Wastewater reuse status in the Gaza Strip, Palestine

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Abstract: Groundwater is the only significant source of water in the Gaza Strip. Currently, special attention has been paid to improve the water resource situation in the regional level. Reuse of wastewater could be one of the main options to develop the water resource in the region. This strategy will lead to reducing the gap of water deficit between supply and demand. The limited reliable data on existing situation and absence of clearly defined reuse policy for wastewater based on economic and health basis make the reuse of wastewater dream more than a reality in Gaza Strip. The paper provides adequate data on wastewater reuse planning. It evaluates the status of wastewater quality and quantity, treatment faculties and reuse applications. In the same time, the paper gives some regional experiences and recommendations for future management of wastewater reuse.

Keywords: wastewater reuse; water management; Gaza Strip.

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1 Introduction

Demands on water resources for household, commercial, industrial, and agricultural purposes are increasing greatly worldwide, and growing urbanisation exacerbates the situation. Water experts and politicians agree that there is an acute water shortage problem in the Mediterranean and Middle East region. They also agree that the problem must be addressed immediately in a regional context. In most Mediterranean countries, the main problem may not be only the security of water in terms of average amount per capita, but also the high cost of making water available at the right place, at the right time with required quality (Angelakis et al., 1999).

Fresh water is a scarce resource in the Gaza Strip. The groundwater is the only current resource in use and it is not enough to meet the current and/or future demand. The main concern of both the people and the Palestinian authorities is having sufficient water to ensure their economic and social development. Due to the tremendous population increase, the water demand increases sharply. The existing situation; an annual recharge of 60 million cubic metres (MCM) and demand of more than 130 MCM, a deficit of approximately 70 MCM, has led to a descend concerning the available quantities of groundwater (Gaza Water Resource, 1996). For different purposes, water demand will rise continuously from 130 MCM in 2001 to 215 MCM by 2020 (Al-Jamal et al., 1997). The stored water in the aquifer will decrease with time and the fresh groundwater (with less than 250 ppm chloride) will not be available in cases depending on the ground aquifer as the only source. The groundwater reserved in aquifer will be about 1,522 MCM in Gaza aquifer by the year 2020 compared to about 2,537 MCM if the treated effluent were used. That means about 1,000 MCM will be saved in the aquifer of Gaza in this period (Afifi, 1998). A sustainable management policy of the available and renewable water resources together with developing new water resources are top priority of the Palestinian Water Authority (1996).

Using treated wastewater could be one of the main options to develop the water resources in the Gaza Strip as it represents an additional renewable and reliable water source (Al-Jamal et al., 1997; Afifi, 2000). Using treated effluent for agricultural purposes would minimise the deficit and would reduce the degradation of the groundwater quality. In the same time, using treated wastewater in agriculture requires a comprehensive policy to avoid any environmental health, social and economic problems. In recent years, many countries started projects for reuse of treated effluents and have developed standards or guidelines concerning using treated water. For instance, the World Health Organization (WHO, 1989) has published guidelines for reusing treated water for agricultural irrigation.

Wastewater reclamation for non-potable use has recently been a priority in the Gaza Strip, which necessitates developing national guidelines. The environmental protection and safeguarding of public health are the main concerns. Therefore utilisation of wastewater in Gaza Governorates should be managed within certain restoration imposed for environmental protection and to safeguard public health. Beside the quality of the effluent for reuse, other factors should be considered in the local level, certainly socio-economical aspects and agriculture policy in the area (Afifi, 2000).

2 Regional wastewater reuse

In most Mediterranean countries, 70–80% of water demand arises from agriculture irrigation (Angelakis et al., 1999). The benefits of promoting wastewater reuse as a means of supplementing water resources in agricultural sector have been recognised in most Mediterranean basin countries. Some of them such as Egypt, Tunisia, Jordan, Israel, Malta, Cyprus, Italy and Spain, concede seriously on wastewater reclamation and several projects are already in operation or are under planning. The practice of wastewater reuse in Al-Jibail in Saudi Arabia is well established and has effectively reduced the pollution and provided water for landscape irrigation (Al-A'ama and Nakhla, 1995).

The wastewater reuse experience in the North West European countries is to a certain degree less challenging than in the Mediterranean countries due to its non-obligatory character of reusing water resources.

In Israel, wastewater reuse is an integral component of the national water management strategy. Many projects expanding the areas irrigated with reclaimed water are under implementation. Agricultural reuse will remain the largest potential market followed by recreational and landscape uses as such. The flow of wastewater in Israel in 1994 was about 293 MCM per year of which 232 MCM are treated (79%) and 194 MCM are reused (66%) (Shelf and Azon, 1996).

The Kingdom of Jordan has a critical shortage of water resources and reclaimed water has become a major component of the national water resources. The Water Authority of Jordan (WAJ) currently operates 14 treatment plants with an annual flow of 60 MCM. By the year 2020, taking into account the population growth and the expansion of sewage systems and treatment facilities, reclaimed wastewater may become a major resource, estimated at 240 MCM per year. Over 90% of this will originate from either As Samra or the Zarqa wastewater treatment plants. The key policy objectives of the Jordan water reuse management plan are to use reclaimed water, where practical, in exchange for present and future use of freshwater and to maximise the returns from reclaimed water resources.

Results of the Tunisian experience in the reuse of treated wastewater permit to confirm the strategy adopted since the beginning of the 1960s for the promotion of reuse of wastewater in agricultural sectors. In 2000, the total volume of treated wastewater was about 156 MCM of which about 20% was reused.

3 Limitation of wastewater reuse in Gaza

Wastewater reuse has still to overcome several challenges and requirements. Future reuse projects in the different activity sectors will depend on a better planning and management of reuse operations based on a real water demand and better institutional, regulatory, and organisational setting. Economic and financial feasibility of water reuse applications needs to be better assessed. Technical aspects need also further study, along with applied research for specific applications. Education, information, and training of farmers and extension services also play an important role in promoting these practices aiming to achieve higher agricultural production without adverse impacts on the environment. The limited reliable data on existing situation of wastewater quality and quantity and the absence of clearly defined reuse policy, which based on economic and health basis, make the reuse of wastewater dream more than a reality in Gaza Strip. Beside the treatment requirements and the quality of the effluent for different reuse purposes, other factors should be considered, certainly socio-economical aspects and adopted regulations in the area.

3.1 Wastewater quality and quantity

The planning of using reclaimed water requires determining quantity and quality of the generated wastewater. The quality of water used for irrigation will influence the crop yield, product quality and soil properties. In particular, salinity and boron are important, but also suspended solids, nutrient contents and biological parameters, like BOD_5, pathogenic bacteria, parasites, and viruses, can be relevant for the effluent reuse. On the other side the collected wastewater quantity will affect the management planning, reservoirs facilities and economical feasibility.

Previous studies in Gaza show contradiction figures in regards of water consumption and wastewater generation. The main reason for this finding was that the studies were depending mainly on theoretical calculations of wastewater generation in Gaza Strip. Within this study, a comprehensive monitoring programme has been carried out to determine the quantity and quality of raw wastewater in the different areas in the Gaza Strip. The programme has been carried out in six different urban areas where the readings of houses water metres are collected for one week. Also the municipality figures for water demand in the same areas are analysed. Generated wastewater was determined via three different methods. First it was measured directly from wastewater network using electronic metres. The second and third calculations were based on water demand given from municipalities and household water meter readings. The quality of wastewater has been analysed based on the grab samples collected for working and weekend days. The following points summarise the main finding.

- Table 1 shows the water use for household in the studied locations in Gaza as litre per capita and day (l/c.d) based on one week monitoring and collected data from the municipalities. The average of water use for domestic purposes varies from 149 l/c.d in parts of Gaza City to 93 l/c.d in Rafah City. The average consumption is around 118 l/c.d for all locations.
- Table 2 summarises the results of the field measurement of wastewater quantities generated in the network and calculated generated wastewater from the average water consumption. The result shows that the wastewater generation is around 80% of water use for domestic purposes. The average quantities of generated wastewater in the Gaza Strip are around 110 l/c.d in Gaza City and Northern areas and 72 l/c.d in Southern areas and refugee camps. An average figure for Gaza Strip is of about 95 l/c.d.
- Table 3 presents the organic matter, nitrogen and biological contamination level in the different studied areas in Gaza Strip. The biological oxygen demand (BOD) varies between 44 gram per capita and day (g/c.d) in Southern area (Rafah) and 66 g/c.d in Northern Gaza Strip. A BOD average figure of 50 g/c.d is acceptable for Gaza Strip. The analyses carried for heavy metals and toxic elements shows that the raw sewage is nearly free from these elements, which threaten the reuse of treated effluent.
- The expected quantity of generated wastewater can be calculated based on the average water consumption (Table 1), wastewater generation (Table 2) and percentage of planned wastewater collection network system. Table 4 illustrates the annual potential of wastewater generation. This quantity is a good potential to minimise the shortage of water sources in the area.

Table 1 Water use for household in the studied locations in Gaza based on one week monitoring and collected data from the municipalities

Name of urban area	*Household metre readings (municipality data) (l/c.d)*	*One week monitoring (field survey) (l/c.d)*	*Average (l/c.d)*
Jabalia	143	125	134
Sheik Radwan	174	124	149
Shejaia	105	137	121
Shaboura	87	100	93.5
Tel-Sultan	85	105	95
Average – Gaza Strip	118.8	118.2	118.5

Table 2 Generated wastewater calculated from the average water consumption and measured flow in the network

Name of urban area	*80% of average water demand (l/c.d)*	*Direct measurement (l/c.d)*	*Average (l/c.d)*
Jabalia	107.2	128	117.6
Sheik Radwan	119.2	94	106.6
Shejaia	96.8	124	110.4
Shaboura	74.8	65	69.9
Tel-Sultan	76	67	71.5
Average Gaza Strip	94.8	95.6	95.2

Table 3 Organic matter, nitrogen and biological contamination level in the different studied areas in Gaza Strip

Parameter	*Shejaia*	*Jabalia*	*Tel Sultan*	*Shaboura*	*Sheikh Radwan*
BOD g/c.d	47	66	44	45	50
COD g/c.d	96	135	95	97	109
TN g/c.d	15.3	13	12	10	13
FC/100 ml	1.6×10^6	7.9×10^6	2.0×10^6	2.4×10^6	4.4×10^6
FS/100 ml	1.2×10^6	1.1×10^6	3.0×10^6	2.3×10^6	4.0×10^6
FS/FC ratio	0.67	0.9	0.76	0.78	0.85

FC: faecal coliform; FC: faecal streptococcus; TN: total nitrogen and COD: chemical oxygen demand.

Table 4 Annual potential wastewater generation in the Gaza Strip

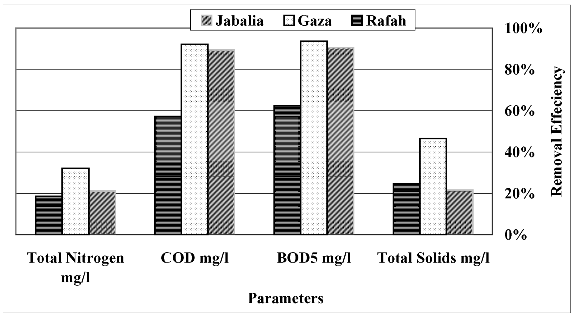
Year	*2000*	*2005*	*2010*	*2015*	*2020*	*2025*
Population in million	1.121	1.342	1.841	2.287	2.580	2.910
Water consumption MCM	45.02	58.81	80.65	116.89	131.87	148.72
Wastewater generation MCM	36.02	47.05	64.53	93.51	105.50	118.98
% Connected to network	50	65	75	85	90	95
Treated effluent MCM	18.01	30.58	48.39	79.48	94.95	113.03

3.2 Wastewater treatment facilities

In the planning and implementation of wastewater reclamation and reuse, the intended water reuse applications dictate the extent of wastewater treatment required for the quality of the finished water, and the method of distribution and application. In Gaza Strip wastewater treatment has been considered since 1970. Stabilisation ponds were the technology proposed at that time. During the Israeli occupation period, there was no real attention towards improvement of wastewater treatment and reuse. Greater attention has been paid to improve this sector following the coming of the Palestinian National Authority (PNA) in 1993 in cooperation with international agencies. A considerable improvement was achieved in term of BOD quality in some treatment plants.

There are three wastewater treatment plants (WWTP) operating in the Gaza Strip. Jabalia WWTP in the northern part of Gaza Strip, which uses stabilisation ponds and aerated lagoons techniques with a capacity of 8,000–10,000 m^3 daily. Anaerobic ponds followed with bio-towers treatment system is used in Gaza WWTP to treat 40,000–45,000 m^3 daily flow and finally Rafah WWTP, which has an aerated lagoon with average daily flow of about 4,000 m^3. The effluents of all these plants are discharged to the sea or to the surrounding sands (Islamic University-Gaza, 2002). Figure 1 presents the removal efficiency of the three treatment plants for total solids, BOD, COD and total nitrogen.

Figure 1 Removal efficiencies of the main Gaza wastewater treatment plants



In 1998, the Gaza WWTP has been rehabilitated by the US Agency for International Development (USAID) to meet the needs of the population of Gaza Governorate in 2005 with total wastewater inflow of 35,000 m^3/day. According to the municipality, the quality has been highly improved. The current inflow of the treatment plant is 45,000 m^3/day, which exceeds the capacity of the plant.

According to Gaza Municipality figures, the annual operation and regular maintenance of the plant is US$ 55,500.00 with an average of US$ 0.04 per cubic metre. The existing ponds and trickling filter in Gaza Treatment Plant seem to be a good combination and the treatment cost becomes relatively acceptable. The activated sludge system could be a good system where the effluent quality can meet the required quality for reuse and recharge. The main problem of the activated sludge is the high operational cost, which is beyond the affordability of most Palestinians. The Palestinians have to adopt a treatment system taking into consideration three main points: availability of land, effluent quality and operational costs.

3.3 Social acceptance

For the success of the wastewater reuse projects it is crucial that the farmers and the potential customers accept the use of treated sewage water for irrigation (Afifi, 1997). It requires specific public awareness strategies: a greater focus on inter-sectoral and multi-disciplinary approaches and a need to understand the target group's priorities, knowledge and practice vis-à-vis specific behaviours and inhibiting factors. Behaviour with respect to water reuse practices involve at the community level changes of a broad range of their current practices. In order to sustain the change in these practices, it is necessary not only to provide knowledge and skills to people involved in water reuse, and to reinforce and monitor their behaviour locally, but also to establish regional and national systems of supply and maintenance of materials and equipment.

4 Potential of reuse application

In the Mediterranean basin, wastewater has been used as a source of irrigation for centuries. The use of treated wastewater for irrigation in agriculture combines three advantages. First, it eliminates part of the demand for synthetic fertilisers and contributes to decrease levels of nutrient in receiving waters (rivers, sea, ocean, lakes). Second, the practice increases the available agricultural water and third, it may eliminate the need for expensive tertiary treatment.

However, treated wastewater usage is dependent on several factors, supply and demand, treatment requirements and storage and distribution facilities. In addition, wastewater reuse is often associated with environmental and health risks. As a consequence, its acceptability to replace other water resources for irrigation is highly dependent on whether the health risks and environmental impacts entailed are acceptable. In the following, the major types of reuse will be discussed.

4.1 Agricultural use

A significant fraction of freshwater is consumed for irrigation in Gaza and it is estimated as about 60% of total water demand (50% could be covered from treated effluent). In Israel, 42% of the reclaimed water is used for irrigating and 30% for groundwater recharge. In California, agricultural irrigation accounts for approximately 63% of the total volume of the reclaimed water used within the state (California State Water Resources Control Board, 1990).

The constituents of concern in using reclaimed water for agricultural irrigation are salinity, sodium, trace elements, excessive chlorine residual, and nutrients. Sensitivity is generally a function of a given plant's tolerance to these constituents encountered in the root zone or deposited on the soil edge. Reclaimed water tends to have higher concentrations of these constituents than the ground or surface water from which the water supply is drawn. The types and concentrations of constituents in reclaimed wastewater depend upon the municipal water supply, the influent waste streams (i.e., domestic and industrial contributions), amount and composition of infiltration in the wastewater collection system, the wastewater treatment processes, and the type of storage facilities. In most cases, the reclaimed water is of acceptable quality if the municipal potable source is acceptable.

The supplier of reclaimed water must quantify the seasonal demands, as well as any fluctuation in the reclaimed water supply, to assure that the demand for irrigation water is met. To assess the feasibility of reuse, the reclaimed water supplier must be able to reasonably estimate irrigation demands and reclaimed water supplies.

4.2 Groundwater recharge

The purposes of groundwater recharge using reclaimed water include

- *Establish saltwater intrusion barriers in coastal aquifers*. Pumping of groundwater aquifers in coastal areas may result in seawater intrusion into the aquifers, making them unsuitable as sources of potable supply or for other uses where high salt levels are intolerable.
- *Provide further treatment for future reuse*. Infiltration and percolation of reclaimed water takes advantage of the subsoil's natural ability for biodegradation and filtration, thus providing additional in site treatment of the wastewater and additional treatment reliability to the overall wastewater management system. It may eliminate the need for costly advanced wastewater treatment processes. The treatment depends on the method of recharge, hydro-geological conditions, requirements of the downstream users, and other factors.
- *Augment potable or non-potable aquifers*. Groundwater recharge helps provide a loss of identity between reclaimed water and groundwater. This loss of identity has a positive psychological impact where reuse is contemplated and is an important factor in making reclaimed water acceptable for a wide variety of uses, including potable water supply augmentation.
- *Provide storage of reclaimed water*. Groundwater aquifers provide a natural mechanism for storage and subsurface transmission of reclaimed water. Irrigation demands for reclaimed water are often seasonal, requiring either large storage facilities or alternative means of disposal when demands are low. In addition, suitable sites for surface storage facilities may not be available, economically feasible, or environmentally acceptable. Groundwater recharge eliminates the need for surface storage facilities and the attendant problems associated with uncovered surface reservoirs, such as evaporation losses, algae blooms resulting in deterioration of water quality, and creation of odours. Also, groundwater aquifers serve as a natural distribution system and may reduce the need for surface transmission facilities.

While there are obvious advantages associated with groundwater recharge, there are possible disadvantages to consider (Oaksford, 1985);

- Extensive land areas for operation and maintenance, including the groundwater reservoir itself, may be needed for spreading basins.
- Energy and injection wells for recharge may be heavily costly.
- Recharge may increase the danger of aquifer contamination. Aquifer remediation is difficult, expensive, and may take years to accomplish.

- Inadequate institutional arrangements or groundwater laws may not protect water rights and may present liability and other legal problems.
- Sudden increases in water supply demand may not be met due to the slow movement of groundwater and not all added water may be recoverable.

4.2.1 Methods of groundwater recharge

Several methods of groundwater recharge are available:

Riverbank or dune filtration

Recharge via riverbank or sand dune filtration is practiced in Europe as a means of indirect potable reuse. It is incorporated as an element in water supply systems where the source is contaminated surface water. The contaminated water is infiltrated into the groundwater zone through the riverbank and then travels through an aquifer to extraction wells at some distance from the riverbank.

Surface spreading

Surface spreading is a direct method of recharge whereby the water moves from the land surface to the aquifer by infiltration and percolation through the soil matrix. An ideal soil for recharge by surface spreading would have the characteristics of rapid infiltration rates and transmission of water. The geologic and subsurface hydrologic conditions control the sustained infiltration rates.

Soil-aquifer treatment systems

Where hydro-geologic conditions permit groundwater recharge with surface infiltration facilities, movement of the wastewater through the soil, unsaturated zone, and aquifer may obtain considerable improvement in water quality.

Direct injection

Direct injection involves the pumping of reclaimed water directly into the groundwater zone, which is usually a well-confined aquifer. Direct injection is used where groundwater is deep or where hydro-geological conditions are not conducive to surface spreading. Such conditions might include unsuitable soils of low permeability, unfavourable topography for construction of basins, the desire to recharge confined aquifers, or scarcity of land. Direct injection is an effective method for creating barriers against saltwater intrusion in coastal areas. At the same time, it requires water of higher quality than surface spreading because of the absence of soil matrix treatment afforded by surface spreading and the need to maintain the hydraulic capacity of the confined aquifer.

Many criteria specify the quality of the reclaimed water, the groundwater, and the aquifer material that have to be taken into consideration prior to construction and operation. These include possible chemical reactions between the reclaimed water and the groundwater.

4.3 Industrial reuse

Industrial reuse represents a significant potential market for reclaimed water in the USA and other developed countries. Reclaimed water is ideal for many industries where processes do not require water of potable quality. Reclaimed water for industrial reuse may be derived from in-plant recycling of industrial wastewaters and/or municipal water reclamation facilities. Recycling within an industrial plant is usually an integral part of the industrial process and must be developed on a case-by-case basis. Industries, such as steel mills, breweries, electronics, and many others, treat and recycle their own wastewater either to conserve water or to meet or avoid stringent regulatory standards for effluent discharges. Industrial uses for reclaimed water include;

- evaporative cooling water
- boiler-feed water
- process water
- irrigation and maintenance of plant ground.

Cooling water is currently the predominant industrial reuse application. In most industries, cooling creates the single largest demand for water within a plant. Worldwide, the majority of industrial plants using reclaimed water for cooling are utility power stations.

5 Conclusion and recommendations

Water reuse is an integral component of the national water management strategy in many Mediterranean countries. Many projects expanding the areas irrigated with reclaimed water are under implementation. Agricultural reuse and groundwater recharge are the largest potential market of effluent use in Gaza Strip. However, water reuse has still to overcome several challenges. Future reuse projects in the different activity sectors will depend on a better planning and management of reuse operations based on a real water demand. This means a better institutional, regulatory, and organisational setting. Economic and financial feasibility of water reuse applications need to be better assessed. Technical aspects need also further study, along with applied research for specific applications. Education, information, and training of farmers and extension services also play an important role in promoting these practices aiming to achieve higher agricultural production without adverse impacts on the environment. The following recommendations strengthen wastewater reuses policies and practice:

- A policy for wastewater reuse must be established parallel to any further development activity in this field. Institutional mechanisms for implementation of the national policy must be established and legal backing provided for enforcement of regulations. Realistic standards must be adopted to protect public health against adverse environmental impacts.
- For a successful and sustainable implementation of water reuse practices, it is the necessity for development of environmentally sound practices and technologies for reuse in line with proper legislation and guidelines. To secure environmentally sound usage of treated effluent at user group level, it is essential to create general understanding and sensitivity among all parties. Training and public awareness programmes are recommended at different levels for beneficiaries and stakeholder.

- Managerial and technical staff involved in the whole logistical chain must be properly qualified and trained to carry out their functions effectively.
- There is a need for further research and development in areas such as computer modelling of groundwater flows and irrigation methods by conducting pilot projects. The development and implementation of pilot projects is needed for ensuring optimal adoption and assimilation of technical and logistical procedures of wastewater reuse.
- A minor relevant point, which has not been covered within the scope of this paper is the sludge treatment and reuse. Being the second by-product of treating wastewater, sludge treatment and reuse is considered to be a very important aspect, which needs further research activities.
- Probably the most crucial area of a functional and well-accepted system of wastewater reuse schemes is the financing and pricing aspects. The establishment of pricing schemes of treated wastewater requires more analysis and discussion with the objective to create a widely accepted market structure and pricing scheme.

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