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Anthropogenic Impact on Water Resources in the West Bank/Palestine: A Case from Wadi Fara'a Stream—Nablus Area

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Water resources in the West Bank and Gaza Strip of Palestine are scarce and under the threat of depletion and degradation by different land-use activities, the lack of infrastructure that would protect and/or reduce their deterioration, and a lack of resource management plans. The study area that includes Wadi Fara'a is a natural catchment of a great value due to its abundant water resources represented by four groups of springs that irrigate large areas of agricultural lands, and it is a resource under threat. Untreated sewage and wastewater from the surrounding urban areas is directly discharged into Wadi Fara'a. Water samples were collected along the stream and tested to measure levels of contamination. Chemical analyses were performed to measure total dissolved solids (Cl, HCO^3, SO^4, Cu, Mg, Na, and K). Analyses results revealed that there is a high level of contamination in the stream due to different human activities in the area.

Keywords: Palestine, Wadi Far'a, water, contamination, irrigation, and West Bank

Introduction

Water is a crucial and politically sensitive issue in the Middle East (Deborah et al., 2001). Water resources are not uniformly distributed (El-Fadel et al., 2000). Water resources in the West Bank and Gaza Strip are very limited (Collins, 1991) and currently a serious shortage problem exists (ARIJ, 1998), which would be aggravated in the near future as a result of population growth and the increasing demand (Al-Weshah, 2000), with consequent potential to trigger water contamination.

There has been a tremendous amount of literature directed toward current and probable future droughts in the region. The present climatic conditions are not promising (Issar, 1995; Houghton et al., 1996). Therefore, improper assessment of and/or planning for water resources could fail to anticipate climate variability, especially droughts. Groundwater in the West Bank of Palestine is located in three major basins (Bashir and Mimi, 2005): western, northeastern, and eastern (Allan, 2001). This article is a preliminary investigation to the existing water quality, specifically major constituents and contaminants in one catchment areas of the eastern basin (Wadi Fara'a).

Study Area

The West Bank of Palestine is located (Figure 1) west of the Jordan River and covers an area of approximately 5,600 km^2. It is the home of 1.9 million people (PCBS, 1997). The West Bank is a small area with a high population density, a diversity of natural resources, cultural heritage (MOPIC, 1999a), and strife-ridden political climate, which make its landscape and natural resources vulnerable to the impact of growing population.

The study area of the Wadi Fara'a drainage basin is located on the northeastern slopes of the West Bank within the eastern basin and has an area of 330 km^2; it is inhabited by 47,320 people. Its highest elevation is 704 m above sea level in the western parts and decreases gradually to reach 320 m below sea level near the Jordan River. The area has two groundwater basins, one in the northeast, which lies under the upper Wadi Fara'a, and the other in the east, which lies under the lower Wadi Fara'a springs (Ghanem, 1999).

The basin is fertile and is considered to be a highly sensitive groundwater recharge area compared with the remaining areas in the West Bank. The study area has 70 wells and four groups of springs (Al-Nubani, 2000) that contribute flow to the main watercourse, which irrigates about 500 donums (1 donum = 1,000 m^2) of agricultural land (ARIJ, 1998). The soil in this area can be classified as sandy, clay, and sandy-clay (MOPIC, 1999b). The soil formation is an asset for cultivation practice, where the climate of the area is hot in summer and warm in winter. This climate pattern enables the farmers to produce vegetables earlier than other areas (ARIJ, 1996). Its agricultural value, fertile soil, water availability, and climate make Wadi Fara'a an agriculturally productive area (500 donums) (MOPIC, 1999c). Its topography is gently sloping to the east. Although soil formation enhances cultivation practices, the low precipitation rates and high evaporation rates make rain-dependent agriculture less efficient. For this reason, most of the cultivated areas are irrigated by traditional methods using furrows or ponds, with an efficiency of 45%. Other modern techniques are sprinklers with efficiency of 60% to 70% and a drip system with efficiency of 80% (ARIJ, 1996).

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Figure 1. West Bank location map.

There are 47,320 inhabitants in the Wadi Fara'a in addition to 120,000 inhabitants of the city of Nablus. The area has approximately 30 Palestinian communities and eight Israeli colonies. The population in Wadi Fara'a and Nablus for the year 2005 was forecasted to be 45,000 and 134,116, respectively (PCBS, 2006). (because of unstable political conditions).

The area is the home of different land-use activities. Untreated domestic water, animal waste, and solid-waste dumping sites are playing a major role in water contamination in the area. In addition to those contributors, wastewater is released to the study area from major surrounding urban areas—Nablus City (MOPIC, 1999d).

The average rainfall in the area is 450 mm/year and decreases moving from the west to the east. Because the area is located in a semi-arid region, evapotranspiration is very high and estimated to be 2,000 mm/year and the amount of recharged rainwater is minimal and estimated to be 60 million m^3 per year. The amount of runoff is approximately 4.49 million m^3 per year (Ghanem, 1999) and directly flows into the Jordan River.

Data Sources and Methods

Water samples were collected from 10 sites along the watercourse, three samples from each site (Figure 2), from the headwaters of the basin, near the first group of springs (Main Fara'a Spring) to the downstream of the area (Jifftlik Canal) in August 2001. Sample analyses were carried out in the Center for Environmental and Occupational Health Science (CEOHS) at Birzeit University/Ramallah, West Bank. The parameters total dissolved solids (TDS), Na, NO^{-3}-N, pH, Cl^-, HCO^{-3}, Ca, Mg, SO^{-4}, and K were tested to investigate the level of contamination in the stream. Parameters such as fecal coliform, N and P groups, biochemical oxygen demand, chemical oxygen demand, and dissolved oxygen were not included in this study but would have enriched the study. The reasons for not including these parameters was limited funding and time constrains. Sampling sites were spatially referenced by using global positioning system. These sites were added to the study map by using edArc-View GIS version 3.0 (Environmental Systems Research Institute Inc, ESRI, 1996, USA).

Results and Discussion

The sewage network of Nablus City discharges with an open pipe directly into the Wadi Fara'a at Al-Bathan site. This waste is diluted with the fresh water coming from the springs and continues down to the agricultural land to be used for irrigation. Untreated wastewater flows in Wadi Fara'a, contaminating water in the stream, springs, and crops. The wastewater system in the area consists of cesspits/septic tanks and open channels, as well as the industrial wastewater from Nablus City, which flows directly into the Wadi Fara'a. The many open channels of wastewater from the Wadi Fara'a refugee camp combine to make a main channel that flows directly to the south, joining the stream at the site of Al-Malaqi Bridge.

Chemical analyses of major constituents revealed that the major and minor water constituents in the Wadi Fara'a catchment basin demonstrate high-level concentrations of several inorganic compounds (TDS, Na, NO^{-3}N, pH, Cl^-, HCO^{-3}, Ca, Mg, SO^{-4}, and K) as given in Table 1. Although most of these compounds are of minor concern, the NO^3 levels are significant enough to be a health concern. The maximum accepted contaminant level for nitrates in drinking water in the United States is 10 mgN/L (US EPA, 2002). Excessive amounts more than 10 mgN/L can result in serious illness and sometimes death. This contaminant is especially dangerous to the health of babies because of the conversion of nitrate to nitrite in the body, which interferes with the body's ability to absorb oxygen (US EPA, 2002) and could cause shortness of breath, a symptom called *Blue Baby Syndrome*, within days.

The presence of urban areas; human activities such as agriculture, animal breeding, farming, industrial waste from the nearby city of Nablus; and the wastewater/sewage water from the surrounding developed areas all exert anthropogenic pressure on the quality of surface water and groundwater in the basin. The amount of NO^{-3}N in the stream is a result of pollution coming from municipal waste, sewage, and fertilizer and pesticide application in agriculture (Favara et al., 2000). It is clear that the highest records of NO^{-3} N are in three sites: Al-Bathan, Wahat Bathan, and Al-Malaqi Bridge. In the other sampling sites, NO^3 values are more constant (<22 mg/L).

Referring to the TDS, surface water in the area can be classified (Carroll, 1962) as fresh water (0 to 1,000 mg/L), mostly in the far upper stream where TDS reach less than 400 mg/L (Main Fara'a Spring, Wadi Fara'a 100 m downstream, Ein Beda

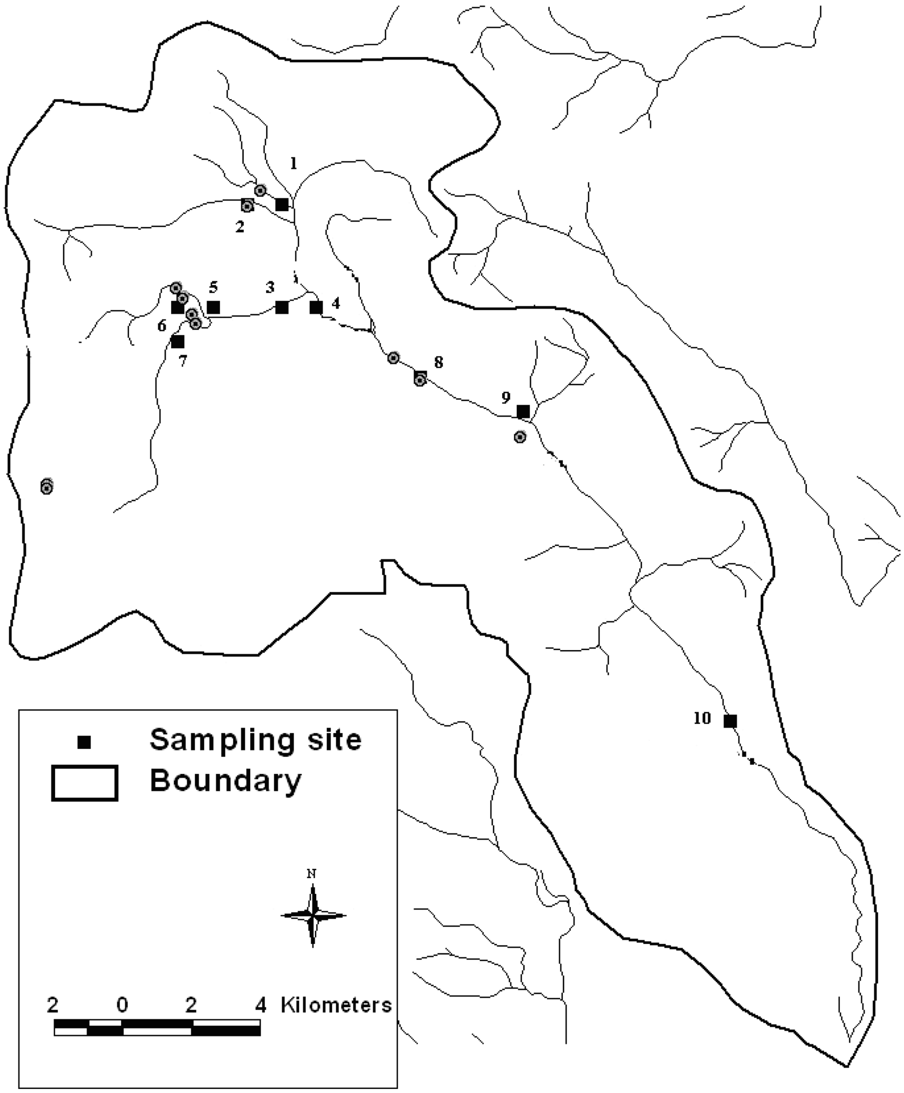

Figure 2. Sampling sites in the watershed of Wadi Fara'a.

and Subyan Spring) and in the middle of the stream where TDS reach 900 mg/L (Miska Spring and Shibli Spring); brackish water (1,000 to 10,000 mg/L) is present downstream where TDS reach 1,200 mg/L (Jifftlik Canal).

Ca and Mg stem from the dissolution of carbonate rocks; the high concentration of Ca is a result of an increasing amount of CO_2 in the water (Kacaroglu and Gunay, 1997). Mg concentration increases as moving downstream to the east towards Jordan Rift Valley because of water–rock interactions.

Na and K concentrations in the stream have the same distribution as NO^3 concentration, which reflects the fact that the existence of Na is due to wastewater and sewage diluted in the stream and also from the discharged industrial mineral waste. Na concentration is high at the far downstream end due to rock weathering and water–rock interaction. High Na concentrations results from an increasing salinity level. K is an indicator of anthropogenic effects on water due to agricultural practices using fertilizers such as KNH4 (Ghanem, 1999).

The concentration of SO_4 reflects the nature of evaporitic carbonate rocks and its source from fertilizers, animal waste, septic system, sewage, and industrial waste (US EPA, 2002). High concentration of Cl is due to evaporitic Cl-bearing rocks in the alluvium formation that contains a high amount of NaCl (Ghanem, 1999). Intensive uses of fertilizers, animal waste, septic system, industrial waste are the main source of Cl in the stream (US EPA).

The data in Table 1 show that water contamination is high in the middle of the upper part of the study area (Al-Bathan, Wahat Bathan, and Al-Malaqi Bridge) and at the far downstream end of the stream (Jifftlik Canal), which means that these contaminants are accumulating along the water courses, where they are finally used in irrigation and the remainder joins the Jordan River. It is clear that most of the agricultural land in the lower part and in the mid-part of the study area is under the threat of contaminated water coming from the upper part of the study area.

Table 1. Water samples analysis

Sampling site number	pH	Ec (μs/cm)	Total dissolved solids* (mg/L)	Cl (mg/L)	HCO3 (mg/L)	NO^3-N* (mg/L)	SO4 (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)
1	7	637	334	43	231	2.94	3	96	19	23	1
2	8	722	382	43	235	3.61	21	108	15	43	2
3	7	548	274	32	203	2.94	2	80	15	21	3
4	8	560	394	31	205	3.39	3	91	12	23	4
5	7	1748	921	304	382	14.68	6	92	24	229	25
6	7	1725	860	295	344	9.49	3	86	22	229	17
7	8	1852	678	336	305	15.58	5	98	21	248	22
8	7	783	415	84	248	4.52	6	81	32	41	3
9	8	701	370	61	232	3.61	5	68	39	33	4
10	7	2400	1200	529	273	4.97	4	115	100	210	16

US (EPA, 2002) drinking water quality standard: $NO^3 = 10$ mgN/L, Total dissolved solids = 500 mg/L accessed 2005, Title page: Ground water and drinking water, List of drinking water contaminants and MCLs: web page: http://www.epa.gov/safewater/mcl.html#mcls

Sampling sites name	Main Fara'a Spring	Wadi Fara'a 100 m downstream	Ein Beda	Subyan Spring	Al-Bathan	Wahat Bathan	Al-Malaqi Bridge	Miska Spring	Shibli Spring	Jiftlik Canal
Sampling site number	1	2	3	4	5	6	7	8	9	10

Most of the solid wastes are disposed randomly over the landscape, near houses, open spaces, and roadsides. The dumped waste either at designated dumping sites (60%) or random sites (40%) is mostly burned with no control or supervision and without any mitigation measures (ARIJ, 1996). Dumping sites are not designed properly to protect the surface or ground water and the waste leachate percolates into the aquifers. In addition, solid waste burning causes air pollution, which adversely affects the public health.

Conclusions and Recommendations

Human impact on environment and natural resources is affecting these resources everywhere on earth, but the level of degradation is varying. Wadi Fara'a as a case study in the West Bank shows that the level of human impact is alarming, and contamination to water resources is serious due to the fact that water is used in agriculture. By sampling water through the stream, analyzing these samples, and comparing the level of contaminants in these samples with other areas (US EPA, 2002), it became clear that the water in the study area is degraded and needs attention. Further studies are needed in other areas in the West Bank to construct water treatment plants in the most sensitive areas; action (water resource management plans and treatment plants) is needed to maintain water resources in this area where water is scarce and threatened. Inclusion of other parameters, such as fecal coliform, N, and K groups, biochemical oxygen deman, chemical oxygen demand, and dissolved oxygen, is necessary to achieve comprehensive assessment of anthropogenic impact on water resources both on stream water and groundwater.

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