

Heavy Element Accumulation in Aquatic Beetles of the *Genus Enochrus* (Coleoptera: Hydrophilidae) in Erzurum Province

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Abstract

In the present study, fourteen heavy elements (Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Br, Sr, Pb) accumulation in sediment, water and *Enochrus* spp. species organs (total body) were evaluated. For this purpose, water, sediment and *Enochrus* spp. were collected from nine wetland sites in Erzurum province (Turkey). Measurements of heavy elements were made with Energy Dispersive X-Ray Fluorescence (EDXRF) spectrometer. The results showed that there are differences in element concentrations between species and stations. Insects were mostly found in industrialized areas. The water samples' heavy element levels were compared with national water quality standards. The values of some heavy elements found at higher concentration than the acceptable limits.

Keywords: Aquatic Coleoptera; EDXRF; Pollution; Wetland

Introduction

All matters (living and non-living) are made up of elements and almost every manufactured product involves the elements. Elements including heavy metals and metalloids are all occur naturally in the Earth's crust and are usually present certain degree in all environments. They are form of inorganic and organic compounds and their natural and man-made sources continuously enter the ecosystem and pose a serious damage because of their long time persistence, toxicity and tendency to bioaccumulation, bioconcentration and biomagnification in the food chain [1]. This element accumulation in the food chain creates increasing pressure on all living things every passing day. In the future, it seems that the situation will become more dramatic. Like other ecosystems pollutions, aquatic ecosystems pollution with these contaminants has become a matter of great concern over the last decades. Accumulation occurs in all aquatic invertebrates' tissues, whether or not these elements are essential to metabolism and if the certain threshold concentrations are exceeded, it becomes toxic [2,3].

The terms bioindicator and biological monitor have significant variation in meaning. Bioindicator generally refers to organisms or molecules that provide significant information in regard to quality of environment or environmental changes, whereas biomonitors are the organisms that provide quantitative information about the environment. In this regard, a biomonitor always acts as a bioindicator but a bioindicator does not always a biomonitor [4]. According to Witting, Markert and Rainbow [2,5,6], there are some basic criteria for a suitable biomonitor that it should; have large numbers all over the studying area, have cosmopolitan geographical distribution, be easy and inexpensive to sampling and have well known taxonomy. Today to evaluate ecosystem condition and its quality, biological monitoring methods have been applied widely in ecological research [6-8].

Like other organisms in the ecosystems, insects are exposed to various anthropogenic chemicals and some of them accumulate these chemicals in their body. Insects are largest group of organisms, and have numerous effects on human health because of diversity in their morphology and physiology, their abundance, economic importance [9]. Aquatic insects live or spend a part of their life cycle in different kind of water bodies [10]. Aquatic insects are good indicators of water qualities since they have various environmental tolerant levels [11]. Some of them such as midge and blackfly larva etc. indicate poor water quality and can live in moderately or extremely polluted waters, whereas some of them such as mayfly, stonefly nymph very vulnerable and sensitive to pollution and indicates good water quality [12-14] investigated metal contamination ability of the Odonata larvae and the study suggests that they have an ability to take up metals and appropriate indicator for ecosystem health. Boyd (2009) studied Ni hyper-accumulator insects which feed on Ni hyper-accumulator plants showed that Ni hyper-accumulator insects accumulate more Ni than other insects. Aydoğan *et al.* (2017) [8] studied heavy metal accumulation in some aquatic insects and tissues of

Chondrostoma regium in the same habitat showed that insects accumulated more metals than their environment and due to food of studied fish the metals could be transfer from insect to along the food web.

Hydrophilidae is one of the largest families of Coleoptera, and some feature of Hydrophilidae make them good biomonitor for heavy element such as it has worldwide distribution, well known taxonomy and larvae and adults live in different environmental conditions. Hydrophilidae are water scavenger beetles and generally occur in shallower regions of wetland with abundant macrophytes and feed mainly on detritus, algae and decaying organic matter in contrast to adults, larvae are predaceous, preying on various invertebrates [15]. Hydrophilidae are present in low dissolved oxygen content water indicating the hardy nature of these beetles [16]. The aquatic Coleoptera of the genus *Enochrus* Thomson 1859 are among the commonest species of the European hydrophilids, and also is the third largest genus in the Hydrophilinae with 223 species placed in six subgenera worldwide [17]. This research attempted to evaluate the potential use of adults *Enochrus* spp. samples as biomonitor of heavy element pollution, as well as classify and compare the health status of freshwater in Erzurum province, Turkey.

Materials and Methods

Erzurum is the biggest city of the Eastern Anatolia Region in Turkey. In addition, it is one of the highest and coldest cities in Turkey. It is very rich in terms of water resources. Industrialization has not improved but economy mostly based on agricultural and livestock activities, trade and winter tourism. In this study, nine different locations (i.e; industrial, roadside, urban, suburban and rural area) were selected. These localities are described in Table 1 and given in Figure 1.

Station Number	Altitude (m)	Coordinates	Station information	Notes on near environment
1	1636	39°54'19"N 40°41'01"E	500 m Western front of Cement factory	Traffic and ash emission from cement factory
2	1669	39°54'38"N 40°41'41"E	500 m Eastern front of Cement factory	Ash emission from cement factory
3	1636	39°56'41"N 40°39'44"E	Aşkale-Trabzon Highway	Traffic pollution, limited human activities
4	1759	39°56'03"N 41°04'24"E	Sugar factory Drainage channel	Sugar factory waste
5	1754	39°57'04"N 41°04'39"E	Erzurum-İlica Highway	Sugar factory waste and traffic pollution
6	1765	40°02'31"N 41°21'05"E	Erzurum-Tortum Highway	Traffic and domestic pollution
7	1819	40°04'35"N 41°21'38"E	Gökçeyamaç Village	Agriculture, livestock and domestic pollution
8	1826	40°06'05"N 41°21'36"E	Akdağ Village (Erzurum)	Contamination due to livestock
9	1766	39°55'59"N 41°08'56"E	Dadaşkent (Erzurum)	Heavy traffic pollution

Table 1: Description of the nine sampling sites in Erzurum province

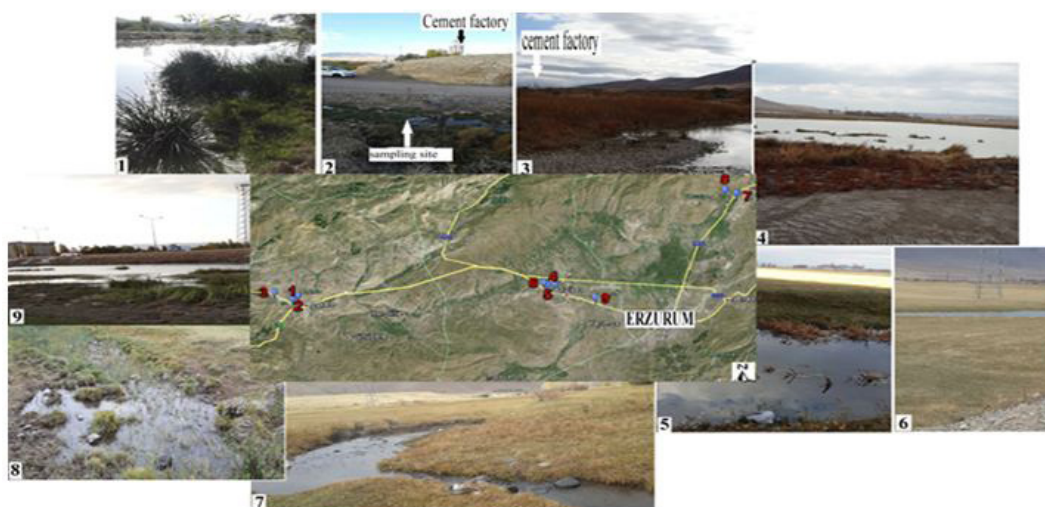


Figure 1: Photos of the nine sampling sites and location in Erzurum province

To determine the extent of element accumulation in nine sites of Erzurum, all samples (*Enochrus* spp. and their abiotic environment) were collected in June, July and August 2014. The samples were collected, identified and analyzed as described in Aydoğan *et al.* (2016; 2017 [8,18]). 1 mm mesh aperture sieve and mouth aspirator was used to collect insect samples and they were preserved in 70% alcohol. Identification was made under stereomicroscope by using male genitalia of insects. The aquatic insects were identified with using taxonomical key to the species level [19,20]. The sediments were taken from 30 cm depth benthic zone. The water samples were taken from 0.5 m depth of stream. 15 cc for water and 3 gr for sediment was enough to analyze in EDXRF. Water and sediment samples were kept in the refrigerator until analysis.

After identification, samples were dried in an oven at 80 °C during 36 h. Concentrations of 14 elements in the samples measured by EDXRF spectrometry. To determine heavy elements, 1 Ci ²⁴¹Am radioactive source and an HPGe detector with resolution ~180 eV at 59.5 keV was used. All samples were excited by using 59.5 keV photons, emitted from ²⁴¹Am radioactive source. All measurements were carried out under vacuum. Water and sediments samples were put in Al sample holder with Mylar films on both sides. Measurement time for water and sediment samples was 4 h. Insects were pulverized, and then, cellulose was added as a binder. Five tons of pressure was applied to make 13 mm diameter pellets of each species. WinAXIL program is used for determinate the concentration of elements in each sample. The model parameters are optimized by means of a nonlinear least squares strategy, using a modified Marquardt algorithm to minimize the weighted (optional choice) sum of differences χ^2 between the experimental data and the mathematical model. The concentration presented in this table has some uncertainties due to EDXRF (maximum ~5%). Possible error sources for these uncertainties are given in Table 2, and the typical spectrum of samples in EDXRF shown in Figure 2. Chemical parameters of the insects, water and sediment samples are given in Table 3.

Nature of Uncertainty	Uncertainty (%)
Counting Statistics	~ 1.00
Systematic errors	~2.00
Peak evaluation procedure	~3.00
Fundamental parameter methods	~3.00

Table 2: Error sources in the experimental results

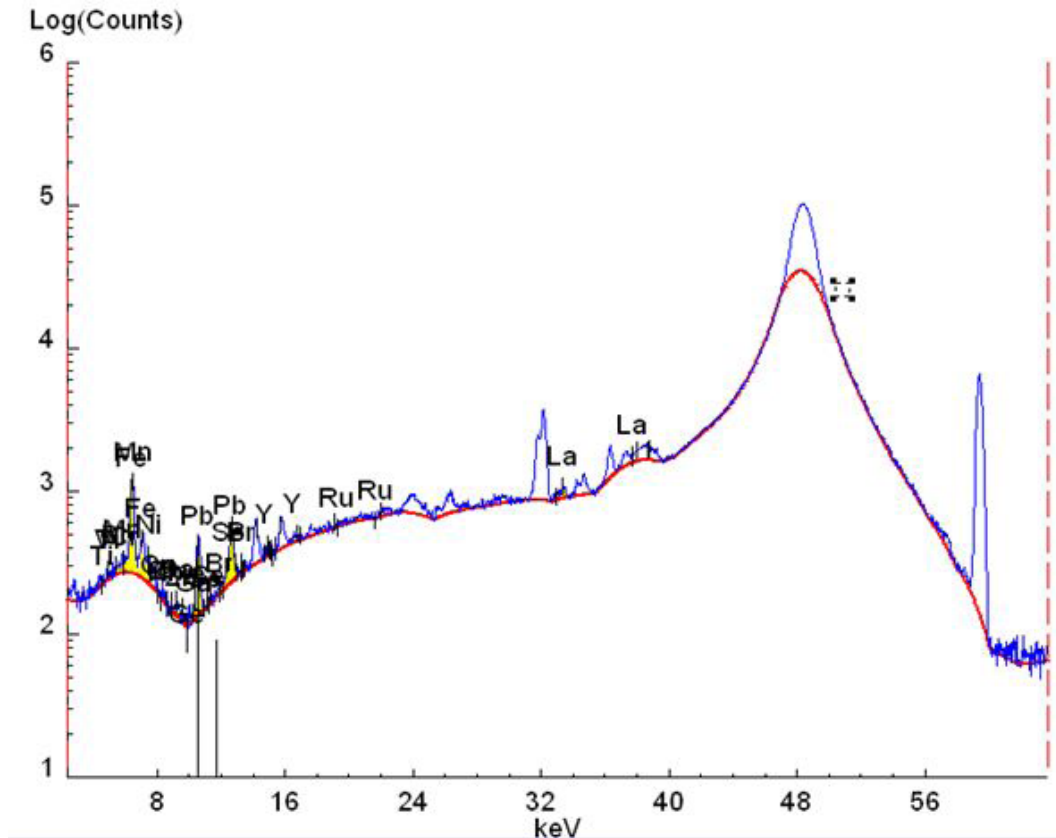


Figure 2: The typical spectrum of a sample in EDXRF

Stations	Samples	Mean ± SD													
		Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Br	Sr	Pb
1	Water	436±6.55	82.6±4.5	22±2.6	6.2±0.26	2.9±0.15	1±0.1	0.3±0.2	0.36±0.15	0±0	0.2±0.1	0±0	0.34±0.1	0±0	1.7±0.25
	Sediment	1.7±0.25	0.32±0.11	849±6.02	0±0	0.13±0.06	0±0	22.3±2.5	9.23±0.25	4.9±0.65	9.5±0.4	10.06±0.5	5.03±0.4	9.6±0.36	10.8±1.04
	<i>E. quadripunctatus</i>	127±5.5	23.3±3.05	18.1±2.8	6.8±1.2	2.8±0.41	2.33±0.41	0.41±0.2	0.42±0.06	0.2±0.1	0±0	0.24±0.1	0±0	320.6±6.1	602±7.21
	<i>E. halophilus</i>	307±8.18	55.3±3.5	46.6±3.5	19±2	1.2±0.2	5.2±0.2	5.1±0.4	1.03±0.14	0.47±0.3	0±0	1.2±0.2	0.6±0.3	0.14±0.05	0.2±0.01
2	Water	321.8±20	63.8±2.7	14.6±2.5	4.9±0.6	2.2±0.2	0.03±0.02	0.5±0.1	0.13±0.05	0.2±0.1	0.2±0.1	0±0	0.25±0.1	0±0	1.9±0.2
	Sediment	1.2±0.25	0±0	663.6±13	231.3±12	244±4.5	8.8±0.4	15±3	7.5±0.4	3.7±0.3	7.3±0.7	8.2±0.3	3.6±0.5	9.5±0.5	2.5±0.5
	<i>E. ater</i>	1.1±0.16	0±0	434±6.1	0±0	185.3±4.1	0±0	9.4±0.3	0±0	2.2±0.2	4±0.4	4.4±0.7	10.1±0.8	0.5±0.3	175.6±5.5
	<i>E. bicolor</i>	0.1±0.02	0±0	73.6±3.5	0±0	87.6±2.5	0±0	1.5±0.3	0.6±0.2	0.5±0.3	1.5±0.1	0.5±0.4	1.9±0.2	0.2±0.1	10.4±1.05
	<i>E. halophilus</i>	147±4.53	0±0	0±0	0±0	3.1±0.4	0±0	0.13±0.05	0.2±0.17	0±0	0.1±0.5	0.13±0.05	0.14±0.05	0.06±0.02	1.8±0.4
	<i>E. segmentinotatus</i>	173±3.8	0±0	7.2±0.2	2.2±0.2	3.1±0.2	0±0	0.13±0.05	0.2±0.1	0±0	0.2±0.1	0.1±0.05	0.1±0.05	0.01±0.003	2.3±0.2
	<i>E. fuscipennis</i>	0.2±0.06	0±0	0±0	0±0	190±10.4	0±0	2.2±0.2	1.4±0.2	4.2±0.2	1.6±0.1	1.03±0.1	4.1±0.3	1.1±0.1	11.4±0.9
	<i>E. quadripunctatus</i>	783±4.3	0±0	32±2.08	10.1±0.8	30.6±3.5	0±0	0.4±0.3	0.2±0.1	1.1±0.17	0.2±0.1	0.26±0.15	0.5±0.2	0.1±0.05	6.2±0.2
3	Water	796.8±5	140.5±8	10.3±0.2	10.1±0.7	4.8±0.4	1.8±0.2	0.7±0.2	0.2±0.1	0.2±0.1	0.2±0.1	0±0	0.2±0.05	0±0	3.23±0.2
	Sediment	1.2±0.2	0±0	662±14.8	240.3±3	245±4.5	9.9±1.1	16.6±1.5	7.8±0.2	3.9±0.6	6.5±1.3	7.5±0.4	4.3±0.3	10±0.8	2.4±0.5
	<i>E. halophilus</i>	3.6±0.4	0±0	0.1±0.02	494.5±13	557.3±11	72±2.2	30.3±1.5	0±0	8.6±0.5	11±1.8	15.6±0.7	16±0.7	2.2±0.3	128.6±3.2
	<i>E. fuscipennis</i>	0.1±0.02	0±0	42.6±2.5	12.3±2.5	20±2	0±0	0.5±0.4	0.33±0.2	0.2±0.07	0.2±0.1	0.3±0.2	0.5±0.06	0.13±0.05	4.4±0.1
	<i>E. bicolor</i>	0±0	0.5±0.1	0.1±0.02	463.6±13	755.6±4	0±0	29.8±0.7	15.3±0.2	8.3±0.3	13±0.7	15±0.5	28.3±1.5	3.2±0.2	108.6±3.2
4	Water	239±3.6	45±3	10.2±0.6	3.3±0.2	2.1±0.4	0.3±0.1	0.2±0.1	0.1±0.05	0.1±0	0.1±0.5	0.1±0.1	0.1±0.04	0±0	0.9±0.05
	Sediment	1±0.1	0±0	467±18.5	0±0	0.1±0.01	0±0	11±1.05	0±0	3.1±0.1	6.2±0.2	6.4±0.4	3.3±0.2	12.5±0.5	2.03±0.05
	<i>E. quadripunctatus</i>	13.9±1.6	3.2±0.2	0.5±0.1	0.1±0.05	0.1±0.01	0±0	125±3	60.6±4.04	45±4.04	56±1.7	67.5±2.2	167±3.6	5.7±0.2	250.3±1.5
	<i>E. bicolor</i>	390±2.5	72±2	15.6±0.7	4.9±0.2	3±0.3	0.5±0.1	0.2±0.1	0.1±0.05	0.6±0.2	0.2±0.1	0.1±0.05	0.5±0.1	0±0	3.2±0.2
	<i>E. segmentinotatus</i>	4.2±0.2	0.7±0.2	0.1±0.05	589.3±4	467.3±2.5	0±0	57.3±2.5	19.2±0.2	50.6±1.1	15.3±1	18.8±0.7	41.3±1.5	2±0.1	134.6±2.5
5	Water	402±3.2	80.6±0.5	17.5±1.3	5.8±0.2	2.2±0.2	0.6±0.2	0.4±0.1	0.13±0.05	0±0	0.1±0.05	0±0	0.12±0.03	0±0	1.9±0.11
	Sediment	0.3±0.05	0±0	0±0	0±0	657.6±2.5	0±0	4.9±0.6	2.2±0.2	1±0.05	1.9±0.2	2.2±0.2	1.2±0.2	1.6±0.5	0.5±0.2
	<i>E. quadripunctatus</i>	0±0	0.4±0.09	0±0	453.6±5	904±5.2	0±0	32.3±2.5	12.3±2.5	11.6±1.1	13±0.2	15.5±0.5	24.1±0.8	3.8±0.3	100±2

6	Water	260 ±3	0±0	11±1	3.5 ±0.5	1.23 ±0.25	0.5± 0.1	0.2 ±0.1	0.13 ±0.05	0.16 ±0.1	0.2 ±0.1	0±0	0.18 ±0.1	0±0	1.26 ±0.2
	Sediment	0.5± 0.1	0±0	0±0	0±0	857.6 ±2.5	20.5 ±0.5	8.2 ±0.2	2.9± 0.15	2.03 ±0.3	3.7 ±0.2	3.6 ±0.2	2.3 ±0.2	4.6 ±0.4	1.36± 0.15
	<i>E. quadri-</i> <i>punctatus</i>	7.5± 0.4	0±0	0.2 ±0.08	0.1 ±0.05	0.14 ±0.05	0±0	74.5 ±1.3	0±0	142 ±2.5	25± 0.7	40.6 ±1.1	432.6 ±15	3.2 ±0.2	504.6 ±5
	<i>E. fuscipennis</i>	5.2± 0.25	0±0	0.1± 0.07	0±0	655 ±5	0±0	49.3 ±2	0±0	35.3 ±3.5	20.8 ±1	25±2	59.3 ±2	2.2 ±0.2	230.3 ±2.5
7	Water	573 ±3.5	0±0	25.6 ±0.7	6.9 ±2	3.9± 0.2	1.2 ±0.2	0.6 ±0.2	0.2± 0.1	0±0	0.2 ±0.1	0±0	0.27 ±0.06	0.23 ±0.05	2.9± 0.36
	Sediment	0.4 ±0.2	0.1 ±0.01	0±0	69.6 ±1.5	949 ±6.5	0±0	5.7 ±1.1	0±0	1.4 ±0.2	3.2 ±0.2	3.5 ±0.5	2.9 ±0.55	5.3± 0.15	1.03± 0.05
	<i>E. bicolor</i>	439 ±4.5	0±0	15±3	0±0	3.9 ±0.2	0.6± 0.2	0.2 ±0.15	0.13 ±0.05	0.1± 0.05	0±0	0.1± 0.05	0.2 ±0.09	0±0	3.7± 0.25
	<i>E. fuscipennis</i>	0.1 ±0.05	0±0	74 ±1.8	22±2	19.6 ±1.5	0±0	1.9 ±0.1	0.6 ±0.1	0.4± 0.2	0.6 ±0.1	0.6 ±0.15	0.9± 0.17	0.06 ±0.02	8.9± 0.25
8	Water	203 ±3.6	35.6 ±3	0.3 ±0.1	2.9± 0.17	1.2 ±0.25	0.3± 0.15	0.1 ±0.05	0.1 ±0	0±0	0±0	0±0	0.07 ±0.02	0±0	0.7± 0.1
	Sediment	70 ±1	0±0	321 ±1.5	0±0	855 ±5	18±2	6.8 ±1.6	4± 0.4	2.1± 0.2	3.7± 0.2	4.06 ±0.6	2.5 ±0.4	7.2± 0.25	1.16 ±0.2
	<i>E. fuscipennis</i>	5.8 ±0.3	0±0	0.1 ±0.07	0±0	0.1 ±0.07	0±0	54.1 ±1.8	26± 1.6	22 ±2	23± 1.8	26.3 ±1.8	54.5 ±3.2	4.16 ±0.2	343.3 ±4.1
9	Water	390 ±5.5	0±0	16.2 ±1.5	5.5 ±0.5	2.9 ±0.15	0.7± 0.2	0.2 ±0.15	0.16± 0.05	0.1 ±0	0.2± 0.05	0±0	0.16 ±0.05	0±0	1.8 ±0.3
	Sediment	0.5 ±0.2	0±0	290 ±3	0±0	927.3 ±2.5	17±2	7.5 ±0.1	0±0	1.6 ±0.5	3.7± 0.2	2.8 ±0.7	2.5 ±0.3	3.5 ±0.5	0.9± 0.17
	<i>E. quadri-</i> <i>punctatus</i>	47 ±2	8.3 ±0.2	5.7 ±0.2	1.7 ±0.3	0.7 ±0.12	0.5± 0.2	0.1 ±0.04	952 ±6.2	531.3 ±7	0±0	100.3 ±2.5	62.3 ±2.5	72.3± 2.5	166.3 ±3.2

Table 3: Heavy element concentration of (Mean ± SD) in water, sediment and *Enochrus* spp. (ppm)

Results

In total, 191 individuals of Hydrophilidae (Coleoptera), belonging to genus *Enochrus* spp. were collected from 9 stations. Six species of genus *Enochrus* Thomson 1859 were determined. Determined species are as follows; *Enochrus (Lumetus) ater* (Kuwert 1888), *Enochrus (L.) segmentinotatus* (Kuwert 1888), *Enochrus (L.) bicolor* (Fabricius 1792), *Enochrus (L.) quadripunctatus* (Herbst 1797), *Enochrus (L.) fuscipennis* (Thomson 1884), *Enochrus (L.) halophilus* (Bedel 1878).

In general, values of some elements like Ti, Cr and Pb are higher in almost all the samples. In all stations of water and sediment samples Ti, Fe, Ni, Br, and Pb were measured. In all *Enochrus* species Fe, Ni, Se, and Pb were measured. The most abundant elements in *Enochrus* spp. were Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, and Pb.

Sediment concentration results show that, in all stations Ti, Fe, Ni, Zn, As, Se, Br, Sr, and Pb were measured. Besides, the highest concentration of Cr was measured in stations 1, 2, 3, 4, and 9; the highest concentration of Fe was measured in stations 5, 6, 7, 8 and 9; the highest concentration of Ti was in stations 8; the highest concentration of Mn was in stations 3. V measured only stations 1 and 7. Heavy element levels in water indicated that Ti, and V had the highest concentration in all stations. Only station 7 had Sr concentration, but there is no Se and Sr concentration in water of all rest stations. In water, the rest of the heavy elements were in lowest concentration. The element concentration in water samples are arranged as Ti > V > Cr > Mn > Fe > Pb > Co > Ni > Cu > As > Zn > Br > Sr > Se and in sediment samples Cr > Fe > Mn > Ni > Co > Se > Sr > As > Cu > Br > Zn > Pb > Ti > V. Results of this study indicates that *E. quadripunctatus* is the best accumulator for certain elements, and followed by *E. fuscipennis* and *E. segmentinotatus*. Compared to the other *Enochrus* species, it appears that *E. quadripunctatus* accumulated the highest level of Ti, Fe, Ni, Cu, Zn, As, Se, Br, Sr, and Pb. The highest concentrations of rest of the elements; in *E. bicolor* was V, in *E. halophilus* Co, in *E. ater* Cr, in *E. segmentinotatus* Mn.

The water quality levels were compared according to Turkish Water Pollution and Control Regulations (TWPCR 2004) [21]. There are four quality classes according to TWPCR: high quality water (I), weakly polluted water (II), polluted water (III), and highly polluted water (IV). According to TWPCR, water in all stations have highly polluted (IV) and polluted (III) water quality in terms of Pb, As, Cr, Co, Ni, Mn, and Se; weakly polluted water quality (II) in regard to Fe, third and fourth stations except to this; high quality water (I) in regard to Zn and Ba. Only the fourth station has Se concentration and has IV water quality. According to the results it was determined that these concentrations adversely affected water quality. The stations 1, 2, 3, 5, 7, and 9 have III and IV water quality in regard to Pb, As, Cr, Co, Ni, and Mn; this can be due to cement factory spreading ash emission, traffic pollution due to highways, and agriculture activities in Gökçeyamaç village. Station 4, 6, and 8 has II water quality in regard to Fe and rests

of the stations have IV and III water quality degree. These results are given in Table 4. Determination of Pb, As, Cr, Co, Ni, and Mn residues in water samples at the stations 7, and 8 where human activity is limited, reveals the extent of the spread. Because in these stations, there are no intensive agriculture or traffic. Ce, Pd, Ba, In, Sn, Nb, Pm, La, and Mo were below the detection limit of EDXRF spectrometry (ppm).

Heavy Elements	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	TWPCR ($\mu\text{g/L}$)			
										I	II	III	IV
Pb	1.7 \pm 0.25	1.9 \pm 0.2	3.23 \pm 0.2	0.9 \pm 0.05	1.9 \pm 0.11	1.26 \pm 0.2	2.9 \pm 0.36	0.7 \pm 0.1	1.8 \pm 0.3	10	20	50	>50
As	0.2 \pm 0.1	0.2 \pm 0.1	0.2 \pm 0.1	0.1 \pm 0.5	0.1 \pm 0.05	0.2 \pm 0.1	0.2 \pm 0.1	0 \pm 0	0.2 \pm 0.05	20	50	100	>100
Cu	0.36 \pm 0.15	0.13 \pm 0.05	0.2 \pm 0.1	0.1 \pm 0.05	0.13 \pm 0.05	0.13 \pm 0.05	0.2 \pm 0.1	0.1 \pm 0	0.16 \pm 0.05	20	50	200	>200
Cr	22 \pm 2.6	14.6 \pm 2.5	10.3 \pm 0.2	10.2 \pm 0.6	17.5 \pm 1.3	11 \pm 1	25.6 \pm 0.7	0.3 \pm 0.1	16.2 \pm 1.5	20	50	200	>200
Co	1 \pm 0.1	0.03 \pm 0.02	1.8 \pm 0.2	0.3 \pm 0.1	0.6 \pm 0.2	0.5 \pm 0.1	1.2 \pm 0.2	0.3 \pm 0.15	0.7 \pm 0.2	10	20	200	>200
Ni	0.3 \pm 0.2	0.5 \pm 0.1	0.7 \pm 0.2	0.2 \pm 0.1	0.4 \pm 0.1	0.2 \pm 0.1	0.6 \pm 0.2	0.16 \pm 0.05	0.23 \pm 0.15	20	50	200	>200
Zn	0 \pm 0	0.2 \pm 0.1	0.2 \pm 0.1	0.1 \pm 0	0 \pm 0	0.16 \pm 0.1	0 \pm 0	0 \pm 0	0.1 \pm 0	200	500	2000	>2000
Fe	2.9 \pm 0.15	2.2 \pm 0.2	4.8 \pm 0.4	2.1 \pm 0.4	2.2 \pm 0.2	1.23 \pm 0.25	3.9 \pm 0.2	1.2 \pm 0.25	2.9 \pm 0.15	300	1000	5000	>5000
Mn	6.2 \pm 0.26	4.9 \pm 0.6	10.1 \pm 0.7	3.3 \pm 0.2	5.8 \pm 0.2	3.5 \pm 0.5	6.9 \pm 2	2.9 \pm 0.17	5.5 \pm 0.5	100	500	3000	>3000
Se	0 \pm 0	0 \pm 0	0 \pm 0	0.1 \pm 0.1	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0	0 \pm 0	10	10	20	>20
Ba	0,00 71	0,00 53	0,01 14	0,0 039	0,00 62	0,0 004	0,0 093	0,0 031	0,0 063	1000	2000	2000	>2000

Table 4: The results for water were compared with national water regulation (TWPCR) (ppm)

Discussion

Aquatic insects are inseparable part of freshwater ecosystems. When food chain is considered, pollutions are able to reach to another organism from one to another, and also at the end human beings. Therefore, protecting the wetlands in turn can protect our safety and welfare. Thus, this research attempted to determine the potential use of aquatic insect communities as biomonitor as well as assess the health status of wetlands in Erzurum province and surrounding.

The concentrations of the fourteen elements were measured different level in insects, water and sediment. The highest pollution levels were found in the samples taken from the industrial sites (1, 2, 4, 5). In field study it was observed that insect samples have abundance in industrial sites and same results were obtained by Pakulnicka et al. (2015) [22]. The element concentrations were found to increase from water to insects in general (water<sediment<*Enochrus* spp.). Thus, it can be said that, heavy elements would be transported to organisms on the higher position from water to insects and along food chains. The studies of Boyd (2009) [23] and Aydoğan et al. (2017) [8] support that result.

In the present study it can be seen that, contaminants residues in *Enochrus* spp. are reflective of environmental quality. The measured element concentrations reflect a clear influence of anthropogenic activities. Element concentration in the *Enochrus* spp. showed differences in accordance to the sediment contamination of each station. High concentrations of the elements in sediment and water samples cause high level of heavy elements in *Enochrus* spp. The heavy element concentrations varied significantly by the sampling sites and species. Station 2, 3, and 4, where anthropogenic activities are intense, have the highest number of individuals. *Enochrus* spp. can survive even the locations which they live in low environmental quality. Therefore, it can be thought that they are tolerant to metal pollution. The results also show that it is possible to analyze element concentrations in these aquatic insects. *Enochrus* spp. fulfill the aforementioned biomonitor criteria like represented in large numbers all over the monitoring area, have numerical abundance, cosmopolitan distribution and easy identifiable.

It is known that proportion to the volume of traffic and close distance from the road lead contribution of Pb level environment and carried by aerial deposition alongside the road [24]. Besides to traffic pollution, industrial activity is major source of heavy metals/metalloids [3]. But some of the stations are away from anthropogenic sources and this can be explained by only atmospheric transportation [25].

To summarize, the data given in this study showed that *Enochrus* spp. are capable of reflecting element bioaccumulation with different levels and embodies all these criteria, thus *Enochrus* spp. can be used in environmental quality monitoring studies. For more information to assess health of environment, long-term biomonitoring must be regularly done. Because long-term biomonitoring of aquatic insect communities may provide insight into how human induced alterations are affecting community structure, ecosystem functions and water quality. It is hoped that the results from this study will provide baseline information in Erzurum province.

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