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AGRICULTURE, WATER AND THE ENVIRONMENT: FUTURE CHALLENGES

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ABSTRACT

Various countries in the Mediterranean Basin and other arid and semi-arid regions are facing a gap between water supply and demand. This gap is closely linked with agricultural production and environmental issues. It is probably due to small amounts of precipitation and low availability of natural water sources. Special ventures have to be undertaken in order to supply water at adequate quality for all requirements. These can be accomplished by development of additional water sources that currently are considered marginal. The additional sources include saline ground water, treated wastewater and runoff water and are usually required to augment the limited supply from the regional conventional high quality local sources. The paper presented options for development of the marginal water sources in arid zones in conjunction with minimising the dependence on high quality water. Domestic secondary effluent is a valuable water source for reclamation however, additional treatment is required to use it for unrestricted purposes. It can be achieved primarily by implementation of the membrane technology, namely ultrafiltration (UF) and reverse osmosis (RO) stages.

KEYWORDS

Holistic; management modelling; membrane technology; water quality; water sources.

INTRODUCTION

Water Sources in And Regions

Pure water is a scarce commodity in many parts of the world, including the Mediterranean Basin and disparate arid and semi-arid regions. Hundreds millions people throughout the globe experience water scarcity or water stress. This gap between water supply and demand is expected to increase next decades due to population increase and per capita consumption along with declining water availability (Piasecki *et al.*, 1999).

Across the world, water gaps are due to a series of factors that include agricultural consumption, industrial development and the intentions of self-sufficiency in food production. Advancement in standards of living, over pumping of ground waters, restricted precipitation due to climate changes and deterioration in quality and supply. All are tied to water demand, agricultural production and environmental issues. The Environmental issues are getting increased attention last decades due to sensitivity to water quality and contamination of aquifers and soils and potential reduction in agricultural productivity. It is associated with contaminants migration into the groundwater and increase in hazardous constituents content, which limit the use for diverse purposes. The accumulation of salts in **the upper** agricultural production soil layers and **as** well in the ground water hinders **as** well natural use of the groundwater and surface waters.

Frequently the limited precipitation and related water shortage is associated with geographical and seasonal distribution. The sharp geographical variation in precipitation and consequently in availability of water is a typical phenomena in *dry* regions. Special venture have to be undertaken in order to supply water and at adequate quality for all needs. Most of available water is consumed for agricultural purposes (Table 1).

Table 1. Water availability and consumption for agriculture, industry and domestic use (Goto, **2002)**

Country	Total available (Billion m³)	Agriculture (% of total)	Industry (% of total)	Domestic (% of total)
Algeria	4.5	60	'	
China	2,829	77	18	5
Cyprus	0.2	74		
Egypt	55.1	94.5		-
Indonesia	2,838	93	1	6
Israel	1.7	64		-
Japan	430	64	17	19
Jordan	1.0	75		-
Korea	77	73	16	11
Lebanon	1.3	68		-
Libya	4.5	87		
Malaysia	580	76	13	11
Morocco	11.1	92		
Philippines	479	88	4	8
Syria	14.4	94	-	
Thailand	410	91	4	5
Tunisia	2.3	86		
Turkey	36.5	73		

'Missing data

However, due to limited availability of water this picture is gradually changing and agriculture will soon rely on marginal water sources, primarily domestic effluent. Actual human water consumption is in the range of **50** to 100 m³/inh·yr, subject to living standards and geographical location (Table **1**; Figs. **1** and 2). The domestic consumption is continuously increasing along with elevated life standards. In developed regions around 70% to **85** % of the domestic water consumed is seweraged and most of it is treated.

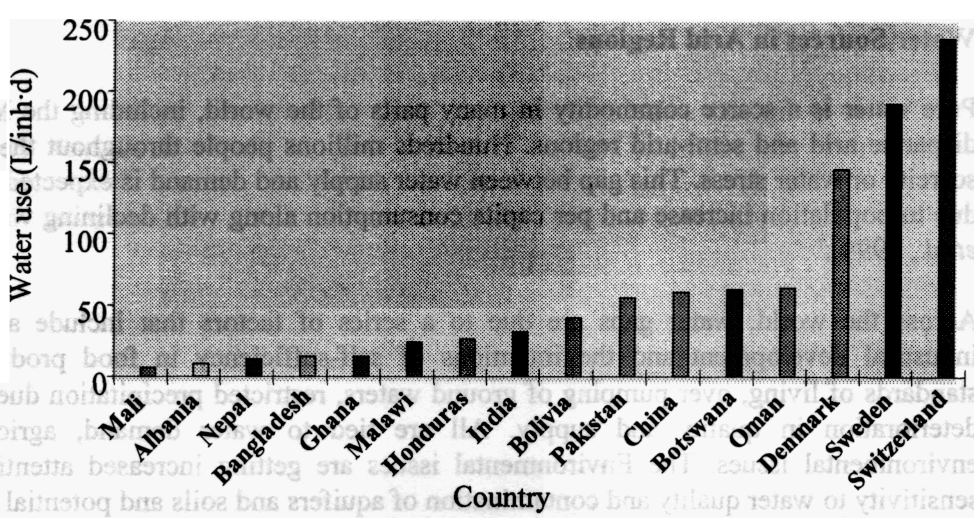

Figure 1. Domestic water use in representative countries (Price, 2002)

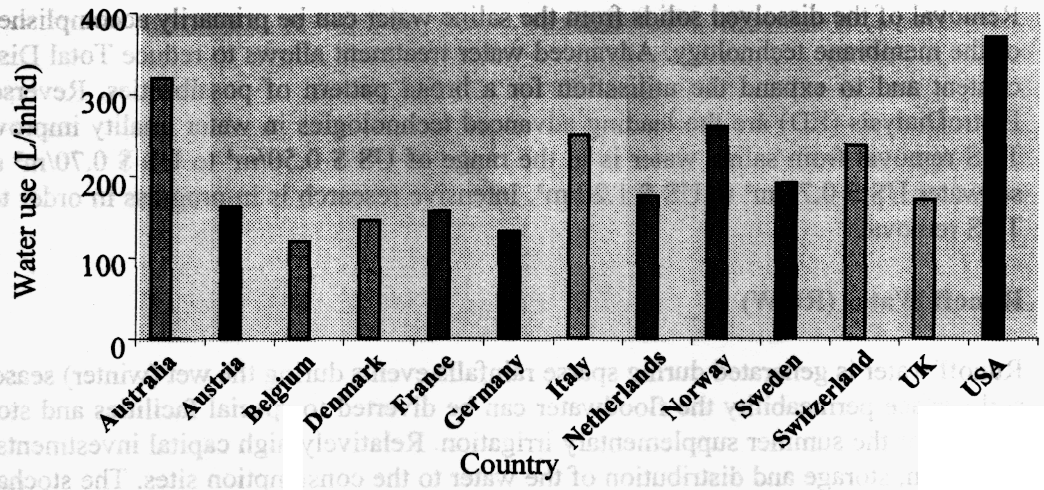

Figure 2. Domestic water use in developed word countries (Price, 2002)

There are several strategies to restrain the gap between supply and 'demand. One common route is to import water from external sources for use in main consumption sites. These include transporting water fiom the Sierra Mountains in Northern California to the southern part of the state, from Malaysia to Singapore, and from Turkey to northern Cyprus. A 400 cm diameter pipe system consisting of two separate branches at a total length of approximately 1900 km is installed to transport water from the sandy dune desert to the fertile coastal strip in Libya (the Great Man-Made River Project, 1989). One brancn conveys water from Tazerbo and Kufrah well fields in the direction of the agricultural strip between Benghazi and Sirt with continuation to Tobruk and the other branch conducts water fiom Sarir Qattusash well fields to the fertile gulf strip between Tripoli and Sirt. Total final flow will be around 2.0×10^6 m³/d.

Complementary water amounts can be obtained in arid regions by using cloud seeding methods in order to enhance precipitation and for aquifer enrichment. **High** quality water can **as** well be pumped from the sea and treated to a drinking quality by implementing membrane technologies.

THE ADDITIONAL **WATERS**

In addition to the above sources water scarcity in arid zones can be expelled by **gradual** development of local marginal water sources. Additional water sources development is subject to regional and periodical needs, economic and environmental considerations, and future prospects (Brimberg *et al.*, 1994). In order to reduce the dependence of water supply on external sources and alleviate the problems associated with over-pumpage, it has become necessary to develop the non-conventional and not yet fully exploited water sources existing primarily in the desert regions. These additional water sources have a number of characteristics.

Saline Groundwater (SGW)

Saline water can be found **as** tail water in fields irrigated by open-surface methods and mainly **as** groundwater in deep fossil aquifers (up to a depth of 1000 m) underlying the Negev Desert and **Sinai** Peninsula (Issar and Adar, 1992). Conventional salinity in saline water is expressed by the Electrical Conductivity **(EC)** and is in the general EC range of 2 to **7** dS/m. Saline water is primarily used for direct agricultural irrigation, and for recreation, industry and toilet flushing. Desalination of saline water looks to be more economic attractive than seawater desalination. Application of saline water for irrigation of agricultural crops is associated with improved fruits quality due to higher sugar content **as** expressed by the BRIX values.

Removal of the dissolved solids from the saline water can be primarily accomplished by implementation of the membrane technology. Advanced water treatment allows to reduce Total Dissolved Solids (TDS) content and to expand the utilisation for a broad pattern of possibilities. Reverse osmosis (RO) and ElectroDialysis (ED) are the leading advanced technologies in water quality improvements. The cost of TDS removal from saline water is in the range of US \$ 0.50/m^3 to US \$ 0.70/m^3 and for conventional seawater US \$ 0.75/m^3 to US \$ 1.20/m^3. Intensive research is in progress in order to reduce the cost for TDS removal.

Runoff Water (ROW)

Runoff water is generated during sparse rainfalls events during the wet (winter) season. In areas with low soil surface permeability the floodwater can be diverted to special facilities and stored for future needs mainly for the summer supplementary irrigation. Relatively high capital investments are required for the collection, storage and distribution of the water to the consumption sites. The stochastic nature of runoff water supply raises reliability issues and difficulties to use this water efficiently. Although the low stability, the high quality water and the potential to retain large volumes are advantageous in regions with scarce conventional waters.

In arid regions ROW can be used efficiently by implementation of water harvesting methods (Boers, 1994). Harvesting methods include collection of the ROW close to the contribution basins and catchment of various sizes (Oron and Enthoven, 1992).

One of the directions that need further attention is the urban runoff. The use of the urban runoff should be linked with the urban planning. Urban planning should take into account broader design aspects besides the water for the general welfare of the community. Urban ROW can be collected and reused for artificial aquifer recharge due to the intense urbanisation processes that limit the free surface areas for natural ground water recharge.

Treated Wastewater (TWW)

Treated wastewater, and primarily domestic treated sewage can be reused for a large pattern of possibilities, primarily for agricultural irrigation (Asano et al., 1992). The major drawbacks of TWW use are the high capital investment in the treatment facilities and equipment, the dual piping system required to distribute it separately from potable water, effluent quality control and additional required precaution to minimise health and environmental risks. Treatment level as related to the purpose of reuse is of extra concern. The nutrients contained in the TWW are, however, beneficial for agricultural use (Oron *et* al., 1991).

THE EXPANDED HOLISTIC APPROACH

When trying to optimize the use of waters, primarily in regions with scarce high quality conventional sources a broad view of all related factors have to be taken into account. That approach allows including most related aspects such as water quality and readability of supply, environmental issues, public concern and safety of food production. The two-linked leading components are: (a) field experiments and related construction and maintenance of the treatment and renovation systems, and (b) development and implementation of management models, taking into account environment, economic and social aspects, allowing to evaluate cost/benefit criteria of different approaches of reducing salinity, pathogens removal and other hazardous inputs.

In most developed countries wastewater treatment is compulsory. The producer of the wastewater is responsible for the treatment prior to disposal or to reuse by the interested organisations. Domestic wastewater is primarily treated in stabilisation pond systems. Stabilisation ponds are mainly popular in small communities and in regions with abandon land. In large urban areas the wastewater is treated implementing advanced methods. The advanced svstems include aerated lagoons, activated sludge, anaerobic phases and lately also Sequential Batch Reactors (SBR). Industrial wastewater is mostly treated separate streams on the manufacturing yard to adequate levels and subsequently is disposed to the main sewerage systems.

In the greater Tel-Aviv area (Dan Region, Israel)) the domestic wastewater is treated in a combination of activated sludge and nitrification and denitrification phases. Annual raw sewage discharge is currently around $120x10^6$ m^3/yr, treating the wastewater of a population of about $1.4x10^6$ inhabitants (Kanarek and Michail, 1996). The effluent is subsequently injected into the aquifer (Soil Aquifer Treatment, SAT) and then pumped for irrigation (Fig. 3). The Dan Region plants demonstrates the holistic approach (a) wastewater treatment; (b) additional treatment during effluent flow to the coastal aquifer; (c) increased water storage in the aquifer; (d) prevention of sea-water intrusion, and (e) effluent pumping from aquifer for agricultural irrigation. The simultaneous targets fulfilled during SAT demonstrate the complexity of the approach however, provide solutions to a series of issues.

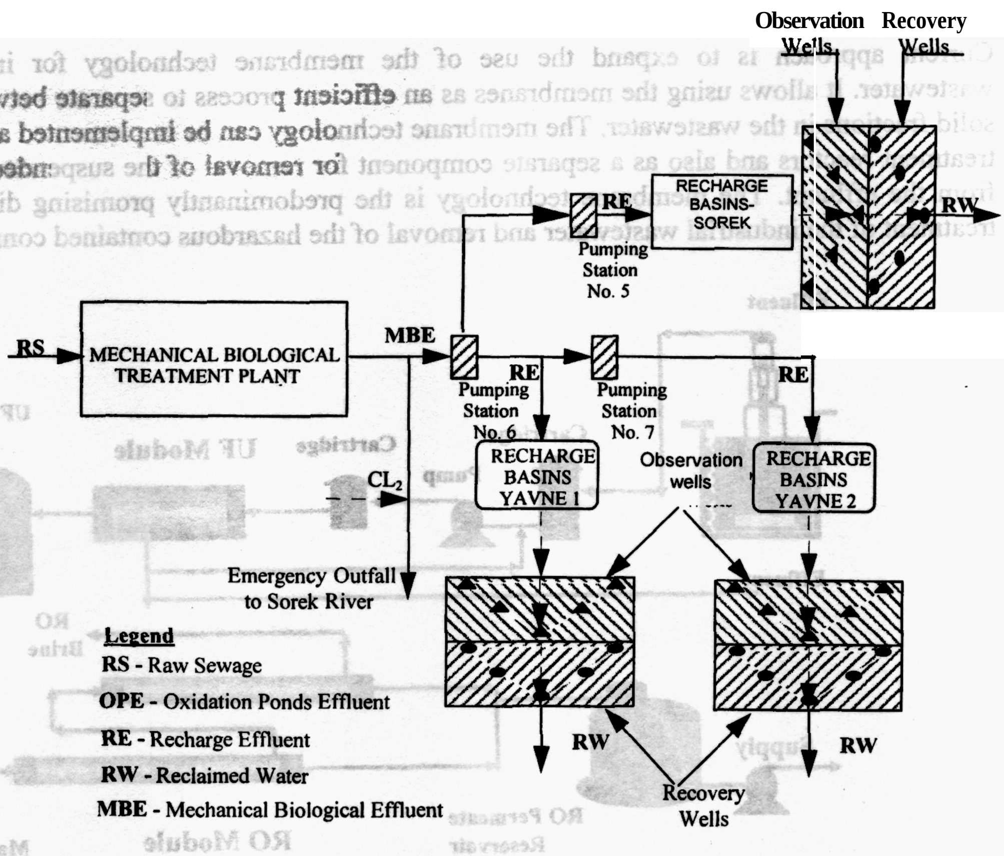

Figure 3. Schematic layout of the treatment plant including the injection ponds of Greater Tel-Aviv (Dan Region, Israel)

Wastewater Separation in the Source of Generation

The difficulties associated with the wastewater quality recalls for advanced approaches. Some of them are based on separation of the wastewater streams (Fig. 4). Treating each waste stream separately allows adapting specific tratemnt method, frequently with less expensive than the composite sewage streams. Streams separation according to quality providers better tratemnt conditions. Subsequently, also reclamation alternatives are improved.

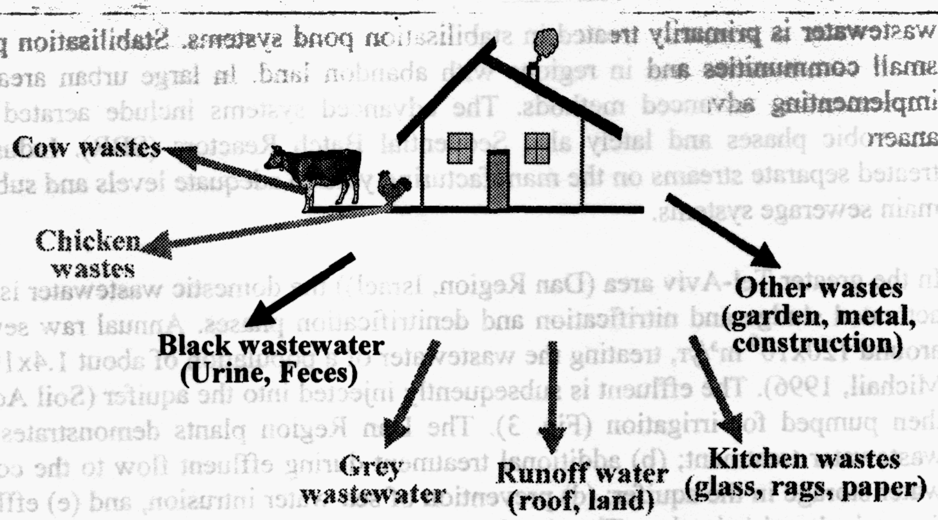

Figure 4. Schematic layout of option of wastewater separation

Wastewater Quality Upgrading for Unrestricted Reuse

Current approach is to expand the use of the membrane technology for improved treatment of wastewater. It allows using the membranes as an efficient process to separate between the liquid and the solid fractions in the wastewater. The membrane technology can be implemented as part of the biological treatment reactors and also as a separate component for removal of the suspended mater and pathogens from the effluent. The membrane technology is the predominantly promising direction also for better treatment of the industrial wastewater and removal of the hazardous contained constituents.

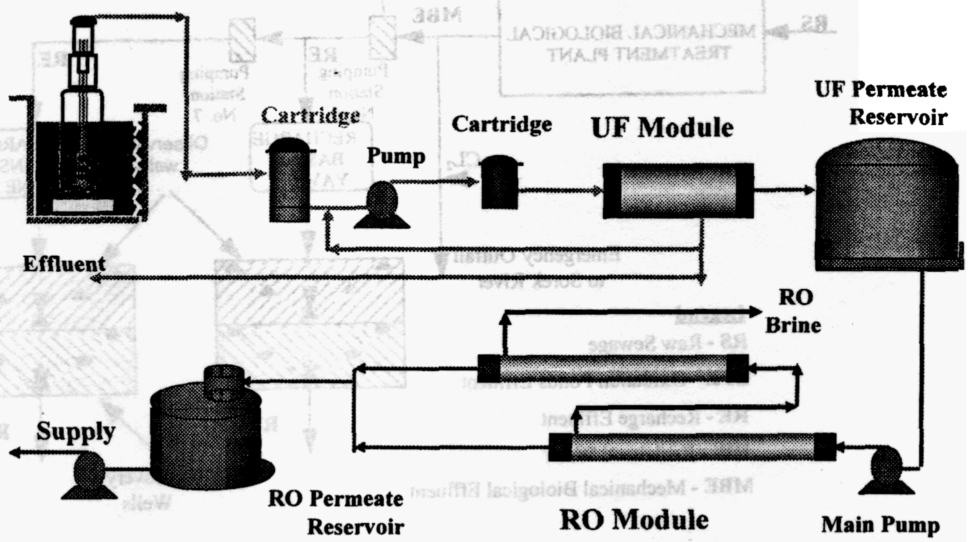

Figure 5. Schematic **layout** of a **two-stage UF and RO** membrane **system for** effluent **upgrading**

One of the favorite directions for resolving simultaneously water shortage issues and effluent disposal problem is to reuse the treated wastewater for agricultural, ornamental imgation. In order to cope with health, environmental issues and agricultural production the treated effluent has to be treated to a quality above the common tertiary level. That can mainly be accomplished by implementing the membrane technology. A two stage membrane systems is proposed, consisting of in series an UF and RO (Fig. 5). The UF stage is served for the pathogens removal and a pre-treatment stage for the successive RO phase. **The RO stage is implemented for the removal of most dissolved scolds.** Extra treatment is required for the removal of some specific constituents such as boron.

CONCLUSION

Based on this study, the following conclusion can be drawn. Sustainable agricultural development requires new advanced solutions for the water production factor subject to environmental constraints. These can be accomplished by combining various treatment technologies and subject to economic considerations. Although the relatively anticipated high expenses, intensive efforts have to be undertaken in these directions.

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