ORIGINAL ARTICLE

Anthropogenic influence of trace metals in sediments of the Al-Qilt catchment, West Bank, Palestine: 1. Contamination factor and bonding forms

Sobhi Samhan · Kurt Friese · Wolf von Tümpling · Herbert Pöllmann · Heinz Hoetzl · Marwan Ghanem

Abstract Al-Qilt catchment, located east of both the Ramallah and Jerusalem districts is strongly influenced by waste waters discharged from Israeli settlements and Palestinian urban centers. In this research, our aim was to verify the chemical status of the surface sediments from the Al-Qilt catchment during 2008/2009. For this purpose, 36 surface sediment samples were collected and analyzed with ICP/MS within the fraction of below 63 μm. The extent of contamination of trace metals from Al-Qilt sediments sites were measured by evaluating the contamination factors (CF) from digestion by aqua regia and additionally by sequential extraction steps using the BCR-method. On the basis of the calculated CF, sediments appear particularly contaminated with Zn, Cu, Ag, Sn, Cd, Hg, Bi, and B. Three regions, Wadi Sweanit, Ras Al-Qilt, and Qalandiah have been identified as critical points of contamination. Trace metal inputs to the Al-Qilt catchment need to be kept under strict control in the future since Ras Al-Qilt is considered as one of the important springs in the area and is used for domestic purposes. Moreover, it will be susceptible to pollution if no action is taken to decrease the pollution at the upstream of Al-Qilt.

S. Samhan (✉) · K. Friese · W. von Tümpling
Department Lake Research, UFZ-Helmholtz Centre
for Environmental Research, Magdeburg, Germany
e-mail: subhisamhan@yahoo.com

H. Pöllmann
Institute of Geosciences, Martin-Luther-University
of Halle-Wittenberg, Halle, Germany

H. Hoetzl
University of Karlsruhe (UKA), Karlsruhe, Germany

M. Ghanem
Palestinian Hydrological Group (PHG), West Bank, Palestine

Introduction

For long time, the water from the Al-Qilt catchment was used for drinking purposes, irrigation, and washing. Today, more than 65,000 people from Palestinian communities (PCBS 2005) and six Israeli colonies totaling to about 15,000 people (PCBS 2003) live in the Al-Qilt catchment. From the wastewater which discharges to the catchment less than 10 % is treated efficiently in the West Bank, whereas most of it discharge untreated into the open environment to the nearest wadis (ARIJ 2007). The wastewater discharge in the Al-Qilt catchment is estimated to about 9,500 m^3/day from the Palestinian communities and to about 4,500 m^3/day from the Israeli colonies, totaling to about 14,000 m^3/day of wastewater treated and untreated. The wastewater which is treated at the Al-Bireh wastewater treatment plant is subsequently mixed with raw wastewater from Qalandiah and runs downstream. To examine the chemical status, water samples were taken within a monitoring program twice a year for the hydro-chemical analyses of major elements (Ca, Mg, Na K, SO_4, NO_3, Cl, and HCO_3) and physical parameters such as, pH, temperature, and turbidity (PWA 2009). Other parameters such as heavy metals that cause pollution due to anthropogenic parameters were analyzed within some special investigation programs for limited studies (PWA 2009).

Based on that knowledge, sediments samples from Al-Qilt catchment were taken to assign the anthropogenic pollution by heavy metals and arsenic. Calculations were done using the average shale values of Turekian and Wedepohl (1961) and by soil samples from Al-Qilt as

references. Moreover, the soils from Al-Bireh, Fawwar, Ras Al-Qilt, and Murashahat were taken as representative reference values since these regions are located far away from human activities and considered as pristine areas within the catchment. Based on these values, the contamination factors were calculated and evaluated for the total contents as well as for sequential fractionation steps that represent the bonding group and speciation of trace metals. These fractionation steps are important for understanding the release and transport of heavy metals within the local environment.

The size of the Al-Qilt drainage catchment is about 174 km² (Fig. 1) and it is situated in the east of the West Bank. Al-Qilt's most important tributaries by lengths are Wadi Al-Ein (7.5 km), Wadi Mukhmas (9 km), Qalandiah (2 km), and Stone Cut (2 km) which are all located at the left, northern bank of the catchment. The study area is characterized by a steep relief with elevations ranging from 800 m.a.s.l. at the western part to −250 m.b.s.l. at the eastern part. Moreover; the rainfall is estimated by 600 mm/a at the western part and it is 150 mm/a at the eastern part, and the average rainfall over the catchment is about 400 mm/a (PWA 2009).

A 50-km long stretch of Wadi Al-Qilt east of both Ramallah and Jerusalem districts and west of the Jordan Valley has been selected for the present study. Freshly deposited and grab sediment samples were collected from Al-Qilt during June and October 2008 and in June and October of 2009 (Fig. 1). Moreover, nine sites were selected to represent the following type of sediments (1) sediments from effluents of treated waste water (Al-Bireh waste water treatment plant), (2) sediments from untreated waste water (Qalandiah and Stone Cut), (3) sediments from wadis that carry waste water and runoff (Mukhmas and Sweanit), and (4) sediments from freshwater (springs such as Fawwar, Ras Al-Qilt, Murashahat, and Sultan).

The aim of this study was to evaluate the quality of the sediment according to trace elements at Al-Qilt catchment to identify contaminated sites. For these sites, the extent of degradation of the ecosystem and environmental should be estimated. This can be achieved by studying the following factors:

1. Calculation of the Contamination Enrichment Factor (CF) for the "aqua regia" fraction to assess the extent of metal pollution and their distribution

2. Calculation of the Contamination Factor (CF) for each step within a sequential extraction scheme (BCR-method, Ure et al. 1993) to get information about the relevance of the different bonding forms
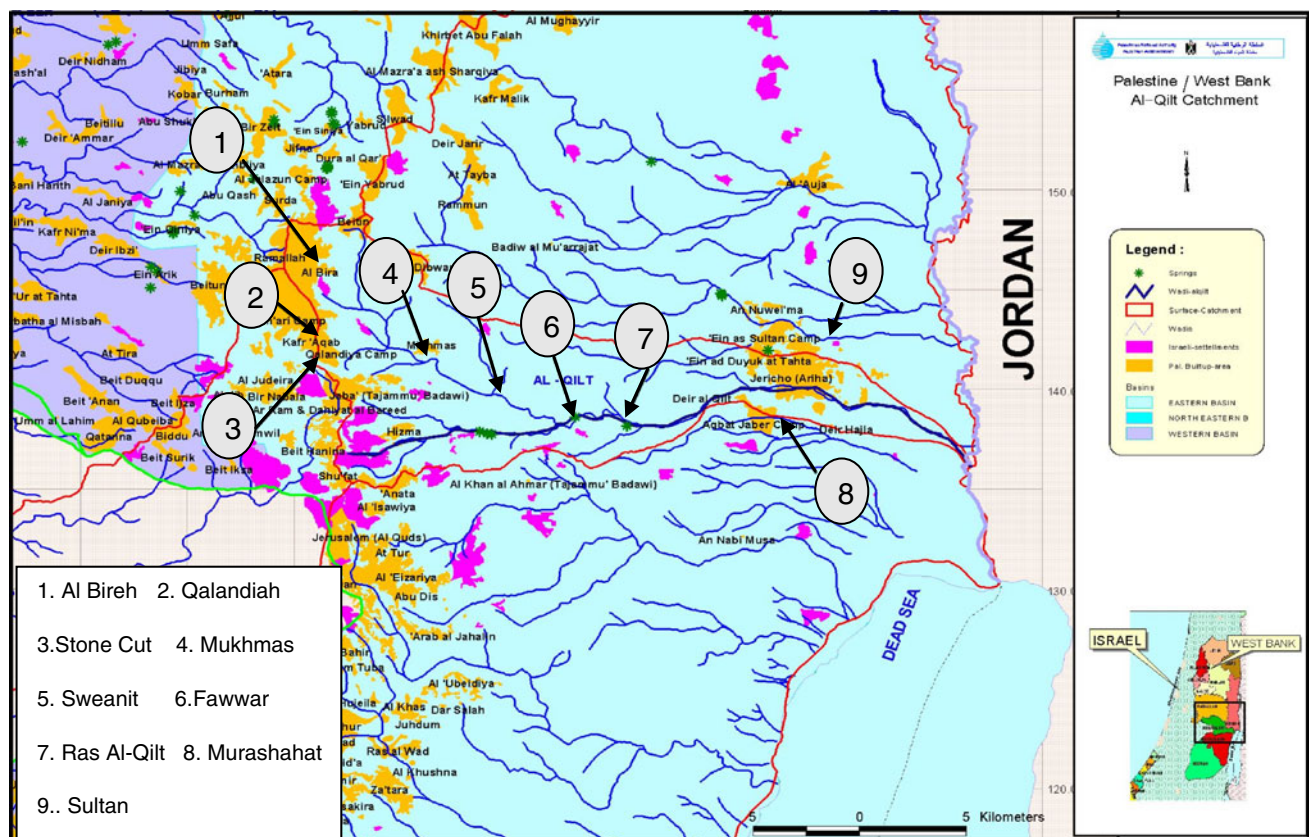

Fig. 1 Study area of Al-Qilt catchment, Springs, distance between sampling sites and major cities (Palestinian Water Authority 2009)

3. Relating the CF to BCR fractionation as a tool for mobility and transport of trace metals

Materials and methods

The collected sediment samples were taken using a plastic grab "non-metallic" sampler to take small batched samples from beneath the top surface (3–5 cm). The 250 ml plastic bottles (Jar) were then preserved at 4° C for analysis.

In the laboratory, the sediment samples were frozen to −25° C to stop microbial activity before they were submitted to "freeze-drying and evaporation" using a CHRIST Delta 1-24 LSC for 4 days. Afterwards, about 200–250 g of the dry material was sieved into 63 μm sub-samples using the sieving unit Fritsch D-55743.

For total digestion, about 0.25 g from the homogenized samples and from the Buffalo sediment Standard Reference Material (SRM 8704) were weighted into 100 ml Teflon digestion tubes and added with 6 ml of concentrated HNO_3 (65 %) and 3 ml of concentrated HCl (37 %). Afterwards, the samples were digested for 2 h using a Microwave (MARS 5) digester. Thereafter, the samples were adjusted with high purity water to 25 ml for analysis. Trace metal contents were measured for Cr, Co, Ni, Cu, Zn, As, Sr, Mo, Ag, Cd, Sn, Sb, Ba, Pb, Bi, and B using a Agilent 7500 ICP–MS Inductive Coupled Plasma Mass Spectrometer and for Hg using a Flow Injection Mercury System (FIMS 400, Perkin Elmer). Samples were analyzed according to Water and Wastewater Standard Methods (APHA 2000) and according to the German Standard Methods for the examination of water, waste water, and sludge (DIN 38414, 1984) methods.

The methodology used for sequential extraction is based on the BCR-method (Ure et al. 1993). About 1 g of the sieved sediment and soil samples (<63 μm) from the Certified Reference Material (CRM BCR-701) were weighted into glass tubes. Table 1 summarizes the subsequent 4 step procedure.

To describe the degree of pollution of a given parameter, the contamination factor is used here as the ratio of the sediment metal content at a given sampling location and the reference value of the respective element (local soil or continental crust value). The Contamination Factor (CF) is expressed as:

$$CF = \frac{Co}{Cb}$$

where Co is the mean content of a given element in the sediment, Cb is the reference value for the respective element

The contamination factor was classified into four groups according to Hokanson (1980) and Pekey et al. (2004). They used the following terminology: $Cf < 1$ for low contamination; $1 \leq Cf < 3$ for moderate contamination; $3 \leq Cf < 6$ for considerable contamination; and $Cf \geq 6$ for very high contamination.

For quality control and quality assurance, the precision and accuracy of the data were checked through repeated analysis ($n = 5$) using the international standard for sediment such as Buffalo sediment Standard Reference Material (SRM 8704) for total digestion and the Certified Reference Material (CRM 701) for BCR fractionation steps. The results were within ±15 % of the certified values for sediment samples, whereas the recovery of most of the elements was within range of acceptance (80–110 %) with the exception of barium (61 %).

Results and discussion

Soil and continental crust as reference values

In this study, we used the pristine soil samples from Sweanit, Fawwar, Ras Al-Qilt, and Murashahat and the continental crust values from Turekian and Wedepohl (1961) as reference values for the calculations. There is an agreement between soil and continental crust values for Cr, Ni, Cu, Sr, Sn, and Pb; on the other hand, the soil reference

Table 1 Reagents and conditions employed for the (BCR) sequential extraction procedure

Step	Fraction	Reagent and conditions
1	Exchangeable	1 g of samples, BCR Ref (701) and 40 ml 0.11 mol l^{-1} CH$_3$COOH, shaken for 16 h at room temperature, centrifuged 3,000×g for 20 min, decant the supernatant, wash the solid, centrifuge then go to the next step
2	Reducible	40 ml 0.5 mol l^{-1} NH$_2$OH·HCl, shaken 16 h at room temperature, centrifuged as in step 1, then the supernatant for analysis
3	Oxidizable	Digested with 10 ml 8.8 mol l^{-1} H$_2$O$_2$, 1 h at room temperature, 1 h at 85 °C and covered samples, 10 ml 8.8 mol l^{-1} H$_2$O$_2$ added, 1 h at 85 °C, reduced volume to 1 ml, extracted with 50 ml of 1 mol l^{-1} NH$_4$COOCH$_3$, pH of solution 2–3, shaken 16 h at room temperature
4	Residual	9 ml 12 mol l^{-1} HCl, 3 ml 16 mol l^{-1} HNO$_3$, Microwave digestion for 2 h, cool, decant the supernatant, centrifuge, then sample for analysis

values for Zn, As, Ag, Mo, Hg, and Cd are higher and for Ba lower than the continental crust values. These variations will affect the calculations for the contamination factor and is important to identify the agreement and disagreement between the soil and continental crust as reference values (Fig. 2).

Contamination factor (CF) calculated from total contents

The results for both the continental crust and soil reference values are shown in Table 2. According to the contamination factor classifications done by Hokanson (1980),

Fig. 2 Soil reference versus continental crust values (median, minimum, and maximum)
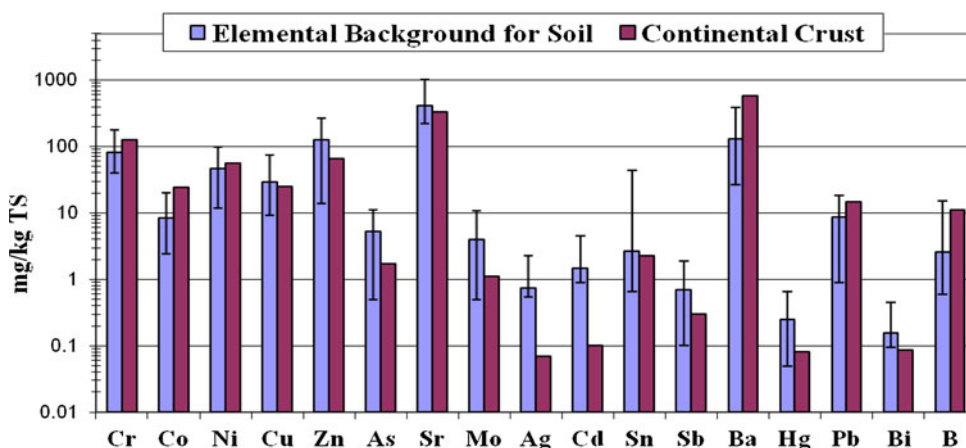
Table 2 Contamination factors trace metals at the Al-Qilt catchment using the Soil Reference (SR) and Continental Crust (CC)

Sampling Sites	Cr	Co	Ni	Cu	Zn	As	Sr	Mo	Ag	Cd	Sn	Sb	Ba	Hg	Pb	Bi	B
SR	82.8	8.3	47.5	29	126.9	5.4	410.5	4	0.8	1.5	2.7	0.7	132	0.2	8.7	0.2	2.6
ALBireh	0.9	1.1	0.8	3.3	5.3	1	0.4	1	29.3	0.5	3.1	3.3	1.4	14.7	4.8	12.5	8.5
Mukhmas	0.9	1.1	0.8	3.3	5.3	1	0.5	0.8	29.3	0.5	2.8	2.3	1.4	6.8	4.1	8	5
Qalandiah	0.9	0.9	1	5.5	3.8	0.7	0.4	0.7	2.9	0.6	3	1.9	1.4	3.3	3.9	6.8	2.4
Stone Cut	0.9	0.7	0.8	1.4	1.4	0.9	0.7	1	1.6	0.6	1.6	2.2	1.7	1	6.1	2.5	1.8
Sweanit	0.7	0.6	0.6	2.5	4.5	0.7	0.6	1.2	23.2	0.5	5.1	1.6	1.9	0.9	1.9	9.1	6.4
Fawwar	1	0.8	0.9	1.7	2.7	1	0.9	1.3	13.1	1	2.9	1.7	1.4	NM	1.5	4.1	6.2
Ras Al-Qilt	0.9	0.7	1	0.9	1.2	0.9	1.3	1.3	2.7	2	1.1	1.2	1.4	0.8	0.8	1.1	1.5
Murashahat	0.9	0.8	0.8	1.4	0.7	1.1	0.9	1.1	0.8	0.6	0.9	0.7	0.8	0.2	1	3.6	10.1
Sultan	0.7	1.1	0.6	0.8	0.7	0.5	0.6	0.3	0.3	1	4	0.4	0.4	NM	2	0.4	0.8

Sampling Sites	Cr	Co	Ni	Cu	Zn	As	Sr	Mo	Ag	Cd	Sn	Sb	Ba	Hg	Pb	Bi	B
CC	126	24	56	25	65	1.7	333	1.1	0.1	0.1	2.3	0.3	584	0.1	14.8	0.1	11
ALBireh	0.6	0.4	0.7	3.9	10.3	3.1	0.5	3.5	314.3	6.9	3.5	7.7	0.3	55	2.8	23.5	4.2
Mukhmas	0.5	0.4	0.6	3.4	8.9	2.5	0.6	3	283.8	7.4	4.4	5.3	0.3	13.5	2.1	16.1	2.2
Qalandiah	0.6	0.3	0.8	6.4	7.4	2.1	0.5	2.6	31.4	9	3.5	4.3	0.3	12.5	2.3	12.8	0.6
Stone Cut	0.6	0.2	0.7	1.6	2.7	2.8	0.8	3.7	17.1	8.8	1.9	5.1	0.4	3.6	3.6	4.7	0.4
Sweanit	0.5	0.2	0.5	2.9	8.8	2.1	0.7	4.3	248.6	7.3	5.9	3.7	0.4	3.5	1.1	17.1	1.5
Fawwar	0.6	0.3	0.8	2	5.2	3.3	1.1	4.6	140	14.7	3.4	4	0.3	NM	0.9	7.6	1.5
Ras Al-Qilt	0.6	0.2	0.9	1	2.2	2.8	1.6	4.7	28.6	30.1	1.2	2.7	0.3	2.8	0.5	2.1	0.3
Murashahat	0.6	0.3	0.7	1.7	1.3	3.4	1.5	3.9	8.6	9.1	1	1.7	0.2	0.7	0.6	6.7	1.5
Sultan	0.5	0.4	0.5	0.9	1.4	1.5	0.7	1.2	2.9	15.4	4.7	1	0.1	NM	1.2	0.8	0.2

All values were calculated based on medium values $n = 36$

CF < 1 in *white*, $1 \leq$ CF < 3 *light gray*, $3 \leq$ CF < 6 *gary* and CF ≥ 6 *dark black*

Pekey et al. ([2004](#)) and by determining the total contents for Cr, Co Ni, As, Sr, Mo, Cd, and Ba, there are scattered pollution points in sediments. Significantly, they are lower than the continental crust reference values for As, Cd, and Mo. These results indicate that there are higher contamination factor values for the investigated sediments (Table [2](#)).

The contamination factors for Sr, Mo, Sb, Ba, As, Cr, Co, Ni, and Cd are classified as moderate contamination to considerable contamination since $1 \leq Cf < 6$. Cu, Zn, Sn, Pb, Ag, Hg, Bi, and B are classified as very high contaminated because $Cf \geq 6$ (acc. to Hokanson [1980](#), Pekey et al. [2004](#)).

Regarding the sites, the contamination factors at Qalandiah, Al-Bireh, Mukhmas, and Sweanit were high compared with other sites in terms of the number of pollutants that pose the highest values of CFs based on continental crust values.

The very high CFs for Ag, Hg, Bi, and B appear at Al-Bireh and at Mukhmas, since the wastewater coming from Al-Bireh is mixed again at Mukhmas with raw wastewater from Qalandiah and Stone Cut. Although the distance from Mukhmas to Sweanit is about 4–5 km, these parameters still have high contamination factors at Sweanit, which means that there must be an additional source in between downstream or these trace elements were transported preferentially as suspended particulate matters downstream.

Contamination factors calculated from sequential extraction

Results revealed that for the highly enriched Zn, Hg, Bi, B, and Cu, there bonding forms must be taken into consideration for an assessment of the contamination factors. By calculating contamination factors for each step of the BCR fractionation (using SR values), this will give indication for the potential of release and mobility.

The CFs for the BCR fractionation steps and the recovery values were within acceptable 15 % error, except for Cd (133 %) and for Ba (58 %) (Table [3](#)).

In general, results for total CFs reveal that Cr, Ni, As, Sr, Cd, and Ba have CFs less than six and therefore do not pose any risk for contamination of the environments and ecosystems. On the other hand; the CFs for Co, Cu, Zn, Mo, Ag, Sn, Sb Pb, and Bi were greater than six for one of the BCR fractionation steps indicating a weak bonding of these trace metals. Moreover, the CFs reflect the potential risk for an easy mobility or transport of these trace metals within the aquatic system. For example, Zn has the highest values of CFs in the first step of the BCR fractionation at Al-Bireh (treated wastewater), Qalandiah (untreated wastewater), and Fawwar spring (groundwater), suggesting that it was released at this stage since this step is classified

as being the most exchangeable fraction which contains metals in loosely held surface associations. Because of the association with "carbonates", these are easy to leach and transport within the aquatic system.

On the other hand, Co, Ag, and Cd have the highest values of CFs at step two of the sequential extraction (reducible fraction) at Sultan spring "groundwater", indicating that Co is released at this stage. Therefore, it is likely that Co is adsorptive bounded to oxides and oxyhydroxides of Mn and amorphous Fe.

Furthermore, Cu, Zn, Mo, Ag, Sb, Pb, and Bi have the highest values of CFs at step three (oxidizable fraction) at Al-Bireh, whereas Cu, Ag, Sb, and Bi show the highest values of CFs within this fraction at Mukhmas (wadi for wastewater) and Cu, Mo, Sb, Pb, and Bi at Qalandiah. The highest CFs within this fraction were found for Sb, Pb, and Bi at Stone Cut and for Bi, Ag, Sn, and Sb at Fawwar spring (groundwater). The display of the highest CFs for these trace elements within the oxidizable fraction relate them to be associated with organic matter and sulfides or that they are occurring in an oxidizable form within the residue.

At least, Ag and Bi were predominant within step four (residual fraction) at Al-Bireh, Mukhmas, and Fawwar. This indicates that these elements can be classified as being "residual" and are not available for the environment.

Finally, the results revealed that for Zn, Ag, Pb, and Bi, the CFs within all four fractions are high (>6) at different sites. This will increase the risk for mobility and transport within the aquatic system from the residual to the exchangeable fraction. Moreover; the trace element fractionation behaves in different manners at the springs. At Fawwar, the uppermost Al-Qilt spring, Ag is released at steps three and four suggesting that it occurs in oxidizable and residual form, whereas it is released at Ras Al-Qilt spring in steps one and two within the exchangeable "carbonate bonded" and reducible "Fe and Mn bonded" forms. However, at Sultan Spring another situation was observed since Co and Pb were released at step two, from the reducible fraction which made it likely that they were bonded to Fe- and/or Mn-oxides/hydroxides. These variations lead to a complex behavior of the trace elements within the unsaturated zone regarding their stability. On the contrary, the CFs for Cr, Ni, As, Sr, Cd, and Ba never exceeded six for all BCR's fractionation steps, which categorize them not to pose impacts at Al-Qilt wadi.

Conclusions

The surface sediment samples of the Al-Qilt catchment are characterized by trace element contents that are typical of aquatic environments located in industrial and densely

Table 3 Contamination factors for the BCR fractionation steps at Al-Qilt, units are in mg/kg and $n = 3$ for each step

Sampling sites	Cr	Co	Ni	Cu	Zn	As	Sr	Mo	Ag	Cd	Sn	Sb	Ba	Pb	Bi
Recovery	101	110	111		111					132		111	58	91	
Al Bireh Step 1	0.68	2.33	1.21	2	61.61	3.08	0.92	1.25	2	0.22	1	3.33	0.48	5	5
Al Bireh Step 2	0.27	0.5	0.57	0.78	18.18	1.5	0.38	1	10	0.6	1	2.5	1.62	3.53	5
Al Bireh Step 3	1.73	0.68	1.34	13.55	7.05	1.43	0.38	10	19	1.04	1	31	2.33	6.17	20
Al Bireh Step 4	0.58	0.5	0.51	1.46	0.79	0.34	0.61	0.35	80.4	0.64	3.7	2.67	1.12	3.7	7.87
Mukhmas Step1	0.75	3	1.42	0.6	3.23	3.04	0.96	1.25	10	0.17	1	3.33	1	2.5	5
Mukhmas Step2	0.27	0.75	0.57	0.33	3.88	1.5	0.6	1	10	0.53	1	2.5	1.47	1.06	5
Mukhmas Step3	1.37	1.45	1.72	7.24	3	1.3	1.3	2.63	9	1.46	1	10	2	5.78	6.2
Mukhmas Step4	1.2	1.3	1.03	1.35	1.1	0.61	1.06	0.58	6.2	0.86	2.87	1.33	2.55	0.78	1.67
Qalandiah Step1	0.75	5.33	3.26	1.2	34.19	1.54	0.54	2.5	2	0.33	1	3.33	0.92	5	1
Qalandiah Step2	0.87	1	1.07	0.89	8.96	3.1	0.35	1	10	0.67	1	5	1.04	15.88	5
Qalandiah Step3	1.12	0.9	1.52	33.71	5.42	2.27	0.49	6.32	5	1.18	2	20	1.58	16.64	12.2
Qalandiah Step4	0.61	0.58	0.66	4.12	0.85	0.58	0.78	0.5	4.8	0.86	5.53	4	0.98	1.96	2.8
Stone Cut Step1	0.88	4	1.74	1.2	2.87	1.54	0.57	2.5	10	0.11	1	6.67	0.8	8	1
Stone Cut Step2	0.45	1	1.18	0.33	1.47	1.7	0.65	1	10	0.33	1	3.75	0.85	5.82	1
Stone Cut Step3	1.33	1.22	1.1	4.52	2.62	1.59	1.16	3.16	5	0.93	1	30	2.46	15.09	12
Stone Cut Step4	0.73	0.78	0.55	0.99	0.68	0.34	0.67	0.42	2.4	0.79	2.7	2.17	1.63	0.8	2.07
Sweanit Step1	0.7	2.33	1.47	0.8	5.19	2.12	0.69	2.5	2	0.22	1	3.33	0.44	2.5	1
Sweanit Step2	0.73	1	0.82	0.44	2.25	1	0.44	1	10	0.4	1	1.75	1.04	0.65	1
Sweanit Step3	1.36	0.9	0.77	2.34	1.45	1.43	1.57	1.58	11	0.93	1	10	3.08	4.18	2
Sweanit Step4	0.47	0.43	0.52	0.57	0.38	0.98	0.5	1.12	4.6	0.86	3.93	0.83	1.27	0.39	1.2
Fawwar Step1	0.75	2.67	1.58	1.4	12.9	2.69	0.89	2.5	0	0.5	0	3.33	0.92	5	1
Fawwar Step2	0.87	0.75	1	5.44	3.94	2.5	0.94	1	0	1.22	0	2.5	0.94	1.76	1
Fawwar Step3	1.66	1.27	1.98	4.45	3.51	1.75	1.43	2.63	10	1.71	6	20	2.42	3.73	9.8
Fawwar Step4	1.05	0.65	0.98	0.72	0.78	0.71	0.72	1.31	12.2	1.07	2.3	0.83	1.08	0.28	0.93
Ras Al-Qilt Step1	0.81	3.33	2.11	0.8	2.1	1.31	1.13	2.5	10	2.17	1	1	1	1.5	1
Ras Al-Qilt Step2	2.67	1	1.36	0.44	0.94	1.95	1.64	1	10	3.24	1	0.75	0.72	0.76	1
Ras Al-Qilt Step3	1.75	0.77	0.95	1.23	0.62	1.78	4.59	1.58	5	2.71	1	4	1.75	1.15	1
Ras Al-Qilt Step4	0.94	0.53	1.18	0.52	0.84	1.01	0.5	1.88	1.8	0.86	0.93	0.67	1.2	0.17	0.4
Murashahat step 1	0.63	3.33	1.68	1	0.84	2.31	0.98	2.5	10	0.67	1	1	1	1	1
Murashahat step 2	0.86	0.75	1.04	0.44	0.36	2.4	1.02	1	10	0.84	1	0.75	0.74	0.59	5
Murashahat step 3	1.01	0.86	0.95	2.28	0.67	1.38	2.22	0.53	5	0.89	1	3	0.71	1.39	1
Murashahat step 4	1.73	1.03	1.17	1.49	1.06	4.94	1.17	2.23	1.8	3.71	0.77	0.83	0.61	0.5	0.8
Sultan Step1	0.88	2.33	1.68	0.8	0.65	0.38	1.12	0	0	3.39	2	0	0.72	5	0
Sultan Step2	3.33	7.75	1.75	1.11	1.29	2	0.25	0	0	1.05	2	0	0.43	43.53	0
Sultan Step3	0.69	0.27	0.57	0.65	0.23	0.16	0.03	1.58	1	0.21	2	0	0.13	1.74	0.2
Sultan Step4	1.28	1.45	0.65	1.22	0.79	0.43	2.39	0.38	0.2	2.21	3.17	0.5	0.37	0.53	0.4

CF < 1 in *white*, $1 \leq$ CF < 3 *light gray*, $3 \leq$ CF < 6 *gary* and CF $\geq$ 6 *dark black*

populated areas. Zn, Ag, Cd, Hg, Bi, and B have CF-values greater than six classifying them as highly polluted. When applying the calculation of CF to single steps of the BCR sequential extraction scheme, a more realistic view on the potential impact of the trace metals to the environment is gained. Considering the first two steps of the BCR scheme (exchangeable, reducible) which are the most relevant fractions from which the metals can be released to the

environment, Cu, Pb, Zn, Ag, Sb, and Bi exhibit CFs greater than six. This can be seen as hints for high risk of pollution by these trace metals.

References

American Public Health Association (2000) Standard methods for the examination of water and wastewater, 20th edn. Washington, DC

ARIJ (2007) Applied Research Institute—Jerusalem: status of environment in the West Bank Territories. Palestine

DIN 38414 (1984) German standard methods for the examination of water, waste water and sludge. Beuth Verlag, Berlin

Hokanson L (1980) Ecological risk index for aquatic pollution control, a sedimentological approach. Water Res 14:975–1001. doi:10.1016/0043-1354(80)90143-8

Palestinian Central Bureau of Statistics (2003) Israeli Settlements in the Palestinian territory, annual report 2002. Ramallah, West Bank, Palestine

Palestinian Central Bureau of Statistics (PCBS) (2005) Revised population projection 2005. Ramallah, West Bank, Palestine

Palestinian Water Authority (2009) Data Base and GIS units. West Bank, Ramallah

Pekey H, Karakas D, Ayberk S, Tolun L, Bakoglu M (2004) Ecological risk assessment using trace elements from surface sediments of Izmit Bay (Northeastern Marmara Sea) Turkey. Mar Pollut Bull 48:946–953

Turekian K, Wedepohl K (1961) Distribution of the elements in some major units of the earth's crust. Geol Soc Am Bull 72:175–192

Ure AM, Quevauviller Ph, Muntau H, Griepink B (1993) Speciation of heavy metal in soils and sediments. An account of the improvement and harmonisation of extraction techniques undertaken under the auspices of the BCR of the Commission of the European Communities. Int J Environ Anal Chem 51:135–151