MANY ASPECTS OF DEALING WITH HIGH NITRATE CONCENTRATION WATER

By:

Rebhy El-Sheikh
M.Sc. Mechanical Engineering
Palestinian Water Authority

Nahed Ghbn
Ph.D. Environmental and Sanitary Engineering
Palestinian Water Authority

Ibrahim Jaber
M.Sc. Economy
Palestinian Water Authority

ABSTRACT

Groundwater is the major source of water in the Gaza strip. The Gaza Governorates as well as other parts of the Palestinian territories suffer from many environmental and health problems, related to various causes. One of these problems is contamination of the groundwater aquifer. The major indicator for that is increasing the nitrate concentration in the groundwater aquifer which is so many times higher than the WHO standards in a lot of the municipal water wells in the Gaza strip. The figure reaches about 500mg/l in some places of the Gaza Strip. Compared to 50 m g NO3/ l according to WHO standards. This is mostly caused by leaching of the untreated or not fully treated wastewater and overuse of pesticides in agriculture.
There are many plans in Palestine to improve the water quality regarding the nitrate concentration, such as evaluation using different denitrification technologies and management of water with high nitrate concentration.

The paper presents and discusses the existing water quality regarding the nitrate concentration and identifies the major aspects to improve the water quality. Moreover, it will evaluate the denitrification technology that fits with Gaza conditions technically and financially. A study area in Gaza Strip has been considered as a pilot project, taking into consideration modifications required on the existing distribution water system.

KEY WORDS

Water, Water treatment, , Denitrification Technologies

INTRODUCTION

The Gaza Strip is a small area, about 40 km long and between 6.4 and 9.6 km wide, with a total area of about 365 km^2. Topographically, it is flat, rising to a maximum of 65 meters above sea level. Sand dunes are the main feature along the coast line, while sandy loess soils, loessial sandy soils, and loess soils prevail in the eastern part of the Strip. The soil east of Gaza Town and in the northeastern part of the strip consists of dark brown clay loams. Many populated areas, including refugee camps, are located among sand dunes and in depressions with lack or no wastewater system in addition to overuse of fertilizers in agriculture in the Gaza strip.

The total population of the Gaza Strip is approximately 960,000, approximately 60% of whom are refugees. The populations are increasing at a rate of 3.8 % per year. With its high population and small area, the Gaza Strip is one of the most densely populated areas in the world with 2,603 people/km^2. Densities in refugee camps themselves are much more than this as it may reach up to over 100,000/km^2.

The ground water of many areas in the Gaza strip is polluted with an excess of nitrate.

Nitrate pollution is caused mostly by fertilizers or wastewater flow to the groundwater.

DESCRIPTION OF THE PROBLEM

The Palestinian territories are suffering from increasing the unavailability of water resources to the Palestinians combined with the associated political complexity to these valuable resources. In the Gaza strip, the main source of water is the groundwater, which is confined in the coastal aquifer. The total water consumption in the Gaza strip for various purposes is about 125 mcm per year. About 43 mcm is used for domestic purposes, and about 82 mcm is used for irrigation and industrial purposes. Most of the water resources in the Gaza strip are polluted by high nitrate and chloride concentration. The major threaten to the Gaza people is increasing the high nitrate that reach more than 300 to 500 mg/l in some places.

Contamination of groundwater by nitrate in the Gaza strip is one the most serious environmental problems facing the society and threatens the public health.

It is well known that the nitrogenous materials are rare in the geologic history of the Gaza strip. Thus it is rare to find sediments composed of nitrate. This leads to a major conclusion that the current nitrate concentration in the ground water is mainly derived from anthropogenic sources. Nitrogen can be introduced to the soil/water system in different forms. It exists in the soil/groundwater predominantly as the nitrate ($NO3^-$) anion or as ammonia ($NH4^+$) cation. Nitrate is a major pollutant of the groundwater in the Gaza strip. It is relatively high in the wells almost over all of the Gaza Strip under the build up areas or near effluent disposal sites. Some wells have nitrate concentration many time exceeding the WHO standards for drinking purposes. The high concentration is believed to be caused mostly by the infiltration to the groundwater aquifer the raw sewage by cesspools or not fully treated wastewater from the wastewater treatment plants in the Gaza strip or overuse of fertilizers in the intensive agriculture.

For showing the indicative history of increasing level of the nitrate in the groundwater aquifer, a group of (5) domestic wells was selected which are distributed in the build up areas through the aquifer in different locations of the Gaza governorates.

The main increase took place between 1980 - 1990 , during this period the average concentration increased from below 50 mg/l nearly in all selected wells to 200-300 and in some cases to 500 mg/l. The maximum reported value of the nitrate was in Rafah , Khanyounis and Northern area areas respectively, where there is no wastewater collection systems, and most of the people depend on cesspools for disposing their wastewater or problems with wastewater treatment and disposal.
Nitrate is toxic for babies and pregnant women. For babies nitrate have chronic bad nutrition effect. Presence of nitrate in drinking water can cause methaemoglobinemy (blue babies). A high nitrate concentration can also have carcinogenic effects and risk of illness of digestive tract for adult population.

PLANNING ASPECTS

The Palestinian Water Authority is the main responsible body for planning, management and regulation of the water resources in Palestine. The main policy for the water authority is to provide the population with water matching with the international regulations and standards regarding quality and quantity.
There are many practices in the Gaza strip for water quality improvement. Some desalination plants were constructed, one plant at Deir Al – Balah with production capacity of $20m^3$/ hr. The second plant at Khanyounis area, with production capacity of $50m^3$/ hr. In both cases, desalinated water is partially pumped into the distribution water networks. Municipalities for a daily operation of about 14 hours are managing these two plants. The third one is newly constructed brackish water desalination plant at the Gaza industrial estate, 400 m^3/day capacity, where the target is limited to provide good quality water for industrial foundations. These desalination plants were constructed mainly to decrease the chloride concentration.
For nitrate removal of water used for drinking purposes the Palestinian water authority intends to construct denitrification plants to be located in the north Gaza where characterized by high nitrate and low chloride concentration. Two technologies were proposed and analyzed which are biological denitrification and reverse osmoses.
The biological denitrification depends totally on bacteria growth that reduces nitrate in the water to nitrogen gas. This process is characterized by its low energy consumption and zero brine. It is a new technology in practice but has many advantages.
An RO desalination plant is the second preferable alternative for water quality improvements. Reveres osmosis is a pressure driven membrane process in which the pressure is driving force for removing the water from aqueous stream. The applied pressure is at least as large as the osmotic pressure difference across the membrane, plus the pressure required to actually force a significant amount of water through the membrane. It can serve to reduce as well nitrate and all TDS in the feed water.
The major issues in the RO system are fouling and scaling of the membranes, so pre-treatment of the feed stream is needed. Moreover the brine rejected

represents about 40% of the total extracted water which means an additional load on the already self exhausted aquifer.

These technologies are commonly used in the world although each of them has its advantages and disadvantages. Each of these technologies were analyzed technically and financially to fit with Gaza conditions.
After screening and analysis it was decided to select a biological denitrification technology in the north Gaza. Feasibility study was done for a pilot biological denitrification technology in addition to a financial analysis for both technologies..

THE PILOT BIOLOGICAL DENITRIFICATION

General ideas

The process by which the toxic nitrate ion is removed from water and converted by bacteria to nitrogen gas is called denitrification. This process is an effective solution to nitrogen pollution, because the end product (nitrogen gas) is harmless. The active bacteria in the process are facultative hetrotrophic – facultative meaning that it can grow both with and without oxygen. Heterotrophic means that it uses an organic carbon.
The process depends on the growth of bacteria in a reactor, which absorbs O_2 resulting from a reaction and makes N_2 be free.
Raw water is discharged into a filter media in order to support growth of Hetrotrophic Bacteria. A carbonaceous substrate (e.g. ethanol) is to be injected with raw water in order to transfer nitrate into gaseous nitrogen. This biological reaction can be put in a general from as:
A (nitrates) + B(carbonated substrate) $\longrightarrow$ reaction products.
Where N_2 will be one of the reaction products.
Having nitrate free water (and O_2 has been absorbed by bacteria), oxygen is added and the water is discharged to a carbon filter (polishing) in order to get rid of solid suspended particles and turbidity.
In order to get rid of the biomass generated in the filter, washing once a day must take place, using treated water. The rejected water is still useful for agriculture purposes after minor treatment (aeration).

Description of the nitrate removal unit

The biological denitrification process consists of three process units

- Bio-mass filter to remove the nitrates. This filter construction will be of cylindrical type and built in protected steel. It is filled by media of immersed bed, the water is directed up-flow, carbonaceous substrate (ethanol) should be injected.
- An aeration cascade to add oxygen to water after denitrification. The biological nitrates removal process consumes all the dissolved oxygen contained in the raw water. However oxygen is necessary in the activated carbon-filter to allow the elimination of any residual ethanol and oxidize the residual nitrite.

- Polishing of the treated water on the activated carbon filter. This to eliminate the suspended solids and the turbidity, to oxidize the residual organic matters created by the biological process and to nitrify the residual nitrates produced by the biological process. This filter works in down flow and the media support activated carbon is in granular form.

In addition , washing equipment for the bio-filter are needed.

Basis of location selection of the pilot project:-

1. An area with high density population
2. Selected wells for treatment and mixing are close to each other so that minor modifications on the distribution system will be encountered.
3. Available area for the construction of denitrification plant at one of the selected site.
4. Nitrate level existing in the feed water will guarantee a safe and efficient operation of the plant.
5. Nitrate level in the treated water allows for mixing with another untreated source provided that mixed effluent for distribution satisfies WHO standards in terms of Nitrate content.
6. Site to be close to agricultural area in order to utilize the washing water rejected from the plant.

Feasibility study

The area in the Gaza Strip characterized by high nitrate concentration while other water contaminants are negligible is the Northern area.

Here, there is no need to reduce chloride concentration (for example) and the RO system for brackish water will be considered in this area to reduce Nitrates for the purpose of comparison.

The Biological denitrification system has been evaluated as one of the challenging solutions in the Northern area.

Upon screening water properties of the different wells in the area, the following two wells have been selected for the case study

Table 1. The proposed wells for the feasibility study

Well No.	**Discharge m^3/hr**	**No 3 Ppm**	**CL Ppm**	**PH**
E156	250	150	161	7.2
Ell B	70	60	106	7.2

The proposal has been based on mixing the two streams from both wells at the inlet of dentitrification plant, resulting in combined properties as follows:-

Table 2. The proposed wells

Well	Discharge m^3/hr	No 3 Ppm	CL Ppm	PH
E156 + E11B	270	127	147	7.2

Where only 200 m ^{3}/hr. will be pumped out of the well E156 for denitrification while 50 m ^{3}/hr will be diverted to mix with the plant effluent for a safe operation of denitrification process.
The denitrification plant, in order to carry out that load will be composed of 4 lines, each 70 m^3/hr capacity as follows:-

1. Four Biological reactors having media support for the hetrotrophic bacteria to grow, working with water flow upwards.
2. Four Aeration cascades in order to oxidize residual Nitrite (No2) and to eliminate residual carbonaceous substrate (Ethanol in our case)
3. Four activated carbon filters to get rid of suspended solids and residual organic material. It works with water flow downwards.
4. A storage tank equipped with washing equipment (pump and blower).
5. One disinfection unit composed of disinfection pump and tank.
6. Aeration pond to collect washing water (to be used for agriculture).

Characteristics of the different components:

Table 3. The characteristics of different components

No	Component	Characteristics
1.	Biological Reactor	Surface area 8.3 m ^{2} Flow rate = 70 m ^{3}/hr Average velocity = 0.234 cm/ sec. Media supporting bacteria growth = 2.5 m thick
2.	Activated carbon filter	Surface area = 8.3 m^2 Flow rate = 70 m^3/hr Average velocity = 0.234 Carbon media thickness = 1.5m
3.	Washing pump	Flow rate = 240 m^3/hr Total head = 4m Average washing velocity = 0.8 cm/sec.
4.	Air Blower	Flow rate = 600 m ^{3}/hr Total head = 3m Washing velocity = 2 cm/sec.
5.	Treated water booster	Flow rate 270 m ^{3}/hr Total head 40 m
6.	Lagoon for aeration of wash water	Surface area = 440 m ^{2} Depth = 2.5 m

Based on above estimates, the effluent from the proposed system will be as follows:

Table 4. Results of the pilot study

No	Source	Flow rate m ^{3}/hr	No 3 Ppm	Cl Ppm	PH
1.	E156 + E11B	270	127	147	7.2
2.	Effluent of Biological denitrification	270	15	147	7.2
3.	Diverted flow from well E156	50	150	161	7.2
4.	Mixing of 2 & 3 above	320	36	149	7.2

The system flow diagram is shown in attached figure 3. This figure indicates the mixing proportions proposed between influent and effluents streams.

Financial appraisal:

Based on estimation and knowledge in the local market, equipment and civil works were sized and cost estimated. A financial analysis comparison has been carried between the Biological denitrification and the brackish water desalination process including the investment and operational costs. The estimated tariff has been investigated in both cases.
It should be pointed out that for both case, quantity of water treated out of the plant is 270 m3/hr . To achieve this discharge of trated water , the quantity entering to the Denitrification plant is 270 m3/hr compared to 415 m3/hr for the brackish water desalination.
Results attached in the annex show that tariff per m3 of water is $0.7 for the Denitrification process against $0.72 for the brackish water desalination process. On the other hand the investment cost is estimated at MUSD 2.7 and the annual operational costs is estimated at MUSD 0.49 for Denitrification process against MUSD 2.19 and MUSD 1.01 for the brackish water desalination process respectively.

Conclusions:

1. The north Gaza is characterized by high nitrate concentration water densely populated and low chloride level. As far as there is no need to lower the salinity of water in this area and the concern is focused only on decreasing the nitrate level, the biological denitrification can be used successfully in the north of Gaza strip without any major problems.
2. According to the financial analysis for the Gaza Strip conditions it has been concluded that although the total investment costs is lower in the case of brachish desalination ,the total operational costs is much lower for

the Denitrification process and the net result reflected almost equal tarrif for both case .

3. Taking into consideration the over exhausted aquifer in Gaza it is clear that more quantities (about 35%) of water should be abstracted in the case of brackish desalination in order to produce the same treated quantity.
4. The Biological Denitrification system, removes nitrate to acceptable level with no negative impacts
5. The main advantages of this technology that wash water can be used safely for irrigation after minor treatment, it does not give variations in PH value, , bacteria used are common non toxic, it is very simple and easy for operation and no major maintenance works are required

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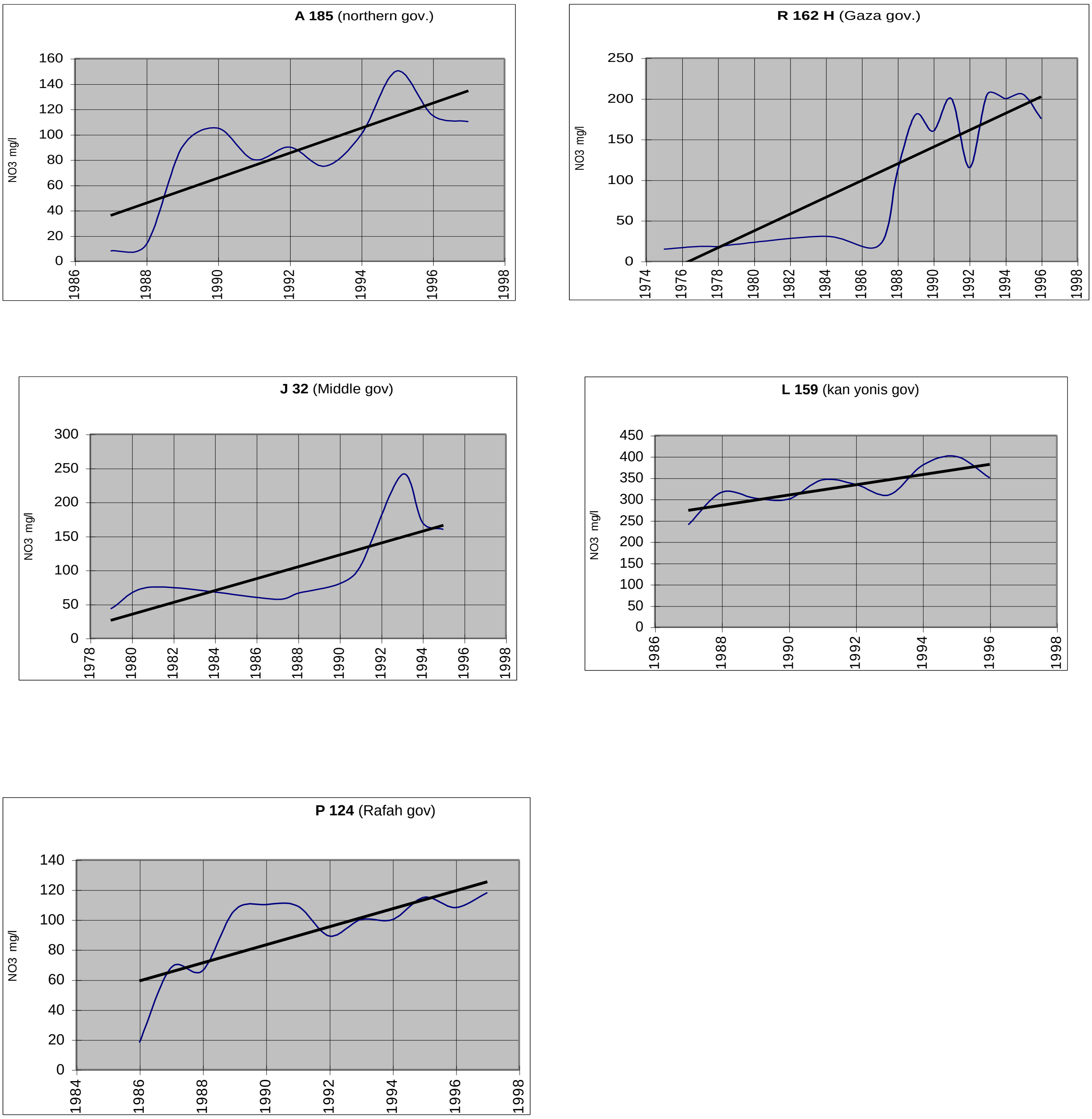

Figure 1. The nitrate concentration in some wells in the Gaza governorates

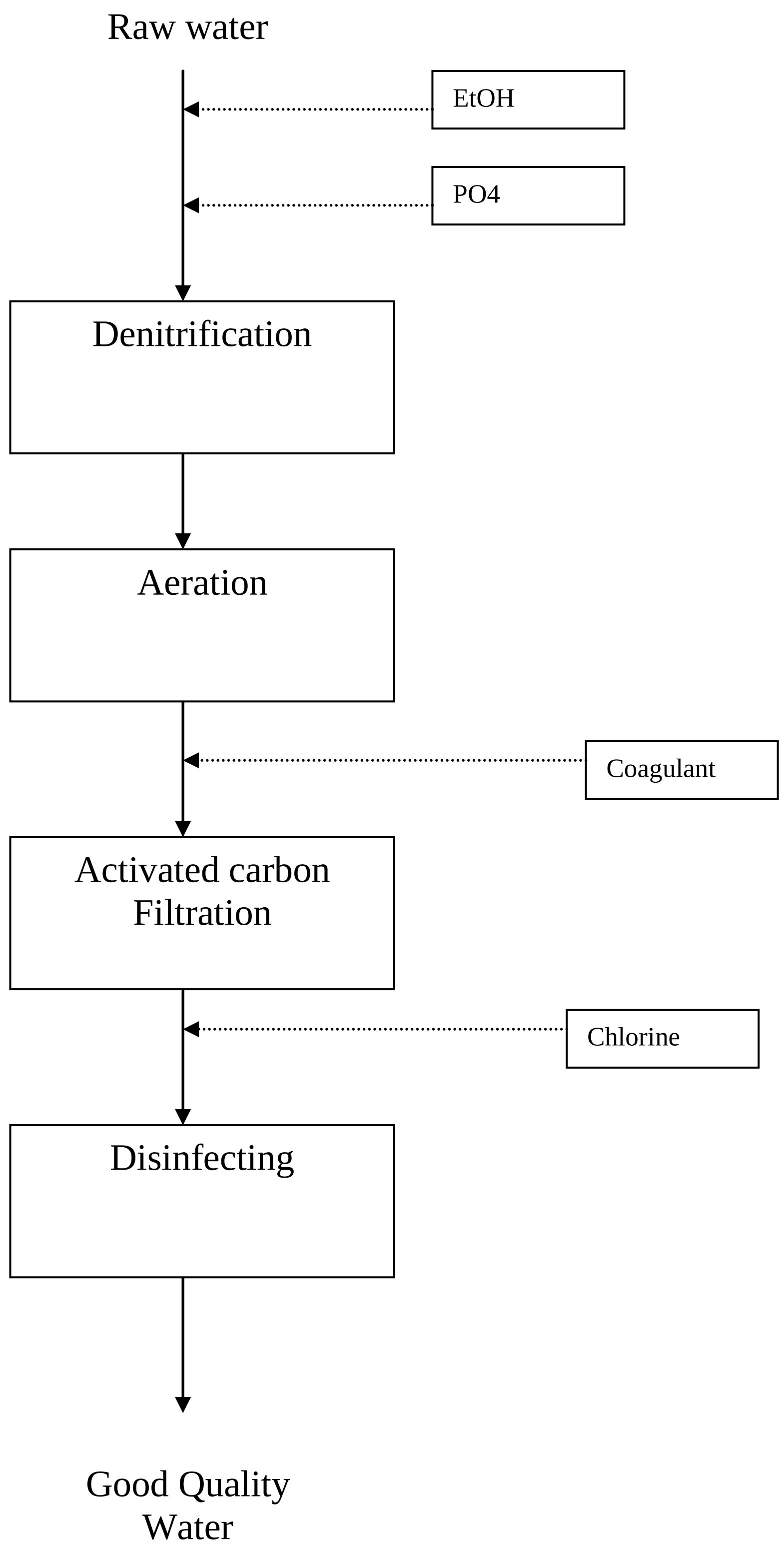

Figure 2. The biological process

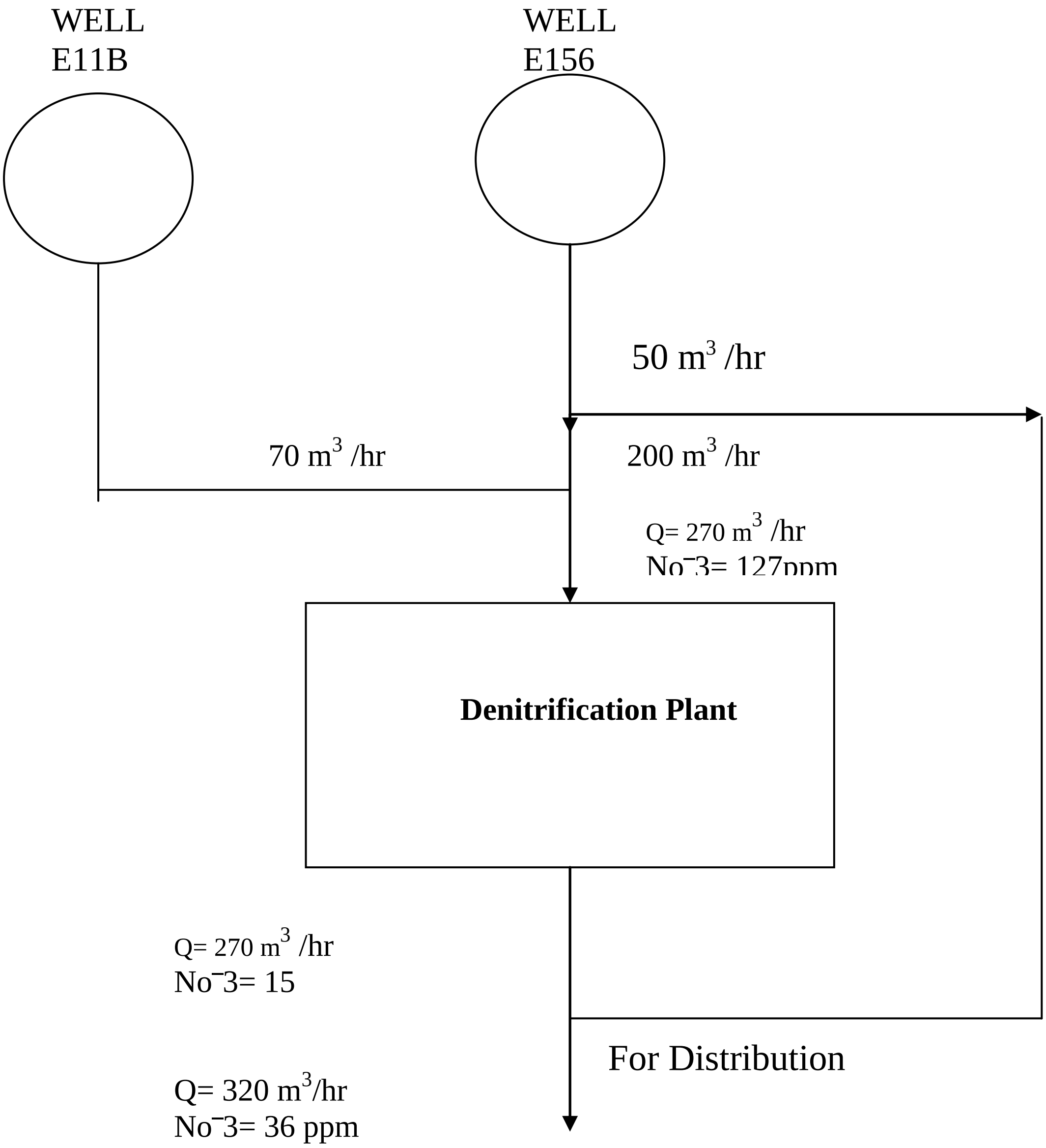

Figure 3: system flow diagram

Table 5. The economical analysis of the brackish water desalination

Brackish Water Desalination							
Interest Rate	8%						
Item	Component	Const.Dat.	Total C.	Life	Factor	Annual Cost	%
Invesment Cost							
	Desalin.Pla.	2000	1,888,250	10	6.71	281,405	
	well Num.2	2000	300,000	25	10.67	28,104	
Total Investment			2,188,250				
Sub-Total						**309,509**	0.23
Operation Cost							
Manpower						28,800	0.02
Electricity						558,383	0.42
Chemical Product						97,110	0.07
Membrane						58,266	0.04
Cost of Well Water						268,920	0.20
Total Ope.Cos.						**1,011,479**	
Total Cost						**1,320,987**	
Total Volume Water Billed Potable	m3					1,942,200	
Cost	$/m3					**0.680**	
	NIS/m3					**2.789**	
Tariff Per M3 To Potable						**0.720**	
Revenues						1,398,384	
Net Resut Per Year						**77,397**	0.06

Table 6. The economical analysis of the Biological denitrification

BIOLOGICAL DENITRIFICATION							
Interest Rate	8%						
Item	Component	Const.Dat.	Total C.	Life	Factor	Annual Cost	%
Invesment Cost							
	Civil Works	2000	350,000	40	11.92	29,351	
	Equpments	2000	2,100,000	10	6.71	312,962	
	well Num.2	2000	260,000	25	10.67	24,356	
Total Investment			2,710,000				
Sub-Total						**366,669**	0.43
Operation Cost							
Manpower						11,664	0.01
Electricity						62,208	0.07
Chemical Product						231,336	0.27
Filtering Material						583	0.00
Spare Parts						2,138	0.00
Cost of Well Water						184,320	0.21
Total Ope.Cos.						**492,250**	0.00
Total Cost						**858,919**	
Total Volume Water Billed Potable	m3					1,302,480	
Total Volume Water Billed Irregation	m4					641,520	
Cost	$/m3					**0.623**	
	NIS/m3					**2.556**	
Tariff Per M3 To Potable						**0.700**	
Tariff Per M3 To Irregation						**0.073**	
Revenues						911,736	
Net Resut Per Year						**52,817**	0.06