WASTEWATER REUSE - INTEGRATION OF URBAN AND RURAL WATER RESOURCES MANAGEMENT

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ABSTRACT

Scarcity of water is increasing globally mainly due to population growth, which leads to increasing agricultural demand. Treated wastewater can be considered as a 'new' resource that can substitute conventional water used for irrigation. This resource can be added to a regional water balance and integrated with its conventional water resources. The paper discusses the introduction of reclaimed wastewater in water-short and water-abundant countries, its contribution to the protection of water resources in particular and environmental protection in general. Further, it describes the benefits derived by the urban and rural sectors from agricultural wastewater reuse in water-short countries, and suggests a feasible beneficial agricultural wastewater reuse scheme for water-abundant countries.

KEWORDS

Rural areas, urban areas, wastewater irrigation, wastewater reuse, integral water resources management

INTRODUCTION

Over a century ago Benjamin Franklin wrote, "When the well is dry, we know the worth of water". Those words have been prophetic. "Water-short countries" are countries in which the water resources amount to less then 1,000 m^3/*capita*/y. At present about 30 countries in the world belong to this group, which roughly includes 260 million people, while many more countries are "candidates" to be included in this "elite club" in the near future. The major reason for the increasing water scarcity in the world is population growth and the resulting agricultural water demand. While in 1940 mankind utilised about 1,000 km^3/y of water (11% of the readily available water), today we consume more then 5,200 km^3/y, i.e. over 55% of the global annual budget of the readily available water.

There are five major possibilities to increase the amount of available water: to improve the efficiency of water utilisation, to build more reservoirs in order to increase the storage capacity of surface water, to further develop and utilise groundwater resources, to reuse treated wastewater, and finally to desalinate seawater. Each of these above possibilities has its economic, environmental and social advantages and disadvantages, which will not be discussed here. This paper focuses only the fourth option - wastewater reuse - which is spreading at an increasing rate around the world.

Wastewater reuse for agricultural irrigation is a rapidly growing practice in arid and semi-arid regions around the world, where treated wastewater serves as an extra source of water available for the rural sector. In these water-short regions, treated wastewater is especially important since it helps ease the economic (and cultural) stress on the rural sector. Such a stress is caused by the increasing urban water demand, which reduced water supply for irrigation in the rural sector. New reclamation and reuse projects have been reported in many countries all over the world, including: African countries, Australia, China, Middle East and Mediterranean countries, South American countries, and USA (e.g., Angelakis *et al.*, 1999; Bahri, 1999; Bonomo *et al.*, 1999; Faby *et al.*, 1999; Mills *et al.*, 1992; Salgot and Pascual, 1996). Wastewater reuse practice is not unique for water-short regions, because new reuse initiatives (mainly in the urban sector) are emerging in temperate climate regions as well (Dixon *et al*., 1999a & 1999b; Kubik, 2000; Nolde, 1995; UK Environment Agency, 2000; WRAS, 1999; and others).

TREATED WASTEWATER AS AN INTEGRAL PART OF WATER RESOURCES

Treated wastewater may be considered as a 'new' water resource, which can be added to the general water balance of a region. This 'new' source can substitute 'conventional' water used in applications that do not require water of drinking quality, while reducing the pressure on the conventional resources. Thus, reclaimed wastewater may help close negative water balances in countries where all the conventional water resources are exploited to their full capacity. Israel, for example, is presently reusing more than 65% of the total municipal and domestic sewage, and it is planned to increase this reuse to 90% during the next decade (Shevah & Valdman, 1999; Shwartz, 1996).

Water-short regions. In regions, which suffer from water scarcity, water resources are exploited to their maximum safe capacity (or beyond). Thus, the stored volumes of both groundwater and surface water are becoming smaller, which leads to shorter retention times. This is generally followed by deterioration of water quality by pollution. Wastewater reuse practice contributes to the enhancement of the quality of conventional water resources by two means:

1. Reducing the pressure on the conventional resources, resulting in larger water bodies and longer retention times.
2. Eliminating one of the main sources of pollution: municipal sewage.

Water abundant regions. Regions with abundant water resources are mostly those regions where no apparent water shortage is observed. Here, the negative effect of pollution may be reduced by dispersion of pollutants in large water bodies where longer retention times facilitate degradation of some of the pollutants. It should be emphasised, however, that the negative effects are reduced, but not eliminated. In these regions, wastewater reuse contributes to the sustainability of the urban sector in several aspects, including the three major ones listed below:

1. By alleviating the stress on conventional water resources
2. By reducing the quantities of water that have to be conveyed over longer and longer distances
3. By reducing the pollution caused by effluents released to the aquatic environment.

WATER AND WASTEWATER RESOURCES MANAGEMENT

Similarities

Wastewater management exhibits several aspects, which are common to the management of conventional water resources as well:

- *Seasonal storage* - wastewater is produced throughout the year while irrigation in many arid and semi-arid regions is practised only during dry summers. Thus, seasonal wastewater storage is required in a similar manner as for raw potable water.

- *Multi-year storage* - conventional water resources flow varies between years. This variation is a result of differences in the total annual precipitation, distribution of rain events, and the intensity (or total precipitation) of each event. Thus, the use of multi-year storage may optimise the utilisation of these resources. As with conventional water resources, some multi-year storage capacity can be used to optimise the exploitation of the wastewater resource. This is especially important in water-short regions, where wastewater can substitute depleted conventional resources in dry years.

- *Spatial extent* - like schemes for conventional water resources utilisation, wastewater reclamation projects may be local, regional or even inter-regional.

- *Multiple sources* - wastewater reclamation schemes may employ wastewater from a single source or from several sources. Schemes with multiple sources are designed to utilise their inputs in an optimal way, in order to obtain the best water quantity and quality.

- *Multiple uses* - reclaimed wastewater can be reused in several sectors:
  - Urban sector - the main uses of reclaimed wastewater are for irrigation of municipal parks and gardens, firefighting, and reclamation of urban streams and rivers. In recent years, some new uses, such as toilet and urinals flushing, and air conditioning in multi-storey buildings, were reported.
  - Industrial sector - the main reuse of wastewaters is for cooling and heating. However, wastewater can be reused for many other purposes in industrial processes where the product does not pose a health risk to the consumers. Reports of wastewater reuse in paper production, chemical industry, industrial concrete production, etc. are becoming more common in recent years.
  - Agricultural sector is the main consumer of reclaimed wastewater, especially in water-short regions. Crops range from industrial crops to freshly-consumed ones, depending on the quality of the treated wastewater.

Reclaimed wastewater can be reused more than once as part of an integrated water resources management. For example, wastewater can be reused for river/stream reclamation, and then withdrawn and reused again for irrigation (Asano *et al*., 1996; Juanico & Friedler, 1999).

Dissimilarities

Wastewater resources management differs from conventional water resources management in several aspects, the most important of which are listed below:

- *Constant and reliable supply* - since this 'new' water source depends only on municipal sewage production and not on precipitation, one of its main characteristics is high reliability. Not only its 'production' is relatively constant during the year, but also it is almost constant between years. This consistency differs from the climate/weather dependent supply of potable water.

- *Increasing annual flow* - urban water demand is generally increasing as a result of increasing urban population. Consequently, the wastewater production in the urban sector is also increasing. This is a reverse trend to the situation of the conventional water resources, many of which are becoming depleted due to over exploitation.

- *Quality and treatment* - the quality of wastewater makes it unsuitable for reuse without proper comprehensive treatment. For the same purposes, water from 'conventional' resources is usually suitable without any treatment. This is especially true for agricultural irrigation, which is the main consumer of treated wastewater in water-short countries. To reuse the reclaimed wastewater in agricultural irrigation, it has to comply with agrotechnical, environmental and public health quality requirements, which may differ. Table 1 presents the main requirements of the above three categories. It can be noted in the table that the quality required for irrigation with treated wastewater is different from the quality requirements for the release of reclaimed wastewater into the environment. Thus, sewage treatment technologies employed in wastewater reuse projects may differ from those used for 'conventional' sewage treatment and disposal. As a result of local constraints, sewage treatment and disposal projects for large urban areas are usually based on intensive treatment technologies. In schemes of wastewater reuse in agriculture, the storage capacity is essential, as discussed below. Thus, in agricultural reuse projects, at least one component, which is an extensive treatment unit providing both storage and effluent polishing, is commonly employed (Friedler & Juanico, 1996).

Table 1: Agrotechnical, Environmental and Public Health Quality Requirements **-** Relative Importance of Various Parameters

Parameter	**Agrotechnical**	**Environmental**	**Public health**
Salinity	**3**	**0-3** Depending on the receiving water body	**0**
Clogging potential	**3** Especially in drip irrigation	**0**	**0**
Pathogens	**2** Farmers and consumers health	**1**	**3**
Heavy metals	**2** Plant uptake	**3**	**1** Non-potable uses
Xenobiotic compounds	**2**	**3**	**0** Non-potable uses
Nutrients	**0** Nutrients can replace costly fertilisers	**3** Eutrophication	**0**
Odours	**1**	**3**	**0**

0 - Not relevant; **1-** Low importance; **2-** Medium importance; **3-** High importance

It should be noted that controlled reuse of wastewater may improve public health instead of endangering it. This is especially true in regions that suffer from water shortage, where illegal irrigation with raw sewage, poorly treated effluents, or water from heavily contaminated rivers and lakes is a common practice. In many cases, discharge of wastewater to water bodies implies unwanted and uncontrolled wastewater reuse in downstream areas.

- *Simultaneous storage and treatment* - the goal of storage of conventional water is solely to balance supply and demand, while storage of wastewater has two goals:
    1. To balance supply and demand.
    2. To perform additional treatment and equalise wastewater quality.

  When the storage units are designed and operated to maximise effluent quality, the long residence time enables the slow-rate bio-chemical reactions to become relevant. These reactions are responsible for the removal of 'hard' pollutants remaining in the effluent of the intensive treatment units (Ernst *et al*., 1983; Juanico *et al.*, 1995; Friedler, 1999; Muszkat, 1999; and others). Common storage and treatment units are wastewater reservoirs and SAT (Soil Aquifer Treatment) units.

  Dual distribution lines - significant differences between the quality of water and wastewater favour the adoption of dual distribution systems. However, the risk of accidental cross-connection between the two distribution systems is higher in practice than it seems theoretically possible. Some regulations have been developed to avoid these cross-connections, however, these regulations have to be further refined.

INTEGRATION OF THE URBAN AND RURAL SECTORS

Wastewater reuse practice results in higher environmental and public health protection, from which both the urban and rural sectors will benefit. However, in order to be successful, wastewater reuse schemes have to be beneficial for both the urban and rural sectors. The benefits to the urban sector are obvious - reduced wastewater treatment and disposal costs. In water-short countries the rural sector will usually benefit directly from this practice, while in water abundant countries the rural sector will benefit indirectly by adopting a role in urban sewage reclamation.

Water-short Countries

Sewage treatment and disposal have been traditionally paid for by the sewage producer - the urban sector. Irrigation with wastewater presents a new element in the financial equation - the farmers who benefit from the treated wastewater. Under several potential different schemes involving the urban and rural sectors, the farmers may purchase the treated wastewater from the urban sector, invest in the sewage treatment plant, or cover the operation and maintenance costs. Thus, the total costs of treatment are shared by both sectors:

- For the **urban sector** this means reduction of the costs of sewage treatment and disposal. A second benefit is the release of some potable-quality water used by the rural sector to meet the increasing urban demand and to reduce water conveyance costs from distant resources.
- For the **rural sector** this means access to a reliable source of water for irrigation at a lower cost than the cost of importing conventional water from distant sources. This enables further agriculture development, which will result in economic benefits to the rural sector.

In countries where potable water supply for irrigation is substituted by reclaimed wastewater as a result of increasing urban demand, some decrease in crops may occur. It is obvious that in this case the farmers should be compensated for the decrease in their revenues.

Water abundant countries

In water abundant countries, wastewater reuse in irrigation is directly beneficial only to the urban sector. In this case agricultural reuse may serve as a polishing treatment of the effluent before its release to the environment, and thus reduce the treatment costs for the urban sector. The rural sector does not have a direct benefit, since the treated wastewater is not needed for agricultural production. Conversely, because of irrigation with reclaimed wastewater, the rural sector may suffer from some decrease in crop yields. In this case, the rural sector should be recognised as an entity which reclaims urban sewage, by further treating urban effluents and reducing the conventional treatment costs. Thus, the urban sector has to pay the farmers for these services. Unless this compensation is implemented, wastewater reuse schemes in water abundant countries will not succeed.

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