, doubling food and water demands. The current trends in water quality and resources management to better cope with such increasing water demands are discussed in this paper, particularly with respect to policy making, management framework and water management technologies. In water quality and resources management, a holistic approach is crucial for sustainable development. Achieving sustainable development requires a fundamental change in the values people hold with respect to the environment. There is a need to develop a national strategic economic framework to develop the water services industry in order to avoid the pitfalls experienced before, such as autonomous decentralization and separation of sewerage services from water services. Socio-political goals must be balanced with economic goals to achieve sustainability in the water services industry. Some common problems faced by the water industry are lack of coordination among various stakeholders, ineffective regulatory structure and poor enforcement, capital expenditure constraints and varied success of privatization of water supply projects. The regulator has an important role to play to drive the efficiency and effectiveness in water services industry; nevertheless there is need for separation of policy and operational functions, so that the utility management can focus on the development of efficient and effective operations without political interference. Water treatment technologies capable of coping with deteriorating river water quality and remove micropollutants, especially

recalcitrant organics such as phenolics, will emerge as rivers become more contaminated with manmade chemicals. Biofilm water treatment processes have been employed in Europe to remove micropollutants so as to meet the stricter new EU drinking water limits. Studies using biofilm processes have shown them capable of removing not only nutrients but also chloroorganics. Technologies to cope with water resources include aquifer recharge and water reuse; these are also discussed in this paper.

1. Introduction

Clean, abundant water provides the basis for agriculture, industry, commerce and transportation, energy production and recreation. Despite its vital significance to our lives, however, population growth, urban development and sprawl and growing competition among users worldwide, exacerbated by periodic drought and possible climate change, are raising concerns over the continued availability of a stable, dependable supply of freshwater for our nation and the world, now and for the foreseeable future (Feldman, 2007).

Over the past several decades, humans concerned with the environment have embraced the notion that one of the most important indicators of the health of natural resources is the quality of the water. It follows that when the quality of rivers, lakes, streams, ponds and wetlands is improved and protected, there will be more healthy lands, wildlife, air and overall environment. The integration, coordination and management of human activities within the natural boundaries of a watershed to protect or improve water quality include a number of activities, such as river basin planning; water quality monitoring and assessment; water withdrawal; hydropower production; planning or permitting, or management; wastewater discharge permit; storm water and other non-point pollution source management; critical-area protection; and wetlands restoration and protection (Ujang and Henze, 2006).

About 97% of the water on the Earth's surface is salty water. Of the freshwater, 77% is stored as snow, polar ice caps and glaciers while 22% is store below ground, soil moisture and swamp water. Water shortage problems are due to it not being available in sufficient quantities and/or quality at locations of high water demands, such as cities, industrial sites and agricultural areas. Such areas are found even in countries where fresh water is abundantly available, such as Malaysia. Examples of such areas in Malaysia are: the city of Kuala Lumpur, petrochemical complexes in Melaka, Kertih, etc, and the Muda agricultural area. In Malaysia water shortage problems surface only during extended dry weather periods, in many arid countries, this is a perennial problem, to the extent that developments are retarded. Of very serious consequence is the limit to food production due to limited availability of irrigation water. As this affects national security and wellbeing, competition for water resources is a potential point of conflict. This would be aggravated as the world population grows; the current world population of about 6 billion is expected to double in 100 years. Thus the search for new water sources, including augmentation and reuse of wastewater. Furthermore, there is a great need to continuously improve the water services industry, especially in developing countries (e.g., Malaysia), where efficient water management is still being planned for. The fundamental keys to reforms lie in addressing both the efficiency and effectiveness on one hand and funding on the other. A self regulatory structure does not work in the water services industry, which is deeply entrenched in a myriad of local Councils, Provinces or States. The lack of an effective structure gradually increases inefficiency of water distribution, leading to flawed cost structures for water operators and poorly determined tariff rates for consumers (Kheong, 2008).

In this paper the current trends in water quality and resources management will be discussed with respect to policy, management framework, and water and wastewater management technologies. For policy and management framework, those in Malaysia will be extensively used as case study.

2. Policy on Water Management

In water quality and resources management, a holistic water policy approach is crucial for sustainable development. Sustainable development, so often used to describe ultimate goals by policymakers seeking to reconcile economic growth with environmental protection, achievement requires among others, embracing of four behavioural changes: adaptability, humility, willingness to learn from mistakes, and enthusiasm. Achieving sustainable development requires a fundamental change in the values people hold toward the environment, whereas the policy plays an important role. The objectives of the policy should be towards achieving the following:

- To establish a transparent and integrated structure for water supply and sewerage services that delivers effective and efficient service to consumers.

- To ensure long term availability and sustainability of water supply including the conservation of water.
- To promote the protection and preservation of watercourses and water catchments.
- To facilitate the development of competition to promote economy and efficiency in water supply and sewerage services industry.
- To establish a regulatory environment that facilitates financial self sustainability amongst industry players in the long term.
- To regulate for the long-term benefit of the consumers.
- To ensure the provision of affordable services on an equitable basis.
- To improve the quality of life and environment through effective and efficient management of water supply and sewerage services.
- To establish an effective system of accountability and governance between industry players.
- To regulate the safety and security of water supply and sewerage systems

Looking at Malaysia as a case study, it can be seen that the national development goals for the water and sewerage industries as outlined in the 7th (1996-2000) and 8th (2001-2005) Malaysia Plans, provide the policy direction for water and sewerage services in Malaysia. Various initiatives have been undertaken in the past to achieve the national developments goals; these are as follows (Kheong, 2008):

Meeting the domestic and industrial demand

During the 7th Malaysia Plan, various water projects had been implemented to meet domestic and industrial demand as well as to meet irrigation requirement. In addition, several actions were undertaken to improve water supply management and to ensure better distribution of water resources among river basins to match supply and demand.

Improving efficiency in water supply system and water quality

In order to provide safe drinking water, several urban and rural water supply programmes were implemented with an emphasis on developing and upgrading source works, storage and treatment plants as well as rehabilitating the distributions systems. The rural water supply programme was expanded, mainly in Sabah, Sarawak and Terengganu, by developing and expanding the pipe connections to existing and new trunk mains, and also the laying of reticulation systems. In addition, various water supply projects were also completed to meet higher demands for water urban centres.

Increasing water supply coverage

National water supply coverage increased from 80% of the total population in 1990 to 89% in 1995. The urban coverage in most states exceeded or was the same as the national urban coverage, which also increased from 96% in 1990 to 99% in 2000. However, water supply coverage for rural areas in Kelantan, Sabah, Sarawak and Terengganu were still relatively low. In the 7th Malaysia Plan, the urban coverage was expected to reach 100% in most states, while the rural coverage was expected to increase to 83% by the year 2000.

Coordinating uneven distribution of water resources

In the 7th Malaysia Plan, the development of inter-State and inter-basin water transfers was further developed to address uneven distribution of water resources, particularly in water stressed States and to ensure long-term sustainability. A more systematic plan was undertaken through inter-State water transfer projects. In the 8th Malaysia Plan, the development of groundwater as an alternative source was also enhanced.

Expanding use of ICT in the water industry

In the 8th Malaysia Plan, the use of ICT was expanded with the establishment of a national information system with a network of databases at the Federal and State levels. The system includes data on water availability and actual usage, and also the projection of demand for water. The application of Geographical Information System (GIS), Supervisory Control and Data Acquisition System (SCADA), telemetry system and customer information and billing systems were expanded to improve the management and operation of water supply services.

Increasing public awareness of the water services industry

The goal of national water services development is also to increase public awareness of the water supply industry in Malaysia, including the importance of water conservation.

Reviewing the privatisation approach

In the 8th Malaysia Plan, the States of Melaka, Negeri Sembilan, Pahang, Perak and Sabah were expected to complete the privatization or corporatization of water supply authorities. By the end of the 8th Malaysia Plan in 2005, it was clear that the value chain of the water services was dichotomized into treatment, which was partially privatized, and distribution, which remained with the State Government. Eventually, privatization was done on a piece-meal basis; this needs to be reviewed to ensure its sustainability.

The challenges facing the water services industry can simply be put down to one of autonomous decentralization. Each agency or entity had its own role to play and as time went by, it developed its own form in response to the socio-political needs. Privatisation seemed to be the panacea to funding constraint for water infrastructure development. In view of the risk, privatized entities signed up concession agreements with some form of guaranteed returns. Privatisation has a strong focus on the economic aspect and based on the key assumption of “willingness to pay”.

It was also clear that the States cannot continue self regulating the water services operators in which they have a direct interest, whether financial or otherwise. There is a need to develop a national strategic economic framework to develop the water services industry in order to avoid the pitfalls of autonomous decentralization. Sewerage services cannot be privatized by itself but should ideally be integrated with water services. Furthermore, socio-political goals must be balanced with economic goals to achieve sustainability in the water services industry.

3. Water Services Management Framework

The management framework determines the sustainability of a nation’s water services. In the Malaysian as a case study, it has surfaced that some of the current problems faced by the water industry are lack of coordination among various stakeholders, ineffective regulatory structure and poor enforcement, capital expenditure (CAPEX) constraints and varied success of privatization of water supply projects. This had prompted the federal government to revamp the existing industry structure to make it more sustainable.

To achieve long-term sustainability, the industry must work towards a full-cost recovery regime. Full-cost recovery must not be full-cost recovery of an inefficient operation or an operation filled with bloated cost. As the regulator drives the water services industry en route to efficiency and effectiveness, the public, particularly the consumers have a vital role to play in understanding the various aspects of the reforms towards full-cost recovery. Public participation is as essential as transparency.

The States cannot continue to regulate the water services industry, which they themselves control or operate. There is a need for separation of policy and operational functions, so that the utility management can focus on the development of efficient and effective operations without political interference. An independent regulator provides vital objectivity in matching desired goals with affordability. It can provide the public with confidence in the integrity of the governance structure.

For the Malaysian case, to drive the Malaysian water services industry reform, the Malaysian National Water Services Commission (or Suruhanjaya Perkhidmatan Air Negara, SPAN) was formed in April 2007. SPAN was established to regulate the whole of the water services industry, defined to include sewerage services, so as to promote holistic and efficient water services, via two main objectives (Kheong, 2008):

1. To support and provide an operating climate that is viable for operators to provide effective management of water and sewerage services; and
2. To protect the interest of consumers of the water and sewerage services in the country

In line with the objectives for SPAN, the policy framework for the Commission covers the following:

- To ensure that there is fair and efficient mechanism for the determination of water tariffs that is acceptable to both users and operators of services;

- To determine and implement tariffs that have been established through appropriate mechanism and tools;
- To increase concerted efforts towards improving the operational efficiency of the industry and in particular the reduction of NRW through short-term, medium-term and long-term programmes;
- To ensure productivity of the industry through promotion of competitive and efficient operators and the monitoring of operator compliance with stipulated service standards, contractual obligations and relevant laws and guidelines;
- To ensure long-term sustainability of quality water and sewerage services through continued capital works development facilitated by a special purpose company *Pengurusan Aset Air Berhad* (PAAB);
- To support long-term sustainability of services through consultative participation in river basin management with respective authorities;
- To ensure that consumers are accounted for through stakeholder participation in relevant decision-making processes;
- To ensure that consumers have a clear channel for communication through the establishment utilization of an industry-related consumer association (i.e. Water Forum);
- To raise awareness on the development of the industry through the dissemination of KPIs for the industry.

Malaysia has taken a bold move in the water services industry reform. It has changed the Federal Constitution to take the power of regulating the industry to the Federal level, a politically mammoth task that was successfully done only with substantial buy-ins. An economic model was then designed to achieve full-cost recovery taking into account the need to settle existing debts, driving efficiency and effectiveness, raising long-term cheap financing whilst balancing the social objectives and raising the customer service levels.

In embarking on the reform, Malaysia studied the regulatory models in various developed countries while recognizing the challenges of the developing world. It has mapped out the direction forward for a holistic water services industry that encompasses water abstraction, treatment, distribution and wastewater treatment in the long term. The journey of a thousand miles starts with the first step; Malaysia has taken a giant step and has begun the journey up the mountain of long-term sustainability.

4. Water Treatment Technologies

Studies carried out on a global basis indicate that only a small percentage of the available water is of good enough quality for human use. Despite that, freshwater resources have been dwindling over the years, both in terms of quality and quantity, while the demand for potable water has been steadily increasing. Global warming, increasing world population and generally increasing incomes mean the demand for water is likely to rise further. If current trends continue, 40% more water is needed by 2024 than at present (Aquarec, 2005). Further, urbanization has resulted in the generation of large volumes of solid and liquid wastes, with increasing pollution of rivers by trace industrial and household chemicals and pharmaceuticals. Because of these the difference between effluent polishing and water treatment is diminishing and the cost of exploiting water resources for whatever purpose has been increasing over the years thereby pushing the unit cost of water beyond the means of the poor. Thus, the need for proper management of water resources has become critical.

With increasing knowledge of health effects of trace pollutants, a more effective yet affordable water treatment system than the conventional one has to be investigated. The conventional water treatment system of coagulation, settling, filtration and chlorination, removes mainly suspended solids; trace and recalcitrant organics would pass through the system. Thus conventional treatment of river water with significant presence of organics and nutrients leads to formation of chlorinated compounds and higher treatment costs. The danger of chlorinated organics and their removal will be elaborated here.

Water treatment technologies capable of coping with deteriorating river water quality and remove micropollutants, especially recalcitrant organics such as phenolics, will emerge as rivers become more contaminated with manmade chemicals. Biofilm water treatment processes have been employed in Europe to remove micropollutants so as to meet the stricter new EU drinking water limits, such as the new EU Drinking Water Directive (EU DWD); the EU DWD has established the use of biofilm processes in water treatment in Europe, such as in northern Italy. Treatment studies using biofilm reactors have shown substantial enhancement of removal by adsorption-biodegradation in packed bed and expanded bed operating conditions (Abdul-Rahman et al., 2003). In those processes removal of nutrient (NH_3-N) was excellent while average removal of COD was over 65% at HRT as short as 6 hours, and more than 60% removal even if COD was below 10 mg/L (Abdul-Rahman et al, 2002). Biofilm processes have also been found effective in removing trace recalcitrant organics, such as those belonging to phenolic compounds (Abd.Rahman et al, 2006). Phenolic compounds result from their use in various industrial processes and as pesticide degradation products. Phenolics, especially chlorophenols, are known for their toxicity and persistence in the environment. Some have been included in the list of priority pollutants of several countries and they are subject to legislation. Toxicity and bioaccumulative potential of chlorophenols increase with degree of chlorination or number of chlorine substituents on the phenolic ring (Loehr and Krishnamoorthy,1988) and chlorophenol lipophilicity (Mohn and Kennedy, 1992). The toxic effect of chlorophenols seems to be linked to a chain reaction of their gradual dechlorination in body fluids and the formation of free radicals interfering with subcellular structures. The formation of peroxides and other products of lipid oxidation results in enzyme deactivation and liver dystrophy. Chronic toxicity studies on carcinogenic properties in some chlorophenols have shown that higher chlorophenols have immunosuppressive effects, are nephrotoxic and interfere with blood formation. Chlorophenols are excreted from the organism mainly in urine, partially free and partially in the form of their sulphate and glucuronide conjugates. Chlorophenols are known for their pronounced organoleptic characteristics, the taste threshold ranging between 0.040-30 μg/L and smell threshold between 30-1600 μg/L (Veningerova et al, 1997). Biofilm process has been found to be capable of removing chlorinated organic micropollutants and heavy metals (Abd.Rahman et al, 2006). Microorganisms present in the biofilm reactor and the metabolite pathway for PCP carried out by these microbes had been investigated. HPLC analysis on influent and effluent indicated that the reductive dechlorination process pathway occured in the reactor, converting PCP to lesser chlorinated compounds (CP, DCP and Phenol) and eventually to CO_2.

5. Water Reuse

In industrialised countries much of the water used for non-potable purposes, such as industrial applications, toilet flushing and irrigation, is unnecessarily treated to potable-water standard. In water reuse, wastewater treated to an appropriate standard, termed recycled or reclaimed water, is reused for a variety of beneficial purposes. Benefits of water reuse include:

- Increasing water resource availability
- Making scarce potable water previously used for non-potable applications available for drinking
- Reduced consumption of expensively treated potable water supplies (cost saving where there is water metering)
- Reduced effluent flow loads to sewers
- Reduced nutrient discharge to water bodies
- Flood prevention potential (storage)
- A less drought sensitive water resource
- Enhanced recreation and tourism opportunities and biodiversity benefits through the restoration/creation of wetlands

In the planning and implementation of water reuse, the reclaimed water application will usually govern the wastewater treatment needed to protect public health and the environment, and the degree of reliability required for the treatment processes and operations. The categories of water reuse are listed below:

Industrial water reuse

Industry is one of the largest consumers of water. Water is used for processes as diverse as mixing, cooling, boiler feed and plant wash-down as well as for washrooms and other sanitary uses. Unlike most residential properties, industry and business are subject to compulsory metering. With the cost of mains water, sewerage and trade effluent rising, businesses are increasingly conscious of the substantial cost savings that water reuse and water conservation can achieve. Besides cost savings, other potential benefits to industry include:

- avoiding water restrictions imposed during periods of drought
- reduced energy and chemical costs through recycling
- removing the need for discharge consents

- good publicity opportunity
- improved company image and reputation amongst the public, customers and own workforce
- helping to achieve certified environmental accreditation (e.g. ISO 14001)
- fulfilling corporate social responsibility commitments.

Domestic water reuse

Conventional toilet flush water is mains supplied water unnecessarily treated to drinking water quality standard, an expensive and energy intensive process. Greywater recycling is an innovative alternative whereby treated greywater is used principally for toilet flushing and watering gardens. Greywater is wastewater from showers, baths, wash basins, washing machines and kitchen sinks although for recycling purposes kitchen sink and washing machine water is normally excluded because it is too greasy and/or contains too many detergents to allow cost effective treatment. Unlike rainwater, greywater requires filtration to remove hair, skin and soap products from the water and chemical or biological treatment prior to reuse. The potential level of human contact with the water in its end use will determine what level of treatment is required. For example greywater used for hosing down vehicles will require a higher water quality because the risk of human contact with the water is greater in highly pressurised systems. Similarly black water (toilet effluent diluted by flushing water) is not recycled because of the even higher level of treatment needed before it is safe for human contact. Public acceptance is also a major barrier here and in some societies only reuse for industrial purposes is accepted.

Direct and Indirect potable reuse

Direct potable reuse (i.e. treated wastewater directly reused for drinking water) is very rare because of the increased potential risk to public health and the negative public perception, even though the technology is well proven and that river water can actually totally be made of treated sewage effluents. Direct potable reuse is only justifiable when there is no other option for example in the desert lands. Currently the only place where direct potable reuse takes place on a municipal scale is in Windhoek, Namibia, where treated wastewater combined with surface runoff is treated to provide potable water (Aquarec, 2005). Direct reuse is common practice for non-potable applications in industry and irrigation. Meanwhile, indirect potable reuse can be planned or unplanned. Conventional water treatment in many countries involves unplanned indirect potable reuse of treated wastewater. That is, water abstracted from rivers to provide drinking water includes treated wastewater that has been discharged upstream. River water may go through several abstraction-treatment-use-treatment-discharge cycles before reaching the sea, as in many rivers in Europe and elsewhere. The pursuit of economies-of-scale has led to a tendency for large down-catchment wastewater treatment plants (WWTP). Planned use by relocating WWTPs and shortening the use–reuse cycle could increase water availability for both industrial, environmental and other purposes.

Water reuse technology is a combination of unit operations in wastewater treatment and water supply treatment plants. For purposes of wastewater reuse, the type of wastewater treatment technology chosen depends on factors such as the type of wastewater; the potential use of the reused water (for potable uses or non-potable uses); capital and operating costs; and, existing local facilities and skills for the maintenance and operation of the selected facility. As wastewater discharge standards for urban areas, hotels, and industries become stricter, more cost effective methods to treat wastewater that could be reused or recycled are likely to be developed. Biofilm processes, having high biomass concentrations, have also been found to be less sensitive to the presence of toxic and inhibitory materials, and more resistant to shock loadings than the dispersed growth systems. Such characteristics are essential where floor space is becoming expensive and yet there is great need to treat and polish effluents before reuse.

6. Water Augmentation Technologies

Current water augmentation technologies will be described based on water harvesting for the purpose of (i) agricultural sector (ii) domestic water supply and (iii) mining and industry application (Santiago et al., 2007).

(i) Agricultural

Sand Abstraction

Water is abstracted from sand-filled river beds during periods in which there is no surface water flowing in the river. In such situations, the sand is fairly saturated. The method involves the use of slotted cast iron or PVC pipes drilled into the sand-filled river bed, connected to a mainline or manifold, and a pumping system. The water pumped out is distributed for use in agricultural or domestic applications. In small-scale, domestic systems wells or casing sunk into the sandy river bed are fitted with simple hand pumps, or a bucket and windlass assembly.

Cloud Seeding

This technique involves the beneficial modification of convective rainfall to increase rainfall production efficiency. As an example, in Southern Africa only about 30% of the atmospheric water vapour reaches the ground as precipitation (Mather and Terblance, 1993); cloud seeding encourages efficient raindrop formation through a collision - coalescence process which is enhanced or accelerated by the introduction of hygroscopic nuclei into a storm updraft at cloud base. Silver iodide crystals are most commonly used as nuclei for raindrop formation, and are released (by rocket or aeroplane) into an appropriate cloud formation.

Tidal Irrigation

This employs special intake structures with gates, which when opened at high tide, allow brackish tidal water to enter irrigation channels leading to the farms to be irrigated. The gates are opened for a period of between 3 and 24 hours depending on the size of the area to be irrigated. Tidal irrigation is coordinated with pumped irrigation, and is used to irrigate low lying areas along a river. Pumped irrigation systems are used for areas at higher elevations.

(ii) Domestic water supply

Rock and Roof Catchments

Rock catchments are simple systems for the collection of rainwater. Siting of these structures should take into account ease of access and the geological structure of the site. The best sites are found on the lower reaches of bare rocks, where runoff losses to soil, vegetation and structures are minimised. Storage may be provided in dams or open tanks. Meanwhile, roof catchments are suitable for individual households, schools and other institutions where sufficient impermeable roof cover exists. To collect rainwater from roof catchments, gutters and ground storage tanks are required. "First flush" water from each shower should be prevented from entering the storage facility to reduce the degree of pollution of the stored water by dust, leaves and bird droppings washed from roof tops into the reservoir.

Fog Harvesting

Fog droplets are much smaller than both raindrops and drizzle drops, with diameters varying from 1 to 40 microns, and fall at velocities ranging from less than 1 cm/s to about 5 cm/s. These low velocities result in fog droplets being influenced even by light winds that can cause the droplets to travel almost horizontally. An appropriate fog droplets-collector, therefore, is a vertical or near vertical surface. Such surfaces can be constructed as vertical mesh panels on which fog droplets are intercepted and condensed.

Groundwater Recharge

Overdrawing of groundwater may lead to land subsidence and salt water infiltration. These may be averted by recharging groundwater storage via infiltration basins or injection wells or bank filtration. If treated effluents are to be used for recharging, they should be thoroughly treated at tertiary level, removing nutrients and micro-pollutants.

Aquifer Storage and Recharge (ASR)

Aquifer Storage Recharge (ASR) is the use of injection wells to recharge aquifers as well as store water in aquifers. This storage provides much higher capacity than could ever be obtained from surface retention (Al-Ajlouni et al, 2007). Thorough soil investigations need to be carried out to ensure that the targeted aquifer offers secure storage. Treated effluent for recharge should be thoroughly treated at tertiary level, removing nutrients and micro-pollutants.

(iii) Mining and industry

Groundwater Harvesting

Borehole depths vary, depending on geological formations. In sedimentary rock formations, depths of between 25 and 200 m are common. Technically, borehole or well development starts with a geophysical investigation to identify a suitable site. Subsequently, the borehole is drilled through the overburden, weathered surface rock, and fractured bedrock. Usually during the drilling process, slotted screens and solid casings are installed to improve the integrity of well. When groundwater is harvested for industrial use, high yield boreholes and wells are drilled on industrial premises and fitted with pumps, powered by electricity, oil, or solar energy, to deliver water for use within the production lines of the industry.

Surface Water Harvesting

Water demands in industrialized areas tend to outgrow the available water supply. Thus, in order to meet demand, it is necessary to transfer of water to the site from another basin. Such inter-basin transfers (IBTs), although expensive, are becoming the only solution to meeting industrial and mining water demands in many areas. The technique involves building large reservoirs to capture runoff in watersheds that may be several hundreds of kilometers away from the centre of activity, and transferring this water by pipeline or canal to the area of use.

Countries all over the world, especially in dry regions, have seen growing pressure on water resources, with increasing demand and costs, for agricultural, domestic and industrial consumption. This has brought about the need to maximize and augment the use of existing or unexploited sources of freshwater. There are many modern and traditional alternative technologies for improving the utility and augmenting the supply of water being employed in various countries, but with limited application elsewhere due to the lack of information transfer among water resources managers and planners.

With respect to remote areas, community water management technologies introduced from outside the community have often used methods and machinery which the communities are unwilling or unable to maintain, due to difficulties in maintaining and repairing machinery or amount of labour required. Often insufficient attention is given to indigenous irrigation and water conservation technologies, which are usually location specific, thus often difficult to identify and describe. Yet it is essential to take this into account when transferring freshwater augmentation technology from one area to another (Santiago *et al*., 2007) as only techniques fitted or adapted to local social and environmental conditions are likely to succeed.

Given the issues identified above, and the increased need for improved water management in the light of decreased availability, it is clear that communities themselves need to be central to the planning and decision-making process with regard to development projects, including selection and implementation of freshwater augmentation technologies. Further, water reuse and augmentation of freshwater resources should build on those practices already in use within the communities or neighboring communities, and should employ those methods and technologies which the communities, themselves, consider to be sustainable. Contrary to popular belief, water reuse and freshwater augmentation technologies are applicable in all areas regardless of the amount of rainfall. Application of the most appropriate technologies may assist communities to postpone investment of scarce financial resources in new development projects, rehabilitate degraded lands, improve water quality, and alleviate water shortages.

7. Conclusion

The current trends in water quality and resources management have been discussed in this paper, particularly with respect to policy making, management framework and water management technologies. In water quality and resources management, a holistic approach is crucial for sustainable development. Achieving sustainable development requires a fundamental change in the values people hold with respect to the environment. There is a need to develop a national strategic economic framework to develop the water services industry in order to avoid the pitfalls experienced before, such as autonomous decentralization and separation of sewerage services from water services. Socio-political goals must be balanced with economic goals to achieve sustainability in the water services industry. Some common problems faced by the water industry are lack of coordination among various stakeholders, ineffective regulatory structure and poor enforcement, capital expenditure constraints and varied success of privatization of water supply projects. The regulator has an important role to play to drive the efficiency and effectiveness in water services industry; nevertheless there is need for separation of policy and operational functions, so that the utility management can focus on the development of efficient and effective operations without political interference.

Water treatment technologies capable of coping with deteriorating river water quality and remove micropollutants, especially recalcitrant organics such as phenolics, will emerge as rivers become more contaminated with manmade chemicals. Biofilm water treatment processes have been employed in Europe to remove micropollutants so as to meet the stricter new EU drinking water limits. Studies using biofilm processes have shown them capable of removing not only nutrients but also chloroorganics. Technologies to cope with water resources include aquifer recharge and water reuse.

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