International Mercury Treaty Enabling Activities Program (IMEAP)

Following the signing of the Minamata Convention on Mercury (the 'Mercury Treaty') in 2013 and the release of the IPEN Minamata Declaration on Toxic Metals, IPEN expanded its Mercury-Free Campaign and developed a broad program of treaty-enabling activities to be implemented in conjunction with IPEN Participating Organizations (POs). The International Mercury Treaty Enabling Activities Program (IMEAP) is geared toward raising awareness about the mercury treaty while generating data on key thematic elements of mercury pollution to help enable countries to implement the Minamata Convention.IPEN launched IMEAP in early 2014 and continues to mobilise resources for IPEN POs to conduct activities that support implementation of the mercury treaty[1].

The key objectives of the IPEN IMEAP are:

1. *Preparing for Treaty Ratification & Implementation:* Creating synergies between NGOs in developing countries with ongoing UN agency or government-led mercury activities and NGO priority-setting.
2. *Enabling Activities to Prepare Countries for Treaty Ratification & Implementation:* Support to NGOs to carry out national and thematic mercury treaty activities.
3. *Communication of Issues Related to Mercury and Treaty Ratification & Implementation:* Global dissemination of project results & south-south collaboration.

The following project forms part of the overall IMEAP activities and contributes to the greater global understanding of mercury pollution issues while providing information that may contribute to Minamata Initial Assessments (MIA) and raise public awareness in preparation for early ratification of the Minamata Convention on Mercury.

[1] IPEN would like to acknowledge the financial contributions from the governments of Germany, Sweden and Switzerland, and the Swedish public development co-operation aid through the Swedish Society for Nature Conservation (SSNC) and other donors. The views herein shall not necessarily be taken to reflect the official opinion of any of these donors, including SSNC or its donors.

Impact of heavy metals from Balkan power plants on inhabitants and the environment

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Summary

This report by IPEN Participating Organization Arnika, entitled '***Impact of heavy metals from Balkan power plants on inhabitants and the environment',*** focuses on the presentation and discussion of data related to contamination by heavy metals at selected locations in the Balkans. Sampling teams conducted monitoring in the field to obtain data about the impacts of coal fired power plants from emissions, and releases (including ash ponds and dumps). The sampled sites were located in Montenegro, Bosnia and Herzegovina, and Serbia. A series of different kinds of samples were taken for analysis, which included both abiotic (sediments, soils and water) and biotic (fish, eggs, cheese, vegetables) and hair samples. The aim of this study was to evaluate the influence of coal fired power plants on local inhabitants and on the environment. Increased concentrations of nickel, chromium and arsenic significantly exceeding local limits for heavy metals, **and** were found in samples of soils and sediments from Tuzla, Bosnia and Herzegovina and in samples from Obrenovac, Serbia, where increased concentrations of cadmium were also detected. Higher concentrations of heavy metals (nickel, chromium, cadmium, arsenic and mercury) in soils and sediments were found closer to the ash landfills in Bosnia and Herzegovina. The fish consumption advisory level for mercury was exceeded in 4 of the 11 samples of fish from Sava River and Cehotina River. Higher levels of cadmium were determined in samples of onions closer to the ash landfills in Tuzla. The results of this study indicate significant contamination in many locations from industrial sources that is impacting on environmental values and food production. Regulatory action, further monitoring and implementation of alternative power sources such as renewable energy technologies will be required to address these environmental impacts.

Introduction

This study is focused on the presentation and discussion of data related to contamination by heavy metals at selected locations in the Balkans. The sampled sites were located in Montenegro, Bosnia and Herzegovina and Serbia. A series of different kinds of samples were taken for analysis, which included both abiotic (sediments, soils and water) and biotic (fish, eggs, cheese, vegetable), and hair samples. The aim of this study was to evaluate the influence of power plants to local inhabitants and on the environment.

Potential sources of contamination

Tuzla power station - is the largest coal-fired power station in Bosnia and Herzegovina. The power station has an installed electric capacity of 715 MW (without the two 32 MW units which no longer operate) and it produces around 3.6 TWh of electricity per year. In addition, it supplies heat for Tuzla and Lukavac. The plant burns 3.800.000 tonnes of coal annually. Units 1-6 are supplied from the **Kreka and Banovići mines**. Compared to world-wide mean trace elemental concentrations in coal, the coal mined at Banovici is significantly **enriched in chromium, nickel and arsenic**.

<<< The fly ash landfill of Tuzla power station borders on arable land

Pljevlja thermal power plant - After the reconstruction carried out in 2009, the new power of the thermal power plant is 218.5 MW. Pljevlja I is fuelled by lignite from strip mines with guaranteed calorific value of 9,211 kJ / kg (2200 kcal / kg). The plant annually consumes an average of 1.35 million tonnes of coal, 3,500 tonnes of fuel oil and 660 tonnes of chemicals (lime, hydrochloric acid, alkali, etc.). The amount of released flue gas is between 1,000,000 Nm^3/h and 2,000,000 m^3/h at operating conditions. The power plant´s flue gas is released into the atmosphere through a chimney with a height of 252 m. The power plant is supplied from the nearby **Coal Mine A.D. Pljevlja**.

The **Nikola Tesla** power plant complex is located on the right bank of the river Sava, approximately 40 km upstream from Belgrade, near the town of Obrenovac. By far the largest in Serbia, with six units with a total installed capacity of 1,650 MW, the complex generates around 16 TWh annually, which covers almost half of Serbia's needs for electricity. Coal is transported about 30 km by rail from the mines, which are capable of supplying a total of 37 million tonnes of coal per year. The ash landfilling is done mechanically through suspension of ash and water, resulting in overflow and drainage of wastewater discharged into the river Sava. In addition to the impact on water pollution, landfills represent a surface source of air pollution as particles of ash. Due to the unfavourable physical and chemical characteristics of the ash and existing methods of ash disposal in open dumps, in dry and windy weather the ash blows around. These power plants use lignite mined from the **RB Kolubara** as fuel.

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The fly ash landfill of Nikola Tesla power plant is located on the edge of the town and borders on houses, gardens and agricultural land.

Sampling procedures and analytical methods

Samples of soils and sediments were taken as mixed samples formed by several partial samples taken in various places of the given locality. Soil samples were taken by means of a trowel into polyethylene containers (V = 500 ml) with screw lids or into polyethylene bags. Samples of sediments were taken by a core sampler into polyethylene containers (V = 500 ml). Mixed samples were homogenized in a steel bowl, some of them quartered after homogenization. During soil sampling, the sampling trowel and core sampler were washed with tap water or with available river or lake water. Samples were stored in a cold and dark environment before analysis. Fish samples were obtained from local fishermen and kept in a freezer wrapped in two polyethylene bags. Egg samples were obtained from local homes, stored in egg boxes wrapped in polyethylene bag and later cooked (boiled). The eggs were stored in a fridge at 4-8°C.Detailed information about samples and sampling procedures are given in **Annex I**.

An ash landfill near Tuzla power plant.

Analytical procedures for samples of soils and sediments were as follows: after transport to the laboratory, samples were homogenised and a representative part (50 g) was used for the determination of dry matter by a gravimetric method. Another representative part was taken for analysis of heavy metals by mineralization procedure. The analytical procedure of mineralization was as follows: 5 g of sample was placed into a beaker together with 30 ml of distilled water and 10 ml of concentrated nitric acid. The sample was boiled for a period of 2 hours. Then it was filtered through a fluted filter paper. Metals were determined in the mineralization procedure by Microwave Plasma Atomic Emission Spectrometer (Agilent Technologies). Mercury was measured directly in solid samples by Advanced Mercury Analyser (AMA 254, Altec). Water samples were measured by Microwave Plasma Atomic Emission Spectrometer (Agilent Technologies). The analysis was conducted at the University of Chemistry and Technology Prague. Heavy metals in foodstuff were determined by standard operating procedures at the State Veterinary Institute, Prague (AS - SOP 70.3 (AAS-hydrides), Cr - SOP 70.72 (GF-AAS), Cd - SOP 70.72 (GF-AAS), Pb - SOP 70.72 (GF-AAS), Hg - SOP 70.4 (AAS-AMA)).

Results and Discussion

The results of the analytical measurement of heavy metals are presented in **Annex II**.

The main contaminants of the environment are nickel, chromium, cadmium, arsenic, mercury, and lead. Nickel dust is responsible for eye, ear, and throat irritation. Long-term intake by breathing can lead to acute bronchitis development, lung function diminishing or cavity inflammation. Chromium (Cr^{III}) negatively impacts the kidneys, liver, immune system and respiratory system. Cadmium is known as a human carcinogen (teratogen). It affects metabolism of other metals, damages the kidneys, bone tissue, and immune and cardiovascular systems. Arsenic is hardly degradable in the environment, but bioaccumulative in the human food chain. It is mutagenic and a carcinogenic metalloid. Mercury is accumulated in the human kidneys and liver. It is known for its adverse effect on human embryos and reproductive functions. It is classified is a possible human carcinogen. Lead is highly bioaccumulative in bones, kidney and liver tissues; it easily passes through the food chain. It negatively influences the nervous, immune, and digestive systems, and blood formation.

Various legal standards and auxiliary evaluation criteria are presented in this chapter. The heavy metals concentrations determined in samples from the investigated locations are then compared to the respective legal standards.

Legal standards

The pollutant concentrations determined in the samples from the investigated sites were compared to maximum or allowed concentrations of these pollutants as defined in national and international decrees, norms and laws.

Concentrations of pollutants were compared with local limits for soils: Pravilnik o Utvrdivanju Dozvoljenih Količina Štetnih i Opasnih Materija u Zemljištu i Metode Njihovog Ispitivanja (Na osnovu člana 25. st. 3. i 4. Zakona o poljoprivrednom zemljištu ("Službene novine Federacije BiH", broj 52/09)), which defines substances that are considered to be pollutants of agricultural land and defines the maximum limits in soils in the

Federation of Bosnia and Hercegovina, and with the Montenegrin Pravilnik o Dozvoljenim Količinama Opasnih i Štetnih Materija i Zemljištu i Metodama za Njihovo Ispitivanje ("Sl. listu RCG", br. 18/97), which defines the maximum allowable amounts of hazardous and harmful substances in the soil, and with the Pravilnik o Dozvoljenim Količinama Opasnih i Štetnih Materija i Zemljištu i Vodi za Navodnjavanje i Metodama Njihovog Ispitivanja ("Sl. glasnik RS", br. 23/94), directing the maximum amount of hazardous and harmful substances in soil and water for irrigation and methods of their analysis. The maximum allowable amount can damage or change the production capacity (fertility) of agricultural land and water quality for irrigation that reaches discharges from factories, the outpouring of landfills, improper use of mineral fertilizers and of plant protection products.

Concentrations of pollutants in samples were also compared with RSL (Regional Screening Levels). These levels were derived using exposure parameters and factors representing the maximum justifiable chronic exposure. This exposure is based on direct contact with target compounds. Regional screening levels were derived by the US EPA (United States Environmental Protection Agency) for some compounds that have a CAS registration number. RSL are concentrations of chemical compounds in the environment (soils, sediments, water and air). If RSL are exceeded, further exploration or removal of contamination should be carried out. Some specifics should be taken into account when RSL are used - such as the content of some substances as a result of geological conditions.

If sediments are intended for use on agricultural land (e.g. after dredging of a pond or river bed), the concentration of pollutants in sediments can be compared with the limits in Decree no. 257/2009 for use of sediments on agricultural soils. This decree defines the maximum possible concentrations of hazardous metals in sediments in this case. The standards are given in **Annex III**.

Limits for drinking water according to the CZ Decree (Vyhláška č. 252/2004 Sb. kterou se stanoví hygienické požadavky na pitnou a teplou vodu a četnost a rozsah kontroly pitné vody) are included for comparison in **Annex III**.

National Recommended Water Quality Criteria – The EPA's compilation of national recommended water quality criteria is presented as a summary table containing recommended water quality criteria for the protection of aquatic life and human health in surface water for

approximately 150 pollutants. **Aquatic Life** criteria lists chemical concentration goals to protect surface water for aquatic life use. The table is given in **Annex III**.

Concentration of contaminants in foodstuffs were compared with limits defined in Commission Regulation (EC) no. 1881/2006, dated 19 December 2006, setting maximum levels for certain contaminants in foodstuffs (see **Annex III**). In the interest of effective protection of public health, products containing contaminants in excess of the maximum levels should not be placed on the market.

According to EPA-823-R-01-001, a **Reference Dose (RfD) for methylmercury** (based on noncancerous human health effects) **is 0.0001 mg methylmercury/kg body weight-day**. It is intended to serve as a level of exposure without expectation of adverse effects when that exposure is encountered on a daily basis for a lifetime. A f**ish consumption advisory level of 0.22 mg mercury/kg fish** was derived based on the Reference Dose for methylmercury. It is assumed that methylmercury constitutes 90% of the total mercury in fish, thus the **fish consumption advisory level of 0.20 mg methylmercury/kg fish** is also used.

The content of metals can be compared with other auxiliary criteria - soil, ground water and soil air pollution criteria according to the methodological guidelines of the Czech Ministry of Environment of 31 July 1996. These criteria are not legally binding; however, and are often applied in the Czech Republic on a voluntary basis. Please see **Annex IV** for the reference.

Evaluation of pollutant levels

The main objective of the research was to determine the concentration of heavy metals in various samples taken at selected locations in the Balkans and compare the measured data with legal standards and limits and with concentrations shown in other studies.

There were **10 samples of soils, 10 samples of sediments and 2 samples of fly ash** taken at several locations. In general, the concentrations of heavy metals in these samples do not reach the pollution limits for non-industrial areas (based on US EPA), except elevated As levels. Local limits for Montenegro were exceeded for As in almost all samples and for Cr in a sample of sediment from a wetland fed by discharge from ash landfill. Local limits for Bosnia and Hercegovina were significantly exceeded for Ni and Cr for all six samples taken. Limits were also exceeded for As in all samples and for Cd in a sample of soil from a meadow in the immediate vicinity of the ash landfill. Higher concentrations of heavy metals (Ni, Cr, Cd, As and Hg) were found closer to the ash landfill. A similar situation was found in Obrenonac, Serbia, where local limits were exceeded for Ni, Cr and As. Increased levels of Cd were also detected in samples.

We can compare measured concentrations with data in other studies. The background levels of Hg in soils are not easy to estimate due to the widespread Hg pollution. Data reported for various soils on a worldwide basis show that mean concentrations of Hg in surface soils do not exceed 1.5 mg/kg. Most top soils contain an increased amount of Hg, especially near mining and smelting areas. The range of Hg in reference soils of China is from 0.015 to 0.294 mg/kg (mean 0.142 mg/kg). The mean content of total Hg in agricultural surface soils and forest soils of Poland is estimated at 0.06 mg/kg (range 0.03–0.284 mg/kg). The range of Hg in urban soils of Poland is 0.13– 0.5 mg/kg. The very broad Hg range, 0.004–1.510 mg/kg, is reported for suburban soils of China. Relatively high Hg contents, up to 0.98 mg/kg (at an average 0.08 mg/kg), are reported for some top soils of the Slovak Republic. Baseline levels for Hg in soils from Belgium vary between 0.09–0.43 and 0.7–0.15 mg/kg. The content Hg in tropical soils of French Guiana is below 0.04 mg/kg.

The world soil average content of **Cr** in soils has been established as 60 mg/kg.

Soils throughout the world contain **Ni** in a very broad range. This means that concentrations, as reported for various countries, are within the range of 13–37 mg/kg.

The world average soil **Cd** concentration is estimated as 0.41 mg/kg. The main factor determining Cd contents of soils is parent material. The average contents of Cd in soils lie between 0.2 and 1.1 mg/kg. Surface soils from major agricultural production areas of the United States contain Cd within the range of <0.01 to 2.0 mg/kg, Cd (geometric mean, 0.175). Cd content in reference soils from different countries range from 0.06 to 4.3 mg/kg. Soils from Sichote-Alin (remote region of Russia) contain Cd from 0.2 to 1.14 mg/kg, with the greatest concentration in flooded soils. Relatively high Cd contents, up to 8.9 mg/kg (on average 0.3 mg/kg), are reported for some top soils of the Slovak Republic.

The overall mean value of total **Pb** for different soils is estimated as 27 mg/kg. Its background average contents given for soils of different countries vary from 18 mg/kg in Sweden to 27 mg/kg in China.

The overall mean value of the total **As** for different soil is estimated as 6.83 mg/kg. The backgound contents of various soil groups range from <0.1 to 67 mg/kg. The range in As in soils of the United States is broad, from <0.1 to 93 mg/kg, and the geometric mean for As in top soils of the United States is reported to be 5.8 mg/kg. As content, 9.7 mg/kg, is reported for surficial materials in Alaska and As range of 4–15 mg/kg in uncontaminated soils of Canada. Background value in Slovakia is given as 7.2 mg/kg. The range of As in soils of Poland is 0.9–3.4 mg/kg. Western Siberia soil contains As content from 18 to 32 mg/kg.

In this context, significantly increased concentrations of **Ni** (74.1 – 322.5 mg/kg) and **Cr** (142.9 – 325.9 mg/kg) were found in samples of soils and sediments from Tuzla, Bosnia and Hercegovina and in samples from Obrenovac, Serbia – **Ni** (<0.1 – 84.7 mg/kg), **Cr** (88.4 – 293.4 mg/kg) - where increased levels of **Cd** (up to 2.9 mg/kg) were also found. The content of As in samples on average is higher than world average background levels. It may be related to combusting coals mined at Banovići, which are significantly enriched in chromium, nickel and arsenic. A previous study in the region investigated the concentration and distribution of some heavy metals (Cr, Co, Co, Pb, Hg, Ni and Zn) in soils on the banks of the river Jala (Bosnia and Hercegovina). Sampling was done at measuring points upstream and downstream of potential sources of pollution. Heavy concentrations in soil samples along the river Jala during the study were: Zn = 74 mg/kg, Cr = 66 mg/kg, Pb = 25 mg/kg, Ni =

180 mg/kg, Co = 24 mg/kg, Cd = 0.48 mg/kg, Hg = 5.4 mg/kg. All the authors concluded that the probable sources of the soil pollution on the banks of the river Jala are industrial plants for the combustion of fossil fuels (especially responsible for emissions of nickel), chemical industries that were working intensively in the past, application of fertilizers and pesticides in agricultural production (zinc and mercury), vehicular emissions, atmospheric deposition (lead), and residential buildings that use fossil fuels for burning.

Sediment of the Spreča River (Bosnia and Hercegovina) has also been analyzed along its course in previous research to investigate and analyze the properties and characteristics of the metal concentration distribution. Average metal concentrations in sediments were: Co = 20.6 mg/kg, Cr = 775 mg/kg, Cu = 70 mg/kg, Ni = 427 mg/kg. The concentrations of Cu, Cr and Ni in sediment samples were much higher than levels reported in sediments from other rivers. The authors concluded that sediments serve as reservoirs for metals and their concentrations are controlled by a variety of physical and chemical factors and that it is important to prevent further contamination by identifying sources of pollution and managing their input into the Spreča River.

There were **5 samples of water** and 1 reference sample taken within our research in Bosnia and Hercegovina. The Criterion Continuous Concentration (CCC) (Aquatic Life criteria for freshwater according to EPA) was significantly exceeded in sample W-5 for Cd and Pb. Determined concentrations of heavy metals can result in an unacceptable effect for an aquatic community. Samples were evaluated in parameters according to the CZ Decree – Classification of Surface Water Quality - as follows: Cd – 5 samples were classified as *very heavily polluted water*, Ni – all 6 were classified as *polluted water*, Pb – 4 samples as *very heavily polluted water*, 1 sample as *heavily polluted water*, Cr – 1 sample as *very heavily polluted water*, 5 samples *heavily polluted water*, and As – 1 sample as *heavily polluted water*, 2 samples as *slightly polluted water*. Sample W-5 was determined as the most polluted - it was classified according to 2 parameters as *very heavily polluted water*.

There were **11 samples of fish and 2 reference fish, 8 pooled samples of eggs, 1 sample of cow cheese, 16 samples of vegetables** (potatoes, onion, carrot and parsley) and 2 reference samples of vegetables taken. Increased levels of mercury were detected in fish samples in comparison with the reference samples of fish. Maximum levels for mercury in foodstuffs (Commission Regulation (EC) no. 1881/2006) were not exceeded. The content of mercury in two samples of fish from the Sava River, Serbia was close to max. levels (0.815 mg/kg (*Esox lucius*) and 0.657 mg/kg (*Esox lucius*)-max. lvl. 1.0 mg/kg). The fish consumption advisory level of 0.22 mg mercury/kg fish was exceeded in fish (*Leuciscus*

cephalus) from Cehotina River, Montenegro (0.233 mg/kg) and in fish (Esox lucius) from a small pond close to the ash landfills in Divkoviči, Bosnia and Herzegovina (0.381 mg/kg). On the other hand, it is assumed that 90% of the mercury in fish is in the form of methylmercury (EPA, 2001). If we divide the mercury content of 0.9, we can use fish consumption guidelines based on the U.S. EPA's reference dose of 0.0001 mg methylmercury / kg of body mass / day. Fish consumption guidelines were calculated using an average body mass of 60 kg and an average fish meal size of 170 grams.

Table 1: Fish consumption guidelines for methylmercury based on the U.S. EPA reference dose.

Fish methylmercury concentrations (ppm/ww)	**Recommended Consumption**
<0.05	unrestricted
>0.05 – 0.11	2 meals / week
>0.11 – 0.22	1 meal / week
>0.22 – 0.95	1 meal / month
>0.95	no consumption

Maximum levels for lead in foodstuffs (Commission Regulation (EC) no. 1881/2006) were exceeded in two samples of onion from gardens near an open part of the ash landfills in Bosnia and Herzegovina (0.22 mg/kg and 0.14 mg/kg- max. lvl. 0.1 mg/kg). The higher level was determined

in the sample closer to the ash landfills. Maximum levels for cadmium in foodstuffs (Commission Regulation (EC) no. 1881/2006) were exceeded in one sample of onion from Serbia (0.067 mg/kg – max. lvl. 0.05 mg/kg).

There were **36 samples of hair** taken in Montenegro, Bosnia and Herzegovina and Serbia and 10 reference samples in Montenegro. There are many factors that affect the deposition of heavy metals in hair. One of the direct results is that a higher content of mercury (0.365 mg/kg on average) was detected in hair samples from Serbia in comparison with other studied locations. The average concentration of mercury in hair varies within a wide range in other studies on reference samples – 0.13 mg/kg (Czech Republic), 0.28 – 0.29 mg/kg (USA), 0.38 mg/kg (Belgium), 0.42 mg/kg (Kazakhstan), 0.56 mg/kg (Italy), 1.1 mg/kg (Sweden), 2.95 mg/kg (Iran), and 7.4 – 14.3 mg/kg (Brazil). Data are related to average population, and the relationship between fish consumption and mercury concentration in hair was cited in previous studies. There are significantly increased concentrations of selected heavy metals in individual samples, but the differences between the measured concentrations do not provide sufficient tools for a statistical approach. According to EPA's reference dose for mercury in human hair, mercury concentrations above 1.0 mg/kg in hair have been related to neurological impairments and other adverse effects. Cadmium concentration above 0.2 mg/kg and lead concentration above 2.0 mg/kg have been related to adverse health effects.

Conclusions

ΛΛΛ A Serbian shepherd grazes his sheep on the edge of a fly ash landfill

This study is focused on the presentation and discussion of data related to contamination by heavy metals at selected locations in the Balkans. The sampled sites were located in Montenegro, Bosnia and Herzegovina and Serbia. Both abiotic (sediments, soils and water) and biological (fish, eggs, cheese, vegetable) samples and hair samples were taken on sites affected by industrial activities.

Industrial activities affect the quality of the environment in the region. Mainly increased concentrations of nickel, chromium and arsenic, significantly exceeding local limits for heavy metals, were found in samples of soils and sediments from Tuzla, Bosnia and Herzegovina and in samples from Obrenovac, Serbia, where also increased concentration of cadmium was detected. Higher concentrations of heavy metals (nickel, chromium, cadmium, arsenic and mercury) in soils and sediments were found in samples closer to the ash landfills in Bosnia and Herzegovina.

In general, river water in Tuzla in Bosnia and Herzegovina is polluted in such a way that concentrations of heavy metals can result in an unacceptable effect for the aquatic community in the water. Mainly increased concentrations of cadmium, nickel, lead and arsenic were found in samples.

The effect on biota by industrial activities was studied in the monitored region. The fish consumption advisory level for mercury was exceeded in 4 of the 11 samples of fish from Sava River and Cehotina River. Higher levels of cadmium were determined in samples of onion closer to the ash landfills in Tuzla.

It is necessary to continuously monitor the occurrence of heavy metals in the environment in the region and to collect and analyze data on the concentrations of heavy metals in biological samples. This will assist in determining conditions and preferential routes of transmission of pollutants into the food chain, food products and human body, and in finding ways to prevent the spread of contaminants into the environment.

Literature

PRAVILNIK, O UTVRDIVANJU DOZVOLJENIH KOLIČINA ŠTETNIH I OPASNIH MATERIJA U ZEMLJIŠTU I METODE NJIHOVOG ISPITIVANJA (Na osnovu člana 25. st. 3. i 4. Zakona o poljoprivrednom zemljištu ("Službene novine Federacije BiH", broj 52/09))

PRAVILNIK, O DOZVOLJENIM KOLIČINAMA OPASNIH I ŠTETNIH MATERIJA U ZEMLJIŠTU I METODAMA ZA NJIHOVO ISPITIVANJE (Objavljen u "Sl. listu RCG", br. 18/97)

PRAVILNIK, O DOZVOLJENIM KOLIČINAMA OPASNIH I ŠTETNIH MATERIJA U ZEMLJIŠTU I VODI ZA NAVODNJAVANJE I METODAMA NJIHOVOG ISPITIVANJA ("Sl. glasnik RS", br. 23/94)

US EPA. Regional Screening Levels. [online] [cit. 2015-03-05]. Available on: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/docs/params_sl_table_run_JAN2015.pdf

US EPA. Human Health: Exposure Assessment [online] [cit. 2015-04-15]. Available on: http://www.epa.gov/oswer/riskassessment/human_health_exposure.htm

Věštník Ministerstva životního prostředí. Metodický pokyn MŽP Indikátory znečištění. Ročník XIV, částka 1, 2014. [online] [cit. 2015-03-31]. Available on: http://www.ippc.cz/dokumenty/DF0545

Metodický pokyn Ministerstva životního prostředí. Kritéria znečištění zemin, podzemní vody a půdního vzduchu ze dne 31.července 1996

Vyhláška č. 257/2009 Sb., o používání sedimentů na zemědělské půdě, Ministerstvo zemědělství, 2009

ČSN 75 7221 (757221) - Jakost vod - Klasifikace jakosti povrchových vod

Vyhláška č. 252/2004 Sb. kterou se stanoví hygienické požadavky na pitnou a teplou vodu a četnost a rozsah kontroly pitné vody.

National Recommended Water Quality Criteria - http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm

EPA-823-R-01-001. Water Quality Criterion for the Protection of Human Health: Methylmercury, January 2001

Evers, D.C., DiGangi, J., Petrlík, J., Buck, D.G., Šamánek, J., Beeler, B., Turnquist, M.A., Hatch, S.K., Regan, K. 2014. Global mercury hotspots: New evidence reveals mercury contamination regularly exceeds health advisory levels in humans and fish worldwide. Biodiversity Research Institute. Portland, Maine. IPEN. Göteborg, Sweden. BRI-IPEN Science Communications Series 2014-34

NAŘÍZENÍ KOMISE (ES) no. 1881/2006 ze dne 19. prosince 2006, kterým se stanoví maximální limity některých kontaminujících látek v potravinách, Úřední věstník Evropské unie, L 364/5, 20.12.2006

International Agency for Research on Cancer. IARC Monographs on Evaluation of Carcinogenic Risks to Humans. [online] Francie [cit. 2015-02-25]. Available on: http://monographs.iarc.fr/ENG/Classification/

JECFA (JOINT FAO/WHO EXPERT COMMITTEE ON FOOD ADDITIVES) Summary and conclusions of the sixty-first meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA), pp. 18-22. Available on http://www.who.int/pcs/jecfa/Summary61.pdf.

Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006

Kabata-Pendias A., Trace Elements in Soil and Plants, CRC Press, Taylor & Francis Group, 2011

Kortenski, J. and Sotirov, A. (2002). Trace and major element content and distribution in Neogene lignite from the Sofia Basin, Bulgaria. International Journal of Coal Geology; 52, 1-4

Spěváčková, V. a kol. Biologický monitoring v České republice-stopové prvky a profesionálně neexponovaná populace. Klin.Biochem. Metab.,(19(40), 2011, No.2, p. 101-107

Zdravotní důsledky expozice lidského organismu toxickým látkám ze zevního prostředí (biologický monitoring) Odborná zpráva za rok 2014, Státní zdravotní ústav Praha, září 2015

Amira Cipurkovic, Jozo Tunjic, Vahida Selimbasic, Abdel Djozic, Ilvana Trumic, Assessment of Heavy Metal Distribution and Contamination in Soils at Jala River Banks, European Journal of Scientific Research, Vol. 127 No 4 December, 2014, pp.392-405

A. Đozić, V. Selimbašić, A. Cipurković, I. Tanjić, M. Uljić, M. Zohorović, METAL POLLUTION ASSESSMENT IN SEDIMENTS OF THE SPREČA RIVER

Annex I.: Sampling sites and procedures

Table 1a: Description of samples of soils and sediments taken **in Montenegro.**

Sample code	Date	GPS	Locality, sampling spot	Sample material, preparation	Type of sample	Comment
MN 04	5.5.2015	43°19'36.04'' 19°18'26.22''	Montenegro, Pljevlja, ash landfills (dry section)	Fly ash		
MN 05	5.5.2015	43°19'32.18'' 19°18'56.81''	Montenegro, Pljevlja, orchard near the ash landfills	Soil		
MN 06	5.5.2015	43°20'2.38'' 19°18'47.74''	Montenegro, Pljevlja, agricultural field near the ash landfills	Soil		
MN 07	5.5.2015	43°19'56.64'' 19°18'37.41''	Montenegro, Pljevlja, meadow in the garden, near the ash landfills	Soil		
MN 08	5.5.2015	43°19'26.89'' 19°18'35.21''	Montenegro, Pljevlja, wetland fed by discharge from the ash landfills, seeping under residential houses	Sediment		

MN 09	5.5.2015	43°19'49.68'' 19°18'37.67''	Montenegro, Pljevlja, garden fence neighboring to the power station	Soil		
MN 13	5.5.2015	43°20'42.52'' 19°19'31.10''	Montenegro, Pljevlja, river downstream from the ash landfills	Sediment		
MN 18	5.5.2015	43°21'40.08'' 19°18'34.14''	Montenegro, Pljevlja, river downstream from the ash landfills	Sediment		

Table 2b: Description of samples of soils and sediments taken **in Bosnia and Herzegovina.**

Sample code	**Date**	**GPS**	**Locality, sampling spot**	**Sample material, preparation**	**Type of sample**	**Comment**
BIH-01	7.5.2015	44.531044 18.598511	Bosnia and Herzegovina, Tuzla, Divkoviči, garden with beds, 500 m from open part of landfill	Soil		
BIH-02	7.5.2015	44.526798	Bosnia and Herzegovina, Tuzla, channel draining water from the landfill into a	Sediment		Visible proportion of ash

		18.59844	river			
BIH-06	7.5.2015	44.552429 18.584229	Bosnia and Herzegovina, Tuzla, Ljepunice i Šikara, meadow in the immediate vicinity of the ash landfill	Soil		Fruit trees, in the vicinity of agricultural fields with corn
BIH-07	7.5.2015	44.521668 18.602798	Bosnia and Herzegovina, Tuzla, concrete channel, immediately behind the drainage of the waste water from ash landfill into the river	Sediment		
BIH-09	7.5.2015	44.531711 18.587537	Bosnia and Herzegovina, Tuzla, agricultural field in the garden, 600 m from open part of landfill	Soil		
BIH-12	7.5.2015	44.527623 18.614789	Bosnia and Herzegovina, Tuzla, concrete river, downstream under the old chlorine factory, upstream from the source of pollution from ash landfill	Sediment		Fecal pollution from the city

Table 3c: Description of samples of soils and sediments taken **in Serbia.**

Sample code	Date	GPS	Locality, sampling spot	Sample material, preparation	Type of sample	Comment
SRB-01	9.5.2015	44.63851 20.08412	Serbia, Obrenovac, wetland aroud the ash landfill	Sediment		
SRB-02	9.5.2015	44.61139 20.09826	Serbia, Obrenovac, agricultural fields for growing crops	Soil		
SRB-03	9.5.2015	44.61139 20.09826	Serbia, Obrenovac, dry section of ash landfill	Fly ash		
SRB-04	9.5.2015	44.62165 20.07561	Serbia, Obrenovac, wetland aroud the ash landfill	Sediment		
SRB-05	9.5.2015	44.56684 20.09140	Serbia, Obrenovac, agricultural field prepared for planting	Soil		
SRB-06	9.5.2015	44.64459 20.02017	Serbia, Obrenovac, agricultural field prepared for planting	Soil		

SRB-07	9.5.2015	44.65295 19.99718	Serbia, Obrenovac, , channel draining water from the landfill into a river	Sediment		
SRB-08	9.5.2015	44.65078 19.91777	Serbia, Obrenovac, Sava River, a few meters downstream from the channel draining water from the landfill into a river	Sediment		

Table 4: Description of water samples from Bosnia and Hercegovina.

Sample code	**Date**	**GPS**	**Locality, sampling spot**	**Sample material, preparation**	**Type of sample**	**Comment**
W-1	25.07.2015.	44.548582 18.760808	Bosnia and Herzegovina, Tuzla, river upstream from the source of pollution from ash landfill	Water, stabilization		Reference site, waste thrown into the river, possibly the ashes from the stove
W-2	25.07.2015.	44.314776	Bosnia and Herzegovina, Tuzla, concrete channel, immediately behind the	Water,		

		18.371664	drainage of the waste water from active ash landfill into the river	stabilization		
W-3	25.07.2015.	44.526798 18.598445	Bosnia and Herzegovina, Tuzla, channel draining water from the closed landfill into a river	Water, stabilization		
W-4	25.07.2015.	44.331909 18.351225	Bosnia and Herzegovina, Tuzla, channel draining water from the closed landfill (from the top of coal ash disposal site)	Water, stabilization		
W-5	25.07.2015.	44.310072 18.351731	Bosnia and Herzegovina, Tuzla, concrete river, downstream ofthe source of pollution from ash landfill	Water, stabilization		
W-6	25.07.2015.	44.330372 18.285393	Bosnia and Herzegovina, Tuzla, river Spreča, downstream of the industrial area and from the source of pollution from ash landfill	Water, stabilization		

Table 5a: Description of samples of foodstuff taken **in Montenegro.**

Sample code	Date	GPS	Locality, sampling spot	Sample material, preparation	Type of sample	Comment
PLZ-E1-E2-E3	29.4.2015	43° 9'54.42" 18°42'49.85"	Montenegro, Piva (Orah)	Egg	Pooled sample of 3 eggs	Reference site
PLZ-E4-E5-E6	30.4.2015	43°9'5.53" 18°50'59.05"	Montenegro, Piva (Seoca)	Egg	Pooled sample of 3 eggs	Reference site
PLZ- FISH-01-02-03	29.4.2015		Montenegro, Piva lake	Fish	Pooled sample of 3 fishes	Reference site
PLZ- FISH-04-05-06	30.4.2015		Montenegro, Piva lake	Fish	Pooled sample of 3 fishes	Reference site
REF-vegetable-02		43°10'17.08" 18°40'2.88"	Montenegro, Piva (Ravno)	Vegetable – potatos and onion		Harvested in September 2014, without the use of pesticides, ref. site
PLJ-EGGS-01	5.5.2015	43°19'36.04'' 19°18'26.22''	Montenegro, Pljevlja, garden on a slope about 100	Egg	Pooled sample of 2 eggs	2-year hens, corn-fed from Serbia 1 ar space, heats with wood, for family use, daily breakfast 2-3 ks, family with daughters 18 and 28

			m from the ash landfill			years of age
MN 10	5.5.2015	43°19'33.90'' 19°19'34.14''	Montenegro, Pljevlja, garden fence neighboring the power station	Vegetable - onion		Harvested in autumn 2014, for family use, without the application of chemical fertilizers or pesticides
MN 11	5.5.2015	43°19'33.90'' 19°19'34.14''	Montenegro, Pljevlja, garden fence neighboring the power station	Vegetable - potatoes		Harvested in autumn 2014, for family use, without the application of chemical fertilizers or pesticides
MN 12	5.5.2015	43°19'33.90'' 19°19'34.14''	Montenegro, Pljevlja, garden fence neighboring the power station	Vegetable - beans		Harvested in autumn 2014, for family use, without the application of chemical fertilizers or pesticides
MN 14	5.5.2015	43°19'36.04'' 19°18'26.22''	Montenegro, Pljevlja, garden on a slope about 100 m from the ash landfill	Vegetable - carrot		Harvested in May 2015, for family use, without the application of chemical fertilizers or pesticides
MN 15	5.5.2015	43°19'36.04'' 19°18'26.22''	Montenegro, Pljevlja, garden on a slope about 100 m from the ash landfill	Vegetable - potatoes		Harvested in autumn 2014, for family use, without the application of chemical fertilizers or pesticides
MN 16	5.5.2015	43°19'36.04'' 19°18'26.22''	Montenegro, Pljevlja, garden on a slope about 100	Vegetable - onion		Harvested in autumn 2014, for family use, without the application

			m from the ash landfill			of chemical fertilizers or pesticides
MN 17	5.5.2015	Near 43°19'36.04'' 19°18'26.22''	Montenegro, Pljevlja, cows graze 300 m away from	Cow cheese		Cows are housed over the winter, the cheese is sold neighbors
PVA- FISH-01	09.07.2015		Montenegro, Pljevlja, River Cehotina	Fish	Sneep *(Chondrostoma nasus)*	Length (cm)-weight (g)-fillet wt. (g) – 29/27-230-29
PVA- FISH-02	09.07.2015		Montenegro, Pljevlja, River Cehotina	Fish	Sneep *(Chondrostoma nasus)*	Length (cm)-weight (g)-fillet wt. (g) – 38/35-445-47
PVA- FISH-03	09.07.2015		Montenegro, Pljevlja, River Cehotina	Fish	Sneep *(Chondrostoma nasus)*	Length (cm)-weight (g)-fillet wt. (g) – 28/24-217-33
PVA- FISH- 04	09.07.2015		Montenegro, Pljevlja, River Cehotina	Fish	Trout (*Salmo trutta*)	Length (cm)-weight (g)-fillet wt. (g) – 26/25-200-31
PVA- FISH- 05	09.07.2015		Montenegro, Pljevlja, River Cehotina	Fish	Trout (*Salmo trutta*)	Length (cm)-weight (g)-fillet wt. (g) – 26/25-200-23

PVA -FISH -06	09.07.2015		Montenegro, Pljevlja, River Cehotina	Fish	Trout (*Salmo trutta*)	Length (cm)-weight (g)-fillet wt. (g) – 25/24-180-17
PVA -FISH -07	09.07.2015		Montenegro, Pljevlja, River Cehotina	Fish	Chub (*Leuciscus cephalus*)	Length (cm)-weight (g)-fillet wt. (g) - 38/34 – 772-83

Table 6b: Description of samples of foodstuff taken **in Bosnia and Herzegovina.**

Sample code	Date	GPS	Locality, sampling spot	Sample material, preparation	Type of sample	Comment
BIH-FISH-01	May 2015		Bosnia and Herzegovina, Tuzla, Divkoviči, small pond, close to the ash landfill	Fish	Pike (*Esox lucius*)	Length (cm)-weight (g)-fillet wt. (g) – 445-620-70
BiH-E-01	28.4.2015	44.53083 18.598697	Bosnia and Herzegovina, Tuzla, Divkoviči, 200 m from the covered part of the ash landfill	Egg	Sample of 6 eggs	2-3 years old hens, hens fed with locally produced corn, a large paddock, people heat coal and wood, eggs sold to about 100 people in the vicinity
BiH-E-02	6.5.2015	44.531711 18.587537	Bosnia and Herzegovina, Tuzla, Divkoviči, 200 m from the covered part of the ash landfill	Egg	Sample of 5 eggs	1 year old hens, hens fed with its own grain, paddock in the garden, people heats coal and wood, only eggs for the family without a woman in product age
BIH-03	7.5.2015	44.534303 18.596702	Bosnia and Herzegovina, Tuzla, garden, 200 m from open part of landfill	Vegetable - parsley		Harvested on the same day, for family use, without the use of mineral fertilizers and pesticides

BIH-04	7.5.2015	44.533825 18.596772	Bosnia and Herzegovina, Tuzla, garden, 250 m from open part of landfill	Vegetable -onion		Harvested on the same day, for family use, without the use of mineral fertilizers and pesticides
BIH-05	7.5.2015	44.53262 18.597437	Bosnia and Herzegovina, Tuzla, garden, 300 m from open part of landfill	Vegetable – onion and celery		Harvested on the same day, for family use, without the use of mineral fertilizers and pesticides
BIH-08	7.5.2015	44.531711 18.587537	Bosnia and Herzegovina, Tuzla, 600 m from open part of landfill	Vegetable – potatoes		Harvested 2014, without the use of mineral fertilizers and pesticides, heating with coal and wood
BIH-10	7.5.2015	44.531711 18.587537	Bosnia and Herzegovina, Tuzla, 600 m from open part of landfill	Vegetable – garlic		Harvested on the same day, without the use of mineral fertilizers and pesticides, , heating with coal and wood
BIH-11	7.5.2015	44.531711 18.587537	Bosnia and Herzegovina, Tuzla, 600 m from open part of landfill	Vegetable – onion		Harvested on the same day without the use of mineral fertilizers and pesticides, , heating with coal and wood

Table 7c: Description of samples of foodstuff taken **in Serbia.**

Sample code	Date	GPS	Locality, sampling spot	Sample material, preparation	Type of sample	Comment
SRB-FISH-01	8.5.2015	44.64459 20.02017	Serbia, Obrenovac, channel draining water from the landfill into a river	Fish	Fish chub (Squalius cephalus)	33.5 cm (whole) and 28.8 cm (without the tail), 0.406 kg (whole) and 6.8 g (filet)
SRB-FISH-02	16.05.2015	N 44.68667 E 20.20283	Serbia, Obrenovac, Sava River	Fish	Pike (*Esox lucius*)	Length/weight/fillet wt. – 445/954/173
SRB-FISH-03	16.05.2015	N 44.68667 E 20.20283	Serbia, Obrenovac, Sava River	Fish	Pike (*Esox lucius*)	Length/weight/fillet wt. – 484/1069/226
SRB –VEGE-01	16.06.2015	N 44.60615 E 20.12573	Serbia, Grabovac	Vegetable - onion		Treated with chemical Talstar 16 days ago
SRB –VEGE-02	16.06.2015	N 44.60925 E 20.10191	Serbia, Grabovac	Vegetable - onion		Not treated with chemicals

SRB –VEGE-03	16.06.2015	N 44.60367 E 20.13196	Serbia, Grabovac	Vegetable - potato		Not treated with chemicals
SRB –VEGE-04	16.06.2015	N 44.63987 E 20.02517	Serbia, Ušće, near the ash landfill	Vegetable - potato		Not treated with chemicals
SRB –VEGE-05	16.06.2015	N 44.63339 E 20.01573	Serbia, Ušće	Vegetable - onion		Not treated with chemicals
SRB –VEGE-06	16.06.2015	N 44.62769 E 20.01366	Serbia, Ušće	Vegetable - potato		Treated with chemicals Tonus and Nospilan
SRB-EGG-01	7.5.2015	44.60603 20.12759	Serbia, Obrenovac	Egg	Pooled sample of 2 eggs	
SRB-EGG-02	7.5.2015	44.61145 20.09925	Serbia, Obrenovac	Egg	Pooled sample of 2 eggs	

SRB-EGG-03	7.5.2015	44.617952 20.103057	Serbia, Obrenovac	Egg	Pooled sample of 2 eggs	
SRB-EGG-04	7.5.2015	44.63391 20.01550	Serbia, Obrenovac	Egg	Pooled sample of 2 eggs	
SRB-EGG-05	7.5.2015	44.639963 20.025332	Serbia, Obrenovac	Egg	Pooled sample of 2 eggs	
SRB-EGG-06	7.5.2015	44.627813 20.013826	Serbia, Obrenovac	Egg	Pooled sample of 2 eggs	

Information about samples of hair are listed together in **Annex II: Results**.

Annex II: Results

Results of the analytical measurement of heavy metals are presented in the following tables.

Table 8: Content of heavy metals in soils and sediments. **The content of elements is given in mg/kg** of **dry matter. Ref – reference site**

Sample code	**Sample type**	**Zn**	**Cd**	**Sr**	**Ba**	**Cu**	**Ni**	**Co**	**Pb**	**Mo**	**Mn**	**Cr**	**As**	**Hg**
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Montenegro:														
MN 04	Fly ash	40.4	1.7	117.6	210.8	38.8	19.7	< 0.1	5.2	9.4	548	116.5	25.2	0.02
MN-05	Soil	64.3	1.3	26.5	102.2	26.7	< 1.0	< 0.1	23.0	18.8	562	37.6	20.9	0.35
MN-06	Soil	82.4	1.1	14.1	63.9	34.7	< 1.0	< 0.1	22.5	31.8	824	34.5	31.3	0.37
MN-07	Soil	54.8	< 1.0	12.7	59.7	18.7	< 1.0	< 0.1	21.6	19.4	1050	24.9	14.9	0.17

Sample code	Sample type	Zn	Cd	Sr	Ba	Cu	Ni	Co	Pb	Mo	Mn	Cr	As	Hg
MN-08	Sediment	119.9	1.9	88.3	190.1	60.5	20.4	< 0.1	29.7	12.6	838	104.1	27.1	0.47
MN-09	Soil	100.2	1.8	25.0	94.7	34.0	< 1.0	< 0.1	28.4	47.4	626	34.6	29.2	0.54
MN-13	Sediment	42.1	1.3	59.4	67.6	25.0	< 0.1	< 0.1	1.2	7.9	633	64.4	41.3	0.38
MN-18	Sediment	60.2	< 1.0	49.7	51.1	30.8	< 0.1	< 0.1	5.4	10.7	614	38.9	34.0	0.50
Bosnia and Hercegovina:														
BIH-01	Soil	91.8	1.1	26.5	132.5	37.9	74.1	< 0.1	24.9	36.4	1303	143.8	18.6	0.14
BIH-02	Sediment	39.1	1.2	74.9	184.5	55.6	322.5	< 0.1	< 0.1	10.0	708	299.5	42.3	0.50
BIH-06	Soil	83.1	2.0	21.3	154.4	49.2	209.5	< 0.1	14.0	54.5	3832	325.9	32.8	0.21
BIH-07	Sediment	62.9	< 1.0	184.8	107.4	56.0	279.9	< 0.1	< 0.1	20.6	1041	260.6	32.4	0.42

Sample code	Sample type	Zn	Cd	Sr	Ba	Cu	Ni	Co	Pb	Mo	Mn	Cr	As	Hg
BIH-09	Soil	77.6	1.2	21.9	113.5	33.8	111.6	< 0.1	28.8	17.6	973	142.9	30.1	0.15
BIH-12	Sediment	75.3	1.5	225.1	115.7	29.2	94.6	< 0.1	34.7	10.2	920	167.5	35.3	0.37
Serbia:														
SRB-01	Sediment	79.4	2.4	66.7	192.7	43.7	42.6	< 0.1	17.4	98.7	1234	293.4	49.9	0.90
SRB-02	Soil	94.8	2.9	28.7	160.7	44.3	22.8	< 0.1	31.7	64.9	1537	118.2	24.9	0.07
SRB-03	Fly ash	25.3	2.9	119.0	171.1	38.3	62.3	< 0.1	6.8	8.0	565	94.3	41.8	0.04
SRB-04	Sediment	62.9	< 1.0	41.8	132.7	32.0	29.5	< 0.1	17.6	36.5	958	132.9	28.8	0.35
SRB-05	Soil	82.8	1.3	27.5	189.8	37.1	12.1	< 0.1	26.1	24.4	1489	102.7	23.1	0.07
SRB-06	Soil	86.9	< 1.0	27.8	198.9	32.6	< 0.1	< 0.1	36.2	26.3	763	88.4	16.0	0.06

Sample code	Sample type	Zn	Cd	Sr	Ba	Cu	Ni	Co	Pb	Mo	Mn	Cr	As	Hg
SRB-07	Sediment	78.5	2.5	98.7	225.7	48.8	54.6	< 0.1	22.3	33.6	853	145.4	58.5	0.44
SRB-08	Sediment	146.4	1.8	67.1	138.4	49.7	84.7	< 0.1	38.5	31.7	1164	176.2	35.7	0.46

Table 9: Content of heavy metals in water from Bosnia and Hercegovina. **The content of elements is given in mg/L.**

Sample code	Sample type	Zn	Cd	Sr	Ba	Cu	Ni	Co	Pb	Mo	Mn	Cr	As	Hg
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
W-1	Water - ref	0.013	0.014	0.636	0.055	0.01	0.029	< 0.01	0.038	< 0.01	0.018	0.06	< 0.003	< 0.001
W-2	Water	< 0.01	< 0.01	1.136	0.048	0.019	0.027	< 0.01	< 0.01	< 0.01	0.012	0.23	0.003	< 0.001
W-3	Water	0.01	0.015	0.401	0.042	0.012	0.025	< 0.01	0.030	0.01	0.142	0.08	< 0.003	< 0.001
W-4	Water	< 0.01	0.013	0.335	0.032	< 0.01	0.024	< 0.01	0.028	0.07	0.136	0.06	0.022	< 0.001
W-5	Water	0.051	0.015	0.457	0.069	0.02	0.029	< 0.01	0.043	< 0.01	0.203	0.08	0.004	< 0.001
W-6	Water	< 0.01	< 0.01	0.343	0.042	0.026	0.037	< 0.01	< 0.01	< 0.01	0.533	0.14	< 0.003	< 0.001

Table 10: Content of heavy metals in foodstuff. **Ref – reference sample.**

Sample code	**Sample type**	**Hg**	**Pb**	**Cd**	**Cr**	**As**
		(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Monte Negro:						
MN 10	Onion	<0.001	<0.02	0.005	<0.05	<0.010
MN 11	Potatoes	<0.001	<0.02	0.010	<0.05	<0.010
MN 14	Carrot	0.001	<0.02	0.013	<0.05	0.030
MN 15	Potatoes	<0.001	<0.02	0.016	<0.05	<0.010
MN 16	Onion	<0.001	<0.02	0.009	<0.05	<0.010
MN 17	Chees	<0.001	<0.02	<0.002	<0.05	<0.010
REF-vegetable-02	Potatoes - ref	<0.001	<0.02	0.008	<0.05	<0.010

REF-vegetable-02	Onion -ref	<0.001	<0.02	0.015	<0.05	<0.010
PLZ-FISH-01. 02 and 03	Fish - ref	0.074	<0.02	<0.002	<0.05	0.030
PLZ-FISH-04. 05 and 06	Fish -ref	0.037	<0.02	<0.002	<0.05	0.140
PVA-FISH-01	Fish	0.047	<0.02	<0.002	<0.05	0.010
PVA-FISH-02	Fish	0.077	<0.02	<0.002	<0.05	<0.010
PVA-FISH-03	Fish	0.054	<0.02	<0.002	0.07	0.020
PVA-FISH-04	Fish	0.038	<0.02	<0.002	<0.05	0.010
PVA-FISH-05	Fish	0.083	<0.02	<0.002	<0.05	0.010
PVA-FISH-06	Fish	0.045	<0.02	<0.002	<0.05	0.010
PVA-FISH-07	Fish	0.233	<0.02	<0.002	<0.05	0.010
PLZ-E1. PLZ-E2. PLZ-E3	Eggs	0.001	<0.02	<0.002	<0.05	<0.010

PLZ-E4. PLZ-E5. PLZ-E6	Eggs	0.001	<0.02	<0.002	<0.05	<0.010
PLJ-EGGS-01	Eggs	0.002	<0.02	<0.002	<0.05	<0.010
Bosnia and Hercegovina:						
BiH-E-01	Eggs	0.014	<0.02	<0.002	<0.05	0.010
BiH-E-02	Eggs	0.003	<0.02	<0.002	<0.05	0.020
BIH-03	Parsley	0.002	<0.02	<0.002	<0.05	0.040
BIH-04	Onion	0.001	0.06	0.005	0.19	0.020
BIH-05	Onion	0.002	0.22	0.017	0.68	0.050
BIH-08	Potatoes	<0.001	<0.02	0.014	<0.05	<0.010
BIH-11	Onion	0.001	0.14	0.025	0.71	0.050
BIH-FISH-01	Fish	0.381	<0.02	<0.002	<0.05	0.140

Serbia:						
SRB-EGG-01	Eggs	0.001	<0.02	<0.002	0.06	0.010
SRB-EGG-02 a SRB-EGG-03	Eggs	0.002	<0.02	<0.002	<0.05	<0.010
SRB-EGG-04; SRB-EGG-05; SRB-EGG-06	Eggs	0.003	<0.02	<0.002	<0.05	0.010
SRB-FISH-01	Fish	0.092	<0.02	<0.002	<0.05	0.080
SRB-FISH-02	Fish	0.815	<0.02	<0.002	<0.05	0.030
SRB-FISH-03	Fish	0.657	<0.02	<0.002	<0.05	0.020
SRB-VEGE-01	Onion	<0.001	<0.02	0.067	<0.05	<0.010
SRB-VEGE-02	Onion	<0.001	<0.02	0.006	<0.05	<0.010
SRB-VEGE-03	Potatoes	<0.001	<0.02	0.013	<0.05	<0.010

SRB-VEGE-04	Potatoes	<0.001	<0.02	0.010	<0.05	<0.010
SRB-VEGE-05	Onion	<0.001	<0.02	0.013	<0.05	<0.010
SRB-VEGE-06	Potatoes	<0.001	<0.02	0.016	<0.05	<0.010

Table 11: Content of heavy metals in hair. The content of elements is given in mg/kg.

Sample code	As	Cd	Cr	Hg	Pb	MeHg	Potential heavy metals sources
Reference locality Montenegro:							
REF-KOSA-01	<0.4	0.060	<2.2	0.201	1.240		Pensioner. trout once a week
REF-KOSA-02	<0.9	0.060	<4.4	0.166	1.940		Hairdresser. trout once a week. colleagues smoke
REF-KOSA-03	<0.3	0.360	<1.5	0.036	0.260		Administrative worker. trout once a week
REF-KOSA-04	<0.3	0.020	<1.5	0.326	0.350		Pensioner. trout/hake once a week. household member smokes

REF-KOSA-05	<0.3	<0.03	1.570	0.172	0.640		Student. trout/tuna 2-3x a week
REF-KOSA-06	<0.2	0.040	0.750	0.044	0.930		Housewife. trout/hake once a week
REF-KOSA-07	<1.5	<0.15	<7.4	0.082	1.210		Trader. trout once a week
REF-KOSA-08	<0.4	0.200	<1.8	0.077	0.620		Caterer. trout 2-3x a week
REF-KOSA-09	<0.1	0.010	<0.5	0.365	0.270		Student. trout 2-3x a week
REF-KOSA-10	<0.1	0.040	<0.7	0.107	1.340		Trader. trout once a week
Average	**-**	**0.099**	**1.160**	**0.158**	**0.880**		
Median	**-**	**0.050**	**1.160**	**0.137**	**0.785**		
Montenegro:							
MNE-KOSA-01	<0.7	0.040	<3.5	0.087	<0.7		Taxi driver. trout once a week. living near a boiler room
MNE-KOSA-02	<1.4	0.190	<7.1	0.129	<1.4		Ecologist. trout once a week. flatmate smokes

MNE-KOSA-03	<0.6	<0.06	<3.2	0.051	<0.6		Mechanic. trout once a week
MNE-KOSA-04	<0.2	0.020	5.170	0.115	0.370		Student. trout once a week. household member smokes. living near a coal mine
MNE-KOSA-05	<0.1	0.020	<0.4	0.229	0.530		Student. flatmate and colleagues smoke. trout/hake/mackerel once a week. living near a coal mine
MNE-KOSA-06	<2.3	<0.23	-	0.086	<2.3		Agricultural engineer. colleagues smoke. trout once a week. living near a boiler room
MNE-KOSA-07	<0.2	0.020	<0.8	0.135	7.840		Economist. household member smokes. trout/hake/sardine once a week
MNE-KOSA-08	<0.3	0.110	<1.4	0.143	7.500		Driver. trout once a week. 3x a week at smoky place
MNE-KOSA-09	<3.6	<0.36	<18	0.265	<3.6		Driver. trout/hake once a week. colleagues smoke
MNE-KOSA-10	<0.4	0.320	<2.1	0.156	<0.4		Housewife. hake once a week
MNE-KOSA-11	<0.9	0.080	<4.4	0.146	<0.9		Self-employed. trout once a week. colleagues smoke

MNE-KOSA-12	<3.1	3.310	<16	0.198	<3.1		Self-employed. trout once a week
Average	**-**	**0.457**	**5.170**	**0.145**	**4.060**		
Median	**-**	**0.080**	**5.170**	**0.139**	**4.015**		
Bosnia and Hercegovina:							
BIH-HAIR-01	<0.1	0.020	<0.3	0.190	0.530	0.059	Chemical technician. trout/carp once a week
BIH-HAIR-02	0.080	0.190	0.240	0.315	3.960	0.091	Technician. trout/carp once a week
BIH-HAIR-03	0.170	0.050	0.210	0.071	0.980	NQ	Housewife. hake once a week. flatmate smokes
BIH-HAIR-04	0.040	0.010	0.320	0.042	0.240		Housewife
BIH-HAIR-05	0.720	0.010	0.160	0.083	0.400		Pensioner
BIH-HAIR-06	0.100	0.020	<0.2	0.198	0.650		Pensioner. trout/hake once a week
BIH-HAIR-07	0.250	0.800	<0.9	0.110	3.120		Locksmith. carp/catfish/mackerel 2-3x a week

BIH-HAIR-08	0.080	0.020	0.320	0.163	0.170		Construction technician. hake once a week. smoky environment
BIH-HAIR-09	0.080	0.210	<0.1	0.113	1.790		Housewife
BIH-HAIR-10	0.060	0.050	<0.1	0.037	2.620		Student. chub/bream once a week. flatmate smokes
BIH-HAIR-11	0.090	0.090	<0.1	0.076	0.380		Pensioner. carp/hake once a week. smoker (20 cig a day)
BIH-HAIR-12	0.160	0.050	0.320	0.062	1.290		Electrical technician. trout/hake once a week. household member smokes
Average	**0.166**	**0.127**	**0.262**	**0.122**	**1.344**		
Median	**0.090**	**0.050**	**0.280**	**0.097**	**0.815**		
Serbia:							
SRB-MAR-01	0.020	0.010	0.600	0.255	0.060		Pensioner. almost do not eat fish
SRB-MAR-02	0.100	0.080	<0.1	1.077	1.840		Farmer. perch. carp once a week. lives and works in a smoky place

SRB-MAR-03	0.210	0.080	0.280	0.024	2.110	NQ	Farmer. almost do not eat fish. lives and works in a smoky place
SRB-MAR-04	0.060	0.030	0.310	0.576	0.970	0.314	Housewife. pike. fish chiton once a week. smoking in household. she eats fish from the channel were fish was caught (chanell from ash dump to Sava river). She lives halfway between TPP and ash dump. cca 500 meters from both. They heat themselves by burning wood in room.
SRB-MAR-05	0.060	0.010	<0.2	0.435	0.320		Housewife. pike. fish chiton once a week. smoking in household. she eats fish from the channel where fish was caught (channel from ash dump to Sava river). She lives halfway between TPP and ash dump. cca 500 meters from both. They heat themselves by burning wood in room
SRB-MAR-06	<0.02	0.090	0.260	0.391	2.310	0.194	Housewife. carp once a week
SRB-MAR-07	0.140	0.010	<0.1	0.142	0.230		Pensioner. Hake. saury once a week
SRB-MAR-08	0.080	0.080	0.200	0.131	0.210		Pensioner. different fish once a week
SRB-MAR-09	<0.1	<0.01	0.910	0.126	0.280	0.079	Trader. hake once a week. smoking in apartment
SRB-MAR-10	0.030	0.070	0.390	0.611	1.550	0.341	Student. trout. mackerel. sea bass 6x a week. sometimes at smoking place. she eats significant canned tuna. she lives 5km from one TPP and 7km from the other and 2km from ash landfill. they

							burn pellets in the room
SRB-MAR-11	1.450	0.020	0.320	0.461	0.240	0.321	Pensioner. almost do not eat fish. smoking apartment
SRB-MAR-12	0.350	0.040	<1.1	0.155	1.400	0.097	Technical engineer in the power plant. hake. carp once a week. smoking apartment. she eats canned tuna and fish from Sava river. she lives 5km from one TPP and 7km from the other and 2km from ash dump. they burn coal but outside
average	**0.250**	**0.047**	**0.409**	**0.365**	**0.960**		
median	**0.090**	**0.040**	**0.315**	**0.323**	**0.645**		

Annex III: Legal standards

Table 12: Legal standards for heavy metals in soils. *The content of elements is given in mg/kg of dry matter.

	Zn	**Cd**	**Sr**	**Ba**	**Cu**	**Ni**	**Co**	**Pb**	**Mo**	**Mn**	**Cr**	**As**	**Hg**
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Local limits - Montenegro	300	2	-	-	100	50	50	50	10	-	50	20	1.5
Local limits – BiH – sandy soil	100	0.5	-	60	50	30	30	50	10	-	50	10	0.5
Local limits – BiH – silty-clay soil	150	1	-	80	65	40	45	80	15	-	80	15	1.0
Local limits – BiH – loamy soil	200	1.5	-	100	80	50	60	100	20	-	100	20	1.5
Local limits - Serbia	300	3	-	-	100	50	-	100	-	-	100	25	2

***Levels of pollution limits – industrial areas (based on US EPA)**	310000	800	-	190000	41000	20000	300	800	5100	23000	-	2.4	43
***Levels of pollution limits – other areas (based on US EPA)**	23000	70	-	15000	31000	1500	23	400	390	1800	-	0.61	10
***Cz Decree - use of sediments on agricultural soils**	300	1	-	-	100	80	30	100	-	-	200	30	0.8

The water quality can be evaluated according to CZ Decree – Classification of Surface Water Quality (ČSN 75 7221 (757221) - Jakost vod - Klasifikace jakosti povrchových vod). In terms of their quality, surface waters are divided into five classes. The classes are given in **Annex III**.

Table 13: Surface water quality classes according to the CZ Decree (ČSN 75 7221)

Class number	**Classification**	**Description**
I	*unpolluted water*	*surface water condition that has not been substantially affected by human activities; water quality criteria do not exceed values consistent with normal natural background in surface streams*
II	*slightly polluted*	*surface water condition that has been affected by human activities; however. water quality criteria attain values that enable the existence of a rich. balanced and sustainable ecosystem*
III	*polluted water*	*surface water condition that has been affected by human activities to such an extent that water quality criteria attain values which need not necessarily provide prerequisites for the existence of a rich. balanced and sustainable ecosystem*
IV	*heavily polluted water*	*surface water condition that has been affected by human activities to such an extent that water quality criteria attain values which permit the existence of an unbalanced ecosystem only*
V	*very heavily polluted water*	*surface water condition that has been affected by human activities to such an extent that water quality criteria attain values which permit the existence of a very unbalanced ecosystem only*

Table 14: Water quality classes and their limit values according to the CZ Decree (ČSN 75 7221)

Parameter	**Unit**	**Class number**				
		I	II	III	IV	V
Cr	µg/L	< 5	< 20	< 50	< 100	≥ 100
Mn	µg/L	< 100	< 300	< 500	< 800	≥ 800
Ni	µg/L	< 5	< 20	< 50	< 100	≥ 100
Cu	µg/L	< 5	< 20	< 50	< 100	≥ 100
Zn	µg/L	< 15	< 50	< 100	< 200	≥ 200
Cd	µg/L	< 0.1	< 0.5	< 1	< 2	≥ 2
Hg	µg/L	< 0.05	< 0.1	< 0.5	< 1	≥ 1
Pb	µg/L	< 3	< 8	< 15	< 30	≥ 30

As	µg/L	< 1	< 10	< 20	< 50	≥ 50

Table 15: Legal standards for physical and chemical indicators for drinking water. The content of elements is given in µg/L.

	Cd	**Cu**	**Ni**	**Pb**	**Mn**	**Cr**	**As**	**Hg**
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Cz Decree – indicators for drinking water	5.0	1000	20	10	50	50	10	1.0

Table 16: Aquatic Life criteria for freshwater according to the EPA.

Pollutant	**CMC (acute) (µg/L)**	**CCC (chronic) (µg/L)**
As	340	150
Cd	2.0	0.25
Pb	65	2.0
Hg	1.4	0.77
Ni	470	52
Zn	120	120

Water quality criterion was derived from data for arsenic (III). The Criteria Maximum Concentration (CMC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

Table 17: Maximum levels for mercury in foodstuffs (Commission Regulation (EC) no. 1881/2006).

Foodstuffs	**Maximum level for mercury (mg/kg of fresh weight)**
Fishery products and muscle meat of fish (excluding species listed below)	**0.5**
Selected fishery products and muscle meat of fish: *Lophius* spp.. *Anarhichas lupus*. *Sarda sarda*. *Anguilla* spp.. *Hoplostethus* spp.. *Coryphaenoides rupestris. Hippoglossus hippoglossus*. *Genypterus capensis. Makaira* spp.. *Lepidorhombus* spp.. *Mullus* spp.. *Genypterus blacodes. Esox lucius. Orcynopsis unicolor. Trisopterus minutus. Centroscymnes coelolepis. Raja* spp.. *Sebastes marinus. S. mentella. S. viviparus. Istiophorus platypterus. Lepidopus caudatus*. *Aphanopus carbo. Pagellus* spp.. *Carcharodon* spp.. *Lepidocybium flavobrunneum*. *Ruvettus pretiosus*. *Gempylus serpens. Acipenser* spp.. *Xiphias gladius. Thunnus*. *Euthynnus*. *Katsuwonus pelamis*.	**1.0**

Table 18: Maximum levels for cadmium in foodstuffs (Commission Regulation (EC) no. 1881/2006).

Foodstuffs	**Maximum level for cadmium (mg/kg of fresh weight)**
Vegetables and fruit. except for root and tuber vegetables. leafy vegetables. fresh herbs. leafy brassica. stem vegetables. mushrooms and seaweed	**0.05**
Root and tuber vegetables ((excluding celeriac. parsnips. salsify and horseradish). petiole vegetables and stem vegetables (except petiole celery)	**0.1**
Muscle meat of fish (excluding species listed below)	**0.05**
Scomber spp.. tuna (*Thunnus. Katsuwonus pelamis. Euthynnus*). *Sicyopterus lagocephalus*	**0.10**
Tuna (*Auxis*)	**0.15**
Engraulis spp.. *Xiphias gladius*. *Sardina pilchardus*	**0.25**

Table 19: Maximum levels for lead in foodstuffs (Commission Regulation (EC) no. 1881/2006).

Foodstuffs	**Maximum level for lead (mg/kg of fresh weight)**
Muscle meat of fish	**0.3**
Vegetable (excluding brassica vegetables. leafy vegetables. fresh herbs. fungi and seaweed)	**0.1**
Fats and oils. including milk fat	**0.1**

Ed. Detailed specifications of contaminants in foodstuffs are given in Commission Regulation (EC) no. 1881/2006.

Annex IV: Auxiliary criteria for soils

Criteria A approximately correspond to the natural concentration level of the chemical substance in the environment; therefore it may serve to estimate the approximate background levels.

Table 20: Auxiliary criteria for soils. The content of elements is given in mg kg^{-1} of dry matter (if not specified).

Criterion	Zn	Cd	Sr	Ba	Cu	Ni	Co	Pb	Mo	Mn	Cr	As	Hg
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
A	150	0.5	-	600	70	60	25	80	0.8	-	130	30	0.4
B	1500	10	-	900	500	180	180	250	50	-	450	65	2.5
C – residential area	2500	20	-	1000	600	250	300	300	100	-	500	70	10
C – recreation area	3000	25	-	2000	1000	300	350	500	160	-	800	100	15
C – industrial area	5000	30	-	2800	1500	500	450	800	240	-	1000	140	20

Criteria A approximately correspond to the natural concentration level of the chemical substance in the environment. The exceedance of criteria A is considered as a contamination of the particular environmental compartment except in areas with a naturally higher abundance of the chemical substance. If criteria B are not exceeded, the contamination is not considered sufficiently significant to justify the need for more detailed information on the contamination, e.g. to start an investigation or monitoring of the contamination.

Criteria B are considered a contamination level that may have negative impacts on human health and individual environmental compartments. It is necessary to gather additional information to find out whether the site represents a significant environmental burden and what risks it poses. Criteria B are therefore designed as intervention levels which, when exceeded, justify the demand for further investigation on the contamination. The exceedance of criteria B requires a preliminary assessment of risks posed by the contamination, the identification of its source and reasons and - according to the investigation results - a decision on further investigation and start of a monitoring campaign.

The exceedance of criteria C represents contamination which may pose a significant risk to human health and environmental compartments. The risk level can be determined only by a risk analysis. The recommended levels of remediation target parameters resulting from the risk analysis can be higher than criteria C. In addition to the risk analysis, assessments of technical and economic aspects of the problem’s solution are necessary documents for the decision on the type of remedial measures.