POTENTIAL OF WASTEWATER REUSE IN GAZA - PALESTINE

ADVANTAGES AND HINDRANCES

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ABSTRACT

The main source of water in Gaza Governorates is Groundwater. The existing situation, with annual recharge of 60 Million Cubic Meter (MCM) and a deficit of approximately 55 MCM/year, has led to reduction in the available quantities of groundwater as well as degradation of water quality . Water demand, for different purposes, will rise continuously from the current level of 117 MCM to about 215 MCM by the year 2020. The stored water in aquifer will decrease with time and the fresh groundwater with less than 250 ppm chloride will not be available if we depend only on groundwater.

Using treated effluent for irrigation will minimise the demand on groundwater for agricultural purposes and will reduce the degradation of the groundwater quality. In this case, the groundwater reserved in aquifer will be about 2537 MCM in Gaza aquifer by year 2020 compared to about 1522 MCM if the treated effluent were not used. That means about 1000 MCM will be saved in the aquifer of Gaza in this period.

Key words:
Wastewater reuse, Water management - Gaza Strip

1. BACKGROUND

The Gaza Strip is a land area located along the Mediterranean sea south-west of Palestine and north of Egypt. The size of the area is ca 365 km^2. About 35% of the area is still occupied by Israeli settlements. The Palestinian population, which is growing fast, is today about 900 000 habitants. The population forecast is approximately 1 400 000 persons in the year 2005(Ministry of Planning and International Cooperation {1}), mainly because of the high fertility rate and the large number of immigrants. The immigration is mainly due to the right of all Palestinians to return to their homeland.

Due to the tremendous population increase, the water demand increased sharply. The yearly replenishment of the aquifer represents about 60% only, which lead to deficit in water balance around 55 Million Cubic Meter (MCM)/ year (Water Resource Assessment Study {2}).

The sustainable management of the available and renewable water resources together with developing new water resources are the main objectives of many projects in the area.
The reuse of wastewater could be one of the main alternative option to develop the water resource in the region, as represents an additional renewable and reliable source. This strategy will lead to reduce the gap of water deficit between supply and demand in Gaza Strip. Another advantages of reuse of waste water is to decrease the pollution of the environment, protection of public health and to protect existing water sources from pollution .

The Northern Governorate of Gaza Strip will be given as a case study . The area consists of three municipalities: Jabalia, Beit Lahya and Beit Hanun, with a population of about 150 000 persons. The sewage plant which serves these municipalities is located in Beit Lahya. 60% of the households are connected to the community sewerage system (Team Engineering Group and SCC-International {3}).

The Northern Governorate of Gaza have a growing population and the water demand is rising. The agriculture is intense as in all of Gaza. The farmers use water from legal and illegal wells for irrigation. Almost all municipal and agricultural water is taken from the groundwater aquifer of Northern Gaza. 79% of the water consumption is used for irrigation (Team Engineering Group and SCC-International {4}). The demand gets higher per capita and the agriculture needs more water when the population grows. The effluent from the sewage treatment plant is at present not acceptable for irrigation. The effluent contains faecal bacteria, parasites (Afifi, S. {5}) and probably viruses. That effluent is now infiltrated into the ground.

The quality of the water in the aquifer in the Beit Lahya area is among the best in Gaza Strip, and the aquifer is very sensitive for contamination.

2. BASIC CONDITIONS GAZA STRIP

2.1 Water demand and water generation

Fresh water is a scarce resource in Gaza Governorates. The most concerns of the both, people and Palestinian Water Authority (PWA) in Gaza Governorates is having sufficient water to assure their economic and social development. The main water source of water in Gaza Governorates is Groundwater , which used for irrigation, industry and domestic purposes. The yearly replenishment of the aquifer is about 60% only. Table 1 gives The available and renewable groundwater quantities in Gaza Governorates 1996 (Palestinian Water Authority {6}).

Table 1 :Available and renewable groundwater quantities in Gaza Governorates 1996 (Palestinian Water Authority {6}).

Governorate	Area (km2)		Available Quantities(MCM)		Renewable Quantities(MCM/yr.)		Demand (MCM)
	Fresh	Brackish	Fresh	Brackish	Fresh	Brackish	Domestic
North	40	6	400	230	10,00	1.50	5.50
Gaza	20	70	200	1040	3.50	10,50	16,50
Middle	2	56	20	780	0,35	8,40	5,50
Khanyonis	8	58	80	740	0,60	5,80	7,70
Rafah	14	53	140	690	2,10	5,40	4,40
Total	84	243	840	3480	16,55	31,60	39,60

* Fresh groundwater salinity is considered < 500 PPM.

* The groundwater qualities inside settlements were excluded.

* Agriculture demands are not included.

Trends in water demand for domestic and irrigation uses are related to many socio - economic aspects. The population growth is the main factor for the projections of domestic water demand. Many scenarios have been set up to express the trends in population change in Gaza Governorates. The scenarios have included population growth rates varying from 2% to 6%, depending on the politic - socio - economic development in the area.

Water demand for different purposes will rise continuously from the current level of 117 MCM to about 215 MCM by 2020 considering population growth rate of 4,5 for 1996-2010 and 3,2 for 2010 - 2020 (Ministry of Planning and International Cooperation {1}) and domestic consumption per capita of 150 litre/ day (Palestinian Water Authority {6}) as will as industrial and irrigation water needs (Table 2).

Table 2 : Projections of Water Demand in MCM in Gaza Governorates

Year	1996	2000	2005	2010	2015	2020
Industry	2	2	4	8	12	16
Domestic	35	53	77	95	100	118
Agriculture	80	80	80	80	80	80
Total	117	135	151	173	192	214

The overall studies of the groundwater balance for the Gaza Strip show that the deficit in water balance can be between 40 and 60 million m^3 per year (Gaza Environmental profile part 2 & 3 {7}). If we depend only on groundwater, the stored water in aquifer will decrease with time and the fresh groundwater of < 250 ppm chloride will not be available.

2.2 Wastewater Reuse

Fresh run off, saline water (sea water desalination) and wastewater are the main marginal water sources in the region .

Wastewater reuse has been identified as an important issue to develop the water resources in many countries in the region . Effluent reuse can be an alternative to groundwater for irrigation or/and recharged to the aquifer. Table 3 illustrate the yearly potential of wastewater generation for the coming years in Gaza Governorates in MCM.

Table 3: Potential of Wastewater Generation in Gaza Governorates in MCM.

	1996	2000	2005	2010	2015	2020
Population (Thousands)*	888	1059	1320	1645	1925	2254
Water Consumption (Domestic)	35	53	77	95	100	118
Wastewater Generation	24.5	40,6	54	66	70	83
Connected to Network %	33	50	65	75	85	90
Treated Effluent	8	20,3	35	50	60	75

* Annual Growth Rates of 4,5 for 1996-2010 and 3,2 for 2010 - 2020 (Ministry of Planning and International Cooperation {1})

About 20 MCM/year of treated effluent can be used for irrigation by year 2000, and 75 MCM/year will be available by year 2020 for both irrigation an recharge .

Figure 1 shows the comparative scenarios of the change of the available groundwater in the both cases , with and without effluent reuse, with the reference to the year 1996. In case of no wastewater reuse, the groundwater stored will decrease from 4326 in 1996 to about 1522 in year 2020, with accumulated deficit of 2798. In addition to that it is expected the fresh g(chloride within 250 PPM) will be not available .

Figure 1 (It will be sent by Fax)

Figure 1: Comparative scenarios of the accumulative deficit of the available quantity of groundwater with and without reuse plan.

Using treated effluent for irrigation will minimise the demand on ground water for agricultural prepossess and will reduce the degradation of the groundwater quality. In this case the groundwater reserved in aquifer will be about 2537 MCM by year 2020 compared to about 1522 MCM if the treated effluent were not used . That means about 1000 MCM will be saved in the aquifer of Gaza in this period. It is expected to have a positive effects on the groundwater quality in the same time.

3. NORTHERN GOýVERNORATE OF GAZA

3.1 Water Resource

The northern area of the Gaza Strip has the highest quantity, with relative best quality of available and renewable groundwater. Table 4 shows the amount of available and renewable groundwater in the area.

Table 4: Available and renewable groundwater in the Northern Governorate (Palestinian Water Authority {6})

Areas	Area (km^2)		Available quantity (MCM)		Renewable quantity (CM C)		Demand (MCM)	
	Fresh	Brackish	Fresh	Brackish	Fresh	Brackish	Domestic	Agri-culture
Northern Governorate	40	6	400	230	10,0	1,2	5,5	20,91
% in the Northern Governorate (% of the Gaza Strip)	47,61	0,02	47,61	0,07	60,42	0,04	13,89	25,32

Fresh groundwater salinity is estimated to < 500 ppm.

Groundwater quantities inside Israeli settlements were excluded.

The annual groundwater replacement in the area is relatively good compared to other parts of the Gaza Strip. Table 5 shows the approximately groundwater balance of the northern area. The estimate water demand in industrial sector and water abstraction in the Israeli settlement in the northern area should be less than one million m^3 per year for each.

Table 5 : The approximately groundwater balance of the northern area.

Inflow components in million m^3/year.		Outflow component in million m^3/year.	
1- Average renewable water (fresh + Brackish).	11.2	1- Domestic abstraction	6.0
2- Return flow domestic.	4.5	2- Irrigation abstraction.	20.9
3- Return flow irrigation.	7.3	3- Industrial Demand	1
4- Northern border Ground - water inflow	5	4- Settlement abstraction	1
Total	28.0	Total	28.9

As a result of nearly equal inflow / outflow in the water balance for the northern area, the deficit is around Nil, this explained the good quality in terms of chloride and electrical conductivity (EC) parameters of the groundwater.

3.2 Water Demand for Irrigation

The water demand for irrigation is a function of the existing and future area of different crops, and their water requirement for optimal growth. The projection of irrigation water demand will depends on the rate of conversion of irrigated land into urban and the conversion of citrus and fruit plantation into vegetable and flowers cultivation areas in the next 20 years.

Many studies show that a minimum change will be made in water demand for irrigation overall in Gaza strip in the next 20 years. This is due to the fact, that decrease in irrigated land area can be compensate by increase in intensive agriculture, with more water demand per area unit. Table 6 shows crops types, cultivated area and water requirement per donum (El-Wali et. al. {8}).

Table 6 : Crops types, cultivated area and water requirement per donum (El-Wali et. al {8}).

	Area in donum			Water requirement
Crop Type	Gaza Strip	Northern Governorate	%Northern Governorate	m3 /donum . year
Vegetable	62217	17112	27,7	750
Citrus	43570	16850	38,7	450
Field crop	37748	2658	7.0	200
Fruit	39450	1511	3.8	250
Ormentats	716	284	39,7	1500
Total	183701	38415	20.91	-

3.3 Potential of wastewater Reuse:-

3.3.1- Wastewater Generation

Water demand in the northern Governorate will rise for domestic purpose continuously from the existing level of 5.98 million m^3 to about 14 million m^3 by year 2020 . In the same case the wastewater generation will increase from current level from around 4.38 to 11.43 MCM / year. Table 7 shows the potential of wastewater generation and possible reuse in the current state and for the next period (2020 year).

Table 7: Potential of Waste Water Generation in the Northern Governorate.

		1996	2000	2005	2010	2015	2020
1	Population in Thousand	149	174	206	259	312	356
2	Water consumption Million m3 / year	5.98	6.99	8.27	10.40	12.53	14.29
3	Wastewater generation Million m3 / year	4.78	5.59	6.62	8.32	10.02	11.43
4	% Collection	60	65	75	85	90	95
5	Collected Wastewater Million m3 / year	2.87	3.63	4.97	7.07	9.02	10.86

1. Population Forecast according to the MOPIC, Scenario 1- modified, 1997)
2. Projection of water consumption 110 l/c.d.
3. Wastewater generation 80% of water consumption.
4. % Collected wastewater, for year 1996 calculated from 3 and 5 and for the years 2000 - 2020 projection according to expected development in the sector.
5. Wastewater collected for the year 1996 measured, for the year follows calculated from 3 and 4.

The current sewage system can collect 60% of the generated wastewater in the area, there with 2,87 million m^3 is collected in the treatment plant according to the new measurements in February 1997.

3.3.2 Agricultural Policy for Treated Effluent Reuse

Effluent reuse can provide the agriculture with a considerable amount of extra water resource. In addition, using treated effluent in agriculture will minimise the water abstraction from groundwater overall in Gaza strip and reduce the degradation of the groundwater aquifer.
The northern Governorate is not excepted from this strategy, specially it is the largest agriculture area with a high irrigation water demand in Gaza strip. Table 8 summarises the water requirement for different crops and water consumption for irrigation per year for Gaza strip compared by the situation in the Northern Governments.

Table 8: Crops types and water consumption for Gaza strip and northern Governorate .

	Water requirement	Irrigation water consume million m3 / year.		
Crop Type	m3 /donum / year	Gaza Strip	N. Governorate	% N. Governorate
Vegetable	750	46,66	12.83	27.5
Citrus	450	17.43	6.74	38.7
Field crop	200	7.55	0.53	7.0
Fruit	250	9.86	0.38	3.8
Ormentats	1500	1.07	0.43	39.7
Total	-	82.57	20.91	25.33

The effluent reuse will provide the agriculture sector with a round 3.63 and 10.86 million m^3 in the years 2000 and 2020 respectively . In the year 2010 about 7 million m^3 of treated effluent can be available for irrigation for citrus and fruit plantation (the current need for citrus and fruit trees in northern Governorate is a round 7 million m^3 , table 8).

The extra treated effluent can be available by year 2020 for aquifer recharge or for industrial purposes.

The projected water abstraction from aquifer will be about 36 million m^3 in the year 2020 for the Northern Governorate without the reuse policy. This quantity will be reduced to around 27 million m^3 in 2020 with effluent reuse policy in northern Governorate and remain by the current abstraction level round 28 million m^3/year (Table 9).

Table 9 Comparative scenarios of the available water resource in Northern Gaza

	Year 1997	Year 2020
Available wastewater (MCM/year)	-	10
Renewable groundwater to the aquifer (MCM)	10,0	10,0
Returned flow (Agriculture and Domestic) and Border flow	16.8	16.8
Total water generation/year	**26.8**	**36.8**
Water consumption in households (MCM)	-5,5	-15,6
Water consumption in agriculture (MCM)	-21	-21
Total consumption of water/year	**-26,5**	**-36,6**
Water Balance (MCM/year)	**0.3**	**0.2**

4. BARRIERS OF WASTEWATER REUSE

Reuse of treated effluent in agriculture is an attractive and well known option, particularly in arid and semi-arid regions. 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 in irrigation, other factors should be considered in the locallevel, certainly socio - economical aspects and agriculture policy in the area which make the most barriers for the wastewater reuse policy .

4.1. Wastewater Quality

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 nutrients contents and biological parameters, like BOD_5 , pathogenic bacteria, parasites and viruses, can be relevant for the effluent reuse.

In the northern Governorate, the reuse of treated effluent was planed for citrus irrigation by the designing of the existing treatment plant. However, the quality of the effluent has been not taken into consideration and the effluent quality is poor and not suitable for reuse purposes (Afifi, S. {5}).

4.2 Water collection and distribution system

The existing treatment plant in Beit Lahya is planed to serve the Governorate of north area (Jabalia, Beit Lahya and Beit Hanun).

The partially or fully connected areas are Jabalia city, Nuzla, Jabalia refugee camp and Beit Lahya. The sewerage system covered only about 60 % of the total population in this villages.

Due to the lack of collection system facility, the total quantity of wastewater collected is 2.87 million m^3 from the generation potential of 4.74 million m^3 according to the last measurement in February 1997. The losses amount is 40% of the potential.

The extending of the sewerage system is very important in the area to have considerable amount of effluent .Table 7 shows the projected quantity of wastewater potential according to the expected improvement in the sewerage collection system to the year 2020.

4.3 Social Acceptance

It is important that the general public is given the possibility to receive information about the importance of reducing the use of groundwater and the necessity of using treated sewage water for irrigation.

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.

A primarily study was conducted by TEAM Group - Palestine to investigate the willingness of the citizens of Gaza to buy products (fruit) irrigated with thoroughly treated sewage (Team Engineering Group and SCC-International {4}). The test group were informed about the irrigation system and the quality of the water. The results from the questionnaires shows that people living in the area are aware of the problem of water shortage (about 80% of the men and about 75% of the women), and that about 82% of the men and about 72% of the women have a positive attitude towards using treated sewage water for irrigation of fruit. To a certain extent (about 65% of the men and 50% of the women) they were willing to buy fruit irrigated with sewage water. Generally, men had a

higher frequency of positive answers to the proposed questions. More public awareness campaign is necessarily to be performed among the farmers and the public.

5. CONCLUSIONS

The water demand in the area clearly exceeds the water supply. The problem will increase in time, with an increasing population and growing water consumption per capita. Different ways of saving water in households and agriculture are possible. One of the most efficient ways of recirculating water is using the treated sewage water for irrigation. Analyses of the wastewater quantity shows that the water quality is satisfactory enough to allow decreasing of groundwater abstraction from the aquifer.
Water collection and distribution system, effluent quality and social acceptance are the most barriers which can be limit the reuse policy.
For a successful wastewater reuse plan, projects should be oriented to improve the collection and treatment system. More public awareness campaign is necessarily to be performed among the farmers and the public.

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