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Using Biological Indicators to Characterize the Natural Flow Regime in Wadi Zomar Stream/Palestine

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ABSTRACT

The Zomar stream has been suffering for over 50 years from a variety of domestic, agricultural and industrial pollution sources together with development pressures in the open spaces that surround the stream. The aim of this study was to assess the physicochemical and microbiological quality of the Wadi Zomar through one-year long monitoring in West Bank, Palestine in order to assess the key factors and variables that play role in the environmental flow regime of the stream. In the base flow conditions, the amount of pollutant load varied temporally according to the amount of load from point sources along the Wadi and spatially with distance from the same sources. Significant variation was observed in response to the hydrological behavior of the catchment. The data shows that commonly the bacterial community in the Wadi is affected by two factors; the first is the cumulative factor from the beginning of the winter season, where the bacterial potential to re-enhancing its growth is limited with more rain events along the hydrological year. The second is flow event dilution where the maximum bacterial removal was noticed at the maximum flood within one flow event. Higher flows and more frequent washout of bacteria led to lower bacterial concentrations. Average total Coliform levels in Zomar stream were 7×10^{16}, 4×10^{16}, 8×10^{16} cfu/100 mL all over the year. During discharge event this average reduced to 7×10^{14}, 4×10^{7}, 1×10^{14} cfu/100 mL showing log removal of 2, 9 and 2.9 for all three sites, Deir Sharaf, Anbta and Tulkarem, respectively. In case of FC, average concentration were 4×10^{13}, 6×10^{12}, 2×10^{11} cfu/100 mL and reduced to 5×10^{9}, 4×10^{5}, 2×10^{10} cfu/100 mL showing log removal of 3.9,7.2,1.

Key words: *Escherichia coli*, *Pseudomonas*, *Enterococcus* and *Klebsiella spatial*, temporal, pathogen, fecal coliform, hydrological parameter, restoration

INTRODUCTION

Despite the lack of appropriate scientific knowledge, there remains a need to initially develop management procedures in the short term to facilitate achieving the longer-term goal of ecological sustainability. One of the challenges in achieving this goal is the development of a flow management system that mimics natural flows. Understanding the dynamics of the stream dependent ecosystems is crucial to evaluate restoration efficiency and effectiveness (Puckridge *et al.*, 1998, 2000; Pettit *et al.*, 2001). Issues include the restoration of condition to clarify and measure the impact of increased water to enter and setting goals for restoration. While assessing the validity of the stream also included the monitoring of many variables, biotic and a biotic (Norris and Thoms, 1999).

Environmental flow have been increasingly recognized as a central issue in sustainable water resources management (Kashaigili *et al*., 2007). Environmental Flow Requirement (EFR) for water resources allocation requires that a certain amount of water to be purposefully left in or released into an aquatic ecosystem to maintain a condition that will support its direct and indirect use values (King *et al*., 2003).

The process of setting environmental flow in a basin will relate to the degree of "environmental health" we wish to maintain in the basin ecosystems. The production of hydrological, chemical, socioeconomic and ecological information about the flow in question is fundamental. Environmental flows are the flows of water in streams that are necessary to keep them healthy; this concept has various key aspects. River flow has regimes to which biotic populations have adapted over millions of years; the flow regime is composed of the following elements (Stewardson and Cottingham, 2002).

Protecting and restoring stream flow regimes and hence the ecosystems they support by providing environmental flows has become a major aspect of stream basin management. There is growing awareness of the pivotal role of the flow regime (hydrology) as a key 'stream' of the ecology of streams and their associated floodplains (Richter and Powell, 1996; Poff *et al*., 1997; Puckridge *et al*., 1998; Bunn and Arthington, 2002; Naiman *et al*., 2002).

This study has introduced the main factors that control the relation between the hydraulic parameters and ecological life that maintain a healthy ecosystem. These factors and mechanism of flow with respect to different kind of biota were based on bacterial content as indicators. The presence of pathogens in one hand indicate the deterioration of life surrounded the stream, in other hand the presence of common flora and Coliform in considerable quantities helps the system to reduce the organic pollution and restore its organic quality. Such balance required special hydraulic conditions that should maintain a balance relation between different kinds of biota to support a healthy system.

MATERIAL AND METHODS

Study area: West Bank climate resembles east Mediterranean climate that is characterized by semiarid with annual rainfall between 400-600 mm/year and high evaporation rate that reach 100 mm/year (OPTIMA, 2007). The effects of climatic variability and climate change on human beings and on the aquatic increase water crisis (Carvajal-Escobar, 2008). It has been recognized for more than a decade that there are strong links between the ecological processes and the hydraulic, hydrological, thermal and sediment logical variables of the stream and that the dynamic flow patterns that are maintained within the natural range of variation will promote the integrity and sustainability of the freshwater ecosystems (Baron *et al*., 2003).

Wadi Zomar exposed to major pollution by human activities caused serious health problems and other economic costs related to water treatment, remediation and locating a new water supply, become evident (Gasana *et al*., 2002). The Wadi Zomar is used as drainage for the sewage from the towns of Nablus, Tulkarem and the villages located at the banks of the Wadi.

The Zomar Stream is the name given to the upper 44 km section of Alexander River running from the mountains of the West Bank to the coastal plain (Fig. 1). The whole Zomar Wadi is located in the northern part of the West Bank and its area is around 55 km^2 as shown in Fig. 1. The hydrographic catchments area of the Zomar Valley is about 22 km long and 5 km wide (OPTIMA, 2007).

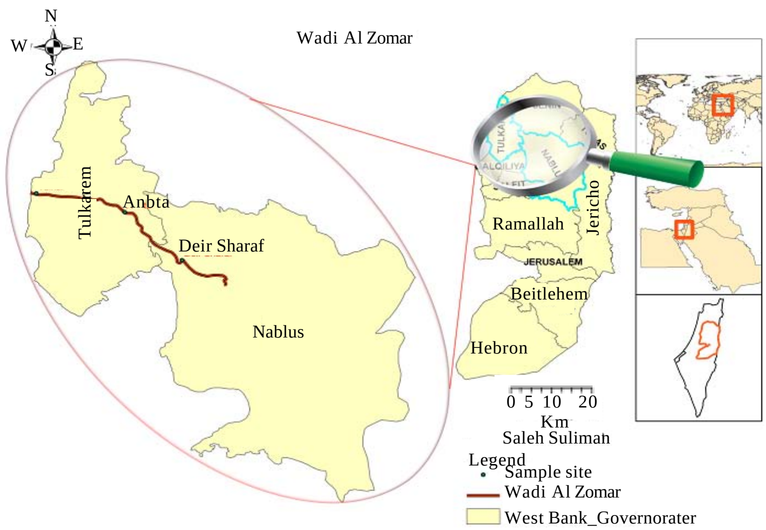

Fig. 1: The Zomar transboundary stream map

Stream restoration is an absolute necessity, with primary ecological and landscape impacts and with high value in terms of its contribution to recreation, quality of life and tourism services (Bar-Or, 2000), however, the recovery of the stream's environmental and social functions have taken an increasingly important place on Palestinians public agenda in recent years. Hydrology strongly controls the transport and fate of microorganisms in water streams (Schaffter and Parriaux, 2002; Collins and Rutherford, 2004), The process-based hydrological modeling tools which use the principles of conservation, destruction and development, has been an article of opinion and are used to simulate these processes in the first place for species that are considered indicators of the nature of the balance of watershed (Bauffaut and Benson, 2003; Coffey *et al.*, 2007).

Data collection: This study was intended to enable estimates of seasonal and annual pollutant loads based on representative storm events, provide a method for evaluating the environmental risk of storm water discharges and their impact on the quality of receiving waters and to aid in identifying the sources of pollutants; Sediment samples were collected after an event at a consistent location near the point where storm water samples were taken. The resulted data out of this study will be used later to construct an environmental flow model in order to suggest the best scenarios with optimum hydraulic conditions that regulate the restoration process and support a sustainable healthy ecosystem in Wadi Zomar.

Selection of sampling site: A total of three sampling locations were selected for the assessment of Wadi Zomar (Table 1, Fig. 1) illustrates the sampling points along the stream.

Samples location: Samples were taken from three locations as shown on Fig. 1:

- **Deir Sharaf:** This location receives high load of sewage and industrial wastes
- **Anbta:** This location was selected to evaluate its effect on self purification occurred because of the long distance between the two sampling points

Table 1: Sampling site identification information

Location No.	Location title	Permanent mark	GPS location North	East	Elevation (m)
1	Deir Sharaf	Dam	32°15´38.21´´	35°10´29.29´´	285.9
2	Anbta	Eman school	32°18´16.95´´	35°07´07.25´´	162.0
3	Tulkarem	Dam	32°19´25.79´´	35°01´14.26´´	55.3

Table 2: The main physical, chemical and common flora for samples from sampling locations at different times during the hydrological year 2009/2010

Location	Sample date	pH	TDS*	Temp.	Cond.	COD*	BOD*	NH4-N*	PO4-P*	NO3*	FC edge	FC mid.	TC edge	TC mid.	Q	Pw
Deir Sharaf	31.1.2010	7.4	154	19.6	307	176.0	51	41.4	1.72	0.3	12*109	2*109	7*1014	5*1012	0.22	3.1
Anbta	31.1.2010	7.6	158	19.2	312	94.8	37	31.2	1.40	0.6	2*1010	8*109	6*1014	4*1013	0.16	2.4
Tulkarem	31.1.2010	7.8	463	20.7	932	142.2	28.2	21.1	0.10	1.2	9*1010	8*109	2*1014	1*1013	0.39	2.8
Deir Sharaf	7.2.2010	7.9	470	19.8	970	120.4	15	11.4	1.20	0.8	12*1012	3*1010	7*1016	2*1012	0.78	3.9
Anbta	7.2.2010	7.1	612	18.6	1240	122.2	35	13.0	0.13	0.7	5*1010	6*109	6*1014	4*1011	0.18	2.6
Tulkarem	7.2.2010	7.2	636	20.1	1298	53.5	20	23.6	1.00	1.1	7*1010	3*108	2*1014	6*1010	0.36	3.5
Deir Sharaf	14.2.2010	7.2	545	20.0	1103	78.5	30	14.4	2.70	0.2	4*1012	8*1010	2*1016	4*1012	0.38	3.6
Anbta	14.2.2010	6.8	682	17.0	1380	99.3	35	10.7	1.90	0.5	6*1012	4*109	5*1014	8*1012	0.18	2.8
Tulkarem	14.2.2010	7.1	783	18.5	1534	105.9	40	19.9	5.50	0.8	2*1013	6*1010	1*1014	3*1012	0.29	3.0
Deir Sharaf	21.2.2010	7.2	458	17.3	910	385.3	180	31.1	10.40	7.7	4*1013	3*1010	7*1016	4*1014	0.10	2.4
Anbta	21.2.2010	6.8	430	18.3	853	385.6	165	26.6	8.14	4.0	8*1011	3*1010	4*1016	8*1013	0.87	2.5
Tulkarem	21.2.2010	7.1	560	21.1	1110	386.0	150	43.2	12.40	3.6	4*1012	2*1010	8*1016	2*1014	0.22	2.9
Deir Sharaf	2.3.2010	7.4	388	20.1	774	67.6	28	38.4	1.20	1.6	5*109	3*108	8*1014	8*106	2.60	5.5
Anbta	2.3.2010	7.6	257	22.7	520	4.6	2	4.6	0.80	1.3	4*105	8*104	4*107	6*106	0.76	3.6
Tulkarem	2.3.2010	7.2	370	21.2	750	29.9	10	20.9	0.60	0.8	2*1011	6*1010	6*1016	4*1015	0.78	3.8

*Units are in mg L^{-1}, FC: Fecal Colifor, TC: Total Coliform units are cfu/100 mL, discharge (Q) (m^3 sec^{-}), PW: Wetted Perimeter (m), EC: Electrical Conductivity (µS cm^{-1}), Temp.: Temperature (°C), TDS: Total Dissolved Solids, Cond.: Conductivity, COD: Chemical Oxygen Demand, BOD: Biochemical Oxygen Demand

- **Tulkarem:** This location was selected as far as along the Zomar stream after Tulkarem city near the green line

These sites were identified by landmarks and by global positioning system as shown in Table 1.

Sample collection and analysis: The sampling frequency was weekly and after each raining event from three sites. Sample collection lasted from Jan 2010 to March 2010. The samples of raw wastewater were collected in sterile 2-L plastic bottles, stored at 4°C, held in sterile boxes and sent to the laboratory within 1-2 h of collection where they were analyzed within 6 h for microbial parameters and 24 h for other chemical parameters (Donnison and Cooper, 1990). The measured parameters for the storm water analysis are listed in Table 2.

Specific enteric pathogens *E. coli*, *Enterococcus*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa* were isolated and measured according to APHA (American Public Health Association, 2005). Other Cations and Anions were analyzed directly using spectrophotometer and WTW Inolab pH/Oxi meter (American Public Health Association, 2005).

Conceptual model: The composition and structure of native stream ecosystems are strongly linked to natural hydrologic variability by managing stream flows for restoration. A conceptual model for the description, explanation, prediction and control of hydrogeologic conditions (topography, geology and climate) is composed by three systems of physical, chemical and biological parameters (including pathogens and common flora): the Hydrogeologic Environment, the Surface water Regime and biological community.

Conceptual models can be viewed as qualitative or quantitative statements of hypotheses concerning the nature of ecological risks. While it is likely that all risk assessments will require a conceptual model, it is clear that the models will vary with circumstances. To predict the conceptual model for Wadi Zomar restoration, we follow up rain events from the beginning of winter season and the bacterial community was predicted monthly with respect to both actual monthly rain events and cumulative amount of monthly Rainfall. We are tried to assess the whole factors and variables that control the process of natural restoration for the Wadi, as well as, the spatial and temporal parameter that affect the whole process. Such identification of the hydrological, chemical and related biological community can help for building a new visualized model where the optimal condition where the healthy environment is exist can be predict by adjusting different recognized key factors out of this work. In Natural River at normal condition we study the factors that cause stream pollution (deteriorate stream water quality) but in our case we deal with wastewater flow and the exception is the dilution resulted from discharge of fresh rain water in winter season.

Determine the natural flow regime, identifying different parameters that controlling:

- Deterioration of water quality and consequently biota
- Dilution of wastewater that restores or save a healthy environment. This done with reference to point that achieves best condition during one rain events

Statistical analysis: HEC-RAS is a free River Analysis System (RAS) and computer program that models the hydraulics of water flow through natural rivers and other channels. The program is one-dimensional, meaning that there is no direct modeling of the hydraulic effect of cross section shape changes, bends and other two-and three-dimensional aspects of flow. The program was developed by the US Department of Defense, Army Corps of Engineers in order to manage the rivers, harbors and other public works under their jurisdiction; it has found wide acceptance by many others since its public release in 1995. HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The HEC-RAS system contains four one-dimensional river analysis components for: (1) steady flow water surface profile computations; (2) unsteady flow simulation; (3) movable boundary sediment transport computations and (4) water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed Gregory (Gregory *et al*., 2002).

HEC-RAS has the capability to perform inundation mapping of water surface profile results directly from HEC-RAS. Using the HEC-RAS geometry and computed water surface profiles, inundation depth and floodplain boundary datasets are created through the RAS Mapper. Additional geospatial data can be generated for analysis of velocity, shear stress, stream power, ice thickness and floodway encroachment data (Gregory *et al*., 2002).

RESULTS AND DISCUSSION

Wadi Zomar River

Flow events: Figure 2 was processed using the output of two years simulation using HEC RAS, it shows the daily flow events and stages for the hydrological years 2008/2009 and 2009/2010. The HEC RAS model is used to estimate water surface profiles at a range of discharges. (Carvajal-Escobar, 2008).

The average wetted perimeter (Fig. 3) is also calculated from model output. The three flow events chosen to demonstrate the Flow Events Method: bed drying, with less base flow in summer time (mostly waste flow), bar formation and floodplain inundation—are low, medium and high flow events, respectively. Discharges threshold for bed drying (less than 0.14 m^3 sec^{-1}), bar formation (less than 0.4 ms sec^{-1}) and floodplain inundation events (over 3 m^3 sec^{-1}) all indicated as dashed lines, show all three events are episodic and occur at least once each year. These thresholds are, respectively the break-point in the wetted perimeter curve (Fig. 3). Flow must drop below threshold value, mentioned above, before the large area of the bank edges being exposed and rise above thresholds for bar formation and floodplain inundation. The threshold discharges and magnitudes

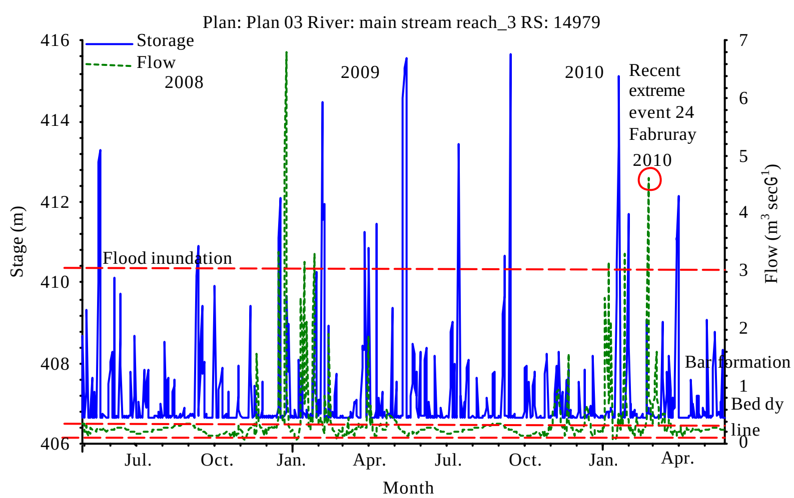

Fig. 2: Two years flood event in Zomar stream using HEC RAS program

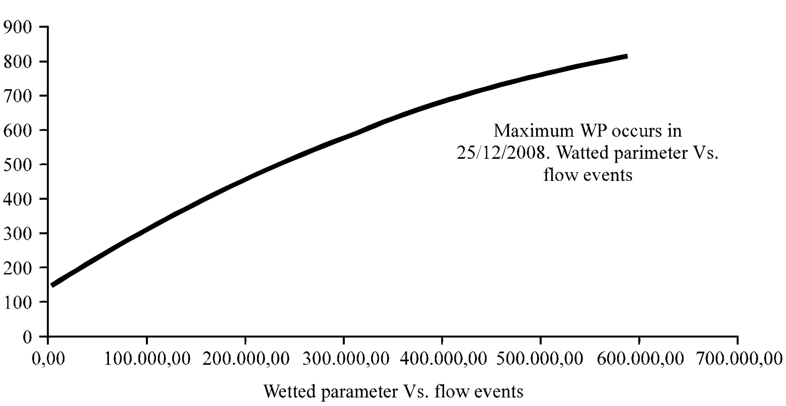

Fig. 3: Wetted parameter values for 2 years using values computed by HEC RAS program

for these flow events are visualized in Fig. 2 which were generated using the HEC RAS modeling program for a 2 years flood in Zomar stream. Figure 3 also visualized the maximum flood event through the 2 years period that occurs in 28 December 2008. Such extreme flood events occurs at least once each three years, however the flow event begin pass quickly to return to the base flow within 5-7 days later. Therefore, the recurrence in flood inundation through the years, as well as the amount of base flow still the main factors that play roles in the process of keeping healthy environment surrounding stream path.

The data shows that an average of five bed drying events occurs each year, most of these events occur in September and October at the beginning of winter season. In the previous 2 hydrological years, the significant rainwater events delayed to December which allowed more drying and exposure of the bed. The presence of dry period in the first 2 months of winter season enhance a very bad and unhealthy condition for the community surrounding the stream, moreover a lot of spring that discharge some water to the stream dried in a condition that make all the water in the stream consist of small amount of pure waste with huge amounts of nutrients that facilitate the excessive bacterial and pathogens growth.

Spatial and temporal Hydrochemical variation: The main physical, chemical values and common flora for samples from different locations are present in Table 2.

In general, all physicochemical parameters vary according to the hydraulic status of the Wadi, in the extreme drought conditions (directly before the rain event), most of the stream content is wastewater. However, the pH values was found relatively about 6.8, this neutral pH support the growth of several types of bacterial species mainly pathogens along the stream, while in wet conditions the pH value raise to around 8 which promote alkaline favor species to be more dominant. The same role of hydraulic related parameters is applied for COD (Chemical Oxygen Demand) with values range between 4.6 to 386 mg L^{-1} and maximum BOD (Biochemical Oxygen Demand) 150 mg O_2 L^{-1} in wet conditions and 2 mg O_2 L^{-1} in dry one. NH4-N reach 43.2 mg L^{-1} in dry conditions directly before the storm and 4.6 mg L^{-1} in the maximum discharge conditions the same trend for PO4-P values with range between 12.4 and 0.8 mg L^{-1} at high flow rate. Spatially, the exception was found in the Deir Sharaf sampling point because of its closure to a point source pollution that resulted from domestic and industrial activities In general the relatively high susceptible point for anthropogenic activity was found near Deir Sharaf point in the upper part and the low susceptible point values was found near Anbta point, with less human activities. The lowest BOD value was measured at Anabta after big storm event at the end of February, this can be referred to high potential of self purification, where no other contaminant contribution. In contrast the Deir Sharaf point shows a high BOD levels, in spite of good discharge (Table 2). As a result, the organic pollutant input to the various locations is not consistent, as indicated by the wide difference between the minimum and maximum BOD values at all locations. The above results reflect the potential of system restore under normal conditions with low pollution load and enough dilution from natural runoff which lead to high self-purification capacity along the stream path (Fig. 1).

On the other hand, the nutrients load (ammonia and phosphorus) along the stream shows well correlation with the BOD values and consequently the fecal Coliform count. Growth of natural digesters such as Nitrosomonas and Nitrobacter will enhance in the presence of nutrients and suitable pH. The high discharge rate can reduce the ability of pathogens for competition and as a result lowers significantly the number of pathogens as more cumulative amount of runoff wash it along the season (Fig. 5, 6). Finally, all of these conditions lead to a good balanced environment in ecological term. This finding is supported by a different researcher (Jannasch, 1968).

Nitrate levels followed a pattern similar to BOD and also appear to be affected with flow discharge. The beginning of storm event, the pollution concentrations shows dramatic temporal shifts, reflecting the so-called first flush effect in the stream then the concentration decrease as storm proceeding (Table 2). The amount of rain and consequently discharge is not highly enough to continue the dilution or self restoration processes for the stream. The problem getting more complicated within summer time. In summer, the high evaporation and absence of precipitation concentrate the pollutants, leading to restricted growth for few types of pathogens, rather than natural digester and other type of common flora. The eluted water from sediments samples shows an increasing in nitrate concentration, this might be refers to nitrates absorption by plants root near the edges that lead to more concentrated amount. Low nitrate in running samples is mainly due to the absence of proper time for oxidation. Table 2 shows a limited Nitrification processes where a sharp decrease in the ammonia level accompanied by a more moderate increase in levels of nitrate in this part of stream begin to occur only downstream.

Location Tulkarem had the lowest ammonia concentrations, where location Deir Sharaf had the highest concentrations. This might be due to the relative ease with which marine organisms consume ammonia. Orthophosphate concentrations were highest at Tulkarem location followed by Deir Sharaf location (Table 2). Both locations are surrounded by agricultural areas besides sewage which may contribute to these relatively high levels (Environmental Protection Agency, 1986). Almost all high concentrations of orthophosphate were followed by algal blooms, as evident by visual observation of both water color (greenish) and the deposits of algae. This enforces the proposed role of phosphorus in the process of eutrophication. Orthophosphate concentrations, however, deviated little during the course of the streams flow.

The nutrients concentration at Deir Sharaf location enhance significantly the persistence of microorganisms, because this location subjected to a continuous sewage discharge with a lot of nutrient that keep the bacterial community active and lower the stream ability for self purification at this section. In contrast Anbta location has different behavior since sampling point so far to sewage discharge point. The restoration process was clearly indicated in Anabta point. For example, ammonia concentration decreases with discharge event, because the main source of pollutants comes from sewage point near Deir Sharaf. This promotes enough time for purification and natural bio-digestion for different kinds of organic pollutants. Tulkarem location also has different behavior from other two sources, since the location of sampling point lies at the end of stream and consist the collector for different source of pollutant along the stream path. In addition to the agriculture lands around this point and the discharge from sewage system of Tulkarem district.

Hydrological parameters and bacterial activities

Biological response: The hydrological year 2009/2010 was typical in term of rain events pattern with regular interrupted period (PWA, 2010). Such regular events enhance what is “cumulative effect" that limited the bacterial growth with time, means that even if concentration is lower, the overall load might be higher. Bacterial communities decrease after each rain events because nutrients and colonies wash out, the bacteria lost the ability to re-build its communities again due to short drought period where the second rain event make further flush out and so on (Fig. 4).

Four pathogens species were isolated out of the samples. These are *E. coli*, *Klebsiella*, *Enterococcus* and *Pseudomonas*. In general for the mid-stream samples, pathogens show decrease with rainfall events in all location except in Deir Sharaf because of nearby wastewater discharge point, where the settled and running samples show increase in all location.

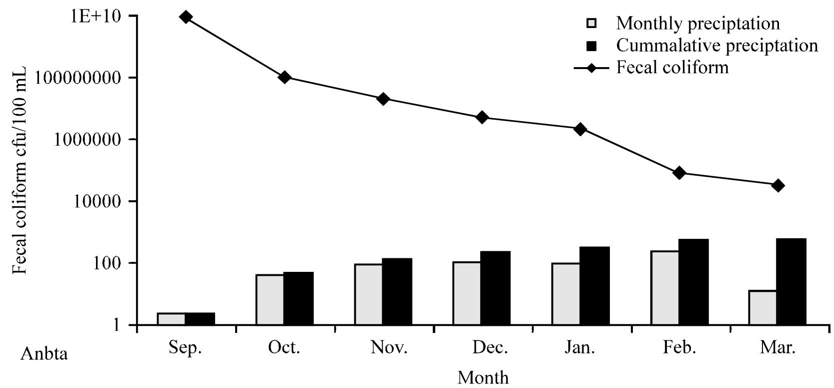

Fig. 4: Relation between bacterial activity and monthly and accumulative rainfall (mm) at Anbta sampling location

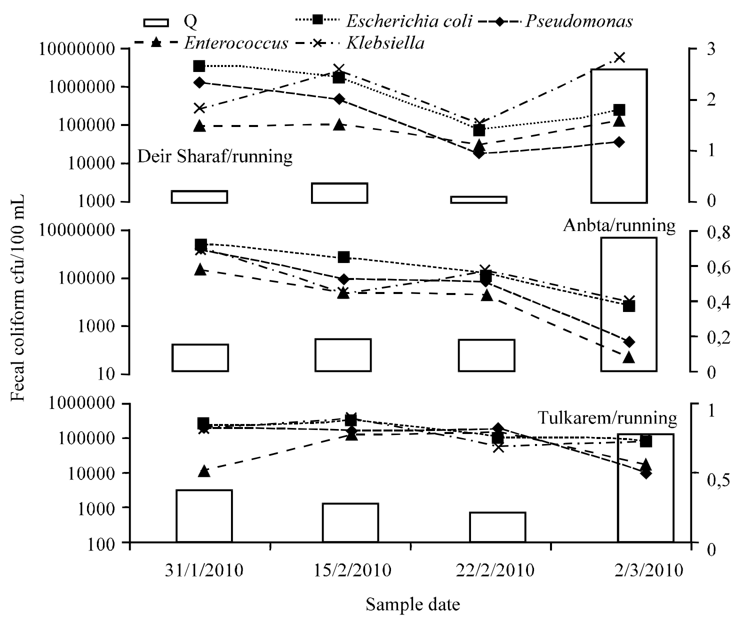

Fig. 5: Relation between pathogenic counts and flow discharge

The results show increasing in survival *E. coli* and to a lesser extent *Klebsiella* as wastewater discharge increase while the density of *E. coli* declined immediately after each rain event. These results agree with study done by Lopez-Torres *et al*. (1988). Carlucci and Pramer (1960) suggested that the organic load improved the survival of these species. *E. coli* and *Enterococcus* densities were more strongly correlated to cumulative rainfall variables than the other microbiological indicators. The presence of fecal and total Coliform effect negatively by amount of stream discharge, this can be clearly noticed in Anbta (Fig.4). The results show that there is evidence that fecal indicator and pathogens bacteria survive longer in sediments than in the overlying water and it has been proposed that sediments serve as sinks of fecal bacteria with the potential pollution of bathing water more than lying which agrees with previous studies (Ashbolt *et al*., 1993; Ghinsberg *et al*., 1994; Howell *et al*., 1996).

The ability of microorganisms, to survive in aquatic sediments implies that fecal Coliform detected in the water column of streams may not always indicate recent contamination but may be the result of sediment re suspension (LaLiberte and Grimes, 1982). Since microbial activity in sediments is greatly encouraged by the presence of organic matter (Millis, 1988; Ferguson, 1994), it is possible that in nutrient-rich environments, microorganisms may survive in sediments for extended periods of time (Davies *et al.*, 1995).

Accurate prediction of pathogen counts and occurrence in Wadi Zomar is attractive risk assessment (USEPA, 2001; Coffey *et al.*, 2007); Table 1 and 2 indicate that there were a broad range of concentration for indicator and pathogenic bacteria in response to hydrological results due to variance of rainfall and discharge accompanied by temporal and spatial conditions couple with limited pathogen data information so that indicator bacteria (fecal and total Coliform) will likely continue to be target microorganisms in the future (Sadeghi and Arnold, 2002; Tian *et al.*, 2002). The *E. coli* load in sediment was investigated (Table 2), as sediments are presumed to be an important mode of transport for fecal bacteria and pathogen to the water stream (Jamieson *et al.*, 2004; Characklis *et al.*, 2005).

Figure 6 shows the relation between BOD and WP which is seams logic, however, increase WP as stream discharge increase will dilute the organic matter found in stream and thus cause decrease in stream BOD level. The wetted perimeter values fluctuated where the maximum wetted perimeter for the events at the end of February in Zomar stream reaches 5.5 m at Deir Sharaf location with BOD 28 mg L^{-1} and the minimum value at base flow reach 2.4 m and BOD 180 mg L^{-1}, Wetted perimeter shows strong negative correlation with BOD. The above results emphasize the role of sustainable discharge from good quality water source (either rain runoff or treated waste water) in keeping self restoration capacity for the Wadi.

In Anbta as WP increase, the bacterial community decrease and thus BOD decrease, this is may be special for this location due to stream self purification because there is no surrounded source that added additional amount of bacteria and organics and the point still influenced by the flush out effect from previous successive storm. Bacterial community show ability to re build up after each rain event especially in places (Deir Sharaf) closed to point source that might hold additional amount of life bacterial cells in addition to nutrient present (Fig. 7). This suggests the role of point source that retarding the natural eco-service in purification.

Discharge was found to be negatively associated with indicator micro-organisms due to dilution effects. Overall, the strength and direction of hydrology-microorganism relationships appear to depend broadly on seasonal characteristics, type of microorganism, sample site disposition

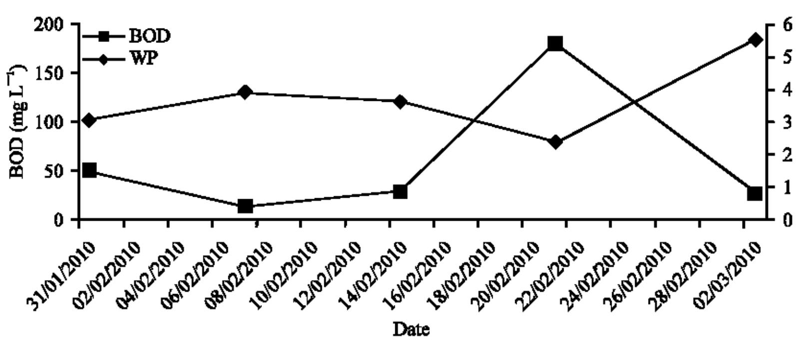

Fig. 6: Relation between WP and BOD at Deir Sharaf

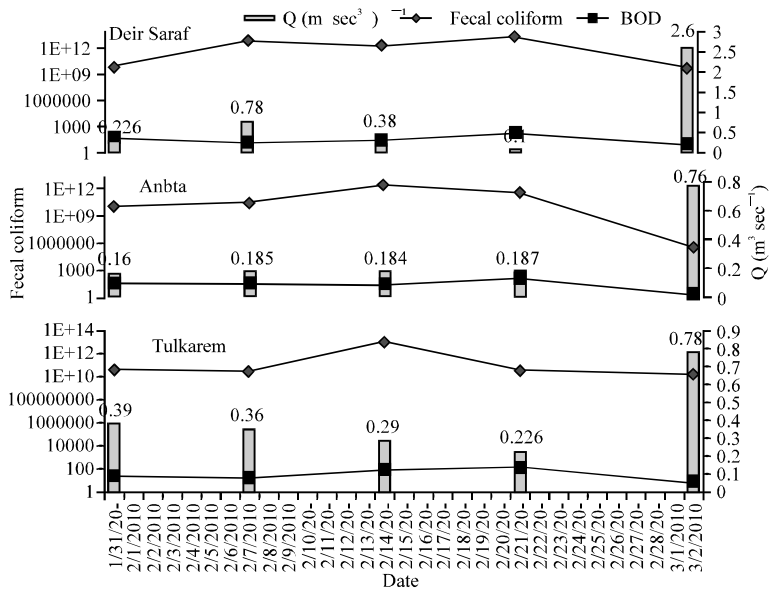

Fig. 7: Relation between bacterial count and nutrient availability at three zones

(e.g., stream order), upstream land use (Lyautey *et al*., 2007) and differences in specific hydrological loading/transport processes.

Biological activity and water quality

Fecal coliform: The Coliform and pathogens count as well show that it is directly influence by the availability of adequate nutrients supply along the stream. Figure 4 illustrate the relation between rainfall load and fecal Coliform count which reduced due to flush out bacterial colonies during and after rain event.

In general the fecal Coliform levels correlated significantly with BOD at all locations. The results for fecal Coliform which covered the monitoring period indicated a decrease during winter and after almost every rainfall. This decrease is thought to be mainly as a result of flood which flush out both the organics and microorganisms. The bacterial counts was found to decrease with distance due to dilution factor which resulted from rainwater tributaries along the stream, The results for fecal Coliform which covered the monitoring period, indicated a decrease during winter and after almost every rainfall.

In general, Coliform bacteria was found to be more in settled samples than in running samples, this because bacteria at settled can form biofilm, so it can build and grow since it have much more residence time than those in running samples. Either it was notice that the size of Total Coliform colony is much large, this is indicating that there is more than one kind of bacteria with different size. It was notice sampling from mid of Wadi have fungi while settled sample have not, since nutrient in settled samples consumed by algae.

Pathogens: In this study, variability in pathogen presence was evaluated for several pathogenic bacteria. The results show that in contrast to the other pathogens, *E. coli* was detected very infrequently during rain event in settled samples, and/or (re) mobilization of bacteria that had proliferated. Pathogenic bacteria count changed significantly with heavy rain caused an increase in stream flow. Overall, seasonal variation in the rates and types of fecal inputs, environmental conditions that influence the persistence of enteric bacteria and hydrological conditions that enhance the transport potential of enteric pathogens within the landscape are factors that may be contributing to the seasonality in outbreaks of enteric disease in semi arid climates (Fig. 8).

Pathogen removal efficiency: Table 2 and 3 give indicator bacteria level and pathogenic bacteria levels in stream. Average TC levels in the stream were 7×10^{16}, 4×10^{16}, 8×10^{16} cfu/100 mL

Table 3: Pathogen types presence and concentration in all sampling locations

			Events sample date			
Sampling site	Sampling type	Sampling date/Pathogen type	31/1/2010	15/2/2010	21/2/2010	2/3/2010
Deir Sharaf	Sediment	*Escherichia coli*	4.8×10^{5}	4.8×10^{7}	1.4×10^{7}	2.7×10^{5}
		Pseudomonas	1.7×10^{5}	1.0×10^{8}	1.2×10^{7}	3.0×10^{6}
		Enterococcus	1.8×10^{4}	2.4×10^{7}	1.9×10^{7}	4.2×10^{5}
		Klebsiella	3.9×10^{5}	5.2×10^{7}	2.2×10^{6}	3.3×10^{7}
	Settled	*Escherichia coli*	2.7×10^{5}	2.3×10^{5}	4.9×10^{4}	3.3×10^{4}
		Pseudomonas	2.0×10^{6}	7.7×10^{6}	1.5×10^{5}	1.4×10^{4}
		Enterococcus	5.3×10^{4}	9.8×10^{4}	3.7×10^{4}	1.2×10^{5}
		Klebsiella	3.0×10^{6}	5.0×10^{5}	4.2×10^{5}	2.0×10^{5}
	Running	*Escherichia coli*	1.2×10^{6}	4.8×10^{5}	1.8×10^{4}	3.6×10^{4}
		Pseudomonas	3.2×10^{6}	1.8×10^{6}	7.2×10^{4}	2.5×10^{5}
		Enterococcus	9.9×10^{4}	1.0×10^{5}	3.0×10^{4}	1.4×10^{5}
		Klebsiella	2.8×10^{5}	2.8×10^{6}	1.1×10^{5}	5.5×10^{6}
Anbta	Sediment	*Escherichia coli*	2.0×10^{5}	8.8×10^{6}	1.4×10^{5}	1.1×10^{4}
		Pseudomonas	1.4×10^{5}	5.3×10^{7}	9.0×10^{4}	3.0×10^{6}
		Enterococcus	1.3×10^{5}	1.6×10^{4}	8.2×10^{4}	2.5×10^{3}
		Klebsiella	2.7×10^{6}	4.5×10^{5}	6.0×10^{5}	2.5×10^{7}
	Settled	*Escherichia coli*	1.4×10^{6}	2.4×10^{5}	5.0×10^{3}	120
		Pseudomonas	1.0×10^{5}	4.7×10^{5}	7.2×10^{4}	1.2×10^{4}
		Enterococcus	2.2×10^{5}	1.1×10^{4}	2.9×10^{3}	370
		Klebsiella	1.1×10^{6}	3.6×10^{5}	3.8×10^{4}	7.9×10^{3}
	Running	*Escherichia coli*	1.9×10^{5}	1.5×10^{5}	1.7×10^{5}	9.4×10^{3}
		Pseudomonas	2.5×10^{5}	3.0×10^{5}	1.0×10^{5}	7.8×10^{4}
		Enterococcus	1.1×10^{4}	1.2×10^{5}	1.3×10^{5}	1.7×10^{4}
		Klebsiella	1.9×10^{5}	3.4×10^{5}	5.5×10^{4}	8.0×10^{4}
Tulkarem	Sediment	*Escherichia coli*	2.0×10^{5}	8.8×10^{6}	1.4×10^{5}	1.1×10^{4}
		Pseudomonas	1.4×10^{5}	5.3×10^{7}	9.0×10^{4}	3.0×10^{6}
		Enterococcus	1.3×10^{5}	1.6×10^{4}	8.2×10^{4}	2.5×10^{3}
		Klebsiella	2.7×10^{7}	4.5×10^{5}	6.0×10^{5}	2.5×10^{7}
	Settled	*Escherichia coli*	1.4×10^{6}	2.4×10^{5}	5.0×10^{3}	120
		Pseudomonas	1.0×10^{7}	4.7×10^{5}	7.2×10^{4}	1.2×10^{4}
		Enterococcus	2.2×10^{5}	1.1×10^{4}	2.9×10^{3}	370
		Klebsiella	1.1×10^{6}	3.6×10^{5}	3.8×10^{4}	7.9×10^{3}
	Running	*Escherichia coli*	1.9×10^{5}	1.5×10^{5}	1.7×10^{5}	9.4×10^{3}
		Pseudomonas	2.5×10^{5}	3.0×10^{5}	1.0×10^{5}	7.8×10^{4}
		Enterococcus	1.1×10^{4}	1.2×10^{5}	1.3×10^{5}	1.7×10^{4}
		Klebsiella	1.9×10^{5}	3.4×10^{5}	5.5×10^{4}	8.0×10^{4}

All units are in cfu/100 mL

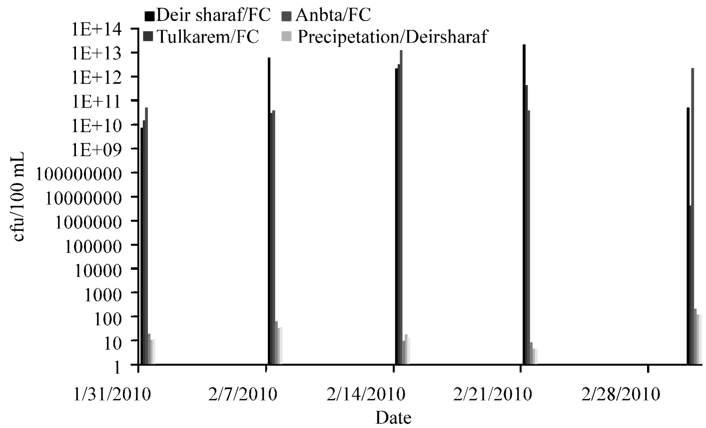

Fig. 8: Fecal Coliform from all locations during the study period

all over the year. During discharge event this average reduced to 7×10^{14}, 4×10^{7}, 1×10^{14} cfu/100 mL showing log removal of 2,9 and 2.9 for all three sites, Deir Sharaf, Anbta and Tulkarem, respectively. In case of FC, average concentration were 4×10^{13}, 6×10^{12}, 2×10^{11} cfu/100 mL and reduced to 5×10^{9}, 4×10^{5}, 2×10^{10} cfu/100 mL showing log removal of 3.9, 7.2, 1 for all three sites, respectively. Fecal Coliform removal for all three sites is represented graphically in Fig. 8.

Average pathogenic concentration in the stream for example, *E. coli* was 1.8×10^{4}, 6.2×10^{4}, 1.7×10^{5} cfu/100 mL and reduced to 3.6×10^{3}, 1.7×10^{2}, 9.4×10^{3} showing log removal of 0.7, 2.6, 1.2, respectively. Site 2 near Anbta showing highest removal (self purification) while Deir Sharaf show lowest removal (close to source point). Among the list of enteric pathogens, *E. coli* is special concern due to public health.

The results shown above indicate the importance of sustainable good quality flow to remove the pathogens and to keep the whole system healthy. Anabta point represents the model for good capacity in self purification and pathogens removal, where the optimal conditions with less additional pollutants are present.

CONCLUSIONS

This study can be considered as the basic block for modeling the hydrological and biological status of the Zomar stream. Different factors that can be considered as indices for the model were well identified such as raw sewage discharge from the cities of Nablus and Tulkarem into the Zomar stream. This source changes the fundamental nature of the ephemeral stream, converting it into a de facto sewage conduit with permanent base flow running. The Zomar stream does show a semi-self-purification mechanism that partly treats the sewage and reduces the organic load in the water. As interruptible stream flow system, two main factors affect positively Zomar stream restoration:

- Discharge amount events, where one rain events were taken to study the stream flow discharge
- Rain frequency (accumulative) and relation of period between each event that trigger a continuous flush out and consequently the ability of bacterial community to re-build up after each event

Better correlation of Pathogens isolation, compared with the other hydrological indicators. Total and Fecal Coliform correlated well with the presence of Pathogens.

Anbta sampling location represents the model for good capacity in self purification and pathogens removal; where the optimal conditions with less additional pollutants are present. The results indicate the importance of sustainable good quality flow to remove the pathogens and to keep the whole system healthy. The highest pathogenic concentration including *E. coli* loading occurred in location of Deir Sharaf dominated by closing to sewage discharge source point. A location containing a cluster of residential dwellings also had substantial loading and had the highest percentage of the total *E. coli* load occurring during base flow conditions. Average *E. coli* loading rates for the entire watershed in sediment were 1.4×10^{7} and 2.7×10^{5} CFU/100 mL, for base flow and storm flow periods, respectively. This suggests the role of point source that complicates the problem and retarding the natural eco-service in purification.

RECOMMENDATIONS

The results of this study indicate the necessity for:

- Creating a sustainable source for good quality runoff water all over the year, that can keep the base flow with low pollution amount and healthy eco-system that has the ability of self restoration
- Establishing a surface flow model depending on the data obtained from this study, to visualize the role of above mentioned two mitigation parameters in the restoration process and to suggest the best required water amount and quality to sustain a healthy flow. The model should be build through incorporating the conceptual model data in this study in proper modeling program, then the first simulation should be run and the data set validate before providing different scenarios depending on actual reference parameters measured and behaviors for bacteria in response to chemical and physical variances. In this context, different parameters related to rain water runoff in the stream and accidental point sources of pollutants along its stream, should be modified to obtain the optimal scenario where the stream can be restored as a natural healthy environment
- Stopping the discharge of additional waste along the stream path, as the study shows its importance in complicating the problem of retarding self restoration along the stream
- The above two points are integrated together through constructing water treatment plants as alternative to provide and keep a good quality base flow in dry season that can support healthy environment as mentioned in the results
- Increasing the public awareness of the issue of water scarcity, stream restoration and pollution sources and supporting a wide range of life with healthy environment. Stakeholders should be raised to ensure public contribution in Zomar restoration
- The results of the project might really be useful for stakeholders and decision makers in the local authorities and institutes and should be taken into account in the process of any coming projects for efficient exploitation
- Further research studies are needed to develop a surface flow model depending on the data resulted from this study and to suggest the best required water amount and quality to sustain a healthy flow

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