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Treated Wastewater Impact on Al Qilt Catchment Area-Palestine*

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Abstract: This study reports on the impact of Al-Bireh wastewater treatment plant beside the sources and types of potential pollutants and presents water quality data for Wadi Al-Qilt drainage basin. Surface water samples were collected over a study period from November 2004, through May 2005 from 13 sampling stations along Wadi Al Qilt and analyzed for physicochemical and hydro biological parameters. According to standard methods for the examination of water and wastewater chemical parameters (Ca^{+2} , Mg^{+2} , Na^+ , K^+ , HCO_3^- , SO_4^{-2} , Cl^- , NO_3^- , BOD_5 , COD , DOC , trace elements such as Ag, Al, Ba, Cd, Co, Cr, Cu, Fe, Li, Hg, Mn, Ni, Pb, Sr, Zn, Be, Se and Mo), physical parameters (pH, turbidity, TDS, EC), microbiological parameter (fecal or total coliform) and hydrobiological parameter (chlorophyll a) were analyzed. The flow measurements were carried out using current meter method. Results revealed major trends for most of measured parameters with decreasing tendencies in pollutants concentration down stream. Dilution factor caused by springs outflows and the self-purification processes within the Wadis bed might be behind the decrease tendencies. Three Wadi samples were trace metals contaminated (aluminum, cadmium and lead), while all water samples revealed microbiological contamination signs. The results obtained for physical, chemical and biological parameters showed that the most polluted section through Wadi Al-Qilt is the part between AWWTP and Wadi Sweanit, indicating pollution of water discharging from springs downstream.

Key words: Water quality management, Wadi Al-Qilt, water pollution, natural resources protection

INTRODUCTION

Groundwater is considered to be the main fresh water resource in the West Bank. Due to the rapid increase of population which can be referred to natural growth and the increasing number of Israeli settlements, the demand for potable water in West Bank for domestic uses has increased in the last two decades.

Jericho water resources are part of the Eastern Aquifer Basin. Groundwater sources in Jericho District are mainly divided between wells and springs. Regarding surface water, several wadi systems in the area have incised steeply into the mountains West of Jericho. The main system in the area is Wadi Al-Qilt system that has a catchment area stretching out from the Jordan River in the East towards Jerusalem and Ramallah in the West. This system

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is fed from three main springs Ein Fara, Ein Al-Fawwar and Ein Al-Qilt. The system of Wadi Al-Qilt springs is the main water source for the Jericho Water Treatment Plant (JWTP). Water is transported from springs to the treatment facility through a 13 km long open transportation canal. This treatment plant is operating only part of the year due to the problems associated with microbiological and other contamination of groundwater. These water quality problems appear regularly during the rainy season (Abed Rabbo *et al.*, 1999). The researchers simulated the treatment process using small scale slow sand filters and suggested the establishment of a sedimentation unit for the removal of increased turbidity during the Winter season. The researchers reported on obstacles for pollution cut from urban Palestinian towns, where erection of urban sewage works are the first priority of the Palestinian Water Authority policy, as the pollution load has been reduced up to 75 and 95% in organic pollutants (TKN and BOD₅, respectively) by Al-Bireh Wastewater Treatment Plant (AWWTP), launched in February 2000. All-Halih (2008) reported that domestic wastewater is of high strength classified as a strong domestic type due to high concentration of pollutants like COD, BOD, phosphorous, ammonia and *Fecal coliform*. Toilet and kitchen sink wastewater are the main sources of pollution.

The drainage basin of Wadi Al-Qilt was chosen for the present study, as there is a lack of data concerning the impact of AWWTP effluent on the self-purification capacity of the season receiving water body (Wadi Al-Qilt). Secondly, evidence of pollution from many springs in this basin as well as the sewage flow along the wadi is a potential health hazard for the local inhabitants and users downstream.

The main aim of this study is to investigate the pollution sources that affect Wadi Al-Qilt and the quality of surface water in the drainage basin, to specify the different pollutants, their possible sources and their actual impact on water resources and to pinpoint on possible measures to improve the situation.

MATERIALS AND METHODS

General Features of Wadi Al Qilt Drainage Basin

Location and Geography

Wadi Al-Qilt is located in the Eastern part of the West Bank. The study area includes part of Ramallah, Al-Bireh and Jerusalem (comprises the Western part of the study area) and part of Jericho (comprises the Eastern part). It represents the major drainage system from the mountain aquifer area between Jerusalem and Ramallah downwards East to the Jordan River with an area of 174.7 km². This catchment is a sub-basin of the Jordan River-Dead Sea basin. The drainage basin of Wadi Al-Qilt is located in the well-known Dead Sea Rift Valley which has elevations in the range of 200 to 250 mbsl in the East and the West of the area, in the vicinity of Ramallah and Jerusalem the mountains rise up to elevations over 800 masl.

Major Wadis

There are two main tributaries in Al-Qilt drainage basin in which the result of their discharge combined with the flow from the five springs form the main stream named as Wadi Al-Qilt. The first tributary is called Wadi Sweanit which originates from the Eastern part of Al Bireh before it combines with the second tributary named as Wadi Fara. Mostly, AWWTP effluent is considered the main source of Wadi Sweanit discharge (Fig. 1).

Sources of Pollution

Mahmoud and Al-Saed (1997) reported that almost 40% of the total Jewish settlements in the West Bank are considered as highly risk potential pollution sources. In general, the

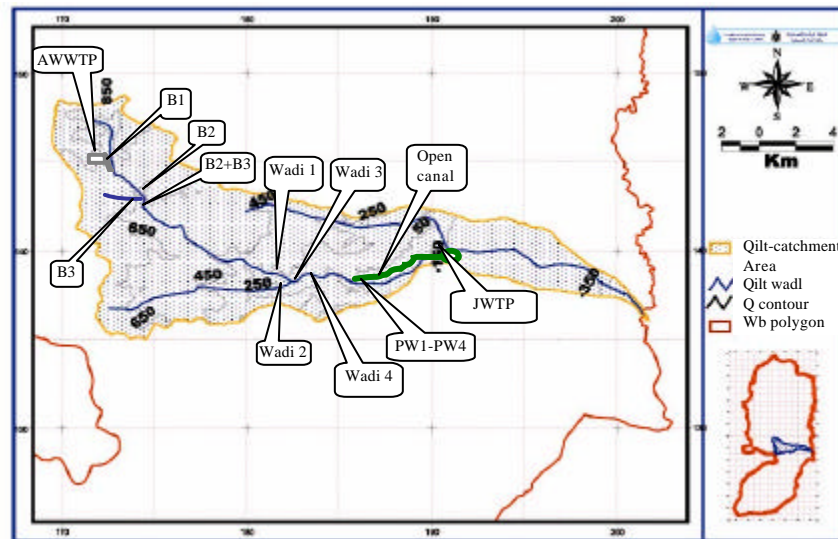


Fig. 1: Sampling stations along the two Wadis

possible sources of pollution from both, Israeli settlements and Palestinian build up areas in Al-Qilt catchment area can be classified as follows: untreated municipal wastewater, seepage from unsanitary dump sites, untreated industrial waste discharging into municipal sewer system or directly into valleys, seepage and runoff of agrochemicals such as fertilizers and non-biodegradable pesticides and stone crushing.

Interviews and personal communications with members from the Palestinian Water Authority (PWA), some people who live near Ein Al Qilt spring and with a person from the Environmental Department at Beit-Eil civil Adm-DCO were conducted between December 2004 and May 2005. The aim of the interviews was to update the data that has been collected throughout the literature review, to identify additional problems with the water resources that are not mentioned in the study.

Field Work

In addition to the inlet of JWTP sampling station, twelve sampling stations were assigned along the two wadis (Fig. 1), starting from AWWTP effluent (as it forms the starting flow in the drainage area), going through Wadi Al-Fawwar, then the open transportation canal which feeds JWTP, ending with the influent to the treatment plant. Fifty six water samples from the wadis were collected and analyzed for different parameters at different dates during the study period. Also, when possible the flow was measured at certain sampling stations. The sampling campaigns from all sampling stations shown in Table 1, were carried out to cover the study period at different frequencies, starting from November (2004) to July (2005).

Water Analysis

The purpose of water analysis was to determine the level of pollution of water flowing in Wadi Al-Qilt. The way to accomplish this purpose was through measuring the water quality parameters, chemical parameters (Ca^{+2} , Mg^{+2} , Na^+ , K^+ , HCO_3^- , SO_4^{-2} , Cl^- , NO_3^- , BOD_5 ,

Table 1: Detailed measurements of pH, turbidity, EC and TDS of all sampling stations along Wadi Al-Qilt

Site ID	Sampling station name	Sampling date	pH	Turbidity (NTU)	EC ($\mu\text{S cm}^{-1}$)	TDS (mg L^{-1})
TP1	Water treatment plant-inlet	29/11/2004	7.91		622	
TP1	Water Treatment plant-inlet	29/11/2004	7.87		603	
TP1	Water treatment plant-inlet	30/12/2004	7.80		607	
TP1	Water treatment plant-inlet	30/12/2004	7.45		639	
TP1	Water treatment plant-inlet	10/01/2005	7.53		613	
TP1	Water treatment plant-inlet	10/01/2005	7.61		611	
TP1	Water treatment plant-inlet	24/01/2005	7.41		500	
TP1	Water treatment plant-inlet	25/01/2005	7.75		605	
TP1	Water treatment plant-inlet	26/01/2005	7.91		590	
TP1	Water treatment plant-inlet	27/01/2005	8.09		584	
TP1	Water treatment plant-inlet	05/02/2005	8.39		698	
TP1	Water treatment plant-inlet	06/02/2005	8.35		702	
TP1	Water treatment plant-inlet	07/02/2005	8.17		515	
B2	Mikhmas Bridge	06/03/2005	7.45		1381	
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	06/03/2005	7.85		1050	
B3	Mikhmas Bridge-Stone Crushing	13/3/2005				
Wadi 1	Wadi Sweanit	13/3/2005	6.57		1087	
Wadi 2	Wadi Fara	13/3/2005	8.11		508	
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	13/3/2005	6.71		608	
Wadi 5	Al Mu'aqar point	13/3/2005	7.75		600	
PW1	Point before split to canal	13/3/2005	7.53		588	
Wadi Fara 1	Wadi Fara 200 m ahead	31/03/2005	7.67		568	
Wadi Fara 2	Wadi Fara 500 m ahead	31/03/2005	7.73		568	
Wadi Fara 3	Wadi Fara 1 Km ahead	31/03/2005	7.91		564	
TP1	Water treatment plant-inlet	14/02/2005	7.08		590	
TP1	Water treatment plant-inlet	15/02/2005	7.12		592	
TP1	Water treatment plant-inlet	16/02/2005	7.20		584	
TP1	Water treatment plant-inlet	22/02/2005	7.17		595	
TP1	Water treatment plant-inlet	07/03/2005	7.08		662	
TP1	Water treatment plant-inlet	08/03/2005	7.16		660	
TP1	Water treatment plant-inlet	09/03/2005	7.27		646	
TP1	Water treatment plant-inlet	14/03/2005	7.06		639	
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	05/04/2005	7.59		1202	
TP1	Al-Qilt and Al-Fawwar	05/04/2005	7.65		458	
B1	AWWTP effluent	16/04/2005	7.65	95.00	1770	975
B2	Mikhmas Bridge	16/04/2005	7.76	162.00	1744	960
B3	Mikhmas Bridge-Stone crushing	16/04/2005	8.40	56.00	1940	1069
B2+B3	Joint point 1	16/04/2005	7.78	129.00	1738	957
Wadi 1	Wadi Sweanit	16/04/2005	8.20	108.00	1750	962
Wadi 2	Wadi Fara	16/04/2005	8.27	2.00	535	296
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	16/04/2005	8.05	73.00	1314	724
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	16/04/2005	7.75	17.00	865	475
PW1	Point before split to canal	16/04/2005	7.80	25.00	660	365
PW2	Canal-500 m ahead	16/04/2005	7.93	22.00	670	369
PW3	Canal-1000 m ahead house	16/04/2005	7.93	23.00	675	373
PW4	Canal-1500 m ahead after house	16/04/2005	7.97	22.00	675	371
B1	AWWTP effluent	15/05/2005	7.92	9.05	1786	985
B2	Mikhmas Bridge	15/05/2005	7.74	26.50	1828	1001
Wadi 1	Wadi Sweanit	15/05/2005	8.32	49.40	1718	944
Wadi 2	Wadi Fara	15/05/2005	8.07	2.00	537	296
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	15/05/2005	8.30	41.10	1400	769
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	15/05/2005	7.87	10.30	845	464
PW1	Point before split to canal	15/05/2005	7.90	7.00	633	340
PW2	Canal-500 m ahead	15/05/2005	8.10	8.35	647	350
PW3	Canal-1000 m ahead house	15/05/2005	7.15	6.83	640	350
PW4	Canal-1500 m ahead after house	15/05/2005	8.18	7.60	655	352

COD, DOC, trace elements such as Ag, Al, Ba, Cd, Co, Cr, Cu, Fe, Li, Hg, Mn, Ni, Pb, Sr, Zn, Be, Se and Mo), physical parameters (pH, turbidity, TDS, EC), microbiological parameter (fecal or total coliform) and hydrobiological parameter (chlorophyll a).

Standard methods for the examination of water and wastewater (APHA, 1995) was used as a reference for all methods of analysis of all measured parameters.

Flow Measurement

The flow was measured at certain points of the system when it was possible due to security situation and presence of check points in the area, especially the flow measurements need some time to be taken. The flow measurements were carried out using current meter method.

RESULTS AND DISCUSSION

In point source pollution, pollutants are discharged from a concentrated and recognizable source while in non-point source pollution, water flows on the surface dissolving and washing away pollutants and soil sediments along its path and finally discharging into receiving waters. Taebi and Droste (2004) mentioned that in urban environments, the most important point source is the discharge from the wastewater collection system; and where a treatment plant exists, this would be treated effluent from the plant.

Variation along Wadi Al-Qilt

During the period of this study (November 2004-July 2005), 56 water samples were collected from the whole accessible sampling stations in Wadi Al-Qilt that would represent the system and analyzed for different parameters (Table 1-5). Three flow measurements campaigns were done during the study period in order to evaluate the variation of pollutant concentration due to dilution process (Table 5).

Several samples from different sampling stations and at different times during the study period were analyzed for Ag, Al, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Ni, Pb, Sr, Zn, Be, Se and Mo. Most of the samples analyzed did not show significant concentrations, except for some samples such as the sample collected on 13/03/2005 from the inlet of the open transportation (TP1). The concentration of Al, Ba, Fe and Zn in that sample was 450, 161, 197, 617 $\mu\text{g L}^{-1}$, respectively.

A major trend as that shown for turbidity for example (Fig. 2) was found through the system (going from the first sampling station at the effluent of AWWTP to last sampling station in Al-Qilt canal; PW4) in decreasing the values of turbidity, EC, TDS, TSS, BOD₅, COD, DOC, Na and Cl. This was due to the dilution process which happens firstly, from the combination of Wadi Fara with the AWWTP effluent at Wadi Sweanit point (Table 5), followed by Ein Al-Fawwar spring discharge into Wadi Al-Qilt and finally by the flow of Ein Al-Qilt spring.

The highest measured values for EC, TDS and TSS were for first sampling stations in the first section from AWWTP effluent and to Mikhmas Bridge. According to Bellos and Sawidis (2005) in addition to high concentration of salts in domestic wastewater which can not be removed in the treatment plant, the leaching of chemical fertilizers spread on agricultural lands by rainwater also causes high values of both parameters.

The reason behind the increase in turbidity value at the point of B2+B3 may be referred to intermix of the flows from the two points which may disturb the sediments after mixing.

Table 2: Detailed analysis of major ions for all sampling stations along Wadi Al-Qilt

Site ID	Sampling station name	Sampling date	HCO ₃ (mg L ⁻¹ as CaCO ₃)	Ca	Mg	Na	K	Cl	SO ₄	NO ₃
				----- (mg L ⁻¹) -----						
TP1	Water treatment plant-inlet	29/11/2004	170	65.4		24.2	3.6	40	37	26
TP1	Water treatment plant-inlet	30/12/2004	165					50	25	23
TP1	Water treatment plant-inlet	30/12/2004	182	86.8		24.0	1.6	48	27	22
TP1	Water treatment plant-inlet	10/01/2005	172	86.8		24.2	4.6	47	30	28
TP1	Water treatment plant-inlet	10/01/2005	180	79.8		24.2	7.0	45	23	29
TP1	Water treatment plant-inlet	24/01/2005	262	264		19.2	6.6	43	25	15
TP1	Water treatment plant-inlet	25/01/2005	154	69		30.1	2.2	34	19	31
TP1	Water treatment plant-inlet	26/01/2005	160	73		25.1	0.0	33	22	29
TP1	Water treatment plant-inlet	27/01/2005	155	69		27.6	0.5	35	25	28
TP1	Water treatment plant-inlet	05/02/2005	156	38		105.0	2.4	38	21	24
TP1	Water treatment plant-inlet	06/02/2005	127	38	10	107.5	2.4	36	21	24
TP1	Water treatment plant-inlet	07/02/2005	138	61		30.1	1.0	29	26	25
B2	Mikhmas Bridge	06/03/2005		20		137.0	14.0	200		17
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	06/03/2005		15		98.0	10.0	117		23
Wadi 1	Wadi Sweanit	13/3/2005		41		115.0	13.1	104		53
Wadi 2	Wadi Fara	13/3/2005		32.4		20.7	0.0	42		20
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	13/3/2005		36.7		77.5	6.3	55		26
Wadi 5	Al Mu3aqar point	13/3/2005		41		32.7	0.6	53		24
PW1	Point before split to canal	13/3/2005		43.1	25	34.16	3.3	58		22
TP1	Water treatment plant-inlet	14/02/2005						26	13	28
TP1	Water treatment plant-inlet	15/02/2005						24	13	27
TP1	Water treatment plant-inlet	16/02/2005						26	13	27
TP1	Water treatment plant-inlet	22/02/2005						26	14	22
TP1	Water treatment plant-inlet	07/03/2005						25	12	11
TP1	Water treatment plant-inlet	08/03/2005						28	25	4
TP1	Water treatment plant-inlet	09/03/2005						29	22	2
TP1	Water treatment plant-inlet	14/03/2005						28	26	28
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	05/04/2005						69	26	8
TP2	Al-Qilt and Al-Fawwar	05/04/2005						24	17	15
B1	AWWTP effluent	16/04/2005		48		211.0	22.0	205		14
B2	Mikhmas Bridge	16/04/2005		45		213.0	25.0	270		19
B3	Mikhmas Bridge-Stone cutting	16/04/2005		58		247.0	33.0	255		41
B2+B3	Joint point 1	16/04/2005		44		199.0	24.0	270		19
Wadi 1	Wadi Sweanit	16/04/2005		51		277.0	26.0	203		23
Wadi 2	Wadi Fara	16/04/2005		27		24.0	0.0	54		19
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	16/04/2005		38		154.0	13.0	162		19
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	16/04/2005		44		63.0	5.0	87		27
PW1	Point before split to canal	16/04/2005		41		42.0	2.0	72		23
PW2	Canal-500 m ahead	16/04/2005		41		42.0	2.0	76		23
PW3	Canal-1000 m ahead house	16/04/2005		41		42.0	2.0	78		23
PW4	Canal-1500 m ahead after house	16/04/2005		41	21	41.0	2.0	97		22
B1	AWWTP effluent	15/05/2005		71	32	180.0	29.0	150		52
B2	Mikhmas Bridge	15/05/2005		73	33	182.0	31.0	178		55
Wadi 1	Wadi Sweanit	15/05/2005		68	33	191.0	31.0	164		60
Wadi 2	Wadi Fara	15/05/2005		56	21	21.0	3.0	43		25
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	15/05/2005		66	30	143.0	23.0	145		51
Wadi 4	Joint Point 3 (Wadi Fara+Wadi Sweanit+ Ein Al-Fawwar)	15/05/2005		71	22	60.0	8.0	79		35
PW1	Point before split to canal	15/05/2005		66	20	33.0	4.0	55		37
PW2	Canal-500 m ahead	15/05/2005		71	21	40.0	4.0	51		38
PW3	Canal-1000 m ahead house	15/05/2005		72	21	36.0	4.0	49		40
PW4	Canal-1500 m ahead after house	15/05/2005		72	21	36.0	4.0	54		39

Table 3: Detailed analysis of BOD, COD, DOC of sampling stations along Wadi Al-Qilt

Site ID	Sampling station name	Sampling date	DOC	COD	BOD
			----- (mg L ⁻¹) -----		
Wadi 1	Wadi Sweanit	13/3/2005		98.0	43
Wadi 2	Wadi Fara	13/3/2005		48.0	19
Wadi 3	Joint Point 2 (Wadi Fara+Wadi Sweanit)	13/3/2005		38.0	36
PW1	Point before split to canal	13/3/2005		46.0	31
B1	AWWTP effluent	16/04/2005	16.71±0.393	172.0	108
B2	Mikhmas Bridge	16/04/2005	17.67±0.141	479.0	136
B3	Mikhmas Bridge-Stone cutting	16/04/2005	29.86±0.785	277.0	58
B2+B3	Joint point 1	16/04/2005	16.88±0.401	338.0	136
Wadi 1	Wadi Sweanit	16/04/2005	17.53±0.926	276.0	53
Wadi 2	Wadi Fara	16/04/2005	3.22±0.058	11.0	9
Wadi 3	Joint Point 2 (Wadi Fara+Wadi Sweanit)	16/04/2005	12.25±0.105	140.0	30
Wadi 4	Joint Point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	16/04/2005	5.89±0.519	58.5	24
PW1	Point before split to canal	16/04/2005	2.00±0.051	54.0	9
PW2	Canal-500 m ahead	16/04/2005	2.00±0.035	52.0	11
PW3	Canal-1000 m ahead house	16/04/2005	1.98±0.103	56.0	12
PW4	Canal-1500 m ahead after house	16/04/2005	1.87±0.079	55.0	14
B1	AWWTP effluent	15/05/2005	16.69±0.200	259.0	80
B2	Mikhmas Bridge	15/05/2005	15.83±0.096	200.0	72
Wadi 1	Wadi Sweanit	15/05/2005	15.63±0.155	151.0	67
Wadi 2	Wadi Fara	15/05/2005	2.0±0.0038	52.0	34
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	15/05/2005	12.26±0.002	116.0	45
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit +Ein Al Fawwar)	15/05/2005	4.92±0.032	96.0	46
PW1	Point before split to canal	15/05/2005	2.46±0.029	54.0	19
PW2	Canal-500 m ahead	15/05/2005	2.56±0.169	48.0	17
PW3	Canal-1000 m ahead house	15/05/2005	2.47±0.0026	48.0	16
PW4	Canal-1500 m ahead after house	15/05/2005	2.87±0.038	58.0	12

Table 4: Total coliform and fecal coliform of various sampling stations through Wadi Al-Qilt

Site ID	Sampling site name	Sampling date	TC	FC
TP1	Water treatment plant-inlet	29/11/2004	TMTC	380
TP1	Water treatment plant-inlet	07/02/2005	135	2
B2	Mikhmas Bridge	06/03/2005		29×10 ³
B3	Mikhmas Bridge- Stone crushing	13/3/2005		11×10 ⁴
B1	AWWTP effluent	16/04/2005		400×10 ³
B2	Mikhmas Bridge	16/04/2005		350×10 ²
B3	Mikhmas Bridge-Stone crushing	16/04/2005		280×10 ²
Wadi 1	Wadi Sweanit	16/04/2005		120×10 ²
Wadi 2	Wadi Fara	16/04/2005		25
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	16/04/2005		210×10 ²
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	16/04/2005		42×10 ²
PW1	Point before split to canal	16/04/2005		10×10 ²
PW2	Canal-500 m ahead	16/04/2005		7×10 ²
PW3	Canal-1000 m ahead house	16/04/2005		8×10 ²
PW4	Canal-1500 m ahead after house	16/04/2005		16×10 ²
B1	AWWTP effluent	15/05/2005		TMTC
B2	Mikhmas Bridge	15/05/2005		TMTC
Wadi 1	Wadi Sweanit	15/05/2005		4500
Wadi 2	Wadi Fara	15/05/2005		48
Wadi 3	Joint point 2 (Wadi Fara + Wadi Sweanit)	15/05/2005		5000
Wadi 4	Joint point 3 (Wadi Fara + Wadi Sweanit + Ein Al Fawwar)	15/05/2005		1200
PW1	Point before split to canal	15/05/2005		128
PW2	Canal-500 m ahead	15/05/2005		139
PW3	Canal-1000 m ahead house	15/05/2005		150
PW4	Canal-1500 m ahead after house	15/05/2005		115

The pH measured for sampling stations through Wadi Al-Qilt showed significant variation and ranges between 6.57 (for Wadi 1 at 13/03/2005) and 8.4 (for B3 at 16/04/2005) during the period of the study. The highest value of pH was measured for the small wastewater stream at the stone crushing station and that is expected to be mixed with some

Table 5: Flow measurements at various sampling stations through Wadi Al-Qilt

Site ID	Sampling station name	Sampling date	Flow (m ³ day ⁻¹)
B1	Al-Bireh WWTP effluent	06/03/2005	5504
B2+B3	Joint point 1	06/03/2005	4683
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	13/3/2005	4380
PW1	Point before split to canal	13/3/2005	47632
B1	Al Bireh WWTP effluent	16/04/2005	4400
Wadi 1	Wadi Sweanit	16/04/2005	1953
Wadi 2	Wadi Fara	16/04/2005	924
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	16/04/2005	2877
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	16/04/2005	12545
PW1	Point before split to canal	16/04/2005	24192
B1	Al-Bireh WWTP effluent	15/05/2005	4597
B2	Mikhmas Bridge	15/05/2005	3076
Wadi 1	Wadi Sweanit	15/05/2005	1072
Wadi 2	Wadi Fara	15/05/2005	1054
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	15/05/2005	2868
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	15/05/2005	14481
PW1	Point before split to canal	15/05/2005	21939

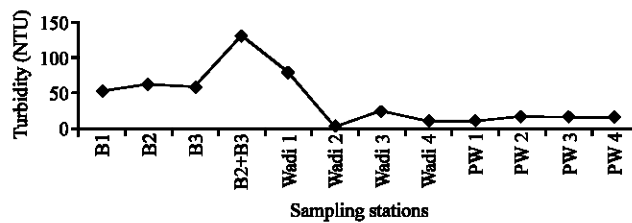


Fig. 2: Variation of average turbidity through sampling stations in Wadi Al-Qilt

wastewater from Qalandia Camp. The increase in pH value referred to the presence of basic components found in domestic wastewater (soaps and detergents). This can be explained by the presence of high concentration of sodium in this sample which was 247 mg L⁻¹. On the other hand, the lowest value of pH found in Wadi 1 may be the result of loss of some sodium and other basic ions by adsorption mechanism on the sediments and clay particles at the bottom of the wadi. Also, the dissolution of carbon dioxide and other acidic gases in the flowing water may increase with time due to the open system with the atmosphere.

As part of the chemical parameters nitrate and chloride are considered as pollution indicators in the evaluation of any water resource. These parameters are generally used for the determination of the level of pollution, type of pollutants and its status. Nitrate is generally an indication of contamination from major nitrogen sources such as a sewage disposal system, animal manure, or nitrogen fertilizers; whereas chloride may originate from dump sites and wastewater containing salt deposits. A similar trend, as for previous parameters due to the dilution process (Table 5) occurred at different points across Wadi Al-Qilt; depression in the concentration was observed. There was a slight elevation in the concentration between AWWTP effluent point (B1) and the point at Mikhmas Bridge (B2+B3). This elevation may be referred to the evaporation process that takes place along the wadi and due to infiltration of part of the flowing water into the bottom sediments. Beside the evaporation and infiltration processes, nitrification during water flow may cause the slight increase in nitrate concentration from B1 to Wadi Sweanit point (Wadi 1).

The four major cations were analyzed during this study, but during the analysis period, calcium and magnesium did not show a significant variation (<100 mg L⁻¹) and according to Palestinian Standard Institution (2004), they are within the allowable concentration for drinking water. Whereas sodium and potassium ions showed a significant variation in their

concentration, the highest concentration of sodium and potassium were 277 (at Wadi 1) and 33 mg L⁻¹ (at B₃) respectively, both measured on 16/04/2005. The minimum concentration of sodium and potassium were 24 and 1.6 mg L⁻¹, respectively, measured at TP1 on 30/12/2004.

High values of COD indicate water pollution, which is linked to sewage effluents discharged from urban areas, industry or agricultural practice. According to Bellos and Sawidis (2005), the input of anthropogenic contaminants (from point discharges mixing with urban and agricultural runoff) causes distinct, but variable, COD concentration peaks, responsible for increasing the concentrations in nutrients and organic carbon in the fresh surface water of the flowing water.

Characterization of Organic Matter Using SUVA Index

Two sets of samples were collected during April and May, 2005 and analyzed for DOC and their UV absorbance were measured at 254 nm. The highest values of DOC and UV absorbance were recorded at AWWTP effluent, Mikhmas Bridge and Wadi Sweanit. The maximum concentration of DOC was 29.86 mg L⁻¹, reported on 16/04/2005 at Mikhmas Bridge for the small stream flowing from the stone crushing station with absorbance value of 45.62 (Table 6). Higher SUVA values indicate that there was an increase in the relative proportion of aromatic carbon in the DOC fraction (Chow *et al.*, 2006). The absorbance and DOC values depends on the relative mix of domestic and industrial wastes and the social-economical profile of the community; type of food consumed and availability of drinking water are among the factors that affect the composition of domestic wastewater. Problems can arise in case of fast wastewater composition changes due to storm events for example (Pons *et al.*, 2004).

Microbiological Analysis

In general, Total Coliform (TC) and Fecal Coliform (FC) are used as indicators for pollution in water analysis. Several samples along the wadis were analyzed for fecal coliform because the flowing water originates from AWWTP effluent and when tested for total coliform gave results that can not be counted. A general trend in the analysis was observed by decreasing the number of fecal coliform colonies going from AWWTP to the open transportation canal. The highest fecal coliform colonies were found for the small stream flowing from the stone crushing station. One of the observations recorded when samples were taken during the two days; the flowing water had a yellow color with bad smell like that of wastewater.

Table 6: Calculated SUVA values for sampling stations through Wadi Al Qilt

Samples collected on 16/04/2005				Samples collected on 15/05/2005			
Site ID	UV Abs (m ⁻¹) (254 nm)	DOC/NPOC (mg L ⁻¹)	SUVA = UV/DOC (L/mg.m)	Site ID	UV Abs (m ⁻¹) (254 nm)	DOC/NPOC (mg L ⁻¹)	SUVA = UV/DOC (L/mg.m)
B1	24.97	16.71	1.49	B1	27.86	16.69	1.67
B2	26.92	17.67	1.52	B2	27.08	15.83	1.71
B3	45.62	29.86	1.53	Wadi 1	26.64	15.63	1.70
B2+B3	27.39	16.88	1.62	Wadi 2	1.11	2.00	0.56
Wadi 1	32.54	17.53	1.86	Wadi 3	19.85	12.26	1.62
Wadi 2	1.60	3.22	0.50	Wadi 4	4.93	4.92	1.00
Wadi 3	19.90	12.25	1.62	PW1	1.29	2.46	0.52
Wadi 4	7.58	5.89	1.29	PW2	1.43	2.56	0.56
PW1	3.72	2.00	1.86	PW3	1.54	2.47	0.62
PW2	3.77	2.00	1.89	PW4	1.86	2.87	0.65
PW3	4.04	1.98	2.04	-	-	-	-
PW4	3.79	1.87	2.03	-	-	-	-

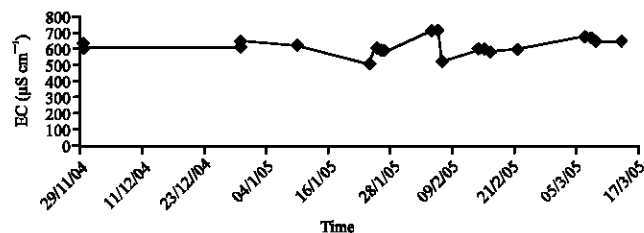


Fig. 3: Variation of EC at JWTP influent (TP1) between November 2004 and March 2005

Variation of pH and Conductivity at TP1

Variation of pH and conductivity with time was studied at the end of the open transportation canal; at JWTP influent (TP1). Considering the variation in measured pH values in the period between November 2004 and March 2005, the highest pH value (8.39) was recorded on 05/02/2005. While the lowest pH value (7.06) was recorded at 14/03/2005. The conductivity of water at the same point varied significantly during the same period and reached a maximum of 702 $\mu\text{S cm}^{-1}$ at 06/02/2005 and a minimum of 500 $\mu\text{S cm}^{-1}$ at 24/01/2005 (Fig. 3). The days between 05-13/02/2005 were heavy rainy days and the water in the canal was very turbid with a bad smell. The highest values of pH and conductivity were observed in that period.

According to Fetter (1994), rocks at the earth's surface are usually fractured to some degree. The fracturing may be mild, resulting in widely spaced joints. Fractures create secondary porosity in the rock. The rain water in the Western part of the study area is considered very high and reaching 700 mm/a. According to Mahmoud and Al-Saed (1997), due to the high urbanization and large built up areas in the Israeli settlements, huge amounts of drained rainwater have been flooded out of these settlements which may affect the public safety and contribute to ecological damage. So, as the heavy rain falls on the catchment area that might be contaminated with wastewater or leachate (generated from waste disposal) or any other pollutants, it will wash down these pollutants and moves them into two directions: part of pollutants move with surface runoff which ends up in the wadis (finally in the open transportation canal) and the second part infiltrates through the geological formations.

Chlorophyll a

Five samples were collected from the end of the open transportation canal during June and July and analyzed for chlorophyll a in the presence of pheophytin. The measured values of chlorophyll a concentration of the five analyzed samples were in the range 9.6 to 16.8 with an average of 13.26 mg L^{-1} . Chlorophyll a is often used as an estimate of algal biomass, with blooms being estimated to occur when chlorophyll a concentrations exceed 40 mg L^{-1} . The measured values of chlorophyll a in the Lake Mantanee (Stanley *et al.*, 2003), were in the range from 0 to 118.5 mg m^{-3} with an average of 11.62 mg m^{-3} . So, the measured values of chlorophyll a with an average of 13.26 mg L^{-1} at the inlet of the treatment plant for flowing water is considered high compared with that of stationary water in lakes.

Heavy Metals

The wastewater influent in AWWTP is considered as combined flow from the residential area and the small industrial facilities in Al-Bireh City. Moreover, the effluent of the treatment plant is combined downstream with the springs' flow, so the dilution process may be the reason behind the low concentration of the various heavy metals. The analysis of several samples is found in Table 7. Three Wadi samples were trace metals contaminated

Table 7: Heavy metals analysis of several samples from Wadi Al-Qilt ($\mu\text{g L}^{-1}$)

Site ID	Sampling point name	Date	Ag	Al	Ba	Cd	Co	Cr	Cu	Fe
B1	AWWTP effluent	16/04/05	0	0	48	3<LOD	5<LOD	0	0	35
B1	AWWTP effluent	15/05/05	0	0	44	5	8	0	0	52
B2	Mikhmas Bridge	15/05/05	0	0	30	0	9	0	0	67
B2+B3	Joint point 1	6/3/2005	0	0	39	0	8	5<LOD	0	8
Wadi 1	Wadi Sweanit	13/03/05	0	0	30	0	6<LOD	0	0	0
Wadi 1	Wadi Sweanit	15/05/05	0	0	13	0	15	0	0	24
Wadi 2	Wadi Fara	13/03/05	0	0	52	0	0	0	0	0
Wadi 2	Wadi Fara	15/05/05	0	0	62	0	2<LOD	16	0	3<LOD
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	6/3/2005	0	0	40	0	0	0	0	0
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	5/4/2005	0	0	32	0	0	9	0	20
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	15/05/05	0	35<LOD	23	0	10	0	0	18
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+ Ein Al Fawwar)	15/05/05	0	0	32	0	17	0	0	2<LOD
PW1	point before split to canal (stagnant water)	13/03/05	0	450	161	0	4<LOD	2<LOD	20	197
PW1	Point before split to canal	15/05/05	0	0	36	0	14	0	0	0
PW2	Canal-500 m ahead	15/05/05	0	0	37	0	16	0	0	13
PW3	Canal-1000 m ahead house	15/05/05	0	0	36	2<LOD	13	0	0	11
PW4	Canal-1500 m ahead after house	16/04/2005	0	0	45	1<LOD	6<LOD	0	0	1<LOD
PW4	Canal-1500 m ahead after house	15/05/2005	0	0	36	4	11	0	0	2<LOD
TP1	Inlet to treatment plant	10/1/2005	0	0	40	0	0	0	0	0
TP1	Inlet to treatment plant	6/2/2005	0	0	21	1<LOD	4<LOD	10	1<LOD	59
LOD			7	40	2	4	7	7	6	7

Site ID	Sampling point name	Date	Li	Mn	Ni	Pb	Sr	Zn	Be	Se	Mo
B1	AWWTP effluent	16/04/05	7		0	26<LOD		169			
B1	AWWTP effluent	15/05/05	7		0	22<LOD		145			
B2	Mikhmas Bridge	15/05/05	7		0	16<LOD		129			
B2+B3	Joint point 1	6/3/2005	7	3	7<LOD	0	527	39	0	0	0
Wadi 1	Wadi Sweanit	13/03/05	8	0	9<LOD	33<LOD	394	27	0	0	7<LOD
Wadi 1	Wadi Sweanit	15/05/05	7		0	9<LOD		127			
Wadi 2	Wadi Fara	13/03/05	0	0	3<LOD	0	190	11	0	0	0
Wadi 2	Wadi Fara	15/05/05	0		0	23<LOD		78			
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	6/3/2005	4	3	4<LOD	26<LOD	393	55	0	0	0
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	5/4/2005	4	5	3<LOD	0	359	30	0	0	0
Wadi 3	Joint point 2 (Wadi Fara+Wadi Sweanit)	15/05/05	5		0	21<LOD		114			
Wadi 4	Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar)	15/05/05	0		0	5<LOD		101			
PW1	point before split to canal (stagnant water)	13/03/05	1<LOD		10<LOD	11<LOD		617			
PW1	Point before split to canal	15/05/05	0		9<LOD	30<LOD		92			
PW2	Canal-500 m ahead	15/05/05	0		0	31<LOD		113			
PW3	Canal-1000 m ahead house	15/05/05	0		0	46		95			
PW4	Canal-1500 m ahead after house	16/04/2005	1<LOD		0	9<LOD		107			
PW4	Canal-1500 m ahead after house	15/05/2005	0		5<LOD	19<LOD		90			
TP1	Inlet to treatment plant	10/1/2005	0	0	4<LOD	9<LOD	175	6	0	0	0
TP1	Inlet to treatment plant	6/2/2005	1<LOD		0	21<LOD		64			
LOD			4	2	15	40	0.5	2	0.3	7.5	8

LOD: Limit of detection

(aluminum, cadmium and lead), while most of the other samples show the presence of various heavy metals such as copper, lead and zinc but under the allowable limit for drinking water (Palestinian Standard Institution, 2004).

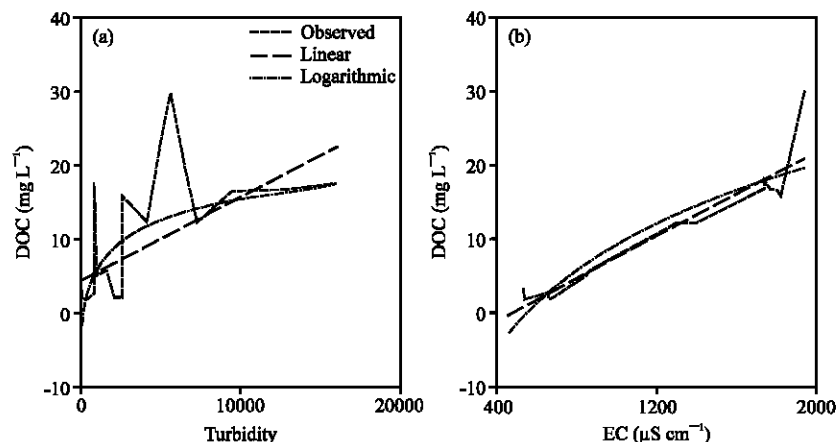


Fig. 4: Correlations of DOC with (a) turbidity and (b) EC

Correlations between Analyzed Parameters

Correlations between analyzed parameters were done using SPSS software. Significant correlations, at 0.01 significance level, were observed between DOC and onsite measured parameters such as turbidity and EC. Such correlations can be used downstream at JWTP to indicate the organic content in the water entering the treatment plant. Linear and logarithmic relations were the best forms to correlate the previous parameters (Fig. 4a, b). Logarithmic relation ($DOC = -3.7372 + (4.1803 * \ln(\text{Turbidity}))$) was better than the linear form between DOC and turbidity, while the linear form was better to describe the other relation:

$$DOC = -6.8254 + (0.0143 \times EC)$$

CONCLUSION

The results obtained for physical, chemical and biological parameters showed that the most polluted section through Wadi Al-Qilt is the part between AWWTP and Wadi Sweanit, indicating pollution of water discharging from springs downstream. Moreover, three springs located in the drainage basin are contaminated with heavy metals, whereas two springs are biologically contaminated. Based on the geological nature of the study area, these springs are directly recharged through fractures and fissures characterizing limestone, so the infiltration of wastewater and other pollutants disposed in the drainage basin will accelerate the deterioration of their quality. According to the field visits made, several sources of pollution may affect water quality downstream such as AWWTP effluent, discharge of wastewater from some Israeli settlements at certain time, stone crushing, human and agricultural activities around Ein Al-Qilt.

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