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FiBRE SERIES

OPPORTUNITIES AND OBSTACLES IN ARTIFICIALLY RECHARGING GROUNDWATER WITH EFFLUENT: A CASE STUDY OF GAZA

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01 Summary

Water is the most vital of commodities. Essential to both human and animal life, its provision has always been, and will remain, a central challenge focus of public policy. Nowhere is this challenge greater than in areas where natural supplies of water are insufficient to meet demand. Hence it is unsurprising that new and innovative techniques for harvesting more water resources are being developed in these areas.

A new approach has been explored by the authors, which evaluates efforts over the past few years to increase water resources by using effluents to recharge natural water supplies in the Gaza Strip. Treated effluent has been used to boost natural water supplies since 2000. By doing so the Palestinian Water Authority (PWA) has managed to free up much needed natural water for human consumption purposes. Furthermore, these efforts appear to be cost effective and hence are appropriate for regions where economic conditions are tough.

Key aspects are:

- Reclaimed water led to a modest rise in the water table in some wells, however in others the impact was dwarfed by the accelerated withdrawal of water during the study period, leading to an overall decline in the water level.
- Using reclaimed water reduced the toxic nitrogen concentration in the natural water rendering it more suitable for agricultural use.
- However, boron levels did increase as did chloride levels although the latter is due to the unusually high levels of chloride in Gaza's drinking water.
- Reclaimed water was found to be economically viable as it could be offered to farmers in the region at a reasonable price relative to the existing sources.

> **"The Palestinian Water Authority (PWA) has managed to free up much needed natural water for human consumption purposes.**

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02 Introduction

As the population of the world expands inexorably, the pressure upon the world's resources continues to mount. Recent years have seen staggering increases in the price of most traded commodities from industrial metals, to agricultural crops and most strikingly, in the price of energy. Whilst all of these goods are important, one of the most pressing challenges facing public policy professionals is the provision of an even more vital commodity: water.

As water is rarely traded internationally, its provision relies less on well functioning markets and more on the quality of local infrastructure and resource management. Providing enough water to meet all of society's needs, from drinking to agricultural uses, has been a consistent challenge for mankind. Areas with little rainfall, low water tables and high temperatures which accelerate the evaporation of existing water supplies, are particularly difficult to deal with. The challenges presented by these conditions are exacerbated in regions where economic conditions are poor and/or where social and political conditions are unstable. There are few regions of the world where these factors come together more clearly than in the Gaza Strip. In this work, Sami Hamdan of the Palestinian Water Authority, Abdelmajid Nassar of the Islamic University of Gaza and Uwe Troeger of the Technical University of Berlin decided to find out if treated effluent could be used to replenish the underground aquifers which are the main source of water in the Gaza Strip.

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03 Conventional and non-conventional water resources

Conventional

The Gaza Strip depends mainly on rainfall for its water supply. Average annual rainfall fluctuates from 200 mm in south Gaza to 400 mm in the north giving a total bulk amount of rainwater of about 115 million m^3. However, of this, only about 50 million m^3 actually replenishes the aquifer, and the rest either evaporates or runs straight out to sea. The total supply to the aquifer was 122 million m^3/year coming from different resources, rainfall infiltration, irrigation return flow, wastewater seepage and transboundary flow (CAMP 2000). The total demand was 164 million m^3, made up largely of 79 million m^3 domestic demand and 79 million m^3 agricultural demand (PWA 2007). This clearly leaves a deficit of about 42 million m^3 every year, and fresh supplies urgently need to be found.

Non-conventional

Clearly, something needed to be done to fill the gap, and the Palestinian Water Authority (PWA) has started investigating the use of non-conventional sources of water such as seawater desalination and artificially recharging the underground aquifers from storm water or treated waste water. It is the last of these, the use of treated waste water, which holds the greatest promise and is the subject of this paper. According to the 2000 study of the Coastal Aquifer Management Program (CAMP 2000), the potential amount of treated wastewater that could be reused in the year 2020 will reach about 60 million m^3 a year, with another 55 million m^3 coming from seawater desalination. The total waste water in Gaza is expanding as the population grows so determining the viability of its use for important sources of water demand such as agriculture is of vital significance. The PWA has already started the reuse of treated waste water from the Gaza wastewater treatment Plant (GWWTP). It is the efficacy of these efforts which the authors of this paper sought to determine.

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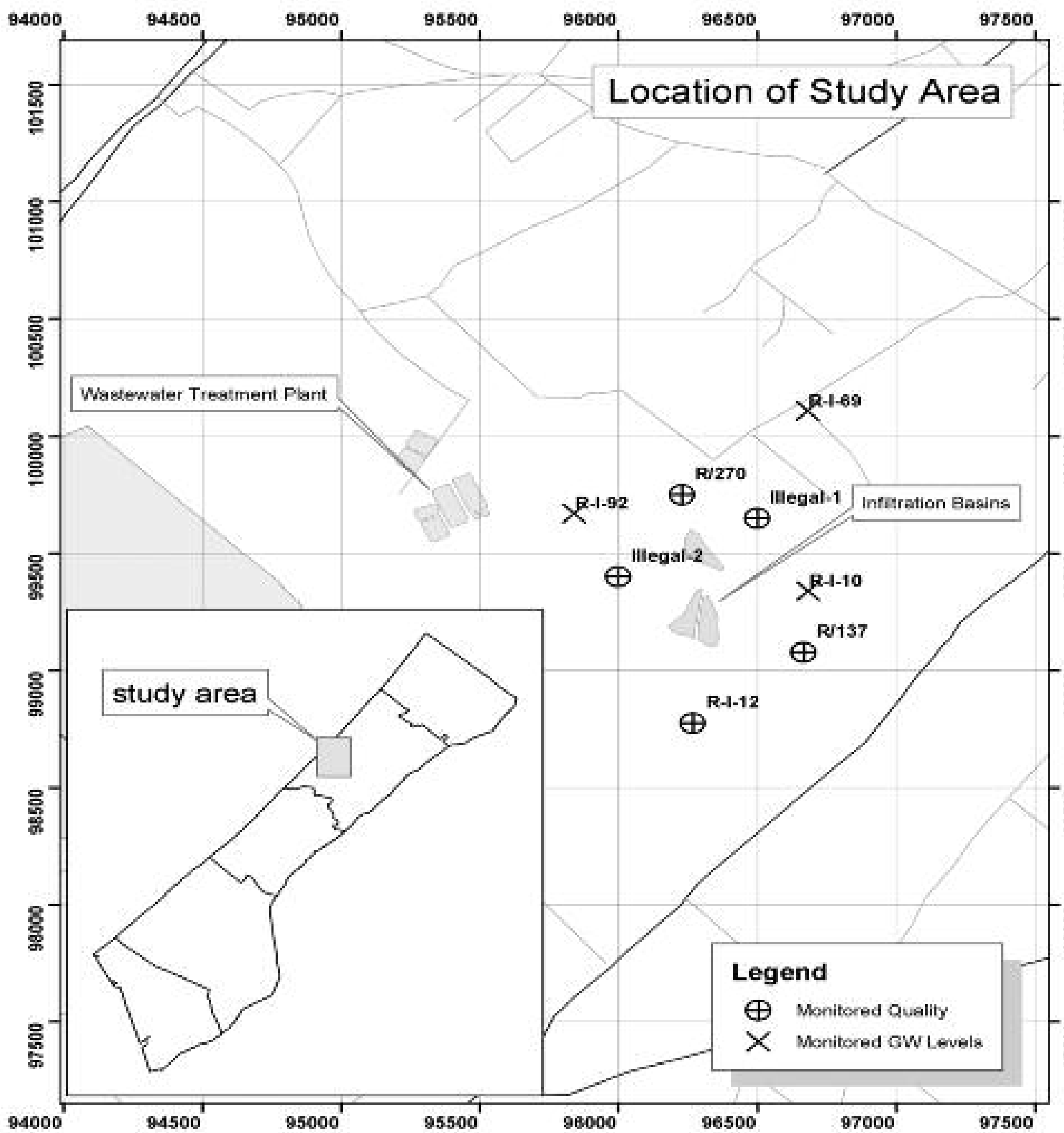
04 Methodology

The first thing that authors did was to review the existing strategic plans of the wastewater reuse. Part of treated effluent (10,000 m^3) from the existing wastewater treatment plant in Gaza was diverted to three spread infiltration basins with a total base area of 3.7 hectares (ha) distributed as pond 1 with an area of 1.1 ha, pond 2 of 1.3 ha and pond 3 of 1.3 ha (CAMP 2001) as shown in Figure 1 below.

Figure 1: Pond and well locations in Gaza



05 Results

The impact on groundwater levels and chemical quality was evaluated based on previous monitoring of the surrounding groundwater wells in different directions. The water samples were analyzed in the laboratory of the Palestinian Ministry of Agriculture using the methodology laid out the American Standard Method Manual.
The infiltration areas located east of the current GWWTP were the focus of investigation. It was at this plant that the Coastal Aquifer Management Program started in 2000, with the help of USAID. The treatment plant receives about 40,000 m^3 every day, and all the effluent used to be pumped out to sea before the construction of the infiltration facilities. Since 2000, about 10 000 m^3 of treated water were pumped into the infiltration basins in three separate spread basins, after one day wetting and two days drying.

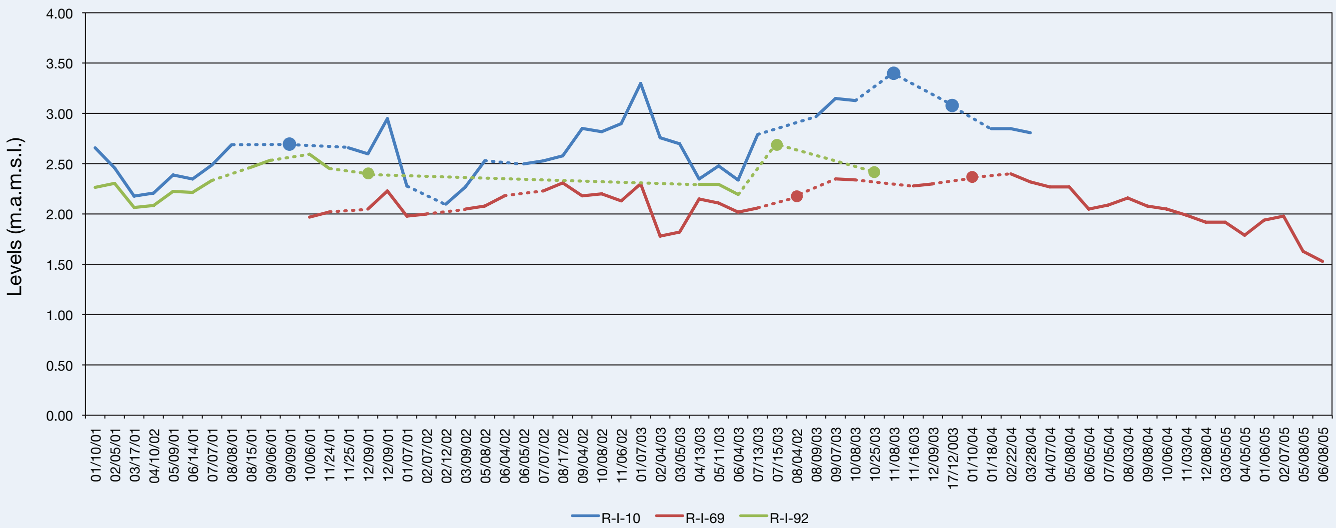
The infiltration basins are set on an area with medium quality groundwater where the chloride concentrations in the area fluctuate between 250 mg/l and 500 mg/l and nitrate level fluctuate between 50 mg/l and 200 mg/l (PWA 2008). The quality of the treated effluent that was being pumped back into the infiltration basins was monitored in the period from January 2002 to November 2004, and it showed a range of chloride level between 400 to 600 mg/l which is a little higher than that in native groundwater. However, the nitrate level in the treated effluent ranged between 20 mg/l to 30 mg/l in the same monitored period, actually lower than the groundwater into which it was being pumped. Hence, it was expected that it would dilute the nitrate concentration in the native groundwater. The readings were close to the Palestinian standards of effluent recharge which are set at 600 mg/l for chloride and 20 mg/l for nitrate (KfW 2005). The original aim was for the wastewater was initially intended to be pumped into the ground from six recovery wells, and monitored from ten surrounding monitoring wells. However, due to political conditions the monitoring wells were not built. This meant the authors were forced to use data from existing operating wells owned by local farmers.

06 Impact on groundwater levels

The groundwater levels in the study area fluctuate from around one to four meters above mean sea level. The area is surrounded by irrigation wells used by farmers, so monitoring the water levels may give only an approximate indication of the impact of infiltration on groundwater levels. What did they find? The evidence in this regard is mixed. One well, (R-I-10, about 500 meters east of the infiltration basin) showed an increase in 2003 after being stable during the earlier testing period.

The other two testing wells (R-1-69 about 1500 meters northeast of the infiltration basin, and R-I-92, about 1000 meters northwest of the infiltration basin) saw declines in groundwater levels. These results are displayed in Figure 2. However, the authors are convinced that this is down to increased water usage during the testing period and had the experiment been conducted under more controlled conditions, then the ground water levels would have risen.

Figure 2: Groundwater levels



07 Impact on groundwater quality

Of possibly even greater importance for considering the future use of treated effluent as a non-conventional way of recharging aquifers is the impact upon water quality. The authors monitored five wells, which included two illegal wells, during the study period and the evidence gathered was, again, somewhat mixed.

Commented the authors, “One area that did seem to be successful was the nitrate concentration”. As Figure 3 shows, nitrate levels in the effluent were well below the pre-existing levels in Gaza’s groundwater. This pays testament to the denitrification process within the wastewater treatment plant. The reduction in the nitrate levels in the groundwater is a major improvement for a region that has historically suffered from excessive levels in its drinking water. This finding backs up research in other regions of the world that also showed reduced nitrification after use of treated effluent.

There was however, a clear deterioration in other aspects of water quality. Chloride levels were found to have risen (see Figure 4). This is unsurprising since the chloride levels in the effluent were significantly higher than those that were present in the pre-treated water resources.

However, the authors point out that this problem could well be mitigated by soil aquifer treatment (SAT) processing of the effluent which would reduce the salinity (chloride level) of the effluent to below existing groundwater levels. There were inconclusive results with regard to the concentrations of boron in the water. Boron is considered toxic by agricultural users when the concentration exceeds a certain threshold (see Figure 5). One well showed an increase while others showed only temporary increases which were soon reversed.

Figure 3: Nitrate Concentrations

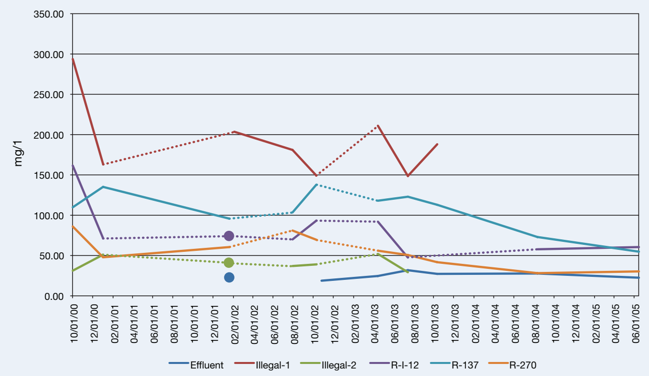


Figure 4: Chloride Concentrations

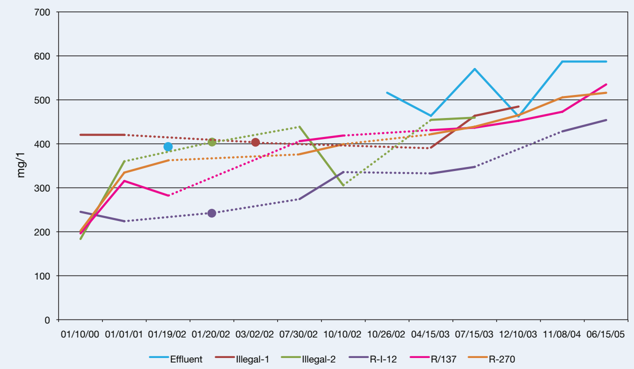
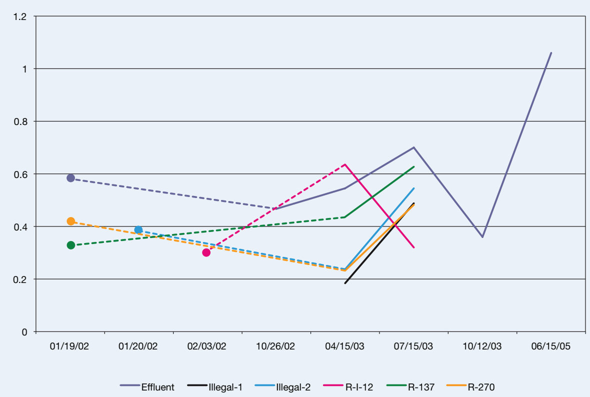
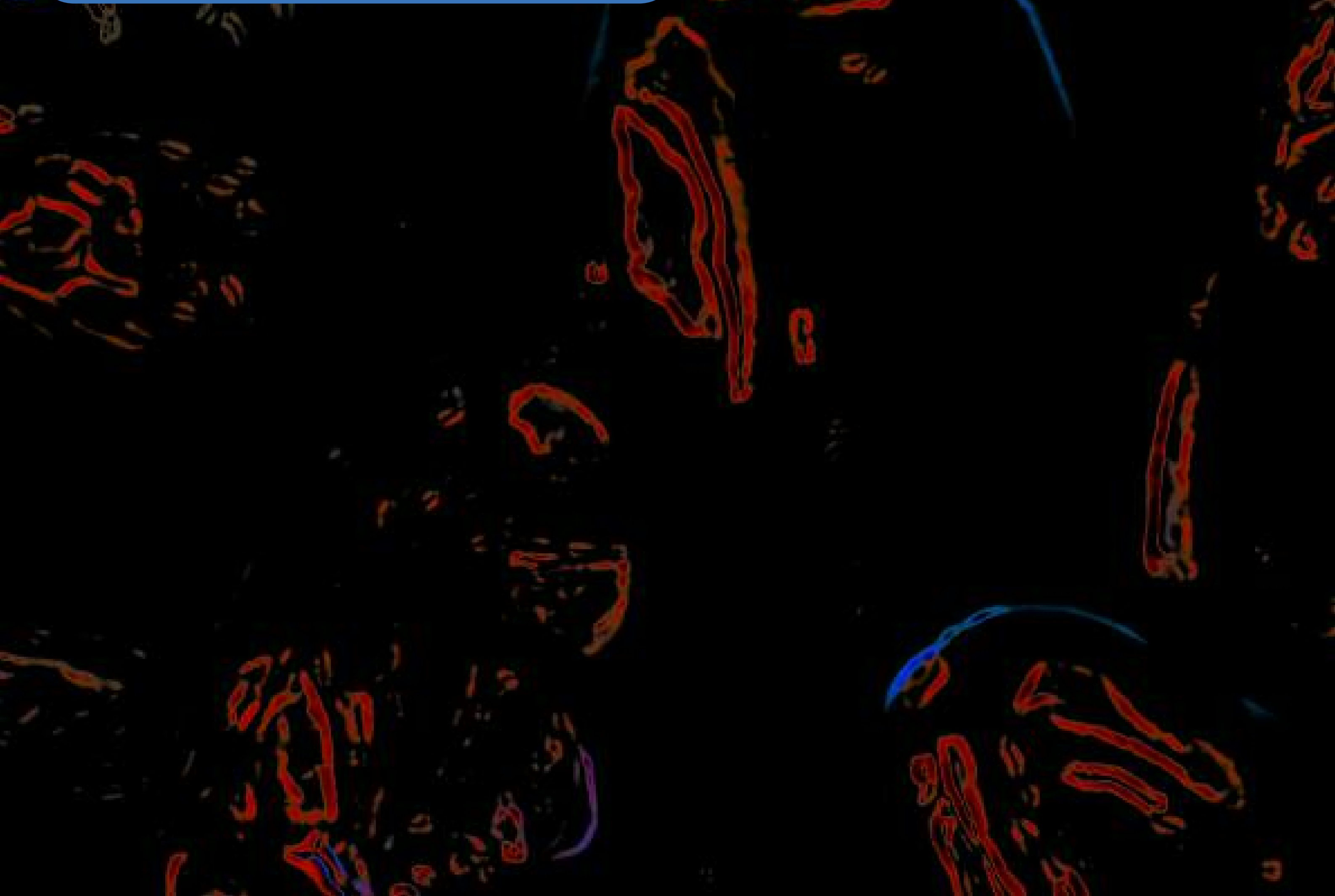


Figure 5: Boron Concentrations



08 Socio-economic impacts

The results of the analysis may be encouraging but when economic resources are limited the economic effectiveness of any achieved results also needs to be carefully considered. The findings from this point of view are encouraging. Wastewater production in Gaza is expected to reach around 35,000 m^3 per day by 2012. The investment cost of the project, including infiltration basins, construction of recovery wells and pipes, totalled US$4.58 million, while the operational cost was US$0.14 million a year. Assuming the investment system will operate for 20 years to infiltrate 35,600 m^3 a day (equivalent to 12.3 million m^3 a year), this will give an initial investment cost of US$0.019 USD for each cubic meter infiltrated. The operation and maintenance for each cubic meter will be US$0.018, giving a total cost of US$0.037 per cubic meter. As the authors suggest, "This seems to represent very good value for money, given that farmers currently pay US$0.5 for each cubic meter pumped for irrigating their crops and have expressed a willingness to pay US$0.14 for a cubic meter of reclaimed effluent".



09 Challenges

According to the authors, users would be encouraged to take the effluent if the reclaimed wastewater is thoroughly treated through the SAT, and the technical problems that occurred in the distribution system and institutional framework were dealt with. 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 environmentally assessed, to prevent hazards for the neighbouring residents. In addition, the authors stress the importance of a public information campaign to raise awareness of the advantages of the new sources, together with economic incentives to purchase reclaimed wastewater, such as prices cheaper than that of water from wells. Greater awareness would help extend wastewater collection, which at present is somewhat patchy. Based on the dwellings that are currently connected to the wastewater network, current wastewater production is 32.7 million m^3 a year for the partial coverage of wastewater networks and it is estimated that this could rise to 51.6 million m^3 if all dwellings where connected to the wastewater network, as shown in table 1.
At population growth rate of 3.5%, the total wastewater production will increase to 80 million m^3 per year in the year 2020. Given that the National Water Plan predicts collection of only about 60 million m^3 per annum in 2020, it is clear that extending collection will remain a challenge in Gaza.

Table 1: Wastewater Production in Gaza governorates*

Governorate	Population (Capita)	Coverage Percent	Wastewater Production (m^3/day)	Production with Full Coverage (m^3/day)
North Area	298125	68.51%	16341	23851
Gaza	546959	79%	48243	61067
Middle area	223679	64%	11420	17843
Khanyounis	299918	20.60%	4942	23988
Rafah	183649	59.79%	8784	14691
			89,730	141,440

Total Production = 32.7 millions M^3/year and 51.6 Millions M^3/year for full coverage, and based on average per capita is 80 l/d

**CMWU 2007*

10 Implications

As the population continues to grow, the search for solutions to seemingly insurmountable problems becomes ever more urgent. The breakthroughs that will advance mankind are likely to come from those who are faced with the most difficult and immediate challenges. The provision of water to a rapidly growing population in an economically depressed and politically unstable region such as Gaza, would surely classify as such.

What the authors have shown is that it is technically feasible and economically viable for treated effluent to be used to recharge aquifers. This could replace the use of drinking quality water for agricultural purposes and, combined with water desalination and the harvesting of storm water, it has the potential to improve the sustainability of water resources in the region. As it was concluded “By 2020, around 22% of total water demand could be satisfied by reclaimed water”.

The team did find that reclaimed water had raised the level of the local water table and decreased the concentrations of nitrates within the water. Unfortunately, the worrying trend of boron in the water is major issue which needs to be overcome. The elevated levels of chloride in the water, whilst being unwelcome, are the result of the particularly high concentration of the chloride in the drinking water, and hence the waste water in Gaza itself. This would not provide an obstacle in areas without high chloride levels in their waste water and with better water treatment this obstacle could be removed in Gaza.

Encouragingly, this study shows that reclaimed water can be provided at prices that are attractive to the potential customers for it: the farmers. However, the challenges outlined in this study emphasize the importance of improved water collection and treatment facilities. These in turn require investment in those facilitates, stable and reliable power systems, an educated and well trained work force and a stable political climate in which the sustainability of water resources gets the prominence in budget decision making that they deserve.

> **“It is technically feasible and economically viable for treated effluent to be used to recharge aquifers.**

11 Further reading

CAMP 2000. Coastal Aquifer Management Program. Volume I. Integrated Aquifer Management Program, Task 3. Gaza, May 2000. Pp 3.1- 3.15

CAMP 2001. Coastal Aquifer Management Program. Feasibility study and Conceptual Design for Gaza Wastewater Treatment Plant, Task 23. Gaza, March 2001. Pp 8.9- 8.10

CMWU 2007. Databases of the Coastal Municipal Water Utility, Gaza, 2007.

KfW 2005. Sludge and Effluent Reuse Study for Gaza Central Area. Concept Report, Volume I, Dorsch Consult, Gaza, July 2005. P3-2

PWA 2007. Agricultural and municipal water demand in Gaza for the year 2006, Gaza, September 2007.

PWA 2008. Databases of the Palestinian Water Authority on groundwater quality and accessed on 4 May 2008.

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