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Full Length Research Paper

Heavy metals in water springs of the Yarmouk Basin, North Jordan and their potentiality in health risk assessment

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The objective of this study is to determine the seasonal water quality variations of the major springs of the Yarmouk Basin of North Jordan. A total of 36 water samples were collected in October 2006 (dry season) and in May 2007 (wet season) and analyzed for temperature, electrical conductivity, total dissolved solids, pH, Pb, Cd, Zn, Cu, Mn and Fe. The pH was found near alkaline ranging from 7.01 - 7.87 and 6.8 - 8.04 for the pre and post-wet season water samples, respectively. Electrical conductivity varied from 300 to 1199 µS/cm and from 424 to 962 µS/ cm for the dry and wet season water samples, respectively. The results of heavy metals analysis indicated that some water samples exceeded the Jordanian. Overall, the results showed that the water springs of the Yarmouk Basin in North Jordan are contaminated with heavy metals that might affect human health as well as the health of the ecosystem.

Key words: Water springs, Yarmouk Basin, heavy metals, Jordan.

INTRODUCTION

The term "heavy metals" refers to any metallic element that has a relatively high density and applies to the group of metals and metalloids with atomic density greater than 4 g/cm^3. Heavy metals are well known to be toxic to most organisms when present in high concentration in the environment. In the last decades, human activities have continuously increased the levels of heavy metals circulating in the environment. Anthropogenic activities such as agriculture, industry and urban life increase content of these elements in soils and waters. Researches relevant to this subject are that of (Nriagu, 1989; Amman et al., 2002; Loska and Wiechula, 2003; Momot and Synzynys, 2005; Abderahman and Abu-Rukah, 2006; Dalman et al., 2006; Ishaque et al., 2006; Adekunle et al., 2007; Chen et al., 2007; Duruibe et al., 2007; Ip et al., 2007; Gutierrez et al., 2008; Kar et al., 2008; Ong and Kamaruzzaman, 2009; Shunsheng et al., 2009; Zorer et al., 2009).

In the present study, an attempt is made to monitor the water springs of the Yarmouk Basin in North Jordan, from the viewpoint of the spatial and temporal variations in heavy metals content and also to evaluate the status of the water springs quality with respect to its usability for drinking and agricultural irrigation purposes. Heavy metals discussed in this paper include Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Manganese (Mn) and Iron (Fe). These metals have been selected firstly due to their toxic effects on living organisms and secondly because their levels are often easily measurable in the water samples.

STUDY AREA

The Yarmouk Basin is located in the northern part of Jordan. Seventy-five percent of this basin lies in Syria. In Jordan, the basin is located between coordinates 32° 20′ to 32° 45′N and longitudes 35° 42′ to 36° 23′ E, covering an area of about 1,426 km^2 (Figure 1). North Jordan between the Zarqa and Yarmouk Rivers (Figure 1) is a key area on the hydrological map of the country. The adjacent mountain areas and heights (Ajlun Mountains and Golan Heights), which stand at 1,200 m above sea level, are the highest uplands to the east of the Jordan Rift Valley. These areas receive high rainfall. In addition, the Yarmouk River flows at the borders between Syria and Jordan which delineates the Northern boundary of the study area, whereas the Jordan River represents the western boundary

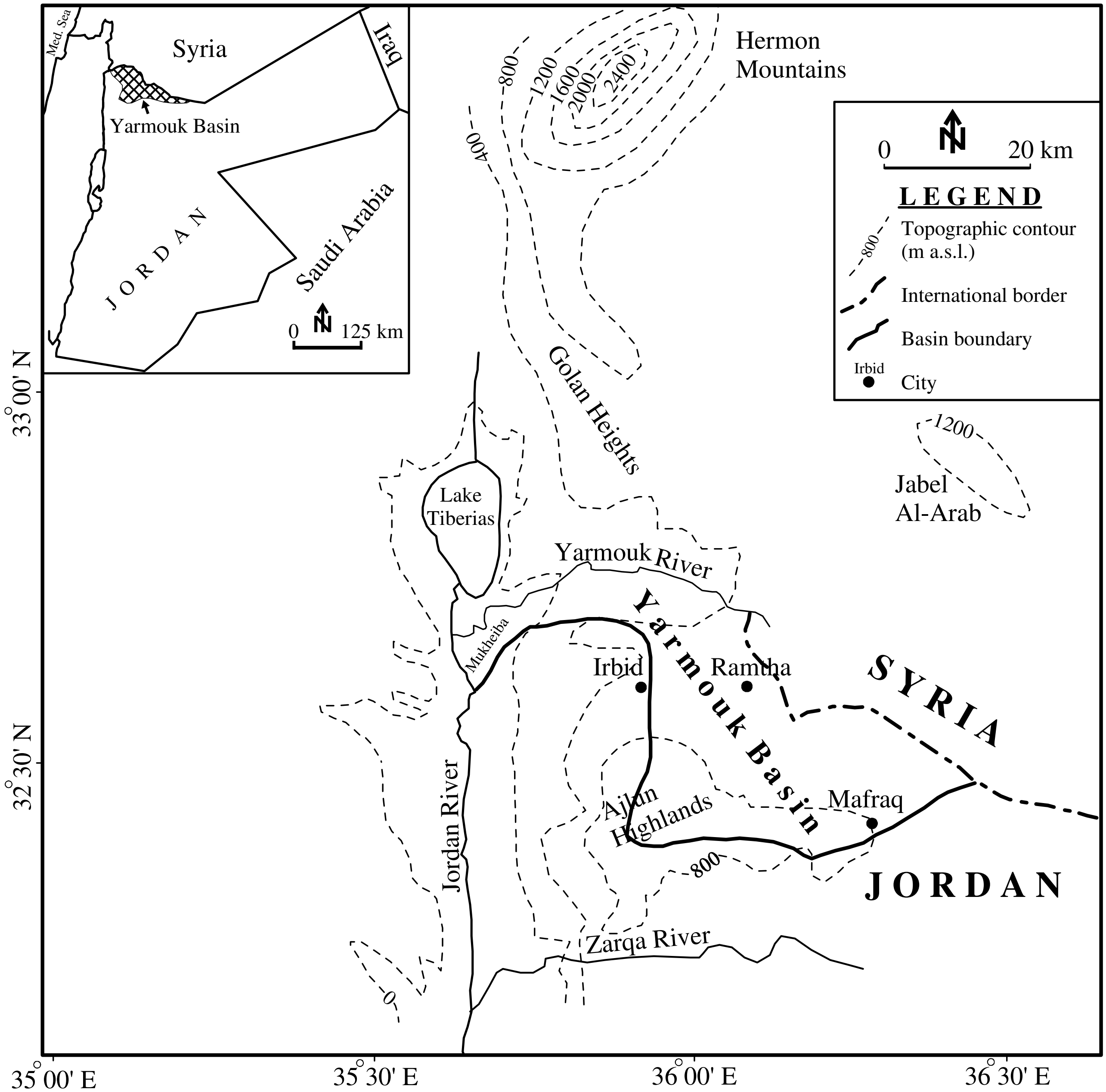

Figure 1. Location map of North Jordan showing principal physiographic features.

(Figure 1). The Yarmouk River originates from Jabel Al-Arab (Syria) and drains from the Jordanian and Syrian territories. In 2006, a major dam (Al-Wehda Dam) between Jordan and Syria was constructed across this river. It is proposed that this dam will supply Jordan with about, 110 MCM/yr of potable water. Water quality of the springs, which discharge into the dam, is of great importance for determining the usability of the stored waters.

The study area is part of the semi-arid region of the Mediterranean climate zones that has a limited amount of rainfall and high temperatures. Meteorological records collected by Jordan Meteorological Department (JMD, 2009; personal communication) in Irbid station (North Jordan) for the period 1955 to 2009 gave the mean annual rainfall and temperatures as 500 mm and 18°C, respectively. Most of the rainfall occurs between November and April, with its peak in January.

SAMPLING AND ANALYSIS

Samplings have been carried out in October 2006 (dry season) and May 2007 (wet season). A total of 36 water spring samples were obtained. The water samples were collected in 1 L pre-cleaned polyethylene bottles, preserved in a cool place (about 4°C) and transported to the laboratory of the Department of Chemistry, Yarmouk University, Irbid, Jordan for further analysis.

The temperature (T), hydrogen ion concentration (pH), electrical conductivity (EC) and total dissolved solids (TDS) were measured in the field by using a mercury thermometer, pH-meter, portable EC-meter and TDS-meter, respectively. Measurements and analyses were performed according to standard methods (APHA, 1998). The evaluated metals were Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Manganese (Mn) and Iron (Fe).

RESULTS AND DISCUSSION

The average prevailing temperature in the Yarmouk Basin was 18°C ± 3.5. This parameter varied with sampling location, time of collection and season of the year. The pH ranged between 7.01 to 7.87 and 6.8 to 8.04 with a mean of 7.31 and 7.58 for the dry and wet season water samples, respectively. The pH values indicate that water is slightly neutral.

The pH values detected in water spring samples were found to be in the permissible range of 6.5 to 8.5 (Jordanian Institution for Standards and Metrology (JISM, 2008)). EC varied from 300 to 1199 µS/cm and from 424 to 962 µS/cm with a mean of 516.1 and 614.7 µS/cm for the dry and wet season water samples respectively. These results are in agreement with those reported by Batayneh et al. (2008).

Scatter plots (Figure 2) are used for illustrating how the solubility of heavy metals varies with water pH and with metal concentration. The stability plots indicate a general decrease in Pb and Cd solubility with increasing pH, which is the usual trend with cationic metals. Solution activity of Cd is consistently higher than that for Pb indicating that Cd may be more mobile in the environment.

The results for Pb in this study showed seasonal and locational variability (Figure 3). Its concentrations ranged between 0.00005 and 0.0155 mg/l for the dry season water samples and between 0.0001 and 0.012 mg/l for the wet season water samples. Most Pb concentrations for both seasons are higher than the maximum permissible concentration level (MPCL) recommended by JISM (2008) (0.01 mg/l) for drinking water. The highest concentration of Pb was detected in spring No. 7 with 0.0155 mg/l for the dry season water sample.

Cd analysis (Figure 4) showed significant differences due to sampling season and sampling location. Cd concentration ranged between 0.00025 and 0.011 mg/l for the dry season water samples and between 0.00009 and 0.005 mg/l for the wet season water samples. These results indicate that most Cd concentrations for both dry and wet season water samples are lower than the MPCL recommended by JISM (2008) (0.003 mg/l) for drinking water. The highest amount of Cd was detected in spring No. 7 with 0.011 mg/l for dry season water sample.

In regard to the concentration of the elements Zn, Cu, Mn and Fe, the differences are too small in both for their location as well as the season (Figures 5 - 8). Zn concentrations ranged between 0.0016 and 1.35 mg/l for the dry season and between 0.0022 and 0.45 mg/l for the wet season water samples (Figure 5). All Zn concentrations of water samples for both seasons are lower than the MPCL recommended by JISM (2008) (4.0 mg/l) for drinking water.

Cu concentrations ranged between 0.0017 and 0.009 mg/l for the dry season and between 0.0034 and 0.0097 mg/l for the wet season water samples (Figure 6). Cu concentrations of water samples for both seasons are lower than the MPCL recommended by JISM (2008) (1.0 mg/l) for drinking water.

Mn concentrations ranged between 0.0001 and 0.02 mg/l for the dry season and between 0.0001 and 0.02 mg/l for the wet season water samples (Figure 7). All of these concentrations for both seasons are lower than the MPCL recommended by JISM (2008) (0.1 mg/l) for drinking water.

Fe concentrations in water samples collected in the dry season ranged between 0.0016 and 0.292 mg/l whereas for the wet season, they were between 0.0004 and 0.092 mg/l (Figure 8). These results indicate that all Fe concentrations for both seasons are lower than the MPCL recommended by JISM (2008) (1.0 mg/l) for drinking water.

On the basis of heavy metals level detected (Figures 3 - 8) and that these springs are distant from anthropogenic activities (mining and old mine sites, industrial, urban development and other human practices), these springs can be divided into three groups. The first group includes the springs that have that has low elements concentrations and have the longest distance from urban and other human activities (e.g. spring No. 16). Springs with the poorest water quality are referred to the third group (e.g. spring No. 7).

Based on heavy metals level detected and distant from anthropogenic activities, it was assumed that water from the third group exhibits mutagenic and probably carcinogenic activity. Summary of springs classification is given in Table 1.

Data in Table 1 showed that Pb and Cd concentrations of water from spring No. 7 are in excess of MPCL. Thus, this spring will be used for estimating the risk assessment. According to the US Environmental Protection Agency (US EPA, 2002) technique, risk is calculated under the condition of this water consumption every day during the whole human lifetime. The water quality standard for calculating risk is also specified for the same period. The daily average amount of drinking water is 3 L; the mean body weight is 70 kg. Under these conditions the dose of a chemical substance taken by a person with drinking water every day is:

$$ADDd = \frac{DW * C}{BW},$$

Where,
ADDd is the dose taken with drinking water;
BW is the body weight, kg;
C is the substance content in water, mg/l;
DW is the mean volume of water drank every day, liters.

Calculations of daily mean dose of the individual uptake of contaminants with water have been performed using data from spring (No. 7). Calculations are given in Table 2. Risk assessment with ingestion exposure can be expressed by the following formula:

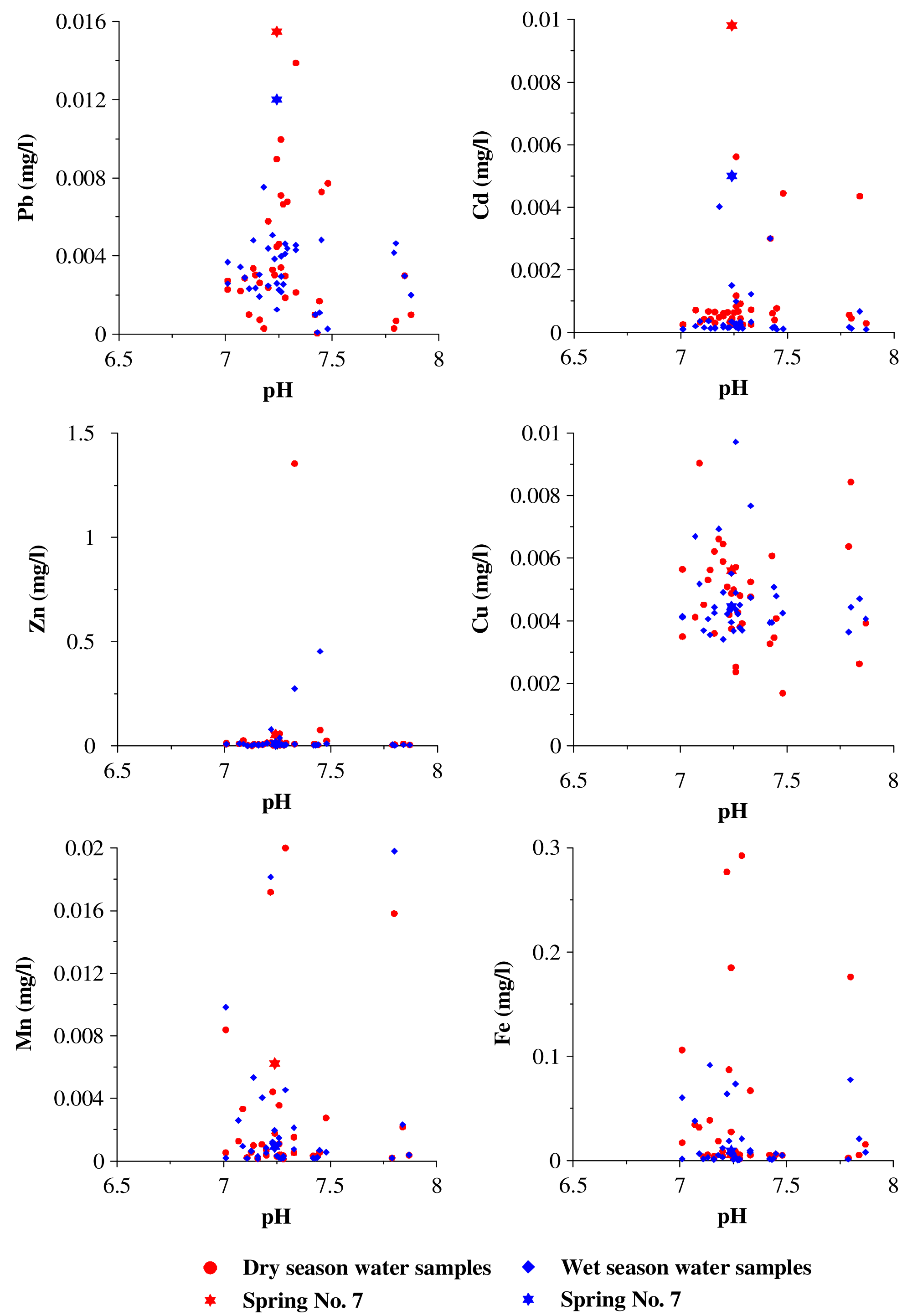

Figure 2. Solubility plots showing the relationship between the pH and heavy metal concentrations in water considering season of the year and 36 springs.

$$Risk = ADDd * UR,$$

Where,
Risk is the risk of adverse health effect estimated as the probability of this effect under given condition;

ADDd is the daily substance dose, mg/kg;
UR is the risk unit specified as a factor of risk proportion depending on the available concentration (dose).

The risk unit UR accepts the true value depending on the

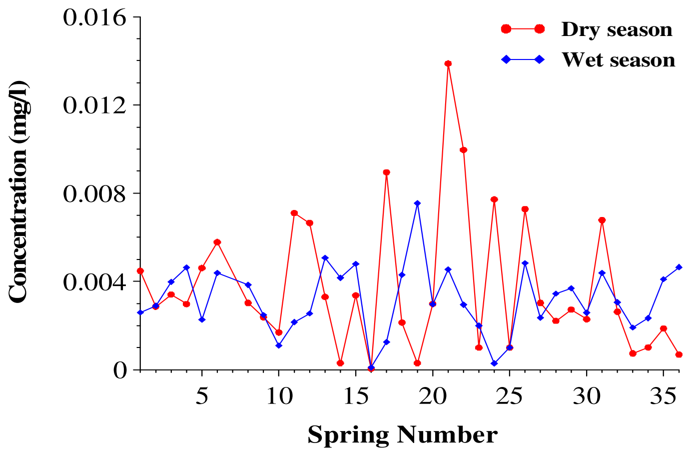

Figure 3. Concentration of Pb in water considering season of the year and 36 springs.

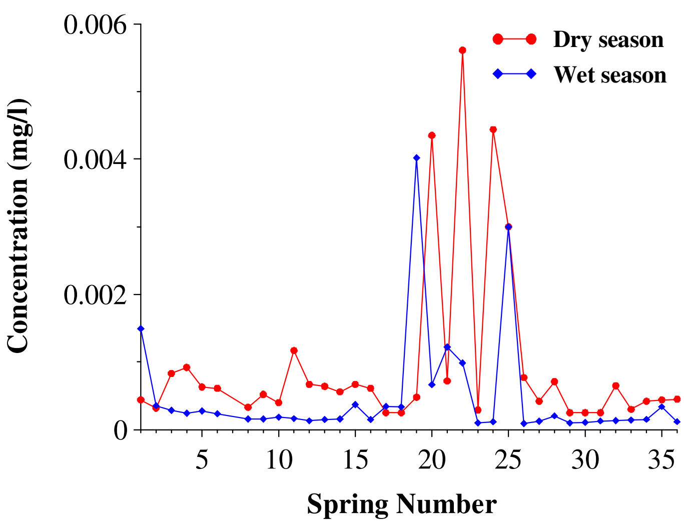

Figure 4. Concentration of Cd in water considering season of the year and 36 springs.

impact (carcinogenic, non-carcinogenic) which this substance has and the substance itself.

Table 2 shows the calculated health risk in cases of using springs water for both seasons. Water contains many different components and the risk of a combined impact of contaminants can be determined from the formula:

$$Risk_{sum} = 1-(1-Risk_1)*(1-Risk_2)*\cdots*(1-Risk_n),$$

Where,
$Risk_{sum}$ is the risk of a combined impact of contaminants;
$Risk_1$ … $Risk_n$ is the risk of impact of each isolated contaminant.

As a result, the combined risk of Pb and Cd for water

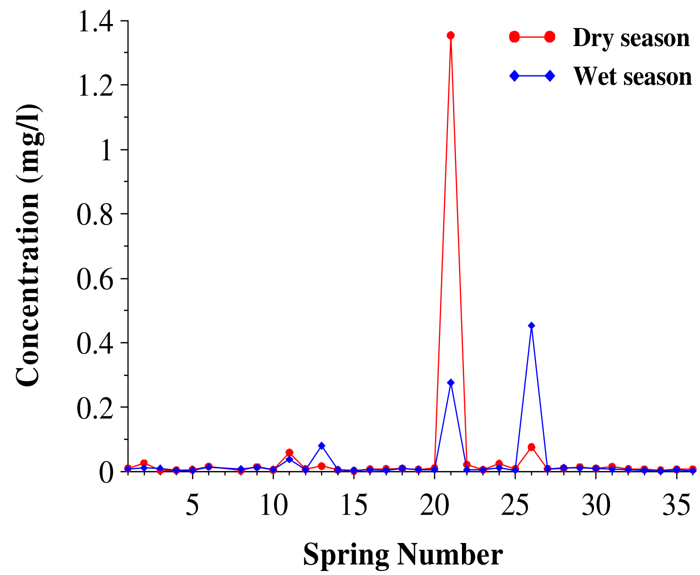

Figure 5. Concentration of Zn in water considering season of the year and 36 springs.

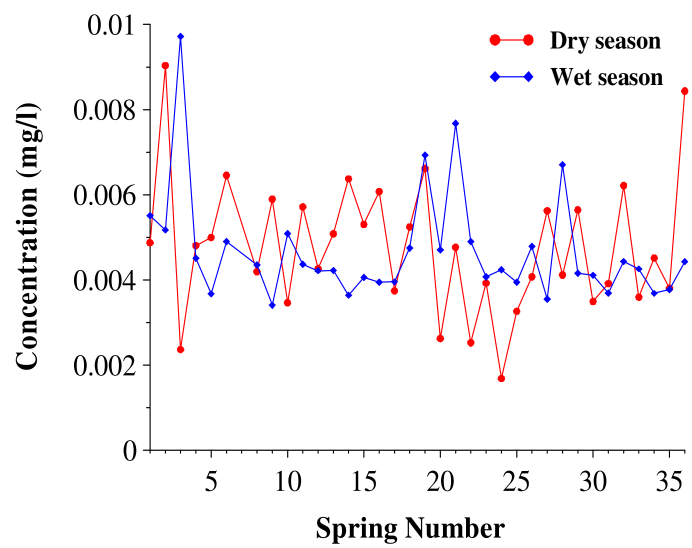

Figure 6. Concentration of Cu in water considering season of the year and 36 springs.

samples in the dry season is 1.68 x 10^{-4} and in wet season is 8 x 10^{-5}. In terms of per capita (10^4 persons) it means that 2 persons would be in danger of oncological (carcinogenic) diseases in the dry season and (for 10^4 persons) it means that 1 person would be in danger of oncological diseases in the wet season. In addition, for the non-oncological (non-carcinogenic) diseases, the estimated values are 2.7 x 10^{-7} and 1.5 x 10^{-7} for the dry and wet season water samples, respectively. In terms of population 10^7 persons, it means 3 and 2 persons are in danger of non-oncological diseases.

Table 1. Summary of classification of selected Yarmouk Basin springs.

Maximum permissible concentration level (MPCL) (JISM, 2008)		Concentration, mg/l					
		Pb	**Cd**	**Zn**	**Cu**	**Mn**	**Fe**
		0.01	**0.003**	**4.0**	**1.0**	**0.1**	**1.0**
Dry season	Group 3: Spring No. 7	0.015*	0.01*	0.054	0.0056	0.006	0.0054
	Group 2: Spring No. 16	0.0001	0.0006	0.007	0.0060	0.0003	0.0043
	Group 1: Spring No. 25	0.001	0.003	0.007	0.0032	0.0003	0.0054
Wet season	Group 3: Spring No. 7	0.012*	0.005*	0.011	0.0044	0.0009	0.0092
	Group 2: Spring No. 16	0.0001	0.0001	0.0045	0.0039	0.0001	0.0007
	Group 1: Spring No. 25	0.001	0.003	0.0042	0.0039	0.0001	0.0016

*Element in excess of MPCL recommended by JISM (2008).

Table 2. Calculated carcinogenic and noncarcinogenic risk of groundwater.

Water source		Substance	C (mg/l)	ADDd (mg/kg)	UR_{cancer}, (mg/kg-day)	$Risk_{cancer}$	$UR_{noncarc}$, (mg/kg-day)	$Risk_{noncarc}$
Dry season	Spring No. 7	Pb	0.015	0.00064	0.0085	544×10^{-8}	0.0000785	5024×10^{-11}
		Cd	0.01	0.00043	0.38	163×10^{-6}	0.0005	215×10^{-9}
		Zn	0.054	0.0023	-	-	-	-
		Cu	0.0056	0.00024	-	-	-	-
		Mn	0.006	0.00026	-	-	-	-
		Fe	0.0054	0.00023	-	-	-	-
Wet season	Spring No. 7	Pb	0.012	0.00051	0.0085	434×10^{-8}	0.0000785	40035×10^{-12}
		Cd	0.005	0.00021	0.38	798×10^{-7}	0.0005	105×10^{-9}
		Zn	0.011	0.00047	-	-	-	-
		Cu	0.0044	0.00019	-	-	-	-
		Mn	0.0009	0.000039	-	-	-	-
		Fe	0.0092	0.00039	-	-	-	-

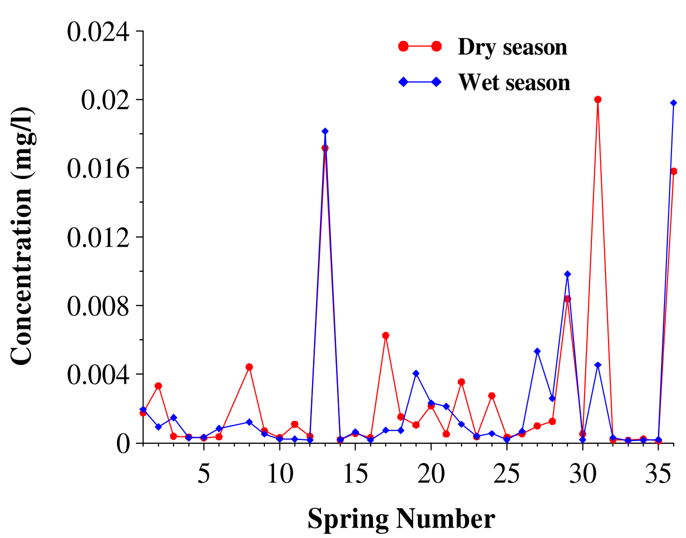

Figure 7. Concentration of Mn in water considering season of the year and 36 springs.

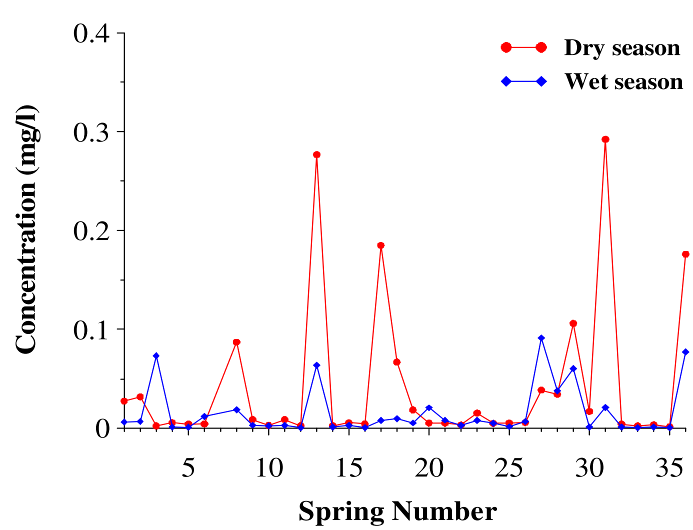

Figure 8. Concentration of Fe in water considering season of the year and 36 springs.

Conclusions

Our data confirmed that the risk of diseases in case of pre-season spring water is two times higher than that of the post-season spring water. Uncontrolled consumption of poor quality spring water may be dangerous for human health. While some spring water is more preferable to people, these springs may still pose a health risk to inhabitants of Yarmouk Basin.

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