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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 $BOD_5$, 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 $km^2$. 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

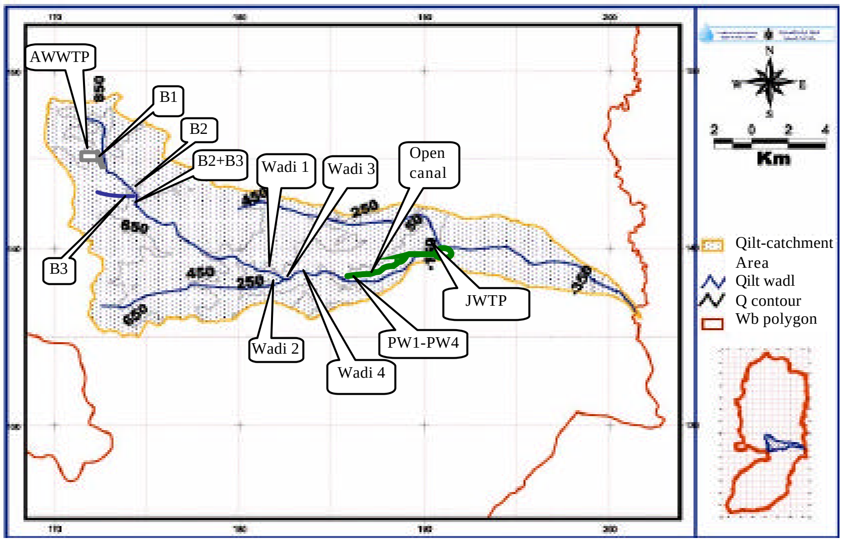


Fig. 1: Sampling stations along the two Wadis

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 (µS $cm^{-1}$) | 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 reatment 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 a head | 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 form 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 $\mu g\ L^{-1}$, 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,TS, $BOD_5$, 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 reatment 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 oint 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 | | $29\times10^{3}$ |
| B3 | Mikhmas Bridge- Stone crushing | 13/3/2005 | | $11\times10^{4}$ |
| B1 | AWWTP effluent | 16/04/2005 | | $400\times10^{2}$ |
| B2 | Mikhmas Bridge | 16/04/2005 | | $350\times10^{2}$ |
| B3 | Mikhmas Bridge-Stone crushing | 16/04/2005 | | $280\times10^{2}$ |
| Wadi 1 | Wadi Sweanit | 16/04/2005 | | $120\times10^{2}$ |
| Wadi 2 | Wadi Fara | 16/04/2005 | | 25 |
| Wadi 3 | Joint point 2 (Wadi Fara+Wadi Sweanit) | 16/04/2005 | | $210\times10^{2}$ |
| Wadi 4 | Joint point 3 (Wadi Fara+Wadi Sweanit+Ein Al-Fawwar) | 16/04/2005 | | $42\times10^{2}$ |
| PW1 | Point before split to canal | 16/04/2005 | | $10\times10^{2}$ |
| PW2 | Canal-500 m ahead | 16/04/2005 | | $7\times10^{2}$ |
| PW3 | Canal-1000 m ahead house | 16/04/2005 | | $8\times10^{2}$ |
| PW4 | Canal-1500 m ahead after house | 16/04/2005 | | $16\times10^{2}$ |
| 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 |

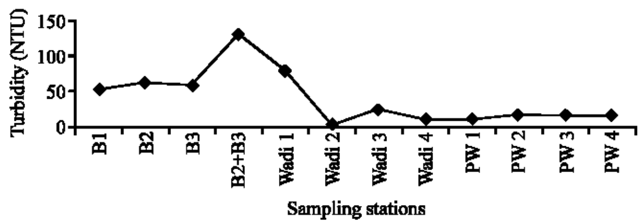


Fig. 2: Variation of average turbidity through sampling stations in Wadi Al-Qilt

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 5 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 $B_3$) 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 | - | - | - | - |

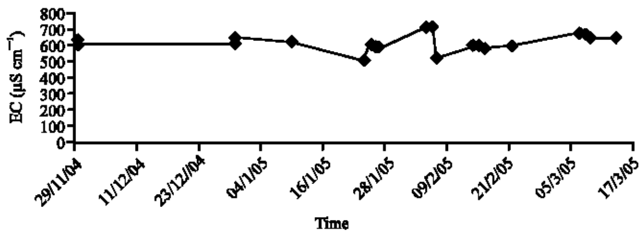


Fig. 3: Variation of EC at JWTP influent (TP1) between November 2004 and March 2005

**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 µS cm$^{-1}$ at 06/02/2005 and a minimum of 500 µS 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 (μg $L^{-1}$)

| 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 (μg $L^{-1}$) | | | 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 (μg $L^{-1}$) | | | 4 | 2 | 15 | 40 | 0.5 | 2 | 0.3 | 75 | 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).

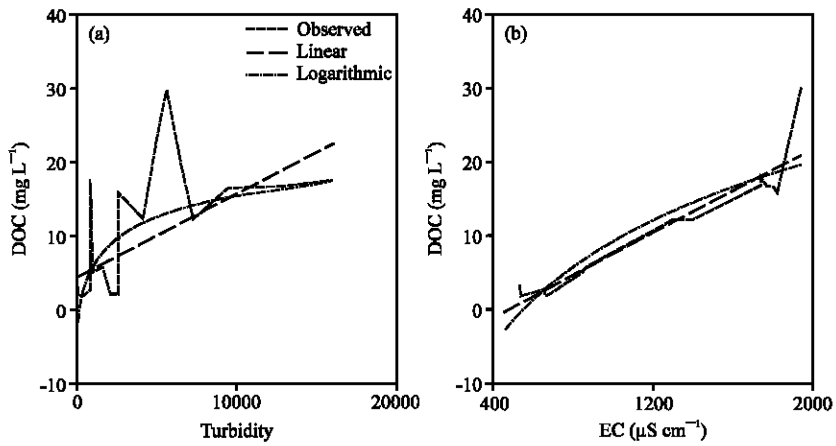


Fig. 4: Correlations of DOC with (a) turbidity and (b) EC

**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 (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.

## ACKNOWLEDGMENT

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