Effect of Overpumping on Water Quality Deterioration in Arid Areas: A case Study of Dead Sea Basin/Jordan

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ABSTRACT

This paper studies the effect of overpumping on water quality deterioration in arid areas/Dead Sea Basin/Jordan. About 500 water samples were analyzed and investigated for the purposes of this study, from different locations in the basin. Results showed that water tables have declined in the range of 3.25 m/y. Abstracting 81.1 MCM of water, a much higher volume than the safe yield of the basin of 57 MCM with an overpumping rate of 142 % of the safe yield. Electrical conductivity increased from 983 µS/cm in Swaqa to 1430 µS/cm in Wala due to overpumping. Groundwater is slightly alkaline with an average pH value ranges between 6.94 -7.63. All water samples are classified as very hard. Values of nitrate ranges from 1 mg/l in Swaqa to 28 mg/l in Heedan. The highest average values of E.coli 42 MPN/100 ml encountered in Heedan while the lowest value is 4 MPN/100 ml in Swaqa and Lajjoun. Piper Classification showed that the type of groundwater in the study area is earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride.

Keywords: Arid Areas, Overpumping, Deterioration, Water quality, Electrical Conductivity.

INTRODUCTION

Main challenges for Jordan is the scarcity of water resources; Jordan is one of the fourth countries with the scarcest water resources in the world, due to overexploitation, semi-arid climate, mismanagements, pollution and population growth during most of the second half of the twentieth century. The climate is generally arid to semi - arid; 90% of Jordan area receives less than 200 mm rainfall per year (Abu-Sharar, 2006). Heavy demands on water resources have been placed by a rapid increase in population, agriculture and industrial development. The gap between water supply and demand is expected to widen due to the continuous increase in the population growth rate. Recently the per capita share of water is 160 m^3 /capita/year, on current trends this will fall to less than 90 m^3 /capita/year by 2025 (Shatanawi et al. 2006) putting Jordan in the category of having an absolute water shortage. Experts consider countries with a per capita water production below 1000 m^3/year to be water-poor country (Hadadin et al., 2010). However, it is important to note that, the amount of water demand exceeded water supplies. In the year 2010, water resources supply were 1114MCM while the demand was 1613MCM, thus the deficit was 499 MCM. (Subah and Margane, 2010). The annual safe yield from the rechargeable aquifers is about 266.5 MCM while the annual abstraction rates are 424.5 MCM (MWI open file, 2012); with an over pumping ratio ranges between 146% in minor aquifers and 235% in

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Received on 16/7/2013 and Accepted for Publication on 25/2/2014.

major ones (El-Naqa and Al-Shayeb, 2009). The annual abstraction of surface water is 214.69 MCM, with the Jordan Rift Valley contributing 108 MCM, springs account for 57.2 MCM and base flows and floods account for 49.4 MCM (MWI open file, 2012). In most regions of the country groundwater is the main source of the water supply for domestic uses. Numbers from the Ministry of Water and Irrigation (MWI) showed that 76% of the drinking water is extracted from groundwater which is the only water source for all uses in most regions of the Kingdom (NWMP, 2008). Overexploitation of groundwater aquifers beyond the annual available quantities causes deterioration of groundwater quality in the exploited aquifers and reduces the sustainability of these resources for future use. The overpumping of aquifers to meet all water demand in the country, led to the lowering of the groundwater table in addition to the low quality of water in some aquifers. Older saline water moves in to replace the fresh water that has been pumped from the aquifers. The total abstraction from the Dead Sea basin in 2011 was 81.1 MCM; the municipal sectors used about 41.78 MCM, the agriculture consumed 28.9 MCM and the remaining used for industry. The safe yield of the basin was 57 MCM; with a pumping rate of 142 % of safe yield (MWI open file, 2012). The overpumping above the safe yield capacity, which is 57 MCM from a large number of wells existing in the basin causes a dramatic drawdown of the water table and consequently affects the groundwater resources in the area. Measured salinity values were found to be more than 1664 ppm in Qatraneh and 1107 ppm in Wala area (MWI open file, 2012). The main objectives of this study are to Investigate the temporal variation of water quality parameters in the Dead Sea basin, determine the areas in the basin which are most influenced by overpumping and deteriorating of water quality and relate it with the safe yield of basin, provides solutions to reverse or at least alleviate the deteriorating status of the basin.

STUDY AREA

Dead Sea Basin is located in the central part of Jordan with a total area of 6874 km^2. The basin lies between coordinates 187664.679 and 256455.773 E and 997532.173 and 1147942.807 N (according to Palestine Belt) Figure-1. It is bounded northward by Jordan valley, Jordan side valleys and Zarqa basin, southward by Jafr basin and Araba North basin, eastward by Azraq basin and westward by the Dead Sea catchment. The area is affected by the Dead Sea transform system, with elevation ranging from 1260 (m.asl) in the northern and southern part of the study area to about 180 (m.bsl) in Safi and Mazraa in Karak directorate. Three main topography features are found in the study area, the plateau feature, highlands toes in the far eastern part and steep slopes in the highlands along the Dead Sea escarpment. There are several wadies running along the study area: Wadi Mujib, Wadi Heedan, Wadi Hasa, Wadi Issal, Wadi Numera, Wadi Abn hammad and Wadi Zarqa Main. The surface water flows westward to the Dead Sea in the lower aquifer and discharges as thermal water in Zarqa Mai'n. The area is classified as a Mediterranean semiarid climate zone that is characterized by low rainfall and high percentage of evaporation. A high topographical gradient towards the Dead Sea occurred in the study combined with a high relief affects the climatic parameter distribution specially rainfall in the area. The absolute daily temperature ranges from 42º C in May to around -2º C in January. The mean annual rainfall ranges from 345 mm in the northern and southern part, decreasing to less than 52 mm in the western part along the Dead Sea coast. The source of continuous base flow in the area is restricted to a number of seepages and springs distributed along the

Dead Sea shore. The outcrop of base flow is fundamentally dependent on the upper aquifer (B2/A7). Within the study area 150 springs are measured and monitored by Water Authority of Jordan (WAJ), the discharge of these springs decreased from 58811 m^3 in the year 1986-1987 to 11006 m^3 in the year 2010-2011 (WAJ open files, 2012). Sewage disposal and septic tank systems are considered one of the sources of groundwater pollution in the area.

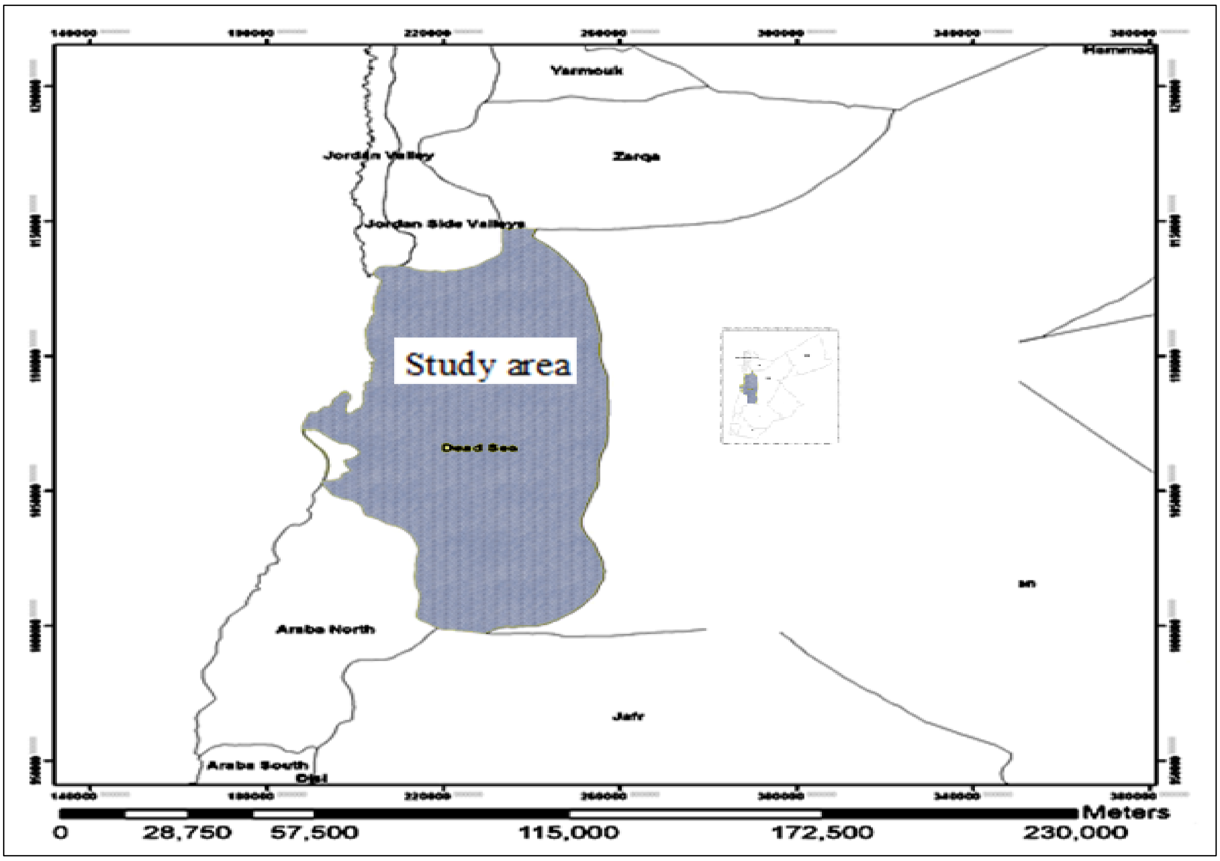

Figure 1. Location Map of the Study Area (MWI, 2012).

GEOLOGICAL SETTING AND HYDROGEOLOGY

The geology of the Dead Sea Basin is affected by a Graben structure formed by subsidence accompanied by the block faulting. The basin is formed due to left-lateral displacement along the segmented Dead Sea transform. It contains a thick accumulation of sedimentary rocks of more than 8000 m thickness (Abu-Ajamieh, 1985). The strati graphical lowest outcropping member is the Paleozoic; Umm Ishrin formation, consisting of sandstone. Followed up by the Lower Cretaceous consisted of two groups: Zarqa Mai'n group consisting of sandstones and Kurnub sandstone group. Followed up by the Upper Cretaceous Ajlun group being mainly a carbonate-dominated sequence. Balqa group Upper Cretaceous - Tertiary follows it. The basin is considered tectonically active due to the presence of various faults and lineament dominating in the area. The main tectonic feature in the area is the Siwaqa Fault, which is strike slip fault with dextral movement of around 5 km. This fault extends in E-W direction from Saudi Arabia to the Dead Sea, where it bifurcates into a northern and a southern branch, the southern branch passing through Shihan Volcano and Ghor Haditha. The vertical throw of the fault is around 150 m to the south (Barjous, 1984). Table (1) summarizes the geological successions and aquifer potentiality in the study area. Groundwater resources within the Dead Sea Basin are found in two different aquifer complexes. The upper limestone aquifer complex (B2/A7), which is the most extensive aquifer complex in the study area. It is composed of Wadi Es Sir Formation (A7) from Ajlun group and Amman Formations (B1 and B2) of Balqa group. Consisted of a carbonate rocks sequence presented by limestone mainly, with an intercalation of cherts and marls. The groundwater flow in this complex is directed from the recharge mounds in the eastern highlands, partly to the western escarpment within the faulted blocks (Sawarieh, 2005). The total available groundwater amount is around 87 MCM/yr (EMWATER, 2005). Due to the presence of faulting system the transmissivity of the upper limestone aquifer is high, the value ranged from 22 m^2/day in Lajjoun well No.13A to 15,590 m^2/day in Heedan well No.5 (MWI open files, 2012). Lower Sandstone Aquifer Complex (Kurnub and Rum) it corps out along the escarpment of the Dead Sea and in the lower reaches of Wadi Wala/Heedan and Wadi Zarqa Mai'n. It consists of thick white sandstone and marl. Water in the sandstone complex comes from different sources like leaking from the upper aquifers, underground flow from Disi area, in addition to a very limited direct recharge to the outcrops. The main recharge sources to this aquifer is leakage from the upper aquifer system, the total discharge from the lower aquifer is around 90 MCM/yr mostly thermal mineralized water, about 20 MCM/yr discharge as base flow in Wadi Zarqa Mai'n (Salameh and Uduft, 1985). Due to the uniformity of the Kurnub aquifer materials, the variation of transmissivity of this aquifer is much lower than the variation in the upper aquifer (Al-Raggad, 2009). The maximum transmissivity values are recorded as 1797 m^2/day and a minimum values are 65 m^2/day (MWI open file, 2012). The water use in the aquifer is restricted to irrigate salt-semi tolerant crops due to high salinity.

Table 1. Geological successions and aquifer potentiality in the study area (Al-Raggad, 2009).

Period	Group	Formation	Lithology	Aquifer Potentiality
Quaternary	Recent Deposit's	Fan , Talus , Terrace Lisan	Sand , Clay , Gravel , Basalt Marl , Clay , Gypsum , Sand , Gravel	Superficial Aquifer
		Undifferentiated	Conglomerate , Marl	
Tertiary	Balqa	Um Rijam (B4)	Chert , Limestone	Semi Aquifer
		Muwaqqar (B3)	Chalk, Marl	
		Amman (B2a)	Phosphate	
		Al Hasa (B2b)	Silicified Limestone	

Upper		Wadi Ghudran (B1)	Chalk , Chalky Marl	Aquifer Complex
	Ajlun	Wadi Es Sir (A7)	Limestone	
		Shueib (A5-6)	Marly Limestone	Aquitard
Cretaceous		Hummar (A4)	Dolomitic Limestone	Semi Aquifer
		Fuheis (A3)	Marl	Aquitard
		Na'ur (A 1-2)	Marly Limestone	Semi Aquifer
			White Sandstone , dolomite.	
Lower	Kurnub	Kurnub Sandstone	Varicolored Sandstone	Aquifer Complex
			Shale , Marl , dolomite.	
Cretaceous	Zarqa	Dardur	Sandstone and Dolomitic Sandstone	
		Mai'n	Sandstone	
		Umm Irna	Silt and Clay	
Paleozoic	Rum	Umm Ishrin	Sandstone , Siltstone	
		Burj dolomite	Shale , dolomite, Sandstone	

Table 2. Methods used for the analysis of quality parameters

Parameter	Analytical Methods
pH	4500-B AWWA/APHA, 2000 pH meter
EC	2510 AWWA/APHA, 2000, Conductivity meter
Ca^{+2}, Mg^{+2}	3500-D 3500-E AWWA/APHA, 2000 EDTA Titrimetric Method
Na^{+}, K^{+}	3500-D AWWA/APHA, 2000 Flame photometery
HCO_3^{-}, CO_3^{-2}	2320-B AWWA/APHA, 2000 Titrimetric Method
Cl^{-}	4500-B AWWA/APHA, 2000 Argentometric Method
NO_3^{-}	4500-B AWWA/APHA, 2000 Spectrophotometer
SO_4^{-2}	4500-E AWWA/APHA, 2000 Turbidity meter
Total Coliform	9221-B AWWA/APHA, 2000 Standard Total Coliform Multiple Tube (MPN) Fermentation Techniques
Faecal Coliform	9221-C AWWA/APHA, 2000 Faecal Coliform MPN

MATERIALS AND METHODS

Hydrochemical analyses were carried out during the period from June to September in 2012; about 70 groundwater samples from ten wells located in different locations in the basin were collected. In addition to collected groundwater samples, historical chemical analysis data for about 430 groundwater samples for more than 110 wells in the study area dating back to 2002 were used which obtained primary from data base maintained by the MWI. Water samples were preserved and analyzed in the laboratory of the Department of Water Resources and Environmental Managements in the Faculty of Agricultural Technology at Al-Balqa' Applied University, for Physical parameters pH, electrical conductivity EC and chemical parameters calcium Ca^{+2}, magnesium Mg^{+}, sodium Na^{+}, potassium K^{+}, chloride Cl^{-}, nitrate NO_3^{-}, carbonate CO_3^{-2}, bicarbonate HCO_3^{-}, and sulfate SO_4^{-2}. The analytical methods used for the analyzed parameter are listed in Table (2) these analytical techniques were performed according to standard method for the examination of water and wastewater (APHA, 2000). Descriptive Statistical Analysis is widely used in water analysis interpretation, due to it's highly ability to summarized large volume of data and gives the chemical relationship between different concentrations (EPA, 2009). It used to summarize water quality data sets in a simple and more understandable form such as mean and standard deviation. The chemical analysis data for 101 water sample were subjected to descriptive statistical analysis tests; descriptive statistical analysis was carried out using SPSS 16.0 and Microsoft Excel software by combining the recent analyzed data with historical data. The Jordanian Standards (JS) and the World Health Organization (WHO) Guidelines for drinking water are mainly considered to evaluate the groundwater sample suitability for drinking purposes. Table (3) shows the JS and WHO Guidelines for drinking water.

Table 3. Jordanian Standard (JS) and WHO Guidelines for drinking water

Parameter	Jordanian Drinking Water Standards (JS No. 286/2008)		WHO Guidelines (2011)
	Permissible Limit	Max Allowable Concentration (in case no better source is available)	
EC (µS/cm)	750	2300	750-1500
Ca^{+2} (mg/l)	100	500	100-300
Mg^{+2} (mg/l)	100	500	150
Na^{+} (mg/l)	200	400	200
K^{+} (mg/l)	10	50	10-50
HCO_3^{-} (mg/l)	100	500	125-350
Cl^{-} (mg/l)	200	250	200-300
NO_3^{-} (mg/l)	45	70	50
SO_4^{-2} (mg/l)	200	500	250
T.C (MPN/100ml)	-	1.1	0

RESULTS AND DISCUSSION

The demand for more water resources for various purposes, mainly for domestic supply and agricultural activities, has been increasing for the last two decades. In Table (4) the water abstraction from the basin for the period 1990-2011 is presented. The annual amount of groundwater extracted has tripled between 1990 and 2004; the abstraction has been increased from 26.3 MCM in 1990 to 75.5 MCM in 2004. The total spring discharge volume was 53,965 m^3 in the year 2000 and falls to 10,584 m^3 in the year 2011; this decreased in spring discharge is due to overpumping and fluctuation in precipitation. Spring discharge was highly affected as the groundwater table decline within the groundwater shed, as a result of overpumping, dropping in the Dead Sea level and climatic change were trend analysis to the time series of the existing climatological records has been conducted in many studies, long trends show a clear decline in the precipitation rates over the area starting from 2003 and continuing through the this year (Al-Raggad, 2009). Some springs in the area are dried due to overpumping, reduction in precipitation and reducing in recharge. A decreasing in discharge in El-Hadeitheh spring occurred, the discharge decreased from 12,530 m^3 to 1,688 m^3 Figure-2. There are very limited numbers of observation wells in the basin, the observation wells are assigned to observe the water level of the upper aquifer. Arainbbh No4 (CD1197) is one of the wells that has a total depth of 355 meters and penetrate the B2/A7 water bearing formation. Monitoring data for almost 24 years (Mar-87 to Sep-11) are represented in Figure-3. The general trend indicates that the water level of the groundwater in the well has been declining in the range of 3.25 m/y with no evidence of replenishment. Results of descriptive statistical analysis of water samples are presented in Table (5). Average EC values for the sample are within the range of 983-1430 μS/cm, wells drilled in Wala area have the highest EC, while wells in Swaqa have the lowest value of EC due to overpumping. A higher evaporation rate in the central and southern parts of the area, frequent occurrences of caliches and salt accumulation in the soils reduce potential for fresh rainwater infiltration into the groundwater. The trend of change in EC with time for represented wells in the study area is illustrates in Figure-4. Selected wells showed increasing trend in EC with the passage of time, an increase of EC value from 1278 μS/cm in the year 2006 to 1507 μS/cm in the year 2010 for Wala No.14 with an increase of pumping rate from 110,208 m^3 to 195,600 m^3**.** The pH values of groundwater in the study area varied between 6.94 in Lajjoun to 7.63 in Heedan, indicating slightly alkaline water. Large scale environmental activities in carbonate rock in Amman Wadi Es-Sir limestone formation (B2/A7) may raise the pH-value (Stone and Thomforde, 1977). According to Subramanian (1999) the water is classified into two groups, soft water in Lajjoun area and hard water in Qatraneh, Heedan, Swaqa, and Wala area. According to Freeze and Cherry (1979) all samples are classified very hard water, the classification of very hard water could be attributed to the overpumping of the wells in the catchments area, in addition to the presence of dissolved calcium and magnesium salts originated from limestone rocks. The average level for calcium ranges from 76.45 mg/l in Swaqa to 112 mg/l in Wala, wells in Wala area have a sharp increase in calcium concentration with time due to increasing of pumping water from 1,777,826 m^3 to 2,213,098 m^3 from the vicinity near these areas. Values of sodium range from 67.75 mg/l in Heedan to 123.77 mg/l in Qatraneh. The ratio of Mg/Ca for all wells is below 1 which indicates that the sources of solute in the shallows aquifers are the dissolution of soluble minerals (Maya and Loucks, 1995). The average values of potassium ranges from 2.71 mg/l in Swaqa to 5.05 mg/l in Heedan, high concentrations result from the presence of silicate minerals from igneous, metamorphic rocks and agricultural activities represented by the addition of fertilizer to the soil present in the recharge areas of these wells, fertilizing with potassium nitrate and manure. The average values for chloride ranged from 113.66 mg/l in Heedan to 191.69 mg/l in Qatraneh. Average bicarbonate value of water in terms of $CaCO_3$ varied from 279 to 340 mg/l, maximum value of bicarbonate (340 ppm) is recorded in Wala. Since the observed pH value is below 8.5; the carbonate values are not detectable for groundwater samples. The average values for nitrate ranges from 1 mg/l in Swaqa to 28 mg/l in Heedan, higher values of nitrate are found in Heedan area, were the potential sources of nitrate are from:

fertilizers, septic tank effluent and municipal sewage (Wilhelm et al., 1996). The average results of the hydrochemical parameters for collected water samples taken from the study area are shown in Table (6). Based on chemical analysis and historical data major elements (cations and anions) in the groundwater of the study area are within permissible limit of JS and WHO Guidelines.

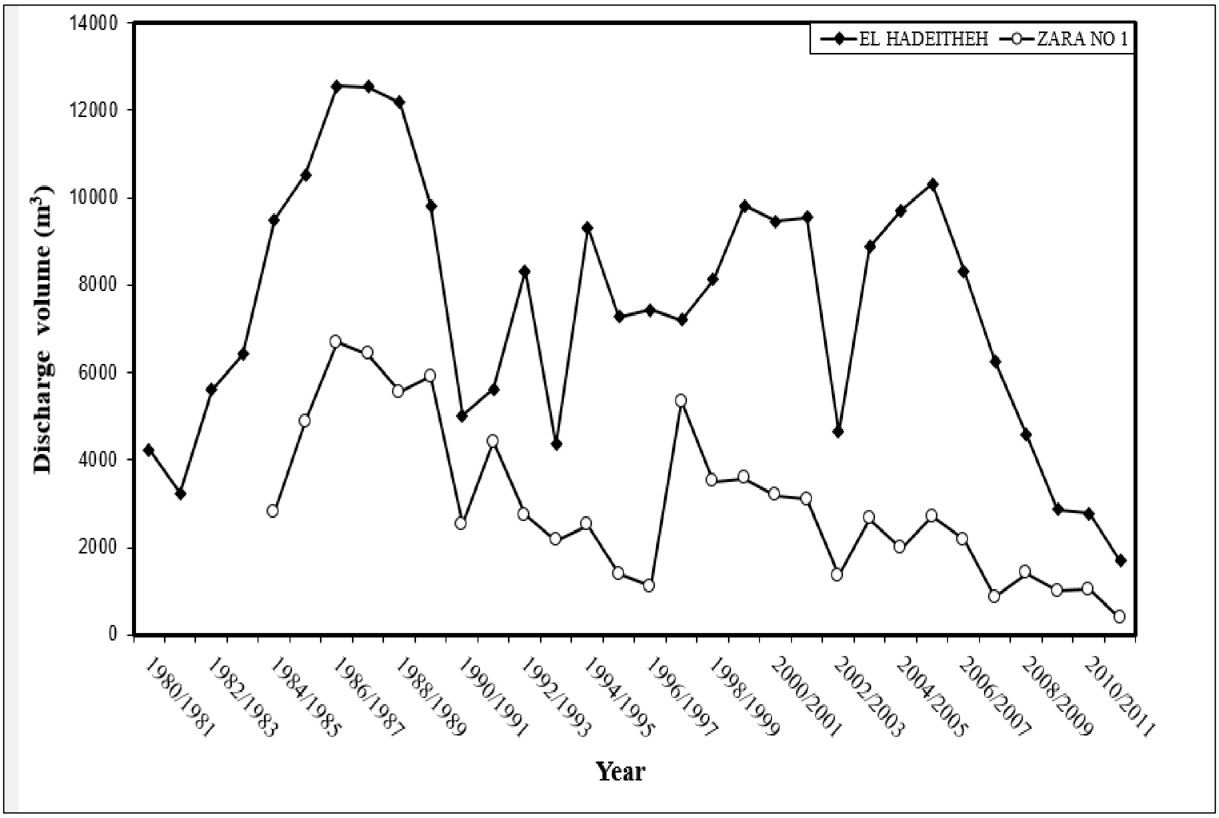

Figure 2. Decreasing in Spring Discharge (MWI, 2012).

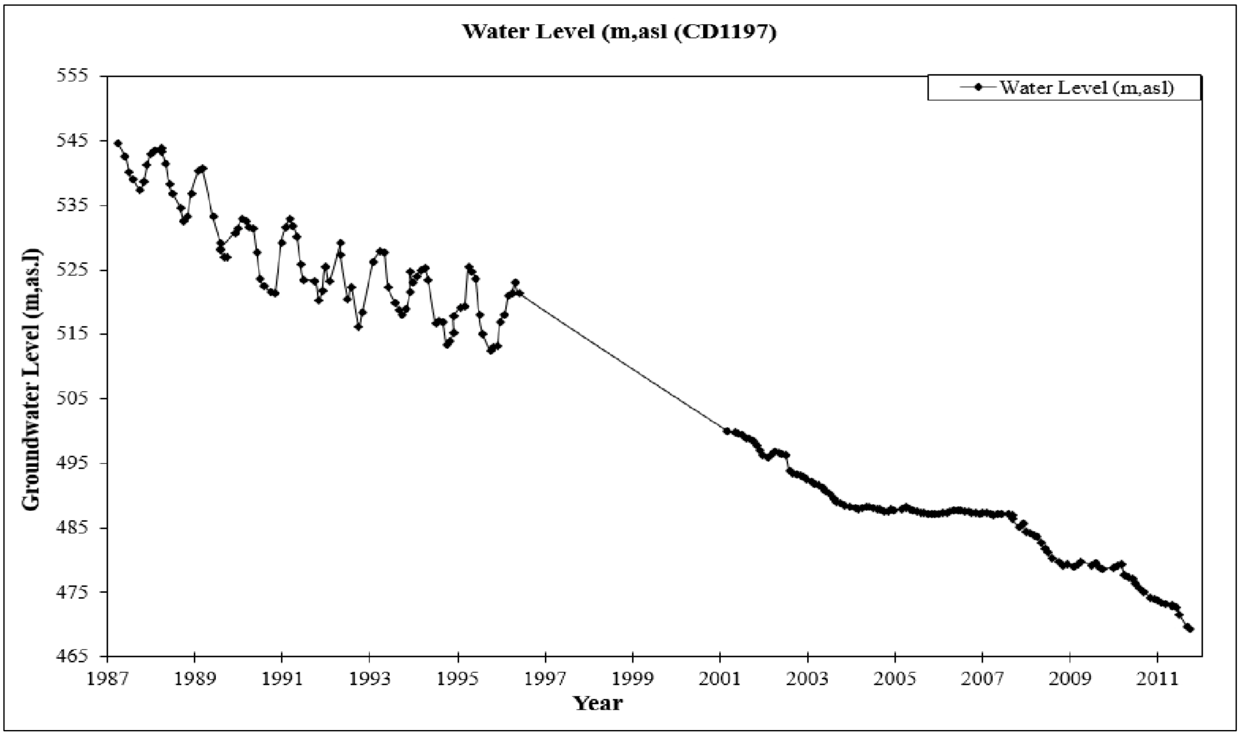

Figure 3. Decline of groundwater level in Arainbbh-4 Observation Well (MWI, 2012).

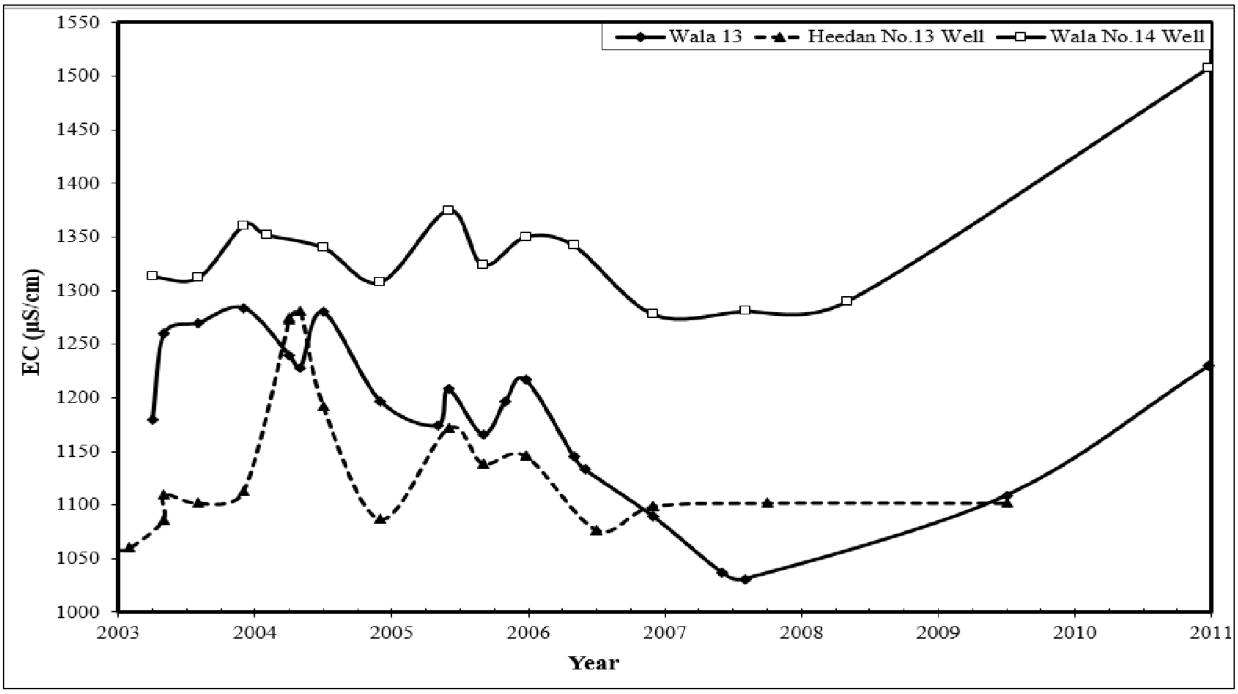

Figure 4. Temporal Variation of EC for the Period 2003-2011(MWI, 2012).

Table 4. Total abstraction from the Dead Sea Basin (MWI, 2012)

Year	Total discharge (MCM)
1990	26.3
1991	29.1
1994	38.2
1997	68.1
1999	66.2
2000	64.2
2004	75.5
2005	71.7
2008	80.6
2009	80.7
2010	80.6
2011	81.1

Table 5. Descriptive statistical analysis of wells in the Dead Sea Basin

Well Name	No. Samples	HCO_3^- as $CaCO_3$(mg/l)	Ca^{+2} (mg/l)	Cl^- (mg/l)	E C (µS/cm)	TH as $CaCO_3$(mg/l)	Mg^{+2} (mg/l)	NO_3^- (mg/l)	K^+ (mg/l)	Na^+ (mg/l)	SO_4^{-2} (mg/l)	pH
Heedan No.13	12	330 ± 13.96*	98 ± 6.15	123± 7.98	1127± 72.73	404 ± 16.94	38.6 ± 2.42	20.7± 3.45	5.61 ± 0.63	72 ± 6.13	102± 13	7.65 ± 0.22
Heedan No.2	9	331± 35.27	104± 11.37	128.7 ± 5.46	1086 ± 113.3	402 ± 10.9	34.5± 8.76	22.85± 1.98	6.9 ± 2.93	79.2 ± 6.65	95.9± 6.87	7.46± 0.36
Heedan No.5	13	279± 34.39	87 ± 5.8	103.3 ±17.25	952 ± 112.5	362± 42.91	35.11 ±8.11	20.8 ± 2.68	4.9 ± .91	61.7± 6.29	90± 13.6	7.82± 0.2
Wala No.4	10	301± 31.52	91.84± 2.9	124 ± 10.78	1100 ± 77.65	397 ± 11.87	40.8 ± 1.42	7.7 ± 1.46	4.1 ± 0.6	94.9 ± 8.0	146± 7.96	7.7 ± 0.1
Wala No.5	8	324± 27.74	145± 6.1	132±8.23	1329 ± 127	546 ± 35.29	44±7.74	7.89± 1.41	4.9 ± 0.34	102.13 ± 5.88	286± 41.29	7.52 ± 0.11
Qatraneh No.24	12	285± 68.07	84.47 ± 8.05	164 ± 38.08	1190 ± 198.9	395 ± 64.9	44.7 ± 12.9	4.9 ± 6.75	4.3 ± 0.68	106.3± 32.47	138±35.22	7.7 ±0.1
Qatraneh No.9	9	293± 20.22	79 ± 3.11	140 ± 15.52	1002± 63.56	358 ± 10.9	39 ± 3.3	1.36± 1.68	3.1 ± 0.46	88.7 ± 6.1	96.5± 4.18	7.62± 0.12

Swaqa No.1A	10	320 ± 22.29	80 ± 5.93	133±9.93	1025 ± 100.17	386± 24.73	41.1± 4	.86± 1	2.35± 1	77.25± 4.77	85.36± 14.1	7.46± 0.18
Qastal 5B	11	204 ± 80.39	70 ± 15.4	92±7.8	787±70	307 ± 9.9	31.8 ± 6.8	15.1 ± 21.5	6.8±5.2	48.9 ± 1.4	32± 4.0	7.7 ± 0.1
Lajjoun KD10	7	236 ± 19.24	44 ± 3.47	99 ± 4.36	667 ± 50.24	194 ± 15.98	20 ±1.14	0± 0	4.8 ± .58	66 ± 4.98	28 ± 6.87	7.74 ± .2

*** Avg. ±SD**

Table 6. Average hydrochemical parameters for collected water samples taken from selected wells in Dead Sea Basin

Sampling Point	No Samples	pH	EC (µS/cm)	Cations (mg/l)				Anions (mg/l)			
				Ca	Mg	Na	K	HCO_3	SO_4	NO_3	Cl
Heedan No.13	7	7.25	933	98	48	74	5	317	90	17.8	137
Heedan No.2	7	7.36	917	124	19	89	12.2	332	97	26.1	136
Heedan No.5	7	7.47	725	83	31	53	4.6	293	70	23.5	92
Wala No.4	7	7.53	925	92	40	101	4.6	298	133	9.8	130
Wala No.5	7	7.46	1063	148	27	97	4.8	320	215	10.0	137
Qatraneh No.9	7	7.80	887	81	41	93	2.6	310	97	0.19	170
Qatraneh No.24	7	7.90	638	74	26	59	5.1	259	52	25.2	96
Swaqa No.1A	7	7.92	833	86	35	73	2.5	300	91	0.3	132
Qastal No.5	7	7.71	737	59	37	48	10.5	181	29	0.23	86
Lajjoun KD10	7	7.74	667	44	20	66	4.8	287	28	0	99

Microbiological Parameters

The microbiological water samples were collected from wells before pumping to distribution stations, were disinfection process is made with chlorine to kill and remove any harmless organisms. The highest average values of total coliforms are 146 MPN/100 ml encountered in Heedan, while the lowest value is 25 MPN/100 ml in Qatraneh, this is due to the human and agricultural activities surrounding the areas in Heedan, high bacterial concentration as a result of surface-water infiltration. A huge amount of water is flooded in land which ultimately seeps into aquifer along with huge amount of bacteria; hence flood irrigation in the affected areas is a major cause of migration of coliforms bacteria into shallow aquifer, which severely polluted particularly in rainy season when comparing with dry season. The average values for E.coli ranges from 4 MPN/100 ml in Swaqa and Lajjoun to 42 MPN/100 ml in Heedan respectively. The average microbiological parameters in the area in the Basin are shown in Table (7). All wells have total coliforms and E.coli values exceed the permissible limit according to JS and WHO Guideline, due to the human and agricultural activities surrounding the areas in Heedan.

Table 7. Average microbiological parameters in the area in the Basin

Area	Escherichia coli MPN/100 ml	Total Coliform MPN/100 ml
Heedan	42	146
Lajjoun	4	35
Qatraneh	8	25
Swaqa	4	28
Wala	28	74

Water classification using Piper diagram

Water samples from governmental drinking wells which are from (B2/A7) aquifer were plotted on Piper trilinear diagram as shown in Figure-5. All groundwater samples are located in (e) hydrochemical facies, the type of groundwater samples of study area is "earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride". This is reasonable cause all wells has the same geological formation and lies in the same aquifer. The presence of one type of water in the samples that have been drawn on Piper evidence that water in B2/A7 aquifer has not been mixed with water from lower aquifer. The water type shifts towards more additions in Ca^{+2}, Mg^{+2}, Cl^{-}, and SO_4^{-2}; this shift can be attributed to over exploitation which enhanced dissolution processes of halites, dolomites. This type of water is characterized by relatively high salinity values. The chemistry of this type originated from the weathering, leaching of sedimentary rocks and the dissolution of salt deposits. Distribution of the groundwater samples in the Piper diagram is shown in Figure-5. The- Figure showed that these samples are characterized by the dominance of Cl + SO_4 over HCO_3. Calcium is the dominant cation in the chemical facies of most groundwater samples, followed by Na and Mg. The order of abundance is: $Ca^{+2} > Na^{+} > Mg^{+2} > K^{+}$ for cations and $Cl^{-} > HCO_3^{-} > SO_4^{-2}$ for anions, water composition of this order is found in all water well samples.

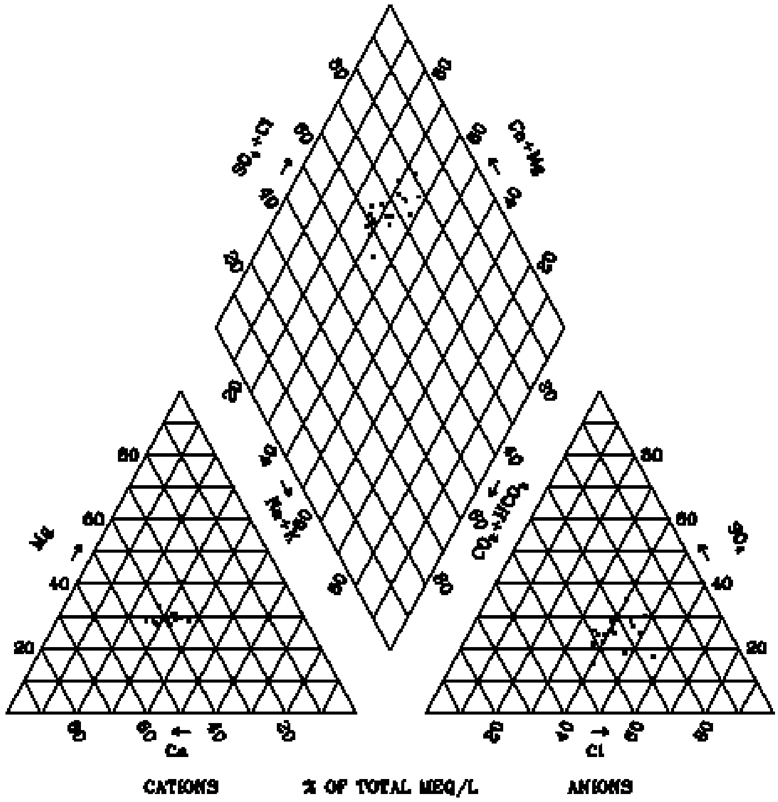

Figure 5. Piper Classification of Groundwater Sample in the Basin.

CONCLUSIONS AND RECOMMENDATIONS

The overpumping from the groundwater aquifers in some areas had led to water level declines and changes in flow directions. Water level fluctuation varied from well to another. The drawdown data from 1987 to 2011 confirms that in monitoring well CD 1197 water levels have declined by 76 m in a 24-year period. Due to extensive exploitation of groundwater in the basin, an increasing of electrical conductivity EC occurred. The pH value of groundwater in the study area is slightly alkaline water. Water in the study area is considered very hard due to the weathering of calcite and dolomite rich rocks exposed in the study area. A high increase in potassium concentration occurred in the last years, concentration tripled in Wala area due to urban expansion in the vicinity of these wells in south Amman, were agricultural activities represented by the addition of fertilizer to the soil present in the recharge areas. The nitrate level classifies the areas of wells in two categories: between 16-28 mg/l in Wala and Heedan and between 1-6 mg/l in Swaqa, Lajjoun and Qatraneh. The results of total coliforms indicated a bacterial contamination in the study area. Piper Classification showed that the type of groundwater in the study area is earth alkaline water with increased portions of alkalis with prevailing sulfate and chloride. The order of abundance is: $Ca^{+2} > Na^{+} > Mg^{+2} > K^{+}$ for cations and $Cl^{-} > HCO_3^{-} > SO_4^{-2}$ for anions. Only one type of water present in the upper aquifer (B2/A7), which means that water from lower aquifer, does not mix with the water in the upper aquifer.

Recommendations

Most of the major negative effects of groundwater use can be forecasted and quantified. Groundwater users should be involved in the management process, as should other people and organizations. To cope with overexploitation situations there is a necessity for making the role and value of groundwater, by conservation of groundwater and other freshwater resources. The objective is short-term, by controlling well construction and keeping the total abstraction small with respect to recharge. Groundwater extraction should be limited to yield the remaining groundwater resources of the basin. This study provides a baseline for the groundwater chemistry in Dead Sea Basin, which will help the water resources managers to focus on the overpumping and its mitigation. It is possible to solve the problem of deterioration in the Dead Sea basin through construction of dams along main wadies to collect runoff water from these wadies as well as increasing the storage capacity of established dams like Swaqa and Walla dams. Implementing the artificial recharge especially in the most exploited areas in the basin like Heedan and Wala areas and installation of sewage network in the areas which is not covered by sewage systems. Other measures include continuous enhancement of the groundwater quantity and quality monitoring networks, substitution of fresh groundwater with marginal water (brackish, treated wastewater) in agriculture. Several dams have been constructed to provide potential for recharge of stored water to ground water aquifers.

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أثر الضخ الجائر في تدهور نوعية المياه في المناطق الجافة: دراسة لحوض البحر الميت/الأردن

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ملخـــص

تدرس هذه الورقة أثر الضخ الجائر في تدهور نوعية المياه في المناطق الجافه/ حوض البحر الميت / الأردن. تم تحليل ودراسة خمسمائة عينة في هذه الدراسة من آبار مختلفة في منطقه الدراسة. أظهرت نتائج هذه الدراسة انخفاض في مستوى المياه بمعدل 3.25 م/ عام وكذلك تم استخراج ما مجموعه 81.1 مليون متر مكعب أعلى من الاستخراج الآمن للحوض 57 مليون متر مكعب اي ما نسبته 142 % من الاستخراج الآمن. زادت الموصلية الكهربائية من 983 µS/cm في سواقة الى 1430 µS/cm في الوالة وذلك بسبب الضخ الجائر. تعد المياه الجوفية قليلة القلوية حيث تتراوح درجة الحموضة بين 6.94 –7.63، وجميع العينات تصنف على أنها مياه عسرة. وتتراوح قيم النترات من 1 ملغم/لتر في سواقة إلى 28 ملغم/لتر في الهيدان. وتشير الدراسة إلى أن نتائج الفحوصات البيولوجية أظهرت وجود تراكيز عالية نسبيا عصيات القولون البرازية والتي تراوحت بين 42 لكل 100 مل في منطقة الهيدان الى 4 لكل 100 مل في سواقة واللجون. أظهر تصنيف بايبر إلى أن نوعية المياه الجوفية في منطقة الدراسة هي مياه قلوية ارضية فيها زيادة قلويات مع سيادة السلفيت والكلوريد.

الكلمات الدالة: المناطق الجافة، الضخ الجائر، التدهور، نوعية المياه، الموصلية الكهربائية.

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تاريخ استلام البحث 2013/7/16 وتاريخ قبوله 2014/2/25.