

Abstract

The Wadi Al Zomar has suffered for over fifty years from a variety of domestic, agricultural and industrial pollution sources together with development pressures in the open spaces that surround the river. The major point pollution sources are effluents that enter the stream through Wadi Al Zomar, the largest of the stream tributaries, beginning with deposition of raw sewage from the western side of Nablus. The wadi receives about seventy pollution sources along its route. These include sewage and effluents from towns, Tulkarem City, stone-cutting industries, landfills, leather factories.

This research focused on self purification in the wadi and also pollutants infiltration from untreated wastewater through top soil at different longitudinal sections in a wadi stream, on the other hand, to identify and quantify the degree of pollutants in the infiltrated water and to identify their potential effect on groundwater quality.

The wadi was sampled during two seasons in order to evaluate variations of wastewater quality under different flow conditions and to evaluate the degree of dilution during winter season as a result of rain runoff. Sampling was performed from February 2012 to March 2012 for winter (wet) samples; three samples from four stations along the wadi were collected during wet period after rainfall event on 22/2/2012, 9 & 19/3/2012. Three samples were taken during dry period on 11, 16 & 29/9/2012.

The discharge of sewage from Nablus City into Wadi Al Zomar (~ 25,000-33,000 m³/day) is the main point source of pollution into the system.

The quality of wastewater flowing in wadi Al Zomar was assessed during dry season in terms of (COD, BOD, NH₄, NO₃, PO₄, fecal coliforms and heavy metals), in addition to physical parameters DO, TSS, TDS, pH, EC and Turbidity. The average concentration of these parameters at the first measuring starting point, St.1 at 4 km from the Nablus west outfall of COD, BOD, NH₄-N, NO₃-N, PO₄ and fecal coliforms were 514 mg/l, 247 mg/l, 74 mg/l, BDL, 4.1 mg/l, 1.32E06 cfu/100ml, respectively. Out of the tested heavy metals (Zn, Fe, Mn, Cu, Cr, Ni and Pb) only Zn, Fe and Mn were detected with value of 0.42, 1.24 and 0.12 mg/L, respectively.

The self purification of the wadi during dry season could only be assessed between St.1 and St.3 because along this part of the wadi there are no pollution inputs, with the exception of a few houses in Anabta who discharge their wastewater ahead of St.3. The COD and BOD concentrations decreased substantially while travelling from St.1 to St.2 (10 km from Nablus West outfall) and marginal change was noticed afterwards till St.3 of “COD and BOD” values at St.1, St.2 and St.3 of (514 and 257 mg/L), (259 and 139 mg/L) and (298 and 135 mg/L), respectively. This shows that the organic matter was removed while travelling from St. 1 to St. 2, especially that the calculated incremental increase of BOD and COD from Anabta houses were 12 and 24 mg/L, respectively. The changes in COD/BOD ratios at ST.1, 2, 3 and 4 were (2.0, 1.9, 2.4 and 2.3) respectively. The COD/BOD ratios at St.1 and St.2 are in conformity with typical ratios of domestic sewage of 2, indicating high biodegradability of organic

matter. Meanwhile, the ratio increased afterwards due to removal of readily biodegradable via self purification processes of organic matter.

Different from the course of the organic matter changes, $\text{NH}_4\text{-N}$ concentration was marginally changed between St.1 and St.2 of respectively 76 mg-N/L to 74 mg-N/L, but afterwards was substantially reduced to 50 mg-N/L at St.3. NO_3 was not detected at St1, St2. Nor St.3. Apparently between St.1 and St.2 heterotrophic bacteria were dominant, while autotrophic bacteria was dominant between St.2 and St.3, and $\text{NH}_4\text{-N}$ reduction was due to simultaneous nitrification - de-nitrification. The DO and pH measured at St.1, St.2 and St.3 were respectively (0.40 mg/L, 7.9), (3.3 mg/L, 7.8) and (0.3 mg/L, 7.7). The PO_4 was marginally changed as the PO_4 concentration at St.1, St.2 and St.3 were 4, 3 and 2.5 mg/L, respectively.

The Fecal Coliforms concentration at ST1, St.2 and St.3 of $1.3\text{E}+06$, $7.4\text{E}+05$ and $2.1\text{E}+05$, respectively, were not significantly different at the 95% confidence interval.

The Zn, Fe and Mn were reduced all the way through from St1. till St.4 from 0.42, 1.24 and 0.12 mg/L to 0.08, 0.11 and 0.04 mg/L, respectively. The other measured heavy metals of Cu, Cr, Ni and Pb were not detected anywhere.

These parameters (COD, BOD, $\text{NH}_4\text{-N}$, PO_4 , FC) were increased at ST.4 due to additional sources of domestic sewage from Tulkarem City, and NO_3 remained zero.

The quality of wastewater flowing in wadi Al Zomar was assessed during dry season in terms of (COD, BOD, NH_4 , NO_3 , PO_4 , fecal coliforms and heavy metals), in addition to physical parameters DO, TSS, TDS, pH, EC and Turbidity. The average concentration of these parameters at the first measuring starting point, St.1 at 4 km

from the Nablus west outfall of COD, BOD, NH₄-N, NO₃-N, PO₄ and fecal coliforms were 509 mg/l, 128 mg/l, 50 mg/l, 1 , 3.4 mg/l, 2.2E06 cfu/100ml, respectively. Similar to the results of the dry period, out of the tested heavy metals (Zn, Fe, Mn, Cu, Cr, Ni and Pb) only Zn, Fe and Mn were detected with value of 0.10, 0.23 and 0.07 mg/L, respectively.

The self purification of the wadi during wet season could only be assessed between St.1 and St.3 because along this part of the wadi there are no point sources of pollution, with the exception of a few houses in Anabta who discharge their wastewater ahead of St.3. The COD and BOD concentrations decreased substantially while travelling from St.1 to St.3 (18 km from Nablus West outfall) of “COD and BOD” values at St.1, St.2 and St.3 of (509 and 220 mg/L), (439 and 138 mg/L) and (242 and 67 mg/L), respectively. At St.4 the COD and BOD concentrations were 246 and 92, respectively, which are less than expected as of the dry season results, most likely due to dilution with rain water. The changes in COD/BOD ratios at St.1, St.2, St.3 and St.4 were 2.3, 3.2, 3.6 and 2.7, respectively. The relatively high COD/BOD values indicate the poor biodegradability of organic matter due to mixing of wastewater with runoff, especially in the un-urban middle part of the wadi coinciding St.2 and St.3.

NH₄-N concentration was sharply decreased from 50 mg-N/L at St.1 to 27 mg-N/L at St.2 and remained almost stable afterwards. Unlike the dry period, nitrate concentration were present at relatively high concentrations at St.1, St.2, St.3 and St.4 of 1.0, 5.6, 4.4 and 2.6 mg-N/L, accompanied with high DO of respectively 4.0, 5.0, 5.0 and 5.0 mg/L. the high DO concentrations had apparently hindered the

nitrification processes. Noticeably, nitrate concentration at St.1 which is the closest to Nablus west outfall and St.4 in Tulkarem city are the lowest indicating denitrification.

The wastewater temperature at the four stations was around 15°C, the relatively high concentration of nitrate. The pH measured at St.1, St.2, St.3 and St.4 were respectively 7.9, 7.8, 7.7 and 7.7. The PO₄ was marginally changed as the PO₄ concentration at St.1, St.2 and St.3 were 4, 3 and 2.5 mg/L, respectively. The PO₄ was marginally changed as the PO₄ concentration at St.1, St.2, St.3 and St.4 were 3.4, 3.2, 1.6 and 1.8 mg/L, respectively.

The Fecal Coliforms concentration at St.1, St.2, St.3 and St.4 of 2.2E+06, 3.5E+06, 8.2E+05 and 3.4E+05, respectively, were not significantly different at the 95% confidence interval.

The Zn, Fe and Mn concentrations were stable all the way through from St1. till St.4 from 0.1, 0.23 and 0.07 mg/L to 0.06, 0.18 and 0.05 mg/L, respectively. The other measured heavy metals of Cu, Cr, Ni and Pb were not detected anywhere.

The rate of infiltration (cm/min) into subsurface was generated based on flow measurement at St.1 and St.2 only and generalized to the whole wadi. This is because along this section of the wadi (St.1 to St.2) (1) there is no pollution input from human activities, (2) vegetation cover is minimal so evapotranspiration could be neglected. The obtained infiltration rate of 0.09 cm/min was also confirmed by double ring infiltrate rate test. Accordingly infiltration rate for other sections of the wadi are calculated based on the double ring infiltration rate test.

The water mass balance assessed for section (1), located between St.1 and St.2, showed that about which 11800 m³ and 10000 m³ were lost during dry and wet season, respectively. Out of this lost water, only 1% was due to evaporation during both seasons, while 43% and 16% were infiltrated into the sub soil during the dry and wet seasons, respectively.

The BOD and COD concentrations during dry season at ST 1, 3 and 4 were respectively [73(4.95), 67(4.95) and 149(8.5)] mg/l and [304.7(62), 212.5(86) and 173(24)] mg/l. These concentrations showed reduction in the measured pollutants COD (35-59) %, BOD (31-72) %.

The ammonia NH₄-N concentrations at St.1, St.3 and St.4 were [55 (4), 68.0(3) and 67.1(15)] mg/l. The results showed substantial decreases in NH₄-N concentrations in St.1 and St.4 by percent of (9-28) %, but in the St.3 the concentration were higher than for surface concentrations by 35 %. The NH₄-N increased from 50.3(2) to 68.0 (3) mg/l.

Fecal coliforms concentrations were sharply decreased at St. 1, 3 and 4 were [5.66(5.5), 26.5(5.6) and 21.3(19.2)]*10³ cfu/100 ml with reduction percent range from 87 to 100%.

The nitrate NO₃-N were presence in infiltrated samples at St.1, St.3 and St.4 were [33(35), 20(18) and 14(13)] mg/l, respectively. In same time the dissolved oxygen increased by 3-folds to 4- folds of DO concentrations of surface wastewater.

Phosphate (PO_4) concentrations increased in St.1 and St.3 and decreased in St.4 in dry season, but in wet season the phosphate increase at St.3 and St.4 (48-200) % and increased in St.1.

The heavy metals in infiltrated samples decreased in case of Zn and Fe in the range of (48-73) % at all stations in the dry season, but for Mn the opposite occurred, the Mn concentrations increased from 1-fold to 6-folds of the Mn concentrations in the surface wastewater.

In wet season, the BOD and COD concentrations at stations 1, 3 and 4 were respectively [33(1), 61(42) and 20(1)] mg/l and [80(8), 181(25) and 157(42)] mg/l. These concentrations showed reduction in the measured pollutants COD (25-84) %, BOD (31-89) %.

The ammonia $\text{NH}_4\text{-N}$ concentrations at St.1, St.3 and St.4 were [9 (2.5), 24(15.5) and 16(6.6)] mg/l. The results showed substantial decreases in $\text{NH}_4\text{-N}$ concentrations in ST.1 and ST.4 by percent of (14-81) %.

Fecal coliforms concentrations were sharply decreased at stations 1, 3 and 4 were [9.53(8.0), 175(28.5) and 7.17(7.4)]* 10^3 cfu/100 ml with reduction percent range from 79 to 100%.

The nitrate $\text{NO}_3\text{-N}$ concentrations were decreased in the infiltration samples at St.1, St.3 by percent range from 22% to 40%, but for ST.4 the concentration increased by from 2.6 mg/l to 4.4 mg/l .

The concentration of PO_4 in the infiltrated wastewater was range of (1.7-4.9) mg/l in both seasons, the results showed increase in PO_4 at most stations except St.4 in dry season and at St.1 in wet season.

The heavy metals were decreased in case of Zn and Fe in the range of (48-73) % at all stations, but for Mn the opposite occurred, the Mn concentrations increased from 1-fold to 6-folds of the Mn concentrations in the surface wastewater.

Chemical mass balance was used to evaluate pollution fluxes lost or added to the system by calculating the difference in fluxes between St.1 and St.2.

The calculated surface flowing fluxes loads in terms of Kg/day of COD, BOD, N and P along the wadi in wet and dry seasons at the four stations showed reduction in the loads due to self purification processes and infiltration into subsurface occurring through the flowing along the wadi. In dry season, the reduction in the fluxes loads from St.1 to St.3 range from (57-69) %. In wet season, the reductions were less than in dry season. The reduction percent from St.1 to St.3 range from (40-70) %. These pollutants relatively increased at downstream (St.4).

The penetrated loads for N, P, COD and BOD loads in section (1) were respectively (623, 37, 1423 and 3653) Kg/d in the dry season and (174, 37, 379 and 1391) Kg/ day in the wet season, these represented percent of (31, 34, 29 and 27) % for total loads enter the system (wadi) in the dry season and (7, 21, 3 and 5) % in the wet season, which indicate large quantities of organic matter, nitrogen and phosphorus infiltrated through soil bed up to 2.0 m deep, these pollutants may be go deep in the ground depend on the chemical and biological processes and finally reach the groundwater.

The sediments samples results at ST.1 and ST.2 showed high values of some heavy metal such as (Cu, Ni, Pb and Cr); Heavy metals may be very mobile in the soil if they are present in the leachate as organic metal complexes.