

Enhancement of Groundwater through Wastewater Reuse in Palestine

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Abstract

The increasing water demand and the fixed water supply in Palestine, in general and in the Gaza Strip, in particular led to depletion of the water systems in both aspects, quantitative and qualitative. The aquifer in the coastal region (Gaza Strip) suffers from high pressure by domestic and agricultural needs. According to CAMP study, the overall water demand is 173 millions m³ (Mm³) per year, where the overall supply is only 122 (Mm³) per year. This means that there is a deficit of about 50 (Mm³) every year. This deficit led to continuous declination of groundwater level and deterioration of groundwater quality. So, an urgent need for new water resources is needed

As a policy in the water resources management, there is attitude to get other non conventional water resources such as seawater desalination and artificial recharge of groundwater from storm water and treated wastewater. The agricultural demand is almost constant since the agricultural areas are limited or even decreased. However, the domestic demand is increasing due to rapid growth of population. This of course increases the produced wastewater, and the treated effluent becomes an important resource of water that improves the water balance in the region. The reuse of this effluent could be accomplished by two ways, either by direct irrigation to farms and/or through artificial recharge to groundwater and then pumped to irrigate farms (reclaimed wastewater). Different crop types are tolerable for different constituents of the reused wastewater. This new resource, of course will enhance the groundwater system by decreasing the agricultural demand and its refreshments through artificial recharge of treated wastewater.

Reuse of wastewater is a strategic option together with seawater desalination forming the non-conventional water resources, where each will contribute of about 60 Mm³ in the year 2020. Part of reclaimed wastewater will be delivered to the farm directly from the treatment plant, and the remaining part will be infiltrated to the groundwater system through spread basins to undergo SAT processes. In the design of each treatment plant, Infiltration of the treated effluents takes the first priority before it is decided to be discharged to the sea or Wadis. The decision support system (DSS) for wastewater treatment and reuse includes all these things for decision makers.

Keywords: *wastewater reuse, water deficit, SAT*

Introduction

Water demand in the Gaza Strip is increasing continuously due to economic development and population increase resulting from natural growth and returnees, while the water resources are constant or even decreasing due to urban development. The Gaza Strip is classified as a semi-arid region and suffers from water scarcity. The renewable amount of water that replenishes the groundwater system is much less than

the demanded amount, and this resulted in deterioration of the groundwater system in both quantitative and qualitative aspects. The Palestinian Water Authority looked for other resources to fill the water gap between the supply and the demand and to attain sustainable water resources management. There are large quantities of wastewater produced by the municipal sewerage systems and the treated effluents are disposed to the sea or flooded without good treatment or control to the surrounding areas and underground aquifer.

Some projects adopted by the Water Authority were starting with the reuse of treated wastewater from Gaza Wastewater Treatment Plant (GWWTP), which is the case study in this paper. An amount of about 10000 m³ is diverted to infiltration basins of an area of four hectares every day (PWA 2004B). The water wells that recover the reclaimed wastewater mixed with native groundwater were monitored for groundwater level fluctuations and chemical analyses of their pumped water.

According to the Palestinian strategy, minimal amount will be used for agricultural purposes such as soil flushing and irrigation of high value crops. It is planned that wastewater reuse will be 34 Mm³ in year 2010 and increases to 63 Mm³ in the year 2020 (PWA 2000). Part of the reused amount will be diverted directly to the farms, and the remaining amount will be artificially recharged through infiltration basins and other schemes to undergo Soil Aquifer Treatment (SAT) processes that purify the effluent.

Water Resources

1. Conventional Water Resources

The Gaza Strip depends mainly on the conventional water resources coming from natural infiltration of rainfall that feeds the Pleistocene sandstone aquifer. Average annual rainfall fluctuates from 200 mm in south Gaza to 400 mm in the north giving bulk amount of water of about 115 Mm³, from which only 50 Mm³ infiltrate to the aquifer and the rest either evaporate or flood and run to the sea. According to CAMP 2001, the total supply was 122 Mm³/year and the total demand was 173 M³ which led to a total deficit of about 50 Mm³ every year.

The population in the Gaza Strip is 1,364,733 in 2004 according to the Palestinian Statistics Bureau (PWA 2004A) and increased to 1,515,924 based on growth rate of 5% leading to a total domestic demand of 80 Mm³ and the total agricultural consumption is 82 Mm³ (PWA 2006) leading to a total demand of 162 Mm³ for domestic and agricultural uses. If this figure is added to the amounts pumped illegally by house wells and other unregistered wells, we could reach the same figure reached by CAMP 2001 which is 172 Mm³ every year. So, there is a problem if annual deficit in the water budget of about 50 Mm³ urging us to find other new water resources.

2. Non Conventional Water Resources

Due to the increasing demand and fixed supply of the groundwater system in Gaza, it became urgent to look for new non conventional water resources to fill the gap in the water budget. The potential resources could be used are seawater desalination, wastewater reuse and storm water harvesting. According to CAMP study, it was

planned that the amounts of treated wastewater that will be reused in the year 2020 will reach about 60 Mm³ every year and other 55Mm³ will come from seawater desalination.

3. Palestinian Water Authority Strategies

The current over exploitation of the aquifer in the Gaza Strip, pushed the Palestinian Water Authority (PWA) toward adopting a new strategy to decrease the load on the aquifer. It is intended to allocate the fresh groundwater for drinking and domestic uses, while brackish and reused wastewater will be used for agriculture. Only very minimal amounts will be used for soil flushing and high value crops. About 94% of the water demand now is abstracted from groundwater and the rest comes from Mekorot company and storm water harvesting (PWA 2000). To achieve sustainable use of groundwater, the abstraction from the aquifer will be reduced to 52% of the total demand, where wastewater reuse and desalination will provide 22% and 19% respectively (PWA 2000).

PWA did with the help of USAID a plan for irrigating 700 hectares south east of Gaza city called Johr El Deik as a pilot test farm. The social survey in Johr El Deik, where reclaimed wastewater is planned to be used showed that most of the local farmers agreed to use this type of water (CAMP 2001). And according to the study of (World Bank 2004B), about 60% of the local people in the Gaza Strip are highly willing to use treated reclaimed wastewater for irrigation use, and about 22% are highly willing to use the reclaimed wastewater for domestic uses such as toilet flushing, washing .etc.

The pilot test farm was well chosen in an area where groundwater quality is bad, and new practice in it will improve the chemical properties of groundwater. The salinity of groundwater at this are ranges from 813 mg/l to 1553 mg/l, while the salinity of treated wastewater ranges from 300 mg/l to 480 mg/l (CAMP 2001). The water will be recovered by six wells while 10 wells will be used for monitoring.

With the assistance of the Spanish Cooperation Agency (AECD), PWA adopted a new demonstration new project to demonstrate the feasibility of treated wastewater in agriculture in terms of social acceptance, impact on soil and groundwater, sustainability and economic revenues. The new project will be complementary to the proposed one above.

Other projects are seen in the horizon of PWA, in the north, middle and south of the Gaza Strip. In the north the effluent is already flooded to the surrounding are of the wastewater treatment plant without control. According to (SOGREA 2001), feasibility study, it was found that the most feasible solution of this flooding effluent is to use controlled infiltration basins if compared with other solutions such as pumping the effluent to the sea or to the future treatment plant in the east of Northern governorate. The Swedish financed study proposed an area of 3600 hectares to be irrigated with treated wastewater (World Bank 2004A). In Rafah city, in the south of the Strip, the existing wastewater treatment plant is efficient and needs upgrading. However 10 hectares closed to the plant are proposed if the effluent is improved and reached WHO guidelines for irrigation (World Bank 2004A).

Case Study in Gaza City

The infiltration areas east of the existing Gaza Waste Water Treatment Plant (GWWTTP) will be tackled here. The basins are located to the east of the existing wastewater treatment plant in South Gaza (Fig. 1). This project started in the year 2000 with help of USAID through Coastal Aquifer Management Program (CAMP) project. The treatment plant receives about 40000 m³ every day, where all of the effluent was pumped to the sea before the construction of the infiltration facilities. In year 2000, about 10000 m³ are pumped to the infiltration basins in three separate spread basins with one day wetting and two days drying.

According to (CAMP 2001), the reclaimed wastewater will be pumped from six recovery wells, and the effect of the infiltration process will be monitored in 10 surrounding wells. However, and due to the Intifada, the monitoring wells were not constructed and the monitoring itself was done in the existing operating wells that owned by the farmers. There was complaining from the local farmers about pollution of their wells. However, PWA took an action and made a team from all Palestinian relevant ministries to monitor the effect of infiltration of the treated wastewater in the area.

1. Impact on Groundwater Levels

The groundwater levels in the zone of study area are fluctuating from one to four meters above mean sea level. The area is surrounded by irrigation wells and monitoring the water levels may not give an exact, but approximate indicator about the influence of infiltration on the groundwater levels. Three operating water wells were monitored after the application of treated wastewater infiltration in the allocated basins. In well R-I-10 which is about 500 meter east from the infiltration basin showed increase in the level of about 0.6 m in the end year 2003, while it was almost constant during the whole period of infiltration since the year 2000 (Fig. 2A). The other monitored wells which are R-I-69 (1500 meter northeast from basins) and R-I-92 (1000 meters northwest from basins) showed slight decrease in the groundwater levels. No doubt that there was input to the groundwater system from the application of infiltration, but the continuous abstraction through irrigation wells in the area hidened the positive influence on the groundwater levels.

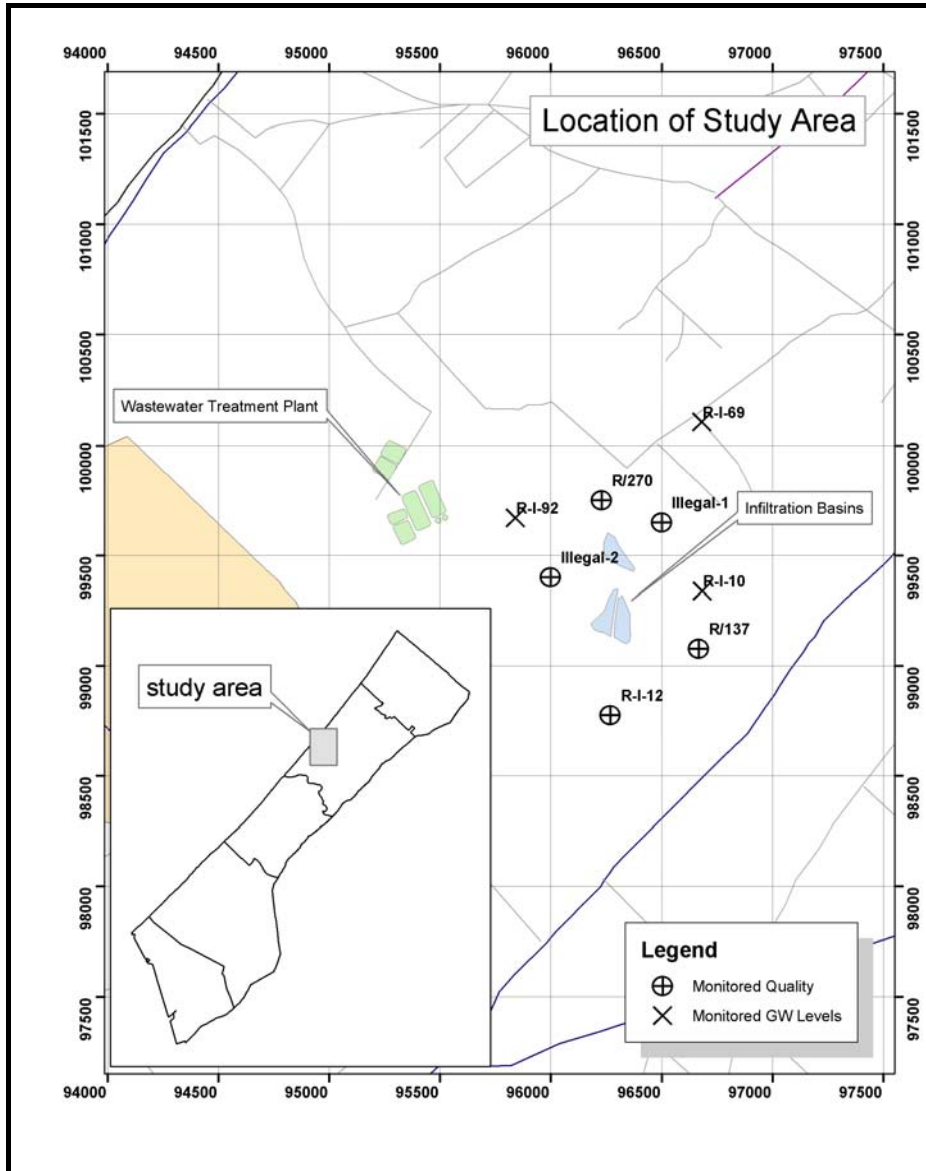


Fig.1 Location map of infiltration area and monitored wells

2. Impact on Groundwater Quality

Five operating water wells in addition to the effluent recharging the basins were selected here to study the effect of wastewater infiltration on the native groundwater. There was clear increase in the chloride ion concentration in the monitored wells since the concentration level in the effluent is more than that in the concentration of the native groundwater (Fig 2B). The chloride ranges in the study area from 200 to 700

mg/l depending on the layer from which water is pumped. Since most of the public water supplied is over 500 mg/l, it is naturally that the sewage has high level of chloride which is affected through the treatment processes of wastewater since it is a conservative matter. So, infiltration affected negatively on the salinity (chloride level) in the native groundwater in the area.

In Fig 2C, nitrate level in the effluent is much less than the nitrate level in all the monitored wells around, indicating that enough denitrification processes occurred in the wastewater treatment plant. Also, there is slight decrease in all the monitored wells, especially in well R-137 which is the closest to the infiltration basins which is about 300 meters east from the infiltration basins. In this case the infiltration has improved the quality of the groundwater in terms of nitrate level, from which most of the water wells in the Gaza Strip suffer.

In the view of agricultural aspect, Boron is considered as a toxic matter when it exceeds 0.5 mg/l even if it is as essential to plants (FAO 2000). Boron in the applied effluent as monitored since year 2002 until year 2005 fluctuates from about 0.4 to 1.0 mg/l. This had negatively affected the neighboring wells, where this effect was clear in the closest well to the basins, where the boron concentration was 0.234 mg/l in Jan 2002 and increased to 0.61 mg/l in June 2005 (Fig 2D). In other wells Boron did not increase clearly. In well R-270, Boron increased from 0.482 mg/l in Jan 2002 to 0.232 mg/l in July 2003 and then decreased again to 0.24mg/l in June 2005. In R-I-12 Boron increased from 0.29 mg/l in Jan 2001 to 0.635 mg/l in April 2003 and the decreased again to 0.2mg/l in June 2005. The latter well results indicate clear influence of native groundwater by Boron. The application of effluent to the infiltration basins was stopped since year 2004 until now based on the public of the area.

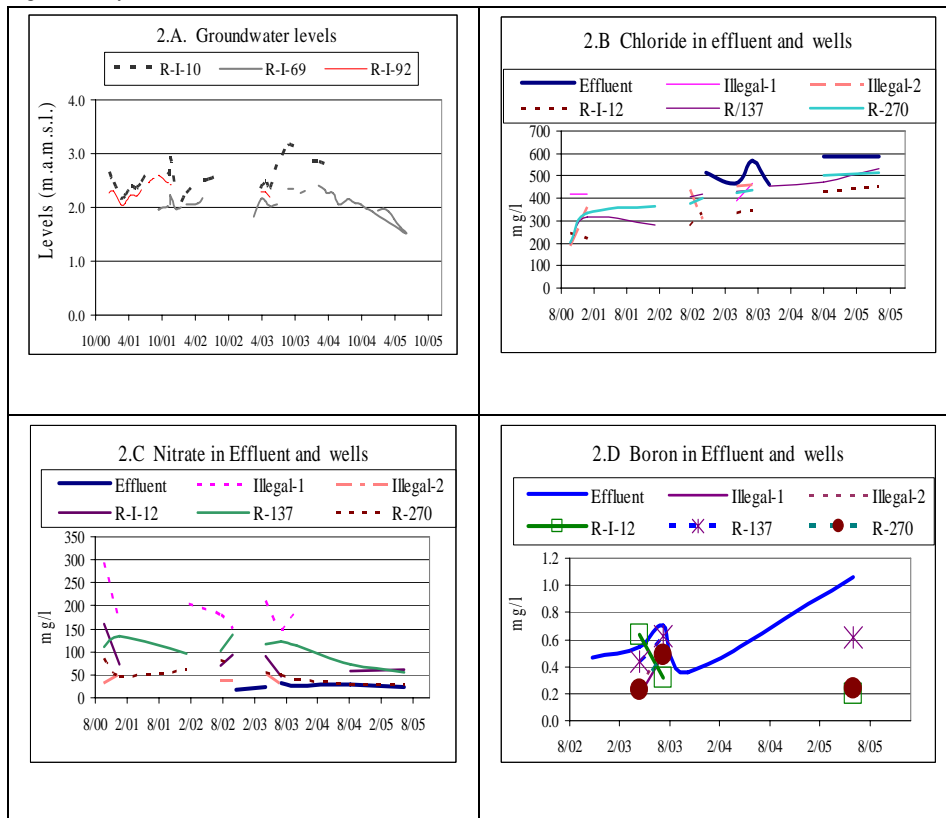
3. Sustainability

Wastewater reuse is one of the most important options in the integrated water resources management. Since it has been adopted by the Palestinian Water Authority as its strategy to fulfill the agricultural demand from reclaimed wastewater, more socioeconomic and technical researches are needed. To convince the users, the reclaimed wastewater should be treated well through the soil aquifer treatment (SAT) in addition to the technical problems occurred in the distribution system. The quality levels of reclaimed wastewater for irrigation should be managed well in terms of suspended solids to avoid plugging of irrigation system, nutrients to adjust fertilization, salinity to estimate leaching of soil and last pathogens for health aspects. The infiltration system itself needs to be assessed environmentally well to prevent hazards for the neighboring residents. From the other side, the public should be aware of the advantages of the new sources, together with economic incentives to get reclaimed wastewater with prices cheaper than that of well water.

The option of reuse of reclaimed wastewater Palestine is still in its early stages. But according the National Water Plan, it will be entered to the management of water resources to have an input of about 60 Mm³ every year in the year 2020. This amount together with comes from planned seawater desalination (55 Mm³ per year in year 2020) will diminish the negative balance in the water resources budget in Gaza Strip. The sustainability of the groundwater system relies on safe water abstraction when it does not exceeds the annual replenishment of the groundwater system through adding

new and non conventional resources such as reclaimed wastewater. The Decision Support System (DSS) is under construction to help the decision maker in making right decisions when, where and how to use this new resource to attain sustainable water resources.

Fig. 2 Quality of wells around infiltration basins



Conclusions and Recommendations

Like other scarce water countries in the region, there is urgent need to look for new non conventional water resources such as reuse of reclaimed wastewater, which has been adopted by the Water Authority to be used for irrigation, and only minimal amount of fresh water to be used for irrigation. This new resource will play an important role together with other resources e.g. seawater desalination and harvesting of storm water in the sustainability of the water resources in the Gaza Strip. However, more efforts are still needed on the socioeconomic and technical aspects. On the technical dimension, the applied effluent should be treated well in the treatment plant so that its constituents do not exceed the standards adopted by the Palestinian Water Authority based on WHO standards, in addition to the well-control on the management

of infiltration spread basins. On the socioeconomic dimension, the public should be prepared to accept the idea of replacing their well water by the distributed reclaimed wastewater for irrigation, and they should be economically encouraged through prices of the received water.

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تحسين المياه الجوفية في فلسطين بإعادة استخدام مياه الصرف الصحي

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سلطة المياه الفلسطينية - فلسطين

إن زيادة الطلب المستمر على المياه في فلسطين بشكل عام وبالأخص في قطاع غزة، مع أن الإمداد المائي هو ثابت بل في تناقص مستمر، فإن ذلك قد أدى إلى تدهور المياه الجوفية من ناحية الكمية والنوعية، حيث أن المنطقة الساحلية والتي تتمثل في قطاع غزة تعاني مصادرها المائية من ضغط شديد من الاستخدامات الأدمية والزراعية، فانه حسب دراسة برنامج إدارة مصادر المياه فإن الطلب الكلى على المياه في قطاع غزة هو 173 مليون م³ كل عام في حين أن معدل الإمداد السنوي حوالي 122 مليون م³، وهذا يعنى وجود عجز مائي حوالي مليون 50 م³ سنويا، وقد أدى ذلك إلى انحدار مستمر لمستوى المياه الجوفية إضافة إلى ازدياد ملوحتها، مما يحتم علينا البحث عن مصادر مياه جديدة. هذا وتوجه إدارة مصادر المياه في الدولة نحو تبني إستراتيجية البحث عن مصادر غير تقليدية مثل تحلية مياه البحر والحقن الصطناعي لمياه المطار ومياه الصرف الصحي المعالجة، حيث أن الطلب على المياه للأغراض الزراعية ثابت او في تناقص، بينما الطلب للاستخدام الأدمى في ازدياد مستمر نتيجة ازدياد السكان، ومن ثم ازدياد كميات مياه الصرف الصحي، حيث أصبحت المياه المعالجة تمثل مصدر مياه هام للتغلب على العجز المائي في المنطقة، كما أن اعادت استخدام المياه المعالجة يمكن تحقيقه بطريقتين، أولهما الري المباشر في الأراضى المزروعة، بينما الطريقة الأخرى عن طريق ترشيح تلك المياه إلى الخزانات الجوفية ومن ثم إعادة استرجاعه من خلال آبار مياه استرجاعي، بحيث يؤخذ بعين الاعتبار قدرة المحاصيل على تحمل المكونات المختلفة في المياه المسترجعة، وبالتأكيد فإن هذه الطريقة تساهم كثيرا في تحسين الخزانات الجوفية للمياه عن طريق تقليل الطلب على المياه للأغراض الزراعية، وكذلك تغذية الخزانات من خلال ترشيح المياه للخزان.

ان إعادة استخدام مياه الصرف الصحي المعالجة قد أصبح خيارا استراتيجيا مع تحلية مياه البحر والذي يعتبر كلاهما كمصادر مياه غير تقليدية، بحيث يساهم كل واحد منهما بحوالي 60 مليون م³ سنويا حسب المخطط في العام 2020، وبالتالي فإن خيار إعادة الاستخدام تأخذ الاولوية عند تصميم المشاريع قبل أن اتخاذ قرارا بتصريفها إلى البحر، وسوف يتم وضع كل تلك المعلومات في نموذج دعم القرار لهذا الغرض. الكلمات المفتاحية: إعادة الاستخدام - العجز المائي - الآبار الاسترجاعية - نظام دعم القرار.