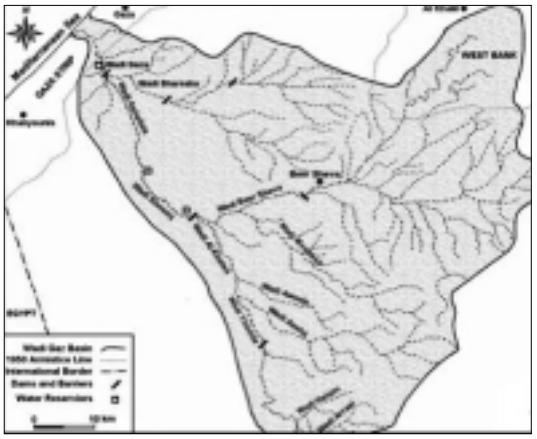
Fig. (5) Distribution of Water Wells inside Israeli Settlements in the Gaza Strip; and Israeli Wells along the Northern and Eastern Borders

Source: Freely from: Applied Research Institute-Jerusalem, (2000), An Atlas of Palestine: The West bank and Gaza, Bethlehem, p.98

REFERENCES

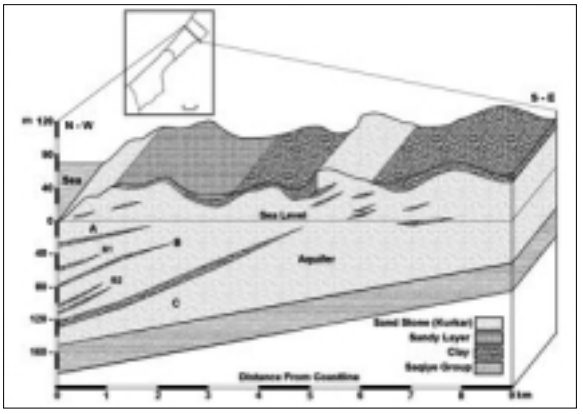
1- Abdul Hadi, A., (1997), «Gaza Water Crisis Worsening», from the Palestinian Report, Jerusalem Media and Communication Center (JMCC), MAY 16 1997, Vol. 2, No. 49, p. 1
2- Al Hallaq, Akram H., (2002), Groundwater Resources Depletion in Gaza Strip: Causes and Effects, (In Arabic(Unpublished Ph.D. dissertation, Ain Shams University, Cairo, Egypt, pp. 149-151
3- Applied Research Institute of Jerusalem (ARIJ), (2003), An analysis on the recent geopolitical situation in the Gaza Strip, Jerusalem, Applied Research Institute of Jerusalem, pp. 1-25
4- Assaf, K., Al Khatib, N., Kally, E., and Shuval, H., (1994), «Water in the Israeli-Arab Conflict,» Palestine-Israel Journal, No. 3, p. 14.
5- Beschorner, N., (1992), Water and Instability in the Middle East, London, International Institute for Strategic Studies, p. 15.
6- Brooks, D. and Lonergan, S., (1994), Watershed: The Role of Fresh Water in the Israeli-Palestinian Conflict, Ottawa, International Development Research Center, pp. 92-134.
7- Elmusa, S., (1996) Negotiating Water: Israel and the Palestinian, Washington, Institute for Palestine Studies, pp.7-14.
8- Giordano, Meredith, Giordano, Mark and Wolf A., (2002), «The Geography of Water Conflict and Cooperation: Internal Pressures and International Manifestations,» The Geographical Journal, Vol. 168, Issue 4, Royal Geographical Society, Gale Group, pp. 293-310.
9- Graisse, J. Jacques, (1999), Assistance to Farmers for Land Development and Training Activities, Palestinian Territories, Project No. 6276.00, Approval under the delegated authority of the executive director, p. 4.
10- Hosh, L., Miller, E., and Isaac, J., (1992), The Palestinian Environment Between the Anvil of Sociopolitical Change and the Hammer of Occupation, Applied Research Institute of Jerusalem (ARIJ), p. 12.
11- Isaac, J. and Hosh, L. (1992), Roots of the Water Conflict in the Middle East, Applied Research Institute, Jerusalem, p. 7.
12- Isaac, J., (1995), «A Sober Approach to the Water Crisis in the Middle East,» A paper presented to International Symposium on the Future of the Mediterranean Area after the Peace Process, UNESCO, Paris, p. 4.
13- Isaac, J., (1999), The Palestinian Water Crisis, Applied Research Institute, Jerusalem, p. 2.
14- Isaac, J., (2000), «The Essentials of Sustainable Water Resources Management in Israel and Palestine,» Arab Studies Quarterly Journal, Vol. 22, Issue: 2, Association of Arab-American University Graduates and Institute of Arab Studies, pp. 1-13.
15- Jerusalem Post, (1986), ز«The brighter side of the Gaza picture,»ن Jerusalem Post, 5 September, p.9.
16- Kuhail, Z, and Zorob, Z. K., (1996), «Potable Ground Water Crisis in the Gaza Strip 1987-1994,» Islamic University Journal, Vol. 4, No. 2, Gaza, pp. 22-66.
17- Libiszewski, S., (1995), Water Disputes in the Jordan Basin Region and their Role in the Resolution of the Arab-Israeli Conflict, Center for Security Studies and Conflict Research, Swiss Peace Foundation, p. 5.
18- Ministry of Agriculture, (1999), An Annual Report about the Amounts of Water Coming From Israeli Mekoroth Water Company, (in Arabic), Unpublished Report.
19- Ministry of Planning and international cooperation, Researches and Studies Center (1995), «The Water Dispute in Palestine,» in Arabic, Palestinian Causes Journal, No. 1, Gaza, pp. 48-68.
20- Myers, C., (1996), Water Management in Gaza in the Palestinian Territories (The West Bank and Gaza Strip), p.1. Internet Source: www.oieau.fr/semidoc/SEMCOM/TEXTE9.htm
21- Nassereddin, T., (1994), «Institutional Aspects of Joint Management of Aquifers by Israel and the Occupied Territories,» in Joint Management of Shared Aquifers; the First Workshop, ed. Feitelson, E. and Haddad, M., Jerusalem: Palestine Consultancy Group and Harry Truman Institute, p. 60.
22- Palestinian Central Bureau of Statistics, (1999), Population, Housing and Establishment Census - 1997, Final Results, Housing Report, Governorates of Gaza Strip, First Part, Ramallah, Palestine. p. 53.
23- Palestinian Committee for Peace and Afro-Asian Solidarity, (1992), The Water Problem in Gaza and Proposed Solution, Development and Socio-Economic Progress, No. 3, p.53.
24- Palestinian Environmental Protection Authority, (1994) Gaza Environmental Profile, Part I, Gaza, the Benevolent for the Gaza Strip Press, p. 55.
25- Roy, S., (1995) The Gaza Strip: The Political Economy of De-Development, Washington, D.C.: The

Fig. (2) Dams, Barriers, and Reservoirs Constructed On the Wadi Gaza Basin



Source: Freely from: Mushtaha, A., (1999), ***The Lower Course of Wadi Gaza Inside the Gaza Strip: Geomorphologic Study***, (In Arabic), Unpublished Ph. D. Thesis, Annelain University, Sudan, p. 66.

Fig. (3) Hydrological Cross-Section of the Gaza Strip's Aquifer

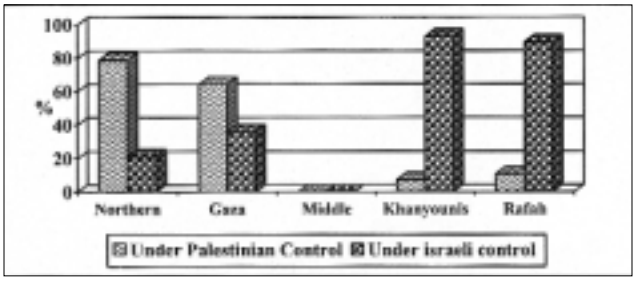


Source: Freely from: Palestinian Water Authority, (2000), **Coastal Aquifer Management Program, Aquifer Status**, Appendix A, Gaza, p. 80

Fig. (4) Areas of Fresh Groundwater (with water chloride < 250 ppm/l)

Source: Freely from: Palestinian Water Authority, (2000), Gaza.

Fig. (6) Ratio of Fresh Groundwater Area under Palestinian and Israeli Control in the Gaza Strip Governorates



The total volume of fresh groundwater remaining in the Gaza Strip's aquifer ranges from 484 to 645 MCM or 8.8-11.7% of the aquifer that contains water that meets the WHO standard of chloride. About a half of that volume is under Israeli control. This fresh groundwater resource is currently depleted due to over pumping of the aquifer. The water balance in the Gaza Strip concluded that the rate of water depletion would be 45 MCM (Al Hallaq, A., 2002). Consequently, the Gaza Strip could run out of fresh groundwater in 14 years time.

This situation led to some families in the Gaza Strip to take these actions:

* Finding free fresh water resources for drinking distant from their houses or buying amounts of such fresh water. The field study showed that about 32% of the total studied families (760 families) did that. 71% of those who did that were suffering from saltiness or contamination of running water in their houses.

* Buying household reverse osmosis desalination units. So, these families did not depend directly on municipal drinking water inside their houses. The field study showed also that 15% of the total studied families have desalination units inside the houses, and each unit is produced 80-100 liters of fresh water daily used for drinking purposes only.

* More population in the Gaza strip are spending part of their limited income on imported bottled water, seeking to avoid health problems caused by the contaminated tap water in the Strip. Public health specialists are warning of a fresh water deficit in the Gaza Strip by 2000s if water resources continue to be depleted as they are being now. According to a grocer from Gaza City, sales of bottled water have increased 20 percent over the past years. Environmentalists are concerned about the effects of the growing freshwater deficit and the declining water quality on public health in the Gaza Strip (Abdul Hadi, A., 1997).

9. Conclusion

Generally, all of the groundwater in the Gaza strip governorates suffers from bad quality. Only two limited areas fulfill the standard requirement for domestic use according to the standards of WHO. One is in the north and the other is in the south west of the Gaza Strip governorates where the Israeli settlements are found. We thought that the Gaza Strip's aquifer has already passed the point of no return. Israel

is responsible for the deterioration and degradation of the Gaza Strip's aquifer. It is still pumping water from the aquifer north and south of the Strip causing a decline in the safe yield of the aquifer. Israel is diverting the Wadi Gaza waters, which recharge the Gaza Strip's aquifer. Settlements in Gaza Strip are located on top of the only fresh water sources and the 6000 Israeli settlers in the Gaza Strip are utilizing more than 5 MCM of fresh water annually. Settlements have running water 24 hours a day, unlike most of the Gaza Strip. According to the Israeli West Bank Data Base Project, the Israeli settlers in the Gaza Strip irrigate some 6,700 dunams (1 dunam = 1000 m2), approximately 60% of the 11,100 dunams cultivated by them. Finally, approximately 1.2 million Palestinians living in the Gaza Strip have 358 MCM of fresh water stored in the aquifer, while 6000 settlers have 287 MCM. It is the age of wonders.

Fig. (1) The Study area: Governorates and Groundwater Basin

Source: After Palestinian Water Authority, (2000), ***Summary of Palestinian Hydrologic Data Volume 2: Gaza***, Gaza Strip, p. 27.

Khanyounis and Rafah governorates. The majority of population and houses throughout Gaza rely on cesspits. About 48% of the houses are dumping raw sewage into the cesspits. This situation is cleared in the Khanyounis, Middle, Rafah, and Northern governorates where Palestinian refugee camps and sand areas are found (Table 2).

As a result of inadequate infrastructure, sewage seepage has contaminated the aquifer. This situation has resulted in rising levels of nitrate (NO3) in the fresh groundwater above World Health Organization (WHO) standard. (50 ppm/l). In recent years, NO3 contamination of Gaza Strip's water has increased rapidly: in 2000 about 77% of Gaza's studied water wells were considered unsuitable for drinking in terms of NO3 levels (Table 3).

Table (2) Occupied Housing Units by Connection to Sewage System

Governorate	Public Sewage System		Cesspit		No Sewage System		No Stated	
	Units	%	Units.	%	Units	%	Units	%
Northern	15846	70.1	6363	28.2	348	1.5	42	0.2
Gaza	41771	86.2	6360	13.1	302	0.6	56	0.1
Middle	1882	9.9	16495	87.3	483	2.6	45	0.2
Khanyounis	776	2.9	25593	94.9	572	2.1	30	0.1
Rafah	6717	42.4	8636	54.5	479	3.0	22	0.1
Total	66992	50.4	63447	47.8	2184	1.6	195	0.2

Source: Palestinian Central Bureau of Statistics, (1999)

Consequently, most of the Gaza Strip groundwater is simply not fit for human consumption. Sampling for NO3 in 2000 found concentration 490 ppm/l in dense areas south of the Gaza Strip, particularly in non-sewered areas. The municipal network that serves the population of the Gaza Strip distributes water of this quality.

Table (3) Suitability of Water Wells for Drinking in Terms of NO3 Concentration

Governorate	Total Wells	Suitable Wells (No_3 less than 50 ppm/l)		Unsuitable Wells (No_3 more than 50 ppm/l)	
		Wells	%	Wells	%
Northern	77	17	22.1	60	77.9
Gaza	63	20	31.7	43	68.3
Middle	49	7	14.3	42	85.7
Khanyounis	61	19	31.1	42	68.9
Rafah	34	3	8.8	31	91.2
Total	284	66	23.2	218	76.8

Source: by author according to the data from Ministry of Agriculture, 2000/2001.

Most governorates have unsatisfactory wastewater collection systems: much of the population relies on cesspit, and where there are sewerage systems, sewage is generally discharge untreated into open channels or Wadis as Wadi Gaza. The absence of wastewater systems in some areas near the Wadi has led to polluting it with wastewater. The Wadi became polluted by the sewage collected from towns and camps situated in the Middle governorate (Nusierat, Bureij and Maghazi camps). The flow of wastewater into Wadi Gaza presents both the health risk of contamination to underlying aquifers and the loss of potential recycled irrigation and industrial resource. The illegal dumping of the solid wastes also pollutes the Wadi. It is possible to say that Wadi Gaza lost its water and environmental prosperities due to the construction of dams by Israel and pollution.

8. Fresh water Scarcity

Population in the study area, currently, faces the problem of fresh water scarcity. About 82% of the total Gaza strip area classified as the areas with water chloride more than 250 ppm/l, and around 96% of total area with water NO_3 more than 50 ppm/l. The remaining of fresh water volume in the Gaza Strip's aquifer is very limited. By looking at the Figure (4) which illustrates the concentration of chloride in the Gaza strip water, and using WHO standard of chloride, 250 ppm/l, we notice that the natural concentration of chloride in the aquifer exceeds that rate in most of the Strip. The best water quality and the freshest water are found in the sand dunes areas in north and south of the Strip where the Israeli settlements are located. The ratio of chloride concentration is less than 250 ppm/l. This zone, which contains fresh water, occupies 64.5 km^2 or 18% of the total area of the Gaza strip, of which 28.7 km^2 or 44.5% of total zone is under Israeli control (Table 4 and Fig. 6).

As presented in Figure (4), the horizontal extent (H_e) of fresh groundwater resources (less than 250 ppm/l) is about 64.5 km^2. Based upon the 250 ppm/l chloride contour, an assumed range of thickness (T) from 30m to 40m defines the fresh groundwater lens, and an effective porosity (E_p) of 0.25, the volume of fresh groundwater (V_{fw}) remaining in the aquifer is estimated from:

$$V_{fw} = T\, H_e\, E_p$$

Table (4) Area of fresh groundwater under Palestinian and Israeli Control*

Governorate	Area of Fresh groundwater (km^2)	Under Palestinian Control (km^2)		Under Israeli Control (km^2)	
		Area	%**	Area	%
Northern	42.10	33.24	78.9	8.86	21.1
Gaza	1.06	0.68	64.2	0.38	35.8
Middle	0.00	0.00	0.00	0.00	0.00
Khanyounis	11.80	0.85	7.2	10.95	92.8
Rafah	9.55	1.02	10.7	8.53	89.3
Total	64.51	35.79	55.5	28.72	44.5

Source: * All areas are computed by author using AutoCAD software, Fig. (4), and interpreted chloride concentration map for Gaza Strip 2000 (1: 100000).

** All ratios are computed by author.

2.1.7 The Indirect Depletion

The Israeli indirect depletion involves: diverting a part of the areaىs natural recharge, diverting the Wadi Gaza waters, and negligence of infrastructure in Gaza Strip during 27 years of Israeli occupation.

1.2.1.7 Diverting a Part of the Area's Natural Recharge

The Israeli authorities have forbidden anyone to dig a well to irrigate his citrus groves because the Gaza Strip has no water. But at the same time, ten meters away on the north and east of 1967 border, (See Fig. 5), they will dig not one well but tens. Several Israeli wells have been drilled in the catchments area of the coastal aquifer, which is inside occupied Palestine but along the northern and eastern border of the Gaza Strip (Nassereddin, T., 1994). According to the information in the Jerusalem Post of 5 September 1986, between 35 and 40 Israeli wells in the eastern Gaza Strip have diverted part of the areaىs natural recharge (Jerusalem Post, 1986). Palestinian water experts argue that these wells have reduced the flow of groundwater to the study area. However, this has been a point of contention among hydrologists. The Israeli sources argue that these wells are blocking the flow of saline water, which damages the aquifer. Others contend that these wells draw on a separate part of the coastal aquifer system and do not affect Gaza's aquifer at all (Brooks, D., and Lonergan, S. 1994). Logically, in our opinion, these Israeli viewpoints are unacceptable. If the water of these wells is saline, why have they been drilled near the Gaza strip border? And what does the Israeli make with this water when as they well understand that using it domestically is unsuitable and using it for irrigation may waste the soil? On the other hand, the Israeli hydrologists contend that these wells are drawn on a separate part of the coastal aquifer and do not affect Gaza's aquifer; geologically this opinion is not right because the Gaza Strip is a small part of the Palestinian coastal plain and its aquifer is a part of the Palestinian coastal aquifer.

These wells which have been dug near the border of the study area extract a great amount of water around 18 hours daily and are pumped to the Negev as irrigation water before crossing the eastern borders (Ministry of Planning and international cooperation, 1995), and replenish the Gaza Strip's aquifer. If we know that each well pumps 200 cubic meters per hour (Shawwa, Isam R., 2000), the total abstraction for about 40 wells is approximately 53 MCM annually. This amount, which is Gazas share of water and naturally flows to recharge the aquifer, is depleted by Israel.

2.2.1.7 Diverting the Wadi Gaza Flow

Wadi Gaza is still an object of dispute between the Palestinians and the Israeli. The Wadi commences in occupied Palestine and flows into the Mediterranean in the Gaza strip coast. Inside the Gaza Strip, it has an estimated average flow of 14 MCM per year or 14% of total runoff in Palestine. Except the flowing in the Wadi during the winter season inside the Gaza Strip, the Gaza Strip never utilizes the Wadi water collected from the catchment area inside occupied Palestine. The Wadi is nearly dry because Israel has blocked the water flow in it. Approximately 32 dams, barriers, and reservoirs were constructed all along the way preventing the water from flowing into the Gaza Strip which otherwise would have provided a valuable source of water to be used for irrigation and for compensation to the lost pumped-out water (See Fig. 2).

The Wadi water would have been a great help to the irrigation in the middle zone of the Gaza Strip (Shawwa, Isam R., 2000). Israel has intensified the water problem by diverting the Wadi Gaza and the coastal aquifer away from Gaza Strip for use in Israel and by settlers in the Gaza Strip itself. These dams are helping now to recharge the aquifers inside occupied Palestine. Conversely, these dams negatively affect Gaza's aquifer. In the past, the aquifer of the Gaza strip was partially recharged from Wadi Gaza that flows during the winter from Al Khalil (Hebron), but Israel stopped its flow. Before the Israeli diverting of the upstream of Wadi Gaza runoff, up to 20 MCM per year, Wadi Gaza was said to have replenished the aquifers under the Gaza Strip (Isaac, J., 1995). That diverting has considerations by affecting on the local environment in the Gaza Strip.

The famous two reservoirs constructed along the Wadi, are Wadi Sheniq reservoir with the capacity of 1 MCM, and the other large one is constructed in the lower section of Wadi Gaza, near the eastern Gaza Strip border to cover an area of about 16 km2 with the capacity of 20-30 MCM annually. Part of the collected floodwater in the reservoirs will become available for Israeli farming. By 1993, Israel was thought to have impounded an average of 1 MCM per year from Wadi Gaza and was planning to impound a total of 9 MCM per year. Palestinian specialists have contended that Israel takes away even larger quantities. However, they probably would be unable to specify those quantities accurately, because only the tail end of the Wadi traverses Gaza (Elmusa, S., 1996).

During 1960s floods occurred in Wadi Gaza. The level of water in the Wadi was raised to more than 5 meters. This water was breaking down the road between north and south Gaza Strip. Currently, there is no any water flowing in the Wadi inside the Gaza Strip except that which flows in it during the winter season. If we consider that the average of water surplus in the study area is 124 mm, and half of that amount (62 mm), according to Thornthwaite, illustrates a runoff, at best the volume of that flow in Wadi Gaza basin, inside Gaza Strip, is estimated at 1.8 MCM annually. Consequently, the study area has lost a great amount of the Wadi fresh water that recharges its aquifer because of the Israeli control over the upper section of the Wadi and the impoundment of its water.

3.2.1.7 Negligence of Infrastructure in Gaza Strip

During 27 years of Israeli occupation in the study area, the quality of surface and groundwater supplies steadily deteriorated and water-related diseases rose (Giordano, Meredith, Giordano, Mark and Wolf A., 2002). The major reasons that led to this situation are the great increase in water consumption by the Israeli settlements that have resulted in rising levels of chlorine, nitrogen, fluoride, salinity, partly through the intrusion of polluted seawater from the Mediterranean, and negligence of infrastructure. During the occupation period Israel did not develop the sewage network or wastewater system in the study area. Consequently, most of the houses are depending on the soaking pits or cesspit and septic tanks. So, inadequate discharge of wastewater has contributed to the contamination of the Gaza Strip's aquifer. 1.6% of Gaza's houses are not served by any wastewater management system, and simply dumping raw sewage onto sand dunes as in the Middle,

governorates) and where the largest block of settlements, Gush Qatif, is located. (Fig 4) The second is found in the north, which is partially (in the Northern governorate) occupied by the northern Israeli settlements. Table (1) and Figure (4) present the areas of fresh groundwater in the study area.

Table (1) Areas of fresh water (with chloride less than 250 ppm/l), (2000)*

Governorate	Area of governorate (km^2)	Area of fresh groundwater (km^2)	% **
Northern	60.6	42.10	69.5
Gaza	72.4	1.06	1.46
Middle	56.4	0.00	0.0
Khanyounis	110.4	11.80	10.69
Rafah	60.7	9.55	15.7
Total	360.5	64.51	17.9

Source:

* All areas are computed by author using AutoCAD software, Gaza Strip map (1: 50000), and interpreted chloride concentration map for Gaza Strip 2000 (1: 100000).

** All ratios are computed by author.

It is clear that the total area of fresh groundwater reaches to 64.5 km2 in 2000 or 17.9% of total Gaza Strip area. The largest area of fresh groundwater is found in the northern governorate (42.1 km2). In Khanyounis and Rafah governorates, it reaches to 11.8 km2 and 9.55 km2 respectively. Some experts indicated that this area decreased from 140 km2 in 1984 to 115 km2 in 1994 (Myers, C., 1996). Subsequently, the annual decrease in fresh groundwater area will be about 5 km2 between 1985 and 2000.

7. Israeli policies in depleting Gaza Strip fresh groundwater

Israel is still the major source of threat on the level of water resources appropriation. It depleted Arabian water in Palestine and still does that. After the occupation of the Gaza Strip and the West Bank in 1967, Israel has increased the rates of groundwater exploitation. This will lead up to depletion of fresh water in the offing. Israelىs interest in the water of the study area is attributed to the Israeli settlement policy adopted by the Israeli government. The Israeli new immigrants basically move to the land, which they see as a missing historical right. This settling trend needs amounts of water that can only be obtained from the Arabian waters. So, this water gains an increased significance in the Israeli strategy, which has taken many adaptability transactions. For example, throughout the occupation, Israel had practiced blatant and formulized discrimination regarding Palestinian water consumption in the Gaza Strip. In 1967 Israel declared all water resources in the occupied territories to be state owned and under the jurisdiction of the military. Strict quotas were placed on Palestinian consumption. To preserve the Gaza Strip's aquifer under the occupation, the military order 158 (which applied only to the Arab

population of the Gaza Strip and not to Israeli settlers) prohibited the drilling of new wells or the rehabilitation of existing wells for any purpose without a permit (Roy, S., 1995). While restriction applied to the West Bank and the Gaza Strip, limits may have been difficult to enforce in the Gaza Strip, where the aquifer is close to the surface and relatively easy to access. With the exception of minimal allowances for increased drinking water, Palestinian pumping quotas were effectively frozen at 1967 (Shqueir, A., 1995). Conversely, Israelis in the study area face less restriction on water drawn from the same sources, and they consume on average eight to ten times for all purposes more than the Palestinians (Brooks, D. and Lonergan, S., 1994).

1.7 Manners of the Israeli Depletion of Fresh Groundwater

It is possible to classify the Israeli Depletion of fresh groundwater in the study area into two ways: the direct depletion and the indirect depletion.

1.1.7 The Direct Depletion

The direct depletion occurs by extracting the fresh groundwater from wells to supply the Israeli settlements inside the study area. According to the satellite images, there are some 308 Israeli built-up areas in the Palestinian territories, excluding military sites, of which at least 18 are in the Gaza strip. These settlements occupy about 16% of total Gaza Strip area and housing an estimated 6429 Israeli settlers (Applied Research Institute of Jerusalem, (ARIJ), 2003). Israeli settlements are often found on the most suitable sites in terms of abundance of groundwater and soil quality (United Nations, 1991). There are a limited number of water lenses under the Gaza Strip, which have fresh water. These lenses are situated around the Israeli settlements in the Gaza Strip and thus are not accessible to the Palestinians even after autonomy (Isaac, J., 2000). For instance, a comparison of the chloride and settlement maps of the Gaza Strip (see Figure 4) reveals that many Israeli settlements have gained access to those fresh water areas with relatively good water quality.

There are more than 40 wells in the settlements within the study area. Most of them were drilled inside Gush Qatif in the southern governorates, Khanyounis and Rafah (Fig 5). About 18 wells of them are presently extracting water. The Israeli settlers in the study area are extracting in average about 5 MCM annually from these fresh water wells. This figure coordinates with some reports and studies which indicate that the total Israeli consumption of the Gaza Strip's aquifer ranges from 4 to 10 MCM annually (Palestinian Committee for Peace and Afro-Asian Solidarity, 1992). Thus, on an annual, per capita basis, Israeli settlers consume 778 cubic meters of fresh water, compared to 120 cubic meters of deteriorating water quality consumed by Palestinian- more than six times as much. In addition, the Israeli National Water Carrier (Mekoroth) extracts another amount of fresh water, 5.4 MCM, from the wells inside the settlements and sells it to the Palestinians in Khanyounis and Middle governorates because the water quality in there is deteriorated due to seawater intrusion, wastewater pollution, and agriculture water return flows. The Palestinian Authority is paying the full cost to Mekoroth, which is about 1.54 Million Dollar, of the 5.4 MCM of water supplied to the governorates (Ministry of Agriculture, 1999).

climate. As we know, rainfall continuously replenishes groundwater supplies; therefore, depletion has only been found to be a problem in certain localized situations or during droughts. Rainfall is one of the renewable fresh water resources in any area. The volume of annual rainfall in the study area is about 129 MCM, based on an average rainfall of 357 mm per year over 360 km2 area. A very small percentage of this water can be used directly by population and farmers. The high evaporation and transpiration rates (about two thirds of the total rainfall) in the study area returns most of the rainfall directly to the atmosphere before it can infiltrate and recharge the aquifer or flow directly to Wadis, storm water drainage systems, or sea. The amount of rainfall, which ranges from 35 to 45 MCM, infiltrates into the aquifer and recharges it. The sand dunes areas (46.14 km2 or 12.8% of the total area of the Gaza Strip) in the south of Gaza Strip, which are completely occupied by Israeli settlements, are considered one of the most rainfall-utilized areas owing to its sandy nature and the evapotranspiration may be as low as 50% of the rainfall (U.S. National Academy of science, 1999). Therefore, most of rainfall infiltrates into the ground. Recharge rates throughout this part of the study area vary temporally as a result of variations in the amount and intensity of rainfall and other climatic conditions. Consequently, the rate of recharge in this area ranges from 7 to10 MCM/year. This figure forms about 20% of the total recharge in the study area.

2,5 Surface Water

There is no permanent surface water on the land of the study area. The small Wadis are of seasonal type as they flow in the winter season during the flood period, which lasts for just a few days every year. The main seasonal Wadi in the study area is Wadi Gaza. It was used to be the only surface water, which has wide catchments area (about 3380 km2) outside the study area. Wadi Gaza, in the Gaza Strip, is a part of this water system, which extends 107 km from Al Khalil (Hebron) Mountains in the east to the coast of the Mediterranean Sea in the west. This part that crosses the Strip is a lower course of this water system. It extends 8.8 km from the Green Line (Armistice line) in the east to the Mediterranean Sea in the west. The width of Wadi's floor ranges from 30 to 270 meters (m), and starts from 30 m above sea level at eastern limits to zero at its mouth. The area of its catchments in the Gaza Strip is nearly 29 km2 or about 0.9% of total Wadi Gaza catchments area. (Fig. 2) The general elevation of the area on both sides of the Wadi ranges from 20-40 m above sea level. By tributaries, this Wadi collects rain waters, which fall on its basin. Overall, these tributaries are naturally main components for Wadi Gaza and they will never be divided artificially. The Gaza Strip must have a share of these waters. Most of the Wadi Gaza basin is under the Israeli control, and the Palestinians in the Gaza Strip is deprived of the Wadi waters because Israel diverts the Wadi Gaza waters, as we will see later, which replenishes the Gaza Strip's aquifers. This Wadi has become dry inside the Gaza Strip, and the Palestinian farmers have lost a main source of waters used in the past to irrigate their lands. They are currently not utilizing the Wadi's waters in supplying their farms with agricultural needs.

3,5 Groundwater

Groundwater is the major and primary natural source of the Palestinians in the

study area, and it is that portion of rainfall that penetrates the earth and gets stored in the aquifers. The study area aquifer is a part of the Palestine coastal aquifer. For its fresh water supply, the study area relies almost entirely on groundwater drawn from its aquifer, with minimal amounts obtained from other sources, such as rooftop rainwater catchments. This aquifer occupies an area that covers the entire land of the Gaza Strip. (See Fig 1) Gaza's Aquifer is often only a few meters from surface. It is also shallow, ranging in thickness from 120 meters near the coast to 10 meters in the east. The slope of the aquifer is from east to west. So, general groundwater flow is toward the Mediterranean Sea in the west. This aquifer consists mainly of sand, sandstone and pebbles of Pliocene to Holocene age. Clayey lenses or layers are found in different areas sloping from east to west too (Kuhail, Z., and Zorob, Z. K., 1996), and are extending inland to a distance 2-5 km. These layers are dividing the aquifer into three sub aquifers, A, B and C, from up to down. The B sub-aquifer is divided into two parts, B1 and B2. Sub-aquifer A is unconfined, whereas sub-aquifers B1, B2 and C become increasingly confined towards the sea. (Fig 3) The deep sub aquifers, B and C, contain saline water underneath the Gaza Strip. Most of the study area water is pumped from sub-aquifer A because it contains the best water quality.

There are 3700 wells drilled within sub-aquifer A. 97% of which are privately owned and used for agricultural purposes, and about 15% of them is fresh wells with chloride less than 250 ppm/l. Approximately 94 wells are owned and operated by individual municipalities and are used for domestic supply (Al Hallaq, A. H., 2002). In 2000, municipal abstraction totaled about 55 MCM/year from 84 wells (39% of which is fresh wells). Also, there are more than 40 fresh wells under the Israeli control and are used by Israeli settlements for agricultural and domestic purposes. These wells pump the best water quality in the study area.

The study area aquifer has an annual safe yield of 60-65 MCM (Sabbah, W., and Isaac, J., 1995), but is currently being over-pumped at the rate of 155 MCM per year. Over-pumping has reduced the Gaza Strip's aquifer to well below sea level and continues to draw it down by 5.1 centimeters (cm) per year in average, but this figure varies geographically from one governorate to another. In Rafah and Khanyounis in the south, for example, this figure was 17 cm and 4.7 cm per year respectively, and 2.4 cm in the north governorate (Al Hallaq, A. H., 2002). This decline reduces the aquifer's hydrostatic pressure, allowing the infiltration of saltwater from the sea and from saline aquifers below and to the east. Saltwater intrusion has already been detected as far as 1.5-2 km inland. While levels of salinity vary geographically, Gaza's groundwater is generally classified as very saline, ranging from 200 to 4500 ppm/l. Salinity increases an average of 15-20 ppm/l per year (Beschorner, N. 1992). This rapid increase has led some predict the total salinization of the aquifer, if there is insufficient additional water to replace that lost to over-pumping (Assaf, K., Al Khatib, N., Kally, E., and Shuval, H., 1994).

6. Fresh Groundwater in the Study Area

There are two main areas in the Gaza Strip that contain fresh groundwater (with chloride less than 250 ppm/l), the first, which has the best quality water, is found in the sand dunes area in south of the Gaza Strip (in Khanyounis and Rafah

1. Introduction

The Gaza Strip depends entirely on groundwater resources for domestic, agricultural and industrial requirements. Groundwater is the major source of fresh water; and is of primary importance to the Palestinians in the Gaza Strip. Groundwater quality is as important as its quantity. In general, the Gaza Strip suffers from bad water quality because of seawater intrusion from the west, lateral flowing of brackish water from the east, and other possible sources of contamination by contact of water with sewage water. The available volume of fresh water in the Gaza Strip is very limited. This volume is also under threat and depletion. Much of the water of the coastal aquifer in the Gaza Strip could be classified as saline. Salinity is affecting many reclaimed areas (Graisse, J. Jacques, 1999).

Since the 1967 occupation of Gaza Strip, Israel has vastly expanded its control over water resources in it. Israel's strategy is to control and derive maximum benefit from all water resources in the occupied territories (Isaac, J. and Hosh, L. 1992). The military occupation had not only several effects on water resources in terms of quantity, but also of quality. While the mountain aquifer system is heavily exploited by Israel, groundwater in the Gaza Strip is already overexploited. This led to serious water quality problems and the partial destruction of the coastal aquifer system. People in the Gaza Strip suffer from water shortage and the very high salinity of their resources out of the coastal aquifer, from which they depend as their only available drinking water resource (Sturm, C., Ribbe, L., and Schwabe, C., 1996). Aquifers in some southwestern and northern parts, where settlements are located, have in many cases lower salinity. Hence, it becomes obvious that the Israeli settlements in the Strip add to its water problems, not only through over pumping, but also as they appear to have been deliberately placed in areas where groundwater quality is the best (Water Resources Action Program «WRAP», 1994).

Currently, most of fresh water with chloride less than 250 parts per million per liter (ppm/l) is found in the aquifers beneath areas of Israeli settlements, while saline groundwater with chloride over 250 ppm/l is found in the rest of the Gaza Strip. Poor water quality, in fact, is one of the Gaza Strip's most serious problems. The Israeli settlements and kibbutzim inside the Gaza Strip itself consume a considerable amount of fresh water, and they severely restricted the Palestinian use of it.

2. Purposes and Scope

This paper summarizes the depletion status of the fresh water in the Gaza Strip that suffers from difficult water crisis in fresh water. This water is only available for Israeli settlers and for very few Palestinians. This paper also explores the Israeli attempts to deplete fresh water directly or indirectly. Moreover, Gaza's fresh groundwater resources have been affected by nitrate pollution due to wastewater return flow from septic tanks or soaking holes. This pollution occurred because of Israel's negligence of the infrastructure in the Gaza Strip during 27 years of occupation.

3. The Study Area

The Gaza Strip (The study area) is a narrow territory of land. It is a coastal plain area with vast expanses of sand dunes. It occupies about 360 square km (km2) along

the Mediterranean Sea and extends northeast from the Sinai Peninsula. This area of land has 40 km of coastline, about 13 km boundary with Egypt, and 59 km boundary with occupied Palestine (Fig. 1).

The area under study has a temperate climate with mild winters and dry hot summers. The winter season officially starts in November and ends in March, causing the precipitation that constitute the major source of fresh water and aquifer recharge (Shawwa, Isam R., 2000). The study area receives an average 357 millimeters (mm) of rainfall per year, more than two thirds of which is thought to be lost by evaporation, and about 1.7% to surface runoff. The remainder recharges its only natural fresh water supply of the Gaza Strip's aquifer, which is located a few meters below it. (Fig. 1)

The study area is generally composed of sandstone. Accordingly, its aquifer is thought to be highly permeable. Its natural replenishment capacity ranges between 35 and 45 million cubic meters (MCM) /year (Myers, C., 1996), and is thought to be tapped by 3700 wells, which extract about 155 MCM in the year 2000 (Al Hallaq, A. H., 2002).

The size of the Gaza Strip current population is more than 1.2 million inhabitants. Approximately 70% of Gaza's population is made of refugees (Roy, S., 1995). High population density and rapid population growth are significant factors in the Gaza Strip, which have much bearing on the present and future state of the environment (Palestinian Environmental Protection Authority, 1994). The Gaza Strip, where most of the inhabitants live in refugee camps, is one of the most densely populated areas in the world (U.S. National Academy of science, 1999), with an average of nearly 3000 people per square kilometer.

4. Data and Methodology:

The primary sources of the data used in this paper are the Palestinian Water Authority (PWA), the Palestinian Ministry of Agriculture (MOA), and Statistical Reports Series. Analysis of freshwater shortage in the Gaza Strip depends partially on field work carried out by the author. A random sample of 760 families have been chosen, and subjected to a detailed questionnaire pertaining to all aspects of water quality and ways of getting fresh water. By using AutoCad Software, some measures are made on the maps to compute and estimate the area and volume of fresh water in the Gaza Strip. This paper attempts to define, analyze, explain the current situation of fresh water of the Gaza coastal aquifer, and explore the attempts of Israel to extract and deplete this water.

5. Water Resources in Gaza Strip

As a basis of discussion, it is important to understand that the fresh water resources available in the study area are limited, scarce, fragile and threatened. The hydrological situation is very critical as the Gaza Strip is not an area with conspicuous water resources (Libiszewski, S., 1995).

1,5 Rainfall

Some causes affect on groundwater depletion. Natural conditions are one of them, specifically climatic factors as rainfall. The wide variation in rainfall received by different parts of the Gaza Strip has been the characteristic feature of Mediterranean

The Israeli policies in Depleting Gaza Strip Fresh Groundwater

Dr. Akram Hassan Al Hallaq

Abstract

This paper highlights the Israeli policies in depleting Gaza Strip (The study area) fresh groundwater. It is known that volume of this water in Gaza Strip's aquifer is very limited. Israel has intensified this problem by direct and indirect depletion of fresh water, with which the Israeli settlements are supplied. These settlements control about 45% of the fresh groundwater stored in the Gaza Strip's aquifer. Israel has stopped Wadi Gaza flow, which used to partially replenish the Strip's aquifer. However, many wells were dug along the northern and eastern borders, and continually pump water. These wells have reduced the flow of groundwater, which recharge the aquifer. Israel also is responsible for the deterioration and degradation of the Gaza Strip's aquifer during the occupation period. This has led to the critical and acute shortage in fresh water.

**** Assistant Professor in Al Aqsa University - Geography Department, Gaza***

السياسات الإسرائيلية في استنزاف المياه الجوفية في قطاع غزة

د. أكرم حسن الحلاق *

الملخص

يلقي هذا البحث الضوء على السياسات الإسرائيلية في استنزاف المياه الجوفية العذبة في قطاع غزة (منطقة الدراسة). ومن المعروف أن حجم هذه المياه في خزان قطاع غزة الجوفي محدود للغاية. وزادت إسرائيل من هذه المشكلة بالاستنزاف المباشر وغير المباشر لهذه المياه ، وذلك من خلال تزويد المستوطنات الإسرائيلية ، التي تتحكم بنحو 45٪ من المياه الجوفية العذبة بخزان القطاع الجوفي. كما أوقفت إسرائيل جريان وادي غزة الذي كان يغذي جزئياً ذلك الخزان. من ناحية ثانية ، قامت إسرائيل بحفر عدد من الآبار على امتداد الحدود الشمالية والشرقية ، تضخ منها المياه بشكل متواصل، مما قلل من تسرب المياه الجوفية التي تغذي الخزان. وتعد إسرائيل المسئولة عن تدهور وتدني خزان القطاع الجوفي خلال فترة الاحتلال ، الأمر الذي أدى إلى نقص حاد وحرج في المياه العذبة.

* *أستاذ مساعد، جامعة الغزة - قسم الجغرافيا، غزة.*