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DISTRIBUTION OF LEAD IN THE WATERS, SEDIMENT, RICE AND VEGETABLE CROPS IN THE BASIN OF THE RIVER BREGALNICA

Snezana STAVREVA-VESELINOVSKA[1],

ABSTRACT

During the period from January to December 1999 year and 2000, 2007 and 2008 field research has been made at 20 measuring points on the river Bregalnica together with its tributaries. The research made during these year on the territory of East Macedonia had an aim to establish the degree of water pollution in the river Bregalnica with its tributaries, and distribution of lead in the sediment, rice and vegetable crops in the basin of the river Bregalnica pollution with heavy metals as a result of direct release of waste water from lead-zinc mines "Zletovo" and "Sasa" as well as from copper mine "Bucim". From the results acquired research while the annual an seasonal dynamics of the lead content in the river Bregalnica with its tributaries was monitored, it can be seen that there is a variation in the values of a relatively wide range between respective measuring sites, monthly variations, which id the consequence of anthropogenic influence upon the living environment.

Key words: River Bregalnica, heavy metals, water, lead, rice, sediment.

INTRODUCTION

Currently, industry and agriculture in Macedonia are co-evolving, often in the same area. Factories are established in the central region where there are paddy fields. Heavy metals such as cadmium and lead are widely used in industry. They enter to the environment from natural and anthropogenic sources. The most important anthropogenic sources of soil pollution to metals are industrial sludge sewage discharging, applying super phosphate fertilizers, burying the non-ferrous wastes in land and closing the agricultural fields to lead and Zinc mines or refining factories (Rowland *et al*., 1997). These metals contaminate food source and accumulate in both agricultural products and seafood through water, air and soil pollution (Lin *et al*., 2004). Cadmium (Cd) and lead (Pb) are two of the most well-known environmental intoxicants to humans.

Lead is a heavy metal considered highly toxic to human and animals. The effects of lead are the same whether it enters the body through breathing or swallowing. The main target of lead toxicity is the nervous system, both in children and adults. Long-term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Some studies in humans showed that lead exposure may increase blood pressure, but the evidence is still inconclusive. Lead exposure may also cause anemia, a symptom showing low number of red blood cells. High-level exposure in males can damage the organs responsible for sperm production. In plants, lead inhibits chloroplast bio generation and photosynthesis due to direct interference with the reaction caused by light or indirect

[1] Professor, University "Goce Delcev" Stip, Macedonia, e-mail: snezana.veselinovska@ugd.edu.mk

interference with the synthesis of carbohydrates, resulting in flaccidity of stomatal guard cells, impairing transpiration and carbon dioxide exchange, and further reducing of carbohydrate synthesis. The toxicity of lead also inhibits DNA synthesis, cell division, and seed germination (Iqbal et al., 2000).

Studies and research of heavy metals in ecosystems have shown that many areas near cities, urban complexes, mines or great road systems contain unusually high concentrations of heavy metals. The soil in these regions is especially contaminated by a wide range of sources of lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As) and other heavy metals. Nriagu (1988) wrote that we may be experiencing "a quiet epidemic of poisoning the environment with heavy metals" by the existent increased quantities of metals that are thrown up into the atmosphere.

Water as the basic component of any living matter is one of the essential factors of the survival of our planet, and cannot be replaced by anything. 71% of the Earth's surface is under water, 98.77% of which is salty and mineral water in the seas and oceans, and 1.23% is fresh water which is available to mankind and other living organisms. 1.19% of freshwater is contained in the Antarctic polar cap, and 0.040% is in rivers, lakes, underground waters and atmospheric water.

Water is the most universal phenomenon in nature, and as a precondition of total life on the planet it – directly or indirectly – influences all human activities in space. As the most significant and most specific component of living matter in all the stages of its evolution, water is the most precious resource on earth that fulfils the needs at the level of planetary survival. It occurs in the form of a uniquely essential and very rich substance in any plant or animal cell, as well as in other elements in the natural environment, and in urban surroundings created by man. Because of this, mankind must pay its full attention to the issue of water, it must make severe efforts to protect and preserve its natural resources with a quality that will provide a future of healthy, rich and long living.

OBJECT OF RESEARCH

This research was performed along the river Bregalnica with its tributaries: the rivers Zletovica, Kamenichka Reka, Osojnica and Kriva Lakavica.

In the first year of research (1999) the material for analysis was taken once a month in the course of the whole calendar year (from January to December). During this period the annual dynamics of the content of heavy metals in the river Bregalnica and its tributaries was monitored, as well as in the river sediment, in leaves and fruits of *Oryza sativa L*, and in some vegetable crops such as *Lactuca sativa, Allium sativum, Capsicum annuum* and *Solanum lycopersicum.*

During the second year of research (2000) the seasonal dynamics of the heavy metals content (Pb, Zn, Cd, Mn, Cu and Fe) was monitored. The material for analysis was taken during the four seasons (spring, summer, autumn and winter).

In the years of research (2007 and 2008) the material for analysis was taken during the four seasons (spring, summer, autumn and winter).

Research was performed at twelve measuring pints along the river Bregalnica with some of its tributaries (rivers Zletovica, Kamechka Reka, Osojnica and Kriva Lakavica) into which the waste waters of the zinc and lead mines "Zletovo" and "Sasa" and the copper mine "Buchim" are being let out.

Water and sediment was taken a material for analysis from all the mentioned measuring points during the two years of research. Exceptions were Kozja and Svina reka after the mine, i.e. T2 and T3, because sediment analysis was not made as it was represented there with fractions of coarse sand and gravel and not with mud, because of the rapid flow of these rivers. These measuring points are located at 1000 m above sea level.

The choice of measuring pints was made according to the location of industrial objects, i.e. lead and zinc mines “Zletovo” and “Sasa”, as well as copper mine “Buchim”. The three tributaries of the river Bregalnica were taken as objects of research because the flotation waste waters of the three mines directly flow into them and continue to contaminate the water of the river Bregalnica. The locations of the measuring points in the frames of the researched area were chosen to be situated before and after the flow of the tributaries of the river Bregalnica, and the measuring point on the river Osojnica is taken to be the control measuring point because there are no industrial objects in its vicinity.

Sampling

Samplings had been carried out during in 1999, 2000, 2007 and 2008 years. Grab water samples (number of samples collected n=20) were collected in polyethylene cans and transported to the Faculty of natural Science, Institute of Biology, Vegetable samples were collected in polyethylene bags during the harvest time. Soil samples at surface level (0-15 cm in depth) were collected from the same locations where the vegetable crops were sampled.

Sample preparation

Water samples (500 ml) were filtered using Whatman No. 41 (0.45 µm pore size) filter paper for estimation of dissolved metal content. Filtrate and as collected water samples (500 ml each) were preserved with 2 ml nitric acid to prevent the precipitation of metals. Soil samples were air dried and ground into fine powder using pestle and mortar and passed through 2 mm sieve. Well mixed samples of 2 g each were taken in 250 ml glass beakers and digested with 8 ml of aqua regia on a sand bath for 2 h. After evaporation to near dryness, the samples were dissolved with 10 ml of 2% nitric acid, filtered and then diluted to 50 ml with distilled water. Vegetable samples were thoroughly washed to remove all adhered soil particles. Samples were cut into small pieces, air dried for 2 days and finally dried at 105^0C in an hot air oven for 24 h. The samples were ground in warm condition and passed through 1 mm sieve. Digestion of these samples (2g each) was carried out using 10 ml of 2% nitric acid, according to the procedure used for soil samples.

Analysis

Heavy metal analyses were carried out using flame atomic absorption Spectrophotometer – PERCIN ELMER 5000, to the Faculty of natural Science, Institute of Biology, Skopje. The calibration curves were prepared separately for all the metals by running different concentrations of standard solutions. Average values of five replicates were taken for each determination and were subjected to statistical analysis.

FAO, USEPA and Macedonian guidelines for maximum limits of metals in irrigation water were compared here. The guideline for maximum allowable limits of metals in soils was adopted from Lacatusu, R, 2005 and for Fe and Mn from Weigert, P. , 1991.

RESEARCH RESULTS AND DISCUSION

The complex approach to determining the distribution of heavy metals in water ecosystems enables us to get relevant data about the level of contamination of ecosystems. The performance of analysis of a number of substrates (soil, sediment, plant organs) represents a key approach to getting valid and reliable conclusions.

The analysis results of the heavy metals content in water often give us only an orientation about the quality of water. The concentration of soluble heavy metals depends on numerous factors such as: characteristics of the water basin, contents of suspended particles (Botelho and ass. 1994; Pelletier 1996), pH value (Tack and ass. 1996), sulphides and phosphates (Reczynska-Dutka 1991), chemical interactions, organic matter and bio-accumulative processes. The relativity of the water analysis results is especially noticed during short or discontinued letting out of heavy metals (Vogel & Chovanec 1992). However, the first picture of the level of contamination of the river ecosystem is based on the analysis of water. The research performed so far about the level of contamination with heavy metals in the river Bregalnica also go in this direction.

The results of the two-year research along the river Bregalnica with its tributaries show intensive contamination of this river with lead. Compared to the analysis done by Whitton et al. (1989) at 60 measuring points in Great Britain (maximum values for lead 22.4 µg/l) and Reczynska-Dutka (1991) at three man-made accumulation lakes in Poland (42.3 µg/l), the data about the lead content in the tributaries of the river Bregalnica (Kozja and Svina Reka, Kamenichka Reka, and the rivers Kiselica and Koritnica) that carry the waste waters of the lead and zinc mines "Zletovo" and "Sasa" are a hundred times higher.

The lead contents results during the two years of research in the waters of the river Bregalnica with its tributaries show variations in values in a relatively wide range between respective measuring sites, monthly variations, as well as differences in values got for the two years as a result of direct letting out of flotation waste waters of the lead-zinc ore from the mines "Zletovo" and "Sasa".

Table 1: Average annual values of lead content in the waters (mg/l) and sediment (mg/kg) of the river Bregalnica with its tributaries

Measuring point		Pb			
		1999		2000	
		water	sediment	water	sediment
T1	r. Bregalnica (Iliovo)	0.19	109	0.15	112
T2	Kozja Reka above the mine	0.02	-	0.02	-
T3	Svinja Reka above the mine	0.02	-	0.01	-
T4	Kozja Reka after the mine	3.03	2899	2.66	3329
T5	Svinja Reka after the mine	3.32	2766	3.88	3065
T6	Kamenicka Reka	1.65	4009	2.14	4275
T7	Kamenicka Reka - after waste deposit	3.02	1223	2.95	1420
T8	Kamenicka Reka - before the dam	1.38	710	1.06	940
T9	Dam Kalimanci	0.15	438	0.12	523
T10	Dam Kalimanci - exit	0.07	87	0.07	97
T11	R. Bregalnica (Istibanja)	0.11	78	0.10	81
T12	R.Bregalnica (Ularci)	0.07	132	0.06	129
T13	R.Zletovica (Ularci)	0.12	275	0.11	374
T14	R. Bregalnica (Balvan)	0.10	325	0.08	353
T15	R. Kriva Lakavica	0.18	541	0.15	609
T16	R. Bregalnica (Dragoevo)	0.15	121	0.07	185
T17	R. Bregalnica (Novo Selo)	0.15	106	0.06	127
T18	R. Kiselica	1.98	758	1.82	812
T19	R. Koritnica	0.42	868	0.58	924
T20	R. Osojnica	0.02	29	0.02	35

At the twenty measuring points along the river Bregalnica with tributaries during the two years of research, only at the measuring points Kozja and Svina Reka that are located above the mine at 1000 m above sea level, and at the measuring point on the river Osojnica next to the village Blatec near Vinica mean annual values (0.01-0.02 mg/l) lower than the values prescribed for Maximum Allowed Concentrations for I and II category of water (up to 0.01 mg/l, Official bulletin of R. Macedonia 18/99). At all the other measuring points mean annual values of the lead content in water (0.07-3.32 mg/l in the first research year; 0.06-3.88 mg/l in the second year of research), are considerably higher than the MAC for the V category of water (>0.03 mg/l). Maximum values of 1.38-3.32 mg/l and of 1.06-3.88 mg/l in the two research years were measured in the waters of the rivers Kozja and Svina Reka after the mine "Sasa", the rivers Kamenichka reka and Kiselica as direct carriers of the waste waters from the two lead and zinc mines "Zletovo" and "Sasa". Our results show that the rivers

Bregalnica and tributaries are highly contaminated with lead that has a very negative effect upon all the other components of the environment, which was confirmed by our research.

The analysis of the lead content in the sediment of the river Bregalnica and its tributaries show that the measuring points situated upstream have a relatively low level of contamination with lead. Namely, the lead content values in the sediment at the measuring points T4, T5, T6, T18, and T19 (the rivers Kozja and Svina Reka, and Kiselica and Koritnica) are considerably higher (710-4009 mg/kg in the first year of research and 924-4275 mg/kg in the second year). The decrease in lead content in sediment can be noticed in the lower course of the river Bregalnica (81-353 mg/kg), while the lowest values were measured at the control measuring point during both years of research; the mean annual value is a hundred times lower compared to the measuring points (T4, T5, T6, T18, and T19). The greatest contaminators of the rivers are the waste waters from the mines "Zletovo" and "Sasa" where the values are increased manifold because of the their waste waters that have relatively high concentrations of heavy metals.

Table 2: Average annual values of lead content in the waters (mg/l) and sediment (mg/kg) of the river Bregalnica with its tributaries

Measuring point		Pb			
		2007		2008	
		water	sediment	water	sediment
T1	r. Bregalnica (Iliovo)	0.22	145	0.25	112
T2	Kozja Reka above the mine	0.01	-	0.04	-
T3	Svinja Reka above the mine	0.02	-	0.03	-
T4	Kozja Reka after the mine	4.22	3599	3.44	4523
T5	Svinja Reka after the mine	5.12	3796	4.97	4021
T6	Kamenicka Reka	1.89	5209	3.45	5575
T7	Kamenicka Reka - after waste deposit	4.55	1623	4.05	1789
T8	Kamenicka Reka - before the dam	2.12	820	2.87	1089
T9	Dam Kalimanci	0.23	542	0.43	620
T10	Dam Kalimanci - exit	0.12	101	0.09	105
T11	R. Bregalnica (Istibanja)	0.21	118	0.19	98
T12	R.Bregalnica (Ularci)	0.11	156	0.09	144
T13	R.Zletovica (Ularci)	0.22	346	0.23	421
T14	R. Bregalnica (Balvan)	0.23	475	0.31	356
T15	R. Kriva Lakavica	0.26	674	0.32	789
T16	R. Bregalnica (Dragoevo)	0.20	146	0.22	255
T17	R. Bregalnica (Novo Selo)	0.23	177	0.26	187
T18	R. Kiselica	2.46	868	2.99	923
T19	R. Koritnica	1.25	921	1.43	1034
T20	R. Osojnica	0.01	45	0.01	46

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Table 2 shows mean annual valus of the lead content in water and sediment in research years 2007 and 2008. These results compared with the results from years 1999 and 2000 are slightly higher. One of the reasons for these higher values is the damage that happened on the waste landfill of the lead and zinc mine “Sasa”.

Rice is an important crop as it is basic food for two thirds of the world’s population. Rice (*Oryza sativa*) is one of the world’s most important cereal crops, providing staple food for nearly a half of the world population. In many developing countries, rice is the main source of food security and is intimately associated with local lifestyles and culture. Rice may be contaminated by lead. So far, there was no report regarding harm from lead contaminated rice to consumers, but this does not mean that there is no lead contamination in rice. Food Control Division of Macedonia (2009) announced that lead in rice grain must not exceed the food hygiene concentration limit (1.0 mg Pb per 1 kg dry weight (DW) of food). Lead may also be a contaminant in bran, the most widely-used rice by product. Rice bran is a good source of vitamins for humans and animals and is valuable as food and feed. A basic knowledge of lead accumulation in rice would be beneficial and essential to rice marketing in the future. Thus, this experiment is aiming to study lead accumulation in roots, shoots/leaves and grains of rice grown in contaminated soils.

Table 3: Average annual values of lead content in the waters (mg/l), soil, leaf and fruit (mg/kg) of the *Oryza sativa L* of the river Bregalnica with its tributaries

	Pb							
	1999				2000			
	water	soil	leaf	fruit	water	soil	leaf	fruit
R. Osojnica	0.03	36.70	3.83	0.83	0.013	38.56	4.06	0.75
R. zletovica	0.14	182.96	13.53	3.80	0.15	181.22	14.36	2.97
R. Bregalnica	0.12	408.68	18.59	3.42	0.12	421.39	18.81	3.99
HS. Bregalnica	0.08	328.54	18.63	3.50	0.07	333.12	18.85	4.09

In Macedonia the production of rice is concentrated in the eastern region along the course of the river Bregalnica, around towns Kochani, Shtip and Vinica, and there are smaller areas around towns Veles and Probishtip. The average return in Macedonia is about 4300 kg/ha. Mean annual values of lead content in the leaf and fruit of *Oryza sativa L.* are lowest at the control measuring point Blatec (3.83 mg/kg in the leaf and 0.83 mg/kg in the fruit), where rice crops are irrigated with the water from the river Osojnica whose lead content in water is 0.02 mg/l and is on the borderline for MAC for I and II category of water, while the lead content in soil is 36.70 mg/kg and is below the borderline for MAC for lead in soil (up to100 mg/kg).

At the other three measuring points where rice crops are irrigated with water from the rivers Bregalnica and Zletovica and the hydroelectric power station “Bregalnica”, mean annual values of lead content vary from 0.08 to 0.14 mg/l while these values are considerably higher than MAC for II and IV category of water (up to 0.03 mg/l, while mean annual values of lead content in soil are between 182.96-408.48 mg/kg dry mass and are considerably higher than MAC for lead in soil.

Table 4: Average annual values of lead content in the waters (mg/l), soil, leaf and fruit (mg/kg) of the *Oryza sativa L* of the river Bregalnica with its tributaries

	Pb							
	2007				2008			
	water	soil	leaf	fruit	water	soil	leaf	fruit
R. Osojnica	0.02	42.70	2.53	0.83	0.01	42.33	4.96	0.92
R. zletovica	0.22	194.56	14.33	3.80	0.23	193.42	16.14	3.78
R. Bregalnica	0.23	378.68	19.29	3.42	0.12	501.29	20. 44	4.65
HS. Bregalnica	0.08	401.54	19.23	3.50	0.07	403.32	21.65	5.26

Table 4 shows mean annual values of the lead content in water, soil, leaf and rice grain measured in the course of the years 2007 and 2008. Compared with the research in the years 1999 and 2000 the obtained values are slightly higher.

As a result of the statistical data processing we got the correlation coefficient which is 0.75 for the lead content in water and rice leaf, and 0.71 in fruit. It shows a strong dependence of lead content in leaf and fruit of *Oryza sativa L.* on the lead content in water it was irrigated with.

Heavy metals in vegetables

Next to oxygen, water is the most important substance for human existence and it is essential for everything on our planet to grow and prosper. Freshwater rivers, lakes and ground water are used to irrigate crops, to provide drinking water and to act as a sanitation system. Although we as humans recognize this fact, we disregard it by polluting our rivers, lakes, and oceans. Most of our water resources are gradually becoming contaminated due to the addition of foreign materials from the surroundings. These include organic matter of plant and animal origin, land surface washing and industrial and sewage effluents. Rapid urbanization and industrialization with improper environmental planning often lead to discharge of industrial and sewage effluents into rivers. In addition to the process of desertification, pollution is also reducing the volume of safe fishing, irrigation and drinking water.

The problem of water pollution due to toxic metals has begun to cause concern now in most metropolitan cities. The toxic heavy metals entering the ecosystem may lead to geoaccumulation, bioaccumulation and biomagnifications. Heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders [3]. Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in biosystems through contaminated water, soil and air.

Therefore, a better understanding of heavy metal sources, their accumulation in the soil and the effect of their presence in water, soil and on plant systems seem to be particularly important issues of present day research on risk assessment. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these are taken up by the roots or foliage. The results of the lead content in vegetable crops that are raised in the river basin of Bregalnica show some differences in relation to the measuring sites. The lowest values were measured at the control measuring point Blatec, in the nearest vicinity of the town Vinica where the water of the river Osojnica (left tributary of the river Bregalnica) are used to irrigate vegetable crops. The relatively low lead content in water (lower than MAC for I and II category of water), and the low level of lead content in soil where vegetable crops are raised, are the reasons for getting low values in the range of 4.15 mg/kg in *Allium sativum*, to 6.81 mg/kg in *Solanum lycopersocum.* At the other measuring points the same values were 3 to 15 times higher when compared to the control measuring point, where relatively high values of lead content in water and soil were measured.

Table 5: Average annual values of lead content in the *Lactuca sativa*,

***Allium sativum, Capsicum annuum and Solanum lycopersicum* (mg/kg)**

	Pb							
	1999				2000			
	lettuce	garlic	pepper	tomato	lettuce	garlic	pepper	tomato
M.Kamenica	90.29	112.19	69.41	99.46	90.53	107.05	74.35	114.03
Ularci	61.54	61.72	14.71	23.84	66.07	71.40	18.49	24.21
Istibanja	55.34	62.14	15.51	19.31	55.66	62.32	1749	19.90
Blatec	5.99	4.77	4.98	6.81	5.89	5.23	5.92	8.34

Most of the laboratory research on bio-sorption of heavy metals indicates that no single mechanism is responsible for metal uptake. In general, two mechanisms are known to occur, viz., 'adsorption', which refers to binding of materials onto the surface and 'absorption', which implies penetration of metals into the inner matrix, Michio, X, 2005. Either one of these or both the mechanisms might take place in the transportation of metals into the plant body. Vegetables take up metals by absorbing them from contaminated soils, as well as from deposits on different parts of the vegetables exposed to the air from polluted environments, Ejaz Ul Islam, Xiao-e Yang and Zhen-li He, 2007.

Difference in metal concentration in vegetables seems to imply that different types of vegetables have different abilities to accumulate the metals. In spite of the mechanism involved in the element uptake by root, plants are known to respond to the amounts of readily mobile type of metals in soil. The order of toxic heavy metal contaminations in vegetables are vary with toxic metals. Different vegetable species accumulate different metals depending on environmental conditions, metal species and plant available forms of heavy metals, Lokeshwari, H., and Chandrappa, G.T, 2006.

The statistical data processing by means using the STATGRAPHICS program for determining the correlation coefficient shows a moderately strong dependence of variables. The correlation coefficient between the lead content in water and in *Lactuca sativa* is 0.82, for *Allium sativum* r = 0.79, for *Capsicum annum* r = 0.84 and for *Solanum lycopesrsicum* r = 0.82.

By means of Kruskal-Wallis test (statistical data processing) of the differences between the medians, when the zero hypothesis is "that there is no statistically significant difference between the values of medians", for the four measuring points we get the p value amounting to p = 0.0001 for lead content in soil, p = 0.00043 in water, and p = 0.0003 in rice leaf. As $p<0.05$ there is a statistically significant difference among the mean values at the four measuring points, at 95% level of trust. The exception to this is the lead content in the fruit where the p value we got by means of statistical data processing is 0.442 and is greater than 0.05, and there is no statistically significant difference at 95% level of trust.

Table 6: Average annual values of lead content in the *Lactuca sativa, Allium sativum, Capsicum annuum and Solanum lycopersicum* (mg/kg) dry weight

	Pb							
	2007				2008			
	lettuce	garlic	pepper	tomato	lettuce	garlic	pepper	tomato
M.Kamenica	94.23	114.69	72.21	99.89	93.23	110.15	79.95	114.03
Ularci	63.64	65.22	16.31	25.44	69.17	73.30	19.56	24.21
Istibanja	59.64	69.04	17.81	21.51	57.31	64.12	19.03	20. 42
Blatec	3.59	4.97	5.13	7.34	5. 91	4.89	4.23	5.12

Table 6 shows mean annual values of the lead content in *Lactuca sativa Alium sativum, Capsicum annum* and *Solanum lycopersicum* (mg/kg) dry weight. Compared with the results from 1999 and 2000 there is an increase in the lead content in vegetables at the measuring points M. Kamenica, Ularci and Istibanja, while at the measuring point Blatec these values show a decrease in the lead content.

CONCLUSIONS AND RECOMMENDATIONS

From the study it is revealed that, untreated sewage and industrial effluents are the main source of pollution to Bregalnica water body and irrigation with contaminated river water containing variable amounts of heavy metals leads to increase in concentration of metals in soil and vegetables, which is grown using the polluted water. Concentration of metals in vegetables will provide baseline data and there is a need for intensive sampling for quantification of results throughout the country. Since cabbage is the least accumulator of metals and metalloids, it may be less risky to eat cabbage than eating lettuce or Swiss chard, from health standpoint.

To avoid entrance of metals into the food chain, municipal or industrial waste should not be drained into rivers without prior treatment. Apart from treating the discharge that enters into the rivers, it is also imperative to utilize alternative measures of cleaning up the already contaminated substrates. Continuous monitoring of soil, plant and water quality together with prevention of metals entering vegetables is a prerequisite in order to prevent potential health hazards to human beings.

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