An integrated approach for solving urban water and wastewater crises in the Arabian Gulf States

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Abstract Various environmental and economic aspects of urban water and wastewater crises in a number of the Arabian Gulf States are discussed. An integrated approach, which considers simultaneously the problems of urban waters (shortage of water supply and problems associated with urban drainage) and those in connection with wastewater (i.e. environmental impact) is proposed. The feasible link between the main factors affecting these problems and the anticipated results encourage the implementation of the proposed approach. The conclusions suggest immediate municipal legislation.

Keywords Urban water; wastewater; water management; integrated systems

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Introduction

Some of countries in the Arabian Gulf States will face severe water shortages, which will require that almost all freshwater resources be allocated for domestic consumption or other municipal and industrial purposes. While Kuwait and Qatar face this problem today, within a 25-year period countries such as Bahrain, Saudi Arabia and United Arab Emirates will have from their current renewable natural water reserves (without desalination) just about the limit of what is needed for survival, with no freshwater available for agriculture. It is estimated (Engelman and LeRoy, 1993) that the available quantity of water from natural renewable sources, excluding desalination in the year 2025 will range from 10 to 20 m^3/person/year. The actual domestic water consumption required in a modern home with indoor plumbing, hot and cold running water and minimal household equipment such as a washing machine ranges from 35 to 70 m^3/person/year. The expected (Nouh, 2000) population growth together with water supply and demand in some of the Arabian Gulf States are shown in Table 1.

In almost all the Arabian Gulf States, treated wastewater supplied for domestic, urban, and industrial use can often generate the only significant and sustainable source of water resources for agriculture, industrial and urban non-potable purposes. Desalinated seawater, estimated to cost about \$1.00/m^3 or more, will not normally be economically feasible for agriculture use. The capital investment in sewerage infrastructure is high, in the order of \$300–\$500/person. However, under certain conditions, a high level of wastewater collection and treatment is essential to protect the public health and to prevent environmental pollution. Thus, the additional marginal cost of treatment, storage and conveyance of purified wastewater required for unrestricted agricultural reuse, meeting strict WHO health criteria, will be only a fraction of the total wastewater treatment and disposal cost or about US\$ 0.10 out of a total of US\$0.35/m^3. Recycling of wastewater can have the multiple benefit of protecting the environment and serving as a major source of water and nutrients for the soil. Some of the Arabian Gulf States (UAE included) have embarked on successful wastewater recycling programs.

On the other side, rare flash floods generated from intensive rainstorms have significant economic and environmental impacts. The floods, if properly managed, can be

Table 1 Water supply and demand in some of the Arabian Gulf States

Country	Population		Per capita water withdrawal (cu. m)						Domestic & Industrial 2025 total-% increase from 1990
	1990 (millions)	2025% increase from 1990	Domestic		Industrial		Irrigation		
			1990	2025	1990	2025	1990	2025	
Saudi Arabia	16.0	166	94	94	10	21	936	623	193
UAE	1.7	77	266	266	100	100	742	478	77
Kuwait	2.1	31	129	129	7	14	212	106	38
Oman	1.8	248	36	73	15	29	677	452	596

a significant freshwater source instead of being a source of public inconvenience and serious environmental impact (see Figure 1 showing flash flood damage to civil constructions in the southwest region of Saudi Arabia, 1982).

Human dimension of urban water and wastewater crises

The most important challenge to nature is the steady increase in population and its demand for more freshwater. In industrialized zones, this is mainly to cater for increased water consumption in existing large urban centers. In developing zones, we not only have the highest rates of population increase and the largest number of people with no access to clean water and adequate sanitation, but also the phenomenon of emerging mega-cities.

It is estimated that by the year 2025, there will be 13 urban conglomerations in the Arabian Gulf States with populations of more than 2 millions (Nouh, 2000). By the same token, if present trends continue, there will be 26 million people in the Arabian Gulf States living in areas suffering from severe water scarcity. Most of these will be in the poorer peri-urban and rural areas. The consequences of this in terms of human health, misery and squalor do not bear thinking about. And yet, if not from compassion then from self-interest, the better-off industrialized zones should sit up and take notice. The situation requires immediate action and preparations for anticipated water crises.

The underprivileged in developing countries are, among others, the potential source of conflict, famine and pandemic disease. Unless there is good environmental public

Figure 1 Flash food damage to constructions in south-west Saudi Arabia, 1982

awareness and governmental commitment to solving environmental impact issues, sustainability of urban sanitation can not be achieved.

Treated wastewater

Potential of Wastewater as a Water Resource

Treated wastewater is the only source of additional water for agriculture, industry and urban non-potable reuse that actually increases in quantity as the population grows, while more water is demanded by urban and industrial sectors. If it is assumed that the total domestic/urban/industrial water supply eventually reaches 125 CM/P/Yr, then it is not unreasonable to estimate, based on experience in various countries, that any where between 65–80% of the incoming water supply can be treated and reused. Thus for example, a city with a population of one million would require a water supply of 125 million cubic metres/year (MCM/Yr) and under optimal conditions, eventually some 80% of that amount could be collected in the central sewerage network, treated and reused in adjacent agricultural areas. In this case, some 100 MCM/Yr of treated wastewater might be made available to agricultural areas adjacent to the city.

The amount of water would be sufficient to irrigate between 10 to 20 thousand hectares depending on the irrigation technology used, the type of crops and other local conditions. If achieved, such treatment and reuse of properly treated and purified wastewater can, without risk to the health of the public, add significant amounts of water to the agricultural sector. Based on water demand for various crops in any of the Arabian Gulf States, 100 CM/P/Yr could provide more than enough water to grow all of the fresh food crops required by the urban population. Alternatively, it could be used for higher valued industrial purposes and even for still higher value, urban, non-potable purposes such as the irrigation of greenbelts, parks, gardens and recreation areas. In some cases, treated wastewater has been successfully used for the flushing of toilets in municipally managed multi-storied buildings.

Sewerage System Infrastructure

A precondition for achieving the above reuse, or any level of treatment and reuse of wastewater, is the construction of a sewerage system infrastructure to collect the wastewater from domestic, commercial and industrial sources for all the major urban areas.

Public Health and Environmental Protection

For urban areas with central water supply to the homes and domestic water consumption of over 50 litres/person/day, local wastewater disposal methods such as septic tanks and percolation pits, can only serve as a temporary palliative. Eventually, as population density increases and as water supply and wastewater flows increase, overflowing septic tanks and percolation pits become the rule, rather than the exception, and the urban environment becomes saturated with the stench and mosquito breeding sites of health menacing wastewater pools and streams. The only solution is the construction of a central sewerage network and wastewater treatment plants, which should be considered as an absolutely essential part of urban environmental protection to assure the public health and welfare regardless of the need to treat and reuse wastewater as a water resource.

Wastewater carries with it the full spectrum of pathogenic bacterial, viral and protozoans of the diseases endemic in the community, and can as well carry pathogenic agents of disease such as cholera, introduced by visitors to the city, coming from epidemic areas. Pools and streams of wastewater in urban areas have, in certain zones, become the main breeding sites of the Culex Pipiens mosquitoes that transmit the disease – filariasis, which can lead in extreme cases to the disfiguring elephantiasis condition.

From the public health point of view alone, a central sewerage system for the collection and treatment of wastewater is vital. However, even if the wastewater is collected in a central sewerage system providing a reduction of public health risks for the urban residents but later dumped untreated into open water, dry river beds (wadis), or lakes, there is the danger of the pollution of surface and/or groundwater sources of drinking water for downstream users with the disease-causing micro-organism from upstream areas. In addition, there are odor nuisances and fish kills in receiving bodies of water such as lakes, rivers and the ocean the pathogenic health problems to recreational areas, seafood and fish harvested from such polluted waters. That same wastewater if properly treated and used on the land can be prevented from ever reaching downstream pollution and can become an important resource.

Under conditions of plentiful year round rainfall and large flowing river, the most commonly practiced solution is treatment of wastewater to a degree that will allow its disposal and dilution in the nearest water bodies. However in the Arabian Gulf States, where rivers have only seasonal flow, the disposal of wastewater effluent to dry riverbeds (wadis) can create serious environmental problems. Under such conditions, wastewater treatment and reuse through land application can solve both the environmental problems as well as create a valuable additional source of water and nutrients for the soil. It has been reported (Shuval *et al.*, 1986) that the fertilizer value of the natural nutrients in wastewater is worth about US$3/CM, which can save the farmer about US$130/Ha/yr in fertilizer costs if he irrigates the land with treated wastewater. Thus, for farmers in the Arabian Gulf States the fertilizer value alone of wastewater can be an attractive incentive.

WHO Health Reuse Guidelines

The World Bank and the World Health Organization became concerned about this anomalous situation and sponsored studies by several independent groups of public health experts and environmental engineers in many parts of the world to reevaluate the scientific basis for wastewater irrigation guidelines and standards. They carried out an extensive scientific evaluation of the epidemiological evidence on health effects associated with wastewater irrigation and developed a new and scientifically sound approach for establishing revised health criteria for wastewater irrigation. The Engelberg report (Engelberg, 1985) summarized these findings and presented a radical departure from previous policy in the area of wastewater reuse guidelines and standards. On the one hand it introduced a strict new approach and numerical standard for removal of helminth eggs from wastewater effluent for agriculture reuse, based on firm epidemiological evidence that helminth-worm diseases caused by protozoans such as ascaris, trichuris and hookworm, were the number one health problem associated with wastewater irrigation in the developing countries.

On the other hand, based on the new epidemiological evidence, and their analysis, they called for a major liberalization of the earlier severe zero risk “California” bacterial guidelines which had evolved unwittingly into the world’s most widely accepted standard, even though its was illogical, irrational and unfeasible from its inception. The WHO carefully coordinated its efforts in developing international wastewater reuse guidelines with all the other United Nations agencies including the FAO, UNEP, UNDP and the World Bank. They also sent out the draft proposals for the new guidelines for review and comments to over 100 health scientists and engineers and to Ministries of Health all over the world.

In November 1987, the WHO convened a Scientific Group on “Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture.” The group carefully reviewed all the previous studies, the new epidemiological evidence, comments received from many experts, and decided to adopt the Engelberg approach and microbial guidelines for wastewater irrigation. The new microbial, health guidelines for unrestricted irrigation of all crops now recommended by the WHO are:

- No helminth eggs per litre of effluent and,
- A mean of 1000 fecal coliforms per 100 ml of effluent.

The above guidelines have been formally approved and adopted by many developed and developing countries all over the world.

In 1992 the United States Environmental Protection Agency together with the United States Agency for International Development, proposed the following as guidelines for the effluent for irrigation of crops eaten raw.

- BOD 10 mg/l
- Turbidity 2 NTU
- Microbial No detectable fecal coli/100 ml
- Chlorine Residual 1 mg/1 CI_2 (after 30 minutes)

Sustainability of urban sanitation

The sustainability of current urban sanitation is questionable. Historically, sanitation has primarily been perceived as a stand-alone issue. Therefore, the ultimate health and environmental impacts of sanitation systems have not been fully considered, nor was a systems approach followed, whereby sanitation is integrated in the management of the urban water cycle as a whole.

Urban sanitation will be considered in its broadest sense – covering the management of human excreta, but also all other wastes generated through human activity in the urban environment. Major factors that undermine the sustainability of urban sanitation are:

Inadequate human sanitation. Under these conditions, human faeces and associated pathogens, extensively contaminate drinking water, soil and the domestic environment.

Poorly planned on-site sanitation. In poor areas, the most common form of sanitation is pit latrines. Often, proper account is not taken of hydrogeological conditions, resulting in groundwater pollution.

Water-borne sewerage, but no treatment. In some zones, sewage is not properly treated. This means surface water in and around such zones is little more than open sewers. This is aesthetically degrading and creates reservoirs for cholera and other water-borne diseases.

Inadequate sewer management. Sewer breaks, blockages, heavy rains and rising water tables could force raw effluent out of sewerage pipes, creating serious health hazards. This situation is also applied in zones with improper drainage facilities. An example is shown in a Figure 2.

Inadequate refuse and solid waste disposal

In many poor zones this is a growing problem. Wastes are dumped indiscriminately, often around points of public water supply. Such conditions contribute to environmental degradation, surface and groundwater pollution, and health problems through vector-borne diseases.

Figure 2 Effect of inadequate urban drainage

Complete water-borne sewerage and treatment

In many affluent places, services provision is comprehensive, but this situation too is unsustainable, mainly for the following reasons:

- *The mixing of waste streams*. Clean water and human excreta are mixed with toxic chemicals and metals from industry. Sewage treatment then results in a problematic sludge and in the discharge of effluents with negative environmental and health impacts.
- *Sludge handling*. This is a vexing problem worldwide. Ocean discharge is unsustainable; agricultural use is bedeviled through the presence of heavy metals; landfilling leads to groundwater pollution; while incineration releases toxic chemicals into the air.
- *Costs*. Energy costs for pumping and treatment are enormous. Even for rich cities the maintenance of deteriorating sewers constitutes an increasingly heavy financial burden. Discharge quality standards, too, are progressively becoming more stringent, leading to substantial cost increases. The deterioration of water quality through effluent discharges also increases the cost of water treatment downstream.
- *Water use*. Flush toilets constitute some 45% of residential demand. Many cities are already water-stressed, and the use of water for transporting wastes is difficult to justify.
- *Secondary pollution*: Enrichment of the aquatic environment with nutrients, through effluent discharges, simulates algae growth. This leads to aesthetic degradation, increased cost of potable water treatment, and the release of algae toxins.

Having in mind all the above factors, the question, which has to be raised, is "can sustainability be improved? Taking a long-term perspective there can be a way forward through the following proposed integrated approach to urban water and waste management.

The integrated approach

In this paper context, "integrated" is defined as satisfying the technological (engineering or scientific), economic, social and environmental requirements when planning the water resources development programs and implementing the complex series of interrelated activities in an efficient and comprehensive manner. This means that the approach sets priorities and targets which must be matched to political and social expectations and the financial resources available. In fact, very few master plans of the 1970s and 1980s ever reached the stage of programmed implementation because they were seldom integrated into the national development planning process and there were many competing priorities for financial resources. Furthermore, water resources development had tended to be regarded as an infrastructure input to a wide range of disparate activities rather than a development arena in its own right. To encompass the whole range of development activities within a framework which is limited by the finite nature of the resources, and the finance available, and seek to optimize the development strategy in terms of supply management, demand management, social equity, economic and environmental sustainability and capacity to undertake the work, required an approach such as the one proposed in this paper.

The proposed integrated approach is based on the following principle objectives:

- To promote a dynamic, iterative, interactive and multisectoral approach to water resources management, including the identification and protection of potential sources of freshwater supply, which integrates technological, socio-economic, environmental and human health considerations.
- To plan the sustainable and rational utilization, protection, conservation and management of water resources based on community needs and priorities within the framework of a national economic development plan.
- To design, implement and evaluate projects and programs that are both economically efficient and socially appropriate within clearly defined strategies, based on an approach of full public participation, including that of women, youth, indigenous people, local communities and people under occupation, in water management policy-making and decision-making.
- To identify and strengthen or develop, as required, in particular in the Arabian Gulf States, the appropriate institutional, legal and financial mechanism to ensure that water policy and its implementation are a catalyst for sustainable social progress and economic growth.

Demand management

Out of the consideration of water both as an economic good and a finite and vulnerable resource comes the concept of demand management. At its simplest, this means that water resources development and management is no longer a question of assessing the resources, matching supply to projected demand and finding the necessary finance to design and implement programs to utilize it. Because of the limited nature of the resources, decisions have to be made on its "best" use, by evaluating the economic, social and environmental costs and benefits of alternatives. Demand management is the application of a range of physical and economic tools to produce greater efficiency in the way in which water is produced and used. It is intended to complement efficient supply management and leads to improved allocation of water among competing users, reduction of wastes, better protection of water quality, improved financial management and, ultimately, to sustainable development.

Of all potential measures available to water resources managers, the implementation of rational pricing policies is known to have the largest impact on the pattern of water use.

In addition, a whole range of techniques exists to reduce water consumption where there is unnecessary use and wastage or where there is a need to conserve the resource. Two major ways of saving water are to be found, for example, first by reducing the amount of water used in industrial production and the wasteful pollution of watercourses and, secondly, by increasing the efficiency of irrigated agriculture. There are also ways of increasing the resource base. Use of low-quality water, recycling, water harvesting, deliberate mining of groundwater where the long-term effects are known, inter-basin transfers and desalination all have to be evaluated in terms of their full economic, social and environmental cost and in relation to the similar range of benefits.

Institutional/legal frameworks and public participation

Finding the appropriate balance between a top-down (centralized) and a bottom-up (community-based) approach to managing water resources is central to achieving integrated water resources management. Creating the appropriate institutional and legal framework to enable development to take place in a sustainable manner is part of the means of achieving this.

The legal and institutional frameworks are the most important implementing mechanisms for integrated water resources development and management, which can be readily achieved by government. In many cases, the existing legislation is not suited to modern conditions or to dealing with questions of environmental sustainability. An overhaul of the water legislation paying particular attention to protection of the resources, water quality and pollution control and providing the enabling framework for demand management is a priority in many countries. Legislation is also required to implement the many aspects of decentralization, delegation and privatization.

Developing the most appropriate participatory techniques (both public and private) is another important element of creating the best environment for development to take place and in establishing a decentralized management system. It is now a well-known fact that community water supplies will not be sustainable if their development takes place without community participation. What is seldom realized is that costly mistakes in the largest schemes can often be avoided and sustainability can often only be achieved if local knowledge is incorporated into the decision-making process and the public will is behind the development. In the case of demand management applied to water supply, for example, the use of tariffs as an economic tool for inducing efficiency may fail if the beneficiaries of a supply are not consulted or if they misinterpret the reasons behind the measures due to faulty or inadequate public information.

The challenge, therefore, is to find the most appropriate water management system, tailored to individual countries, needs, but nevertheless encompassing the guiding principles, which are to be, outlined hereafter.

Based on the above principles, integrated urban water management should consider the collective impact of all possible water-related urban processes (of which the management of human excreta or sewer is only one) on issues such as human health, environmental protection, quality of receiving water, urban water demand, affordability, land and water-based recreation, and stakeholder satisfaction. Individual processes should then be planned and managed in a way that the collective impact be optimized as far as possible. Due account should also be taken of the interaction of processes. The aforementioned constitutes what one could call the technocratic dimension of the approach. However, there is also the human dimension as discussed earlier, which is equally important. This requires stakeholder involvement and demand management. For cities in the Arabian Gulf States, the human dimension and public participation are particularly important. For example, hygiene education and building of managerial capacity can generate major benefits over a relatively short term. It should also lay the foundation to more effectively attend to the technocratic dimension of the proposed approach.

Conclusion

For countries in arid regions, in general, and the Arabian Gulf States, in particular, treatment and reuse of wastewater can be the main, if not only, water resource whose quantity will continue to increase as more water, is used by the urban/industrial sector, and can thus provide a rational and sustainable basis for a limited level of agriculture in such severely water short countries. The amount of treated wastewater may reach as much a 100 cu.m/person/year, which is enough water to meet most normal fresh food demands of the urban population. While desalinated seawater presently costs at least one US dollar/-cu.m and can rarely serve as an economically rational source of water for agriculture, treated wastewater is relatively cheap. Water harvesting of flash floods represents another source of freshwater for urban use. Water collection and treatment should adhere to the WHO guidelines for human health and environment protection. However, it would be wise for countries to make their own independent judgments in establishing health regulations for wastewater reuse and flash flood harvesting, free from the social, economic and political forces that shaped the American standards. Thus, governments can pursue wastewater recycling and reuse problems with a sense of confidence that they are promoting a multivalent strategy of water conservation coupled with environmental and public health protection.

In the integrated approach, social factors should be considered. The decision-maker should be able to consider resource allocation problems in terms of technically defined alternatives and to make investment decisions on the basis of the systematic integration of economic, environmental and social goals.

When multi-objective techniques are combined with macro-economic planning models, water development and utilization are allowed to take place in accordance with social, environmental and economic objectives to yield the optimum integrated benefits. Such techniques have been successfully used in water-short regions of China in recent UN assisted projects.

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