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Quality of Highway Runoff at Two Locations in Amman City: A Preliminary Investigation

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Abstract. Assessment of highway runoff quality is necessary to predict its impact on receiving water bodies and therefore take the necessary preventive measures. The goal of this study is to investigate the quality of highway runoff at two locations in Amman city in Jordan. The study addresses three main factors that affect the quality of highway runoff. These are: (1) Average Daily Traffic (ADT), (2) Antecedent Dry Period (ADP), and (3) rainfall depth. To achieve the goal of this study, two sites of significantly different (ADT) were selected in Amman city. Site 1 is Yajouz highway and Site 2 is a highway in Shafa-Bardan. Average daily traffic (ADT) was measured at both sites by an observer. Runoff samples were collected from the two sites for the rainfall events between November 2009 and February 2010. Collected samples were analyzed for Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pH, and heavy metals content (Cr, Fe, Mn, Cu, Ni, Pb and Cd). In addition rainfall depths for each storm were measured by rainfall gauges installed at both sites. Preliminary results showed that of the heavy metals investigated Zn and Fe were detected at both sites. All other heavy metals were below the detection limit of the atomic absorption used at both sites. Runoff TDS was not significant at any of the two sites while runoff TSS was high at both sites. The results showed that ADP, ADT, and rainfall depth have significant impact on highway runoff quality.

Keywords: highway runoff quality, heavy metals, antecedent dry period, average daily traffic, environmental pollution.

1. Introduction

Jordan is among the countries that has high population growth rate which increases the demand on natural resources consequently increases the release of pollutants to the environment leading ultimately to its degradation. One of the consequences of rapidly increasing population is the increasing demand on vehicles and means of transportation which are source of many pollutants that can find their way to surface and ground waters leading to the deterioration of their qualities. Highway runoff which is runoff that flows across streets and pavements is a major source of pollution to the receiving water bodies as paved areas do not allow contaminants to be absorbed into the soil where they can be filtered. The type, fate and concentration of pollutants found in highway runoff are site specific and are affected by traffic volume, design of the roadway, surrounding land use, climate, accidental spills and storm events characteristics. The storm events are characterized by the number of dry days preceding the storm, storm intensity and storm duration [1].

Pollution of surface water and groundwater by highway runoff have received significant attention world wide ([2], [3], [4], [5]). However, little attention has been paid so far to water bodies' pollution by highway runoff in Jordan. A study by Jiries et al. [6] investigated the quality of street runoff at two locations in the vicinity of Amman, the first location was Amman city center and the second one was in the surroundings of Amman. High levels of Pb, Cu, Cd and Fe were detected in the runoff samples at both sites with the city

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downtown showing higher concentrations for all constituents. Jaradat et al. [7] investigated the quality of rainwater at two locations in Amman. High levels of Ca^{+2} and SO_4^{-2} were detected in addition to heavy metals with Zinc and Lead showing the highest concentrations. Highway runoff along Zarqa River finds its way to the river course which can lead to its pollution. The importance of protecting Zarqa River from pollution by highway runoff is that Zarqa River flows to King Talal Dam (KTD) which flows to King Abdulla Canal that delivers irrigation water to the Jordan Valley which is the food basket for Jordan. In addition, Zarqa River is the only river that passes through Jordan which makes its protection from pollution an environmental priority. This study aims at identifying pollutants and their concentrations in highway runoff at two locations in Amman city. In addition, the study aims at identifying the factors that affect highway runoff quality such as Average Daily Traffic (ADT), Antecedent Dry Period (ADP) which is defined as the dry period between two consecutive rainfall events, and rainfall depth.

2. Study Area

Two sites in the vicinity of Amman, Jordan (Fig. 1) were chosen for this study. Site 1 is located in Yajouz street, and site 2 is located in Shafa Badran Street. The (ADT) was measured for both sites by an observer and is equal to 80400 for site 1 and 16128 for site 2. Runoff from the two locations flows to Zarqa River.

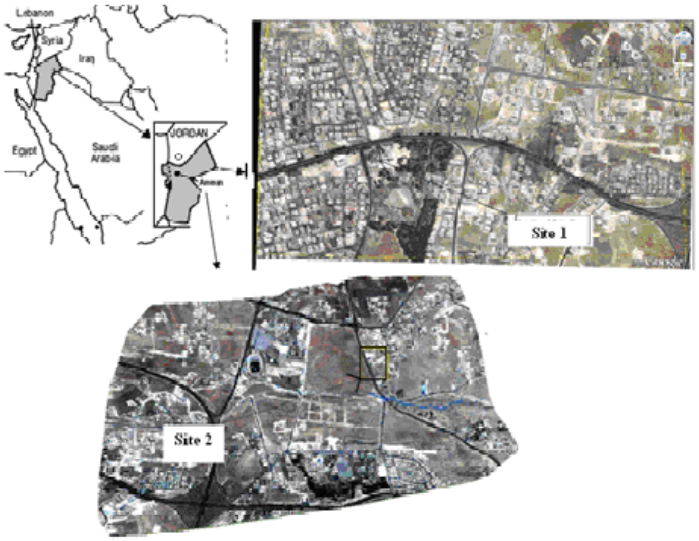

Fig. 1: Location of Amman, Jordan, and the drainage area for the two sites; Site 1-Yajouz Street, and Site 2-Shafe Badran Street.

3. Sampling and Analysis

Rainfall depth for every rainfall event was measured by rain gauges installed at both sites. The two sites were monitored from October 2009 till February 2010. Runoff samples were collected from the two sites and analyzed for the following parameters: Total Dissolved Solids (TDS); Total Suspended Solids (TSS); pH, alkalinity, and the following heavy metals (Zn, Fe, Cd, Ni, Cr, Cu). All samples were analyzed according to the standard methods for the examination of water and wastewater [8]. Heavy metals were analyzed by a thermo elemental Atomic Absorption. Table 1 presents the detection limits for the Atomic Absorption used in the analysis.

Table 1. Detection limits of the Atomic Absorption used

Metal	Zn	Fe	Cd	Ni	Pb	Cr	Cu
Detection limit, mg/l	0.003	0.007	0.03	0.06	0.10	0.05	0.04

4. Results and Discussion

4.1. TDS, TSS, and pH

TDS and TSS concentrations in addition to pH of the street runoff samples collected from the two sites investigated in this study are shown in Figures 2 to 4. Figure 2 shows TDS of the runoff samples and rainfall depths for different (ADPs) at the two sites. The last column of this figure represents the first rainfall event which has the highest ADP. For site 2, there was no runoff at the time of sampling, so no sample was collected from this site for this rainfall event. For site 1, the highest TDS was observed at the first rainfall event which has the highest ADP. For site 2, the highest TDS was observed for the rainfall event that has an ADP of 4 days. The impact of rainfall depth on runoff TDS is observed at both sites. At site 1, at ADP of 34 days, the TDS for this rainfall event was almost equal to the TDS for the first rainfall event. This is attributed to the high ADP, and to the low rainfall depth. On the other hand, at site 2, the TDS for the rainfall event with 38 ADP was high. However due to the high rainfall depth, the TDS was lower than that for the rainfall event with 4 days ADP.

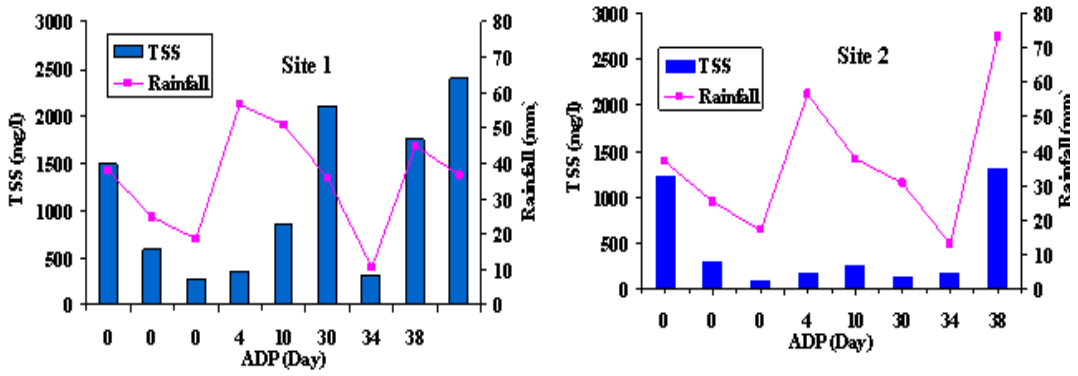

Fig. 2: Rainfall and TDS versus ADP for Sites 1 and 2.

TSS for different ADPs at the two sites is shown in Figure 3. The figure shows that TSS is high at the two sites for long ADP. The highest TSS at site 1 was observed at the first rainfall event which is the last column. At site 2, the highest TSS was observed at 38 days ADP. Strong correlation is also observed between rainfall depth and TSS. This figure illustrates that the higher the rainfall depth is, the higher the TSS, which is analogous to increasing TSS in surface waters with increasing discharge [9].

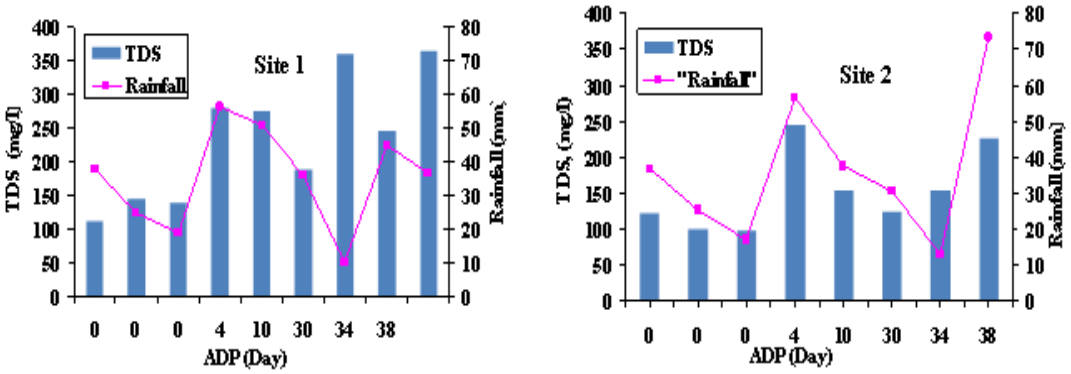

Fig. 3: Rainfall and TSS versus ADP for Sites 1 and 2.

Further investigation of Figures 2 and 3 show that, generally TDS and TSS concentrations at site 1 are higher than those at site 2 which is most probably due to the higher ADT volume at site 1. In addition, Figures 2 and 3 demonstrate the fact that street runoff TDS is function of ADP, rainfall depth and ADT.

Figure 4 shows that pH ranged between 7.1 and 7.7 at both sites. No significant variations in pH levels were observed at both sites. It is noted that a pH drop is observed at high rainfall depth which is most probably due to increasing CO_2 levels in the rainwater.

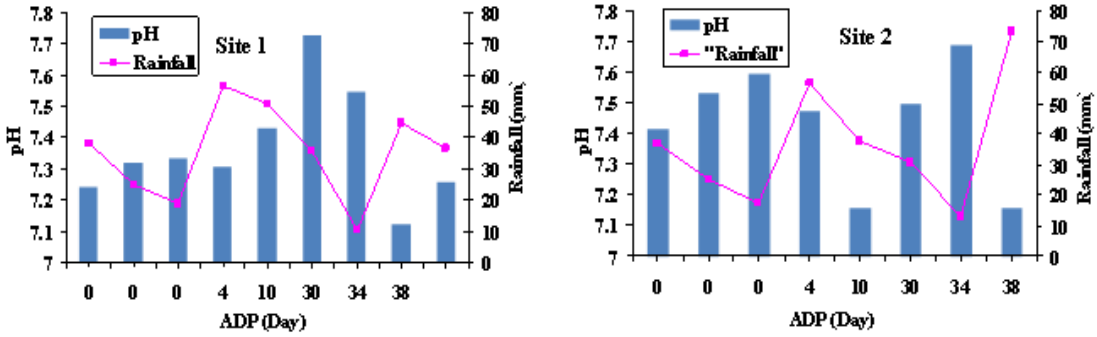

Fig. 4: Rainfall and pH versus ADP for Sites 1 and 2.

4.2. Heavy Metals

Of the heavy metals monitored Cadmium (Cd), Copper (Cu), Chromium (Cr), Nickel (Ni), and lead (Pb) were below the detection limit of the atomic absorption used at both sites. However, Zinc (Zn) and Iron (Fe) were detected at both sites. Figures 5 and 6 show the concentrations of Zn and Fe at both sites, respectively.

Figure 5 shows that the highest Zn concentration was observed at site 1 at the first rainfall event which is due to its accumulation over the long dry period between the two rainy seasons. However, no runoff was observed at the first rainfall event at the time of sampling at site 2. At the other rainfall events, Zn concentration dropped significantly, but it was detected at both sites.

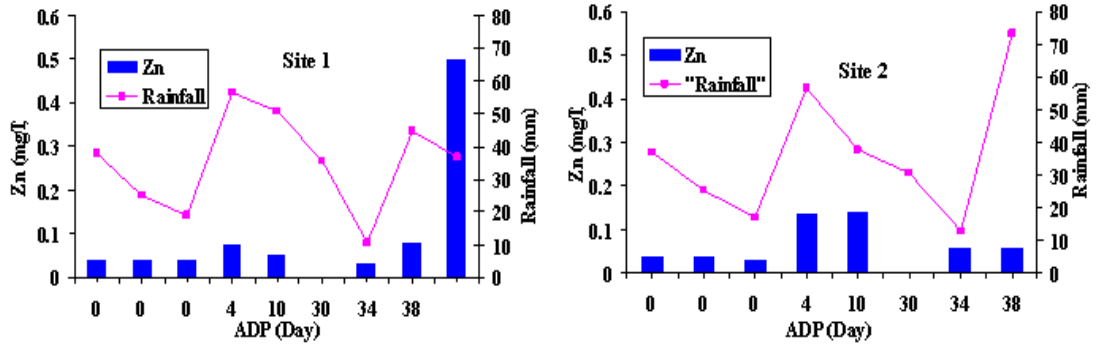

Fig. 5: Rainfall and Zn concentration versus ADP for Sites 1 and 2.

Fe concentration at both sites is illustrated in Figure 6. The highest concentration was detected at site 1 at the first rainfall event, which is again due to the high ADP before this event. Fe concentrations at both sites were low at 30 and 34 days ADP. Fe concentrations at both sites were higher than Zn concentrations. Observation of Fe concentration shows that no significant difference in Fe concentration at both sites was observed. However, it is interesting to note that Fe concentration at 10 days ADP at site 2 is higher than that at site 1 which is due to the higher rainfall depth at site 1 for that rainfall event. Fe concentrations detected at both sites are much lower than those reported by Jiries et al. [6] which is most probably due to the significant difference in the ADT.

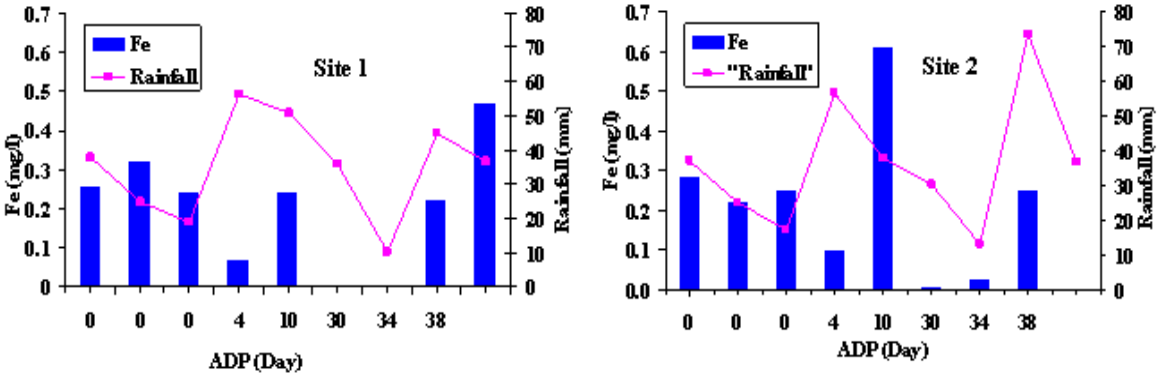

Fig. 6: Rainfall and Fe Concentrations versus ADP for (a) Site 1 and (b) Site 2.

5. Conclusion and Recommendations

An investigation of highway runoff quality at two locations in Amman city was conducted during the pluvial year 2009-2010. The results showed that Cadmium (Cd), Copper (Cu), Chromium (Cr), Nickel (Ni), and Lead (Pb) were below the detection limits at both sites. Zinc (Zn) and Iron (Fe) were detected at both sites. Runoff TDS at both sites was not high. However, runoff TSS was high at both sites.

The results given here are preliminary as the sampling was conducted at two sites for a short period. A more comprehensive sampling program for a longer period at several locations in the vicinity of Zarqa River is recommended to investigate the possible impact of highway runoff on Zarqa River quality.

6. Acknowledgements

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