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Environment and Life Quality by the Example of Surface Water in the Area of HPS-2 Influence (Almaty)

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Abstract - **The article deals with some data on water sample analysis for ten heavy metal content of surface water in the area of the heat power station-2 (HPS-2) influence in Almaty. The samples have been taken from three points: the Kukuzek reservoir, the reservoir for ash accumulation, the pipe of flood gate. The analyses have been conducted using standard techniques: an atomic absorption spectrometer, a spectrophotometer, histological and cytological visual analysis of painted preparations. Water pollution by aluminum (Al) in all the studied objects, and heavy metals such as cadmium (Cd) and manganese (Mn) at two sites has been found. The reservoir visited by people demonstrates the increased biological oxygen demand (BOD_5), because of organic pollution. Three kinds of fish caught in its possess histological abnormalities in gills and a liver, that testifies to potential danger produced by heat power station water usage for the population. The pollution reduction level can be achieved by minimizing the discharge into the storage area and HPS-2 ash accumulation as well as introducing modern plasma-fuel technology on it.**

Keywords – **Biological Oxygen Demand (BOD), Heat Power Station (HPS), Heavy Metals, Maximum Acceptable Concentration (MAC), Plasma-Fuel System (PFS).**

I. INTRODUCTION

Heat power is considered to be a leading industry of a modern industrialized economy. The main trend in the energy power development is center heating system power of towns, agriculture. The development of a central heating is carried out by various HPS heat productivity constructions [1].

Almaty is the largest city in the Republic of Kazakhstan taking into account its population, located in Central Asia that occupies the ninth place in the world by its territory. In 1960-70s of the last century there was a rapid growth of house building based on industry basis that demanded the introduction of central heating system in Almaty. For this purpose powerful HPS-1 and HPS-2 were built, where consumers (population, community agencies, industry) used a hot water from thermal networks according the open circuit abstraction.

The Almaty HPS-2 construction was initiated in 1974, and today it is the largest power station of the city, which produces both heat and electrical power simultaneously and provides the city with hot water. The main fuel in HPS-2 is Ekibastuz coal that is consumed by more than 400 thousand tons and 40 thousand tons of fuel oil a month. HPS-2 JSC "AlES" has a special shooting-range site for holding waste storage. Some collecting dust structures wastewater, a new generation of emulsifiers have been installed recently, that made it possible to reduce emissions. However, the influence of heat and power facilities on ecological environment of the city, in the area of HPS-2, in particular, is still high [2].

One of the most urgent problems of Almaty is the environmental pollution from industrial wastes and hazardous substances coming from heat power tubes.

The wastes containing both inorganic and organic substances go down the rivers and reservoirs. One of the strongest and the most widespread chemical pollutions is contamination by heavy metals. Hundreds of these substances are new compounds which are becoming a source of secondary pollution. Moreover, in closed basins, such as a reservoir, heavy metals concentration can reach a high level that may be dangerous for life.

The area of research is HPS-2 in Almaty. Water bodies associated with the activities of the central heating system have been studied. The ash formed by burning of coal, and the water falls into the reservoir for ash accumulation through the pipes (Fig. 1a). In addition, on the territory of HPS-2 there were additional pipes of flood gates (Fig. 1b) that do not flow into the lagoons. The water from the pipe flows into the flood gates of the Kukuzek reservoir (Fig. 2). The water samples have been taken from three points: 1) the Kukuzek reservoir (~ 100 m from the storage HPS-2); 2) the reservoir for ash accumulation; 3) the pipe of flood gates.

(a)

(b)

Fig.1. Ashes dumps of HPS-2: a) the reservoir for ash accumulation ; b) the pipe of flood gates

Fig.2. The Kukuzek reservoir

II. METHODS AND MATERIALS

The water samples have been analyzed using a standard technique [3]-[4]. To assess their quality concentrations of heavy metals by means of atomic absorption spectrometry have been measured according to standard procedures [5]. The presence of additional physical, chemical and biological indicators have been also determined in the present research work. Water intake was held from 10 to 11 a.m. when the weather was clear and windless [6]-[7].

Water conductivity has been measured by conductivity meter Cond 3110 SET2. To determine its acidity we used pH meter pH 3210 3 TW-Set of the WTW GmbH form with the pH of range 2.00 to 19.99. Biological Oxygen Demand during 5 days has been determined by means of a device OXI TOP IS12.

For microscopic study of gills and a liver nine fish have been caught (three individuals which represent three species). Histology of fish tissue has been carried out according to standard procedures. Statistical processing has been performed by means of Student's test.

The content of acidic residues, phosphorus, phenols, ammonium ions and cationic surfactants has been measured by spectrophotometry Spectroquant SpectroPharo 100 from Merck with in the Range of 320-1100 nm wavelength, a set of standards). Heavy metals have been measured by atomic absorption spectrometer MGA -915 MD.

III. RESULTS OF RESEARCH AND THEIR DISCUSSION

Measurements of acidity (Table 1) water samples showed that the pH of water from the reservoir for ash accumulation is 7,8, the pipe of flood gates is 8,6 and the water taken from the Kukuzek reservoir pH is 9,3. The normative acidity level is exceeded by the pH in the water from the Kukuzek reservoir.

Electrical conductivity (Table 1) in all the sampling points lies within the norm: the Kukuzek reservoir is 335 µS/sm; the reservoir for ash accumulation is 166,5 µS/sm; a pipe is 253 µS/sm. However, reliable significant electrical conductivity exceeding has been marked twice compared to the reservoir for accumulation. It is likely connected with the fact that HPS-2 changes them when filling in reservoir for accumulation (two reservoirs), while water from the reservoir for accumulation is constantly throw down in the Kukuzek reservoir.

The level of dissolved oxygen (Table 1) in the water taken from Kukuzek is 4,115 mg/dm^3, which is the norm and its concentration is 1,4 times more that exceeds the same index in reservoir of ash. It is connected with plant organisms inhabiting there. Mentioned should be noted that algae have not been observed in the reservoir for ash accumulation by us. In other sources of dissolved oxygen concentration was considerably below its norm. For example, in water of ash dissolved oxygen was 3,98 mg/dm^3, while the water from the pipe was 3.34 mg/dm^3.

BOD is one of the most important criteria for the level of water pollution by organic substances: it determines the amount of easily oxidizable organic contaminants in water (Table 1). When examining water samples it has been revealed that the BOD exceeds the norm of 3 times in the Kukuzek reservoir that testifies about a moderate contamination.

When studying the water from the drain-pine, concentration of phosphor and phenol has been measured. It was recorded that phosphor MAC exceeded 4000 times (0,4±0,04 mg/l) as well as phenol concentration also exceeded 2300 times that testifies to a biogenic water pollution and water concentration fuel combustion area.

Table 1: Hydrological indices of water from the reservoir for ash accumulation, the pipe of flood gates, the Kukuzek reservoir, M±m

Indices	Units	Level			Normative level [8]
		Reservoir for ash accumulation	Pipe of flood gates	Kukuzek reservoir	
pH	-	7,8±0,3	8,6±0,4	9,3±0,7	6-9
Electrical conductivity	µS/sm	166±11	253±14	335±23**	30-1500
Dissolved oxygen	mg/dm^3	2,98±0,19	3,3±0,2	4,1±0,3*	Min 4 mg/dm^3 in any period of the year, in a sample collected up to 12 am
BOD$_5$	mg O_2/dm^3	0±0	3,6±0,9	12,0±1,0	should not exceed at 20 °C 6,0 mg O_2/dm^3
* - Represents the statistical difference from settler water samples (Student's test)					

The content of ten metals has been determined in the samples of the area under discussion: Al, Mn, Fe, Co, Ni, Cu, Zn, Pb, Cd, Sr which refer to the 2 and 3 hazard class. For example, in the water reservoir for ash accumulation the exceeding of normative standards of aluminum is 9.3 times, cadmium is 7 times and manganese is 6.5 times accordingly. The concentration of metals in the samples of water of ash (Table 2) showed that there is no excess ratio for the iron, cobalt, copper, nickel, lead, strontium and zinc.

Sanitary standards of aluminum, cadmium and manganese are exceeded in water samples from the pipe (Table 2). Aluminum concentration reached 5.372 mg/l which exceeds the standard of about 11 times. Cadmium was at 0.004 mg/l, exceeding the statutory rate 4 times. Manganese exceeded its standard (1.48 mg/l).

The content of heavy metals in water samples from the Kukuzek reservoir (Table 2): the excess of normalized parameters for iron, cadmium, cobalt, manganese, copper, nickel, lead, strontium and zinc hasn't been observed. However, there was the excess of MAC aluminum 2.8 times.

So we carried out the microscopic study of gills as an organ which keeps in touch with environment and a liver as the most important organ of detoxification of the following fish species that refer to various families: *Carassius carassius* L. (*Cyprinidae*), *Gymnocephalus cernuus* L. (*Percidae*), *Pelecus cultratus* L. (*Cyprinidae*) – and those that are inhabited in the Kukuzek reservoir.

Microscopic description of ordinary ruff gills (*Gymnocephalus cernuus* L.) showed (Fig.3) that most of respiratory cells are small young cells are characterized by basophilic cytoplasm. It can be observed a hyper cellularity of multilayer primary filament gill epithelium, among which there are clearly traced mucous cells – large and rounded with a displaced basal membrane core. Lobular hyperplasia of the gill epithelium in primary interlamellar areas leads to coalescing lamellae.

Lamella is based on a vascular layer of columnar cells. The outer layer of a vascular bed is covered by two layers of flattened respiratory cells, between which mucosal cells have been observed, which are characterized by widening the intercellular space between the outer and inner layers. The majority of cells are in the state of necrobiosis and desquamation. Ciliates *Costia necatrix* (Henneguy, 1883) have been found in gills.

In the gill tissue of *Carassius carassius* L. (*Cyprinidae*) there is hypercellularity multilayer primary filament gill epithelium, mainly due to nuclear polymorphnuclear cells, among which mucous cells large, round with a displaced nucleus basal membrane can be observed (Fig. 4). In this case, the primary gill epithelium hyperplasia in the interlamellar areas is accompanied by a lamellae fusion. Lamella is based on a vascular layer of columnar cells, which is characterized by widening of intercellular space between outer and inner layers. A significant portion of cells is in the state of necrobiosis and desquamation. Swelling can be observed. There are gill filaments, combined into solid polymorphcellular conglomerate with lysis cartilage phenomena.

Depletion of cellular composition of a multilayer primary gill epithelium (there are up to 3-4 cell layers) in *Pelecus cultratus* L. (Fig. 5-6). In the outer layer large mucous cells can be found. In lamellae there is an expansion of intercellular area their detachment from the basal layer can be observed. Individual respiratory cells are under the condition of necrobiosis. There is mucousity of a secondary gill epithelium and desquamation of respiratory cells.

Table 2: Metal concentrations in water from the reservoir for ash accumulation, the pipe of flood gates, the Kukuzek reservoir, M±m

Element	Concentration, M±m, mg/l, $\cdot 10^{-3}$			MAC, mg/l, $\cdot 10^{-3}$ [8]	Hazard class
	Settler	Flood gates	Kukuzek		
Aluminum	4648±314	5372±429,7	1400±112***	500	2
Iron	4±0,18	30±2,1	7±0,35**	300	3
Cadmium	7±0,35	4±0,32	0,2±0,01***	1	2
Cobalt	10±0,7	20±1,4	5±0,35**	100	2
Manganese	650±32,2	1480±118,4	16±1,12***	100	3
Copper	15±1,05	20±1,6	9±0,72**	1000	3
Nickel	1,9±0,095	10±0,7	2±0,14	100	3
Lead	20±1,4	10±0,72	4±0,26***	30	2
Strontium	500±39,4	180±9	500±36,5	7000	2
Zinc	5±0,35	2±0,16	0,5±0,37***	5000	3
* - Represents the statistical difference from settler water samples (Student's test)					

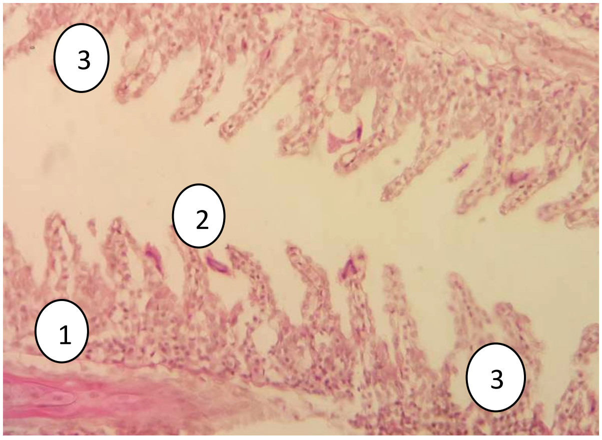

Fig.3. Histostructure of ordinary ruff gills (*Gymnocephalus cernuus* L.)
Increase: ×200; colour: hematoxylin-eosin
1 – The hypercellularity of multilayer primary filament gill epithelium; 2 – parasites *Costia necatrix*; 3 – widening the intercellular area

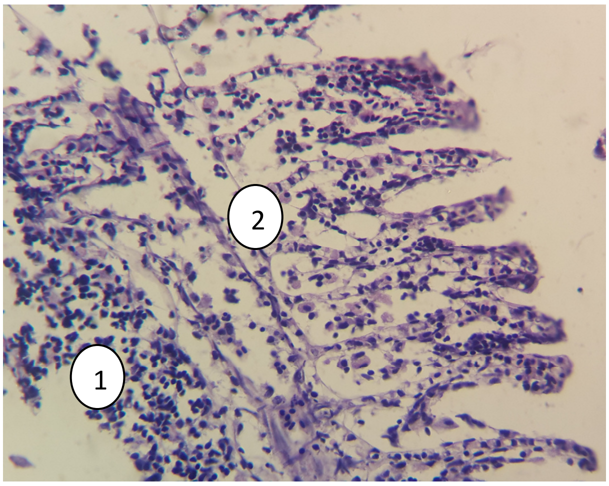

Fig.4. Histostructure of gills *Carassius carassius* L.
Increase: × 200; colour: hematoxylin-eosin
1 – The hypercellularity of multilayer primary filament gill epithelium; 2 – widening of intercellular space

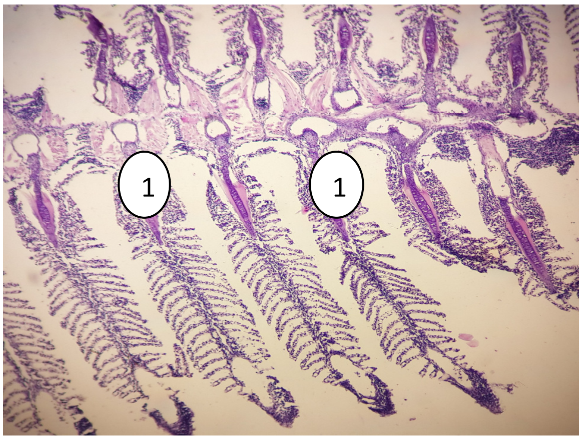

Fig.5. Histostructure of gills *Pelecus cultratus* L.
Increase: ×100; colour: hematoxylin-eosin
1 - depletion of the cellular composition of the multilayer primary gill epithelium

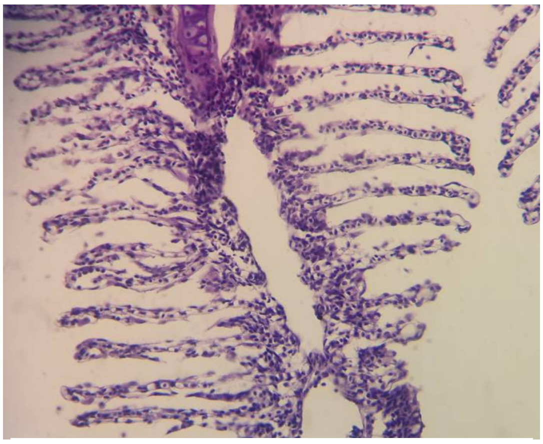

Fig.6. Histostructure of gills *Pelecus cultratus* L.
Increase: ×200; colour: hematoxylin-eosin

In the liver of ordinary ruff (*Gymnocephalus cernuus* L.) hyperemia and expansion of the sinusoids have been marked (Fig. 7). Hepatocytes with a centrally located large nucleus have been observed, too. In individual cells vacuoles can be found, located mainly in a perinuclear area. Also there are hepatocytes containing brown granules.

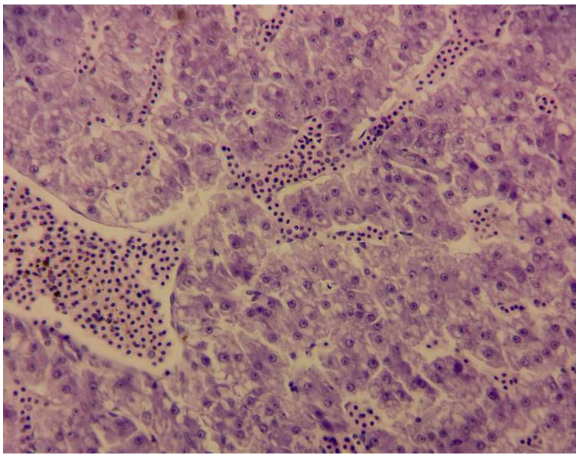

Fig.7. Histostructure of ordinary ruff liver (*Gymnocephalus cernuus* L.)
Increase: ×200; colour: hematoxylin-eosin

In the liver cells of *Carassius carassius* L. there is a pronounced polymorphcellular infiltration (Fig. 8). Hepatocytes with centrally located nucleus are loaded with vacuoles, located in the perinuclear zone. The individual pellets comprise brown hepatocytes. Sinusoids are widened and full-blooded. Stroma is swollen. There is edema around the ducts of the pancreas and diffuse activation of Kupffer cells. Vessel walls are thickened, perivascular edema can be observed.

When studying hepatocytes *Pelecus cultratus* L. (*Cyprinidae*) on microscope they look "delicate" (Fig. 9). All hepatocytes can be divided into two types, the first one has a large, nucleus located in the centre, the other one has nuclei displaced to the periphery. At a high magnificying a microscope there are in large devastated vacuoles in a cytoplasm of hepatocytes. Sinusoids are diffusely enlarged and full-blooded. There is a stromal edema and activation of Kupffer cells.

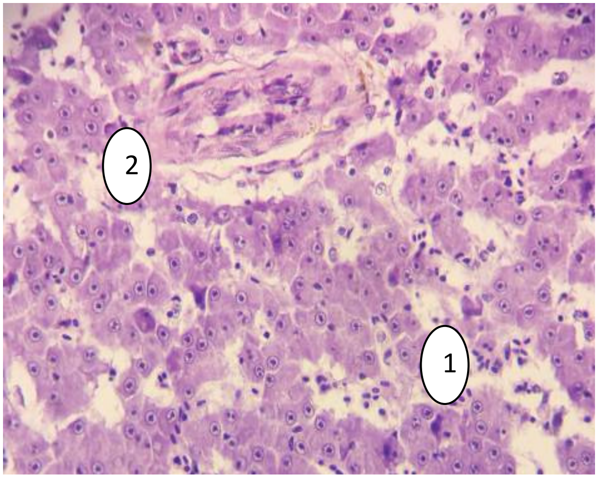

Fig.8. Histostructure of livers *Carassius carassius* L. Increase: ×200; colour: hematoxylin-eosin
1 – Sinusoids dilated and activation of Kupffer cells; 2 - blood vessel

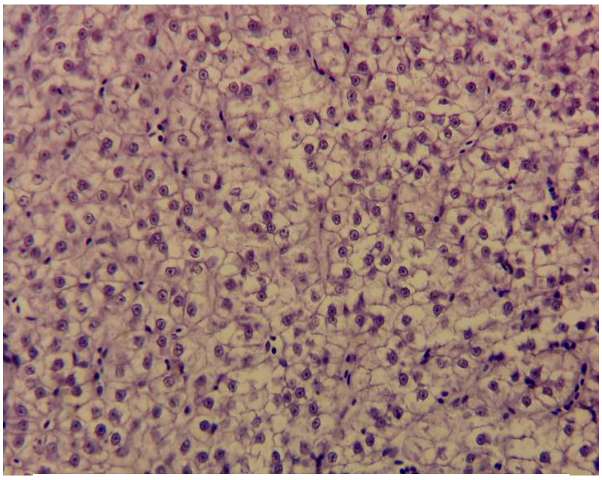

Fig.9. Histostructure of livers *Pelecus cultratus* L. Increase: ×200; colour: hematoxylin-eosin

Based on the data obtained we can give a preliminary assessment of the territory quality of Almaty, subjected to the influence of heat power station-2.

The increasing of the BOD in the reservoir and reducing the oxygen concentration may be a characteristic of eutrophication, accompanied by an active growth of blue-green algae and cyanobacteria that synthesize a large amount of biologically active compounds. Thus, cyanobacteria microcysts produce microcystins representing the class of powerful cyclic heptapeptide toxins that contribute to the development of cirrhosis. Genotoxicity of microcystin and protease inhibitor - aeruginosin microcystins inhibiting the growth of roots, cause chromosomal aberrations, violations of mitotic division and increasing the number of micronuclei has been proved. Strain of cyanobacteria containing aeruginosin exhibits genotoxic effect by altering the cell cycle, while microcystins have a greater mutagenic effect [9].

The surface water, generated by drainage and ash dumps of HPS-2 is contaminated with aluminum, cadmium and manganese. The above mentioned objects: the reservoir for ash accumulation and the pipe of flood gates - reach the Kukuzek reservoir and a high content of aluminum has been observed in it, as the content of this element is reduced by about 3 times when transiting from the reservoir for ash accumulation and the pipe of flood gates towards water reservoirs. The two other pollutants - cadmium and manganese – can be found in the reservoir, their concentrations must not exceed MAC, i.e. when moving the water from reservoir for ash accumulation and the pipe of flood gates there is sewage treatment from these elements.

It appears that the reduction of metal concentration is due to the presence of living organisms in the Kukuzek water that can accumulate them. The experimental studies show that the greatest concentration of aluminum in *Cirrhinus mrigala* is noted in muscle tissue, the second place is occupied by the gills, and finally kidneys, brain and liver [10].

Cd accumulation in immature Japanese flounder depends on a dose and has a specific tissue. The greatest accumulation is in the liver, the kidney, muscle and gills. Here, gills and liver occur to the organs with a high antioxidant activity, but under cadmium impact on the reduction of glutathione, glutathione-S-transferrin, glutathione peroxidase has been marked. Thus, endogenous antioxidants are not capable to prevent the induction of lipid peroxidation, which leads to the morphfunctional disorders in these organs [11].

The toxicological effects of manganese are developed when metal concentration of 4.2 mg/day (body weight 70 kg) penetrates daily, but the body has mechanisms of protection from the toxicity of manganese, firstly because of its low absorbency. Besides, liver detoxification occurs by antioxidant protection and blood arginase [12]. On the other hand, the presence of manganese cause for concern in the neighborhood of HPS-2, since its presence in the air reduces the body's resistance to respiratory infections. Water-soluble compounds (MnO), when adsorbed on solid particles (e.g., ash), can penetrate into the alveoli [13].

All the studied species of fish inhabiting in the Kukuzek reservoir, there are morphological changes in the gill tissue which can be seen in hyperplasia of the primary and secondary gill epithelium, reducing the space between the lamellae, the expansion of intercellular space, cells under conditions of necrobiosis and desquamation that reduces the efficiency of gas exchange [14].

The histopathological pattern of fish liver (hepatocyte vacuolation perinuclear zone, Kupffer cells activation, edema of stroma and pancreatic ducts), is probably due to the complex of factors, including hydro-chemical and heavy metals [15].

The study reveals a synergistic effect of heavy metals [16]. It was established that the liver of juvenile rainbow trout (*Oncorhynchus mykiss*) can accumulate 67-83% of metabolically active Cd, 68-79% Cu and 60-76% Zn when introducing in feed rations containing 500 mcg/g of Cu, 1000 mcg/g Zn and 500 g/g Cd during 28 days. Cd content increases when introducing Cu, while Zn increases the accumulation of Cu. Intracellular accumulation of Zn is less expressed compared to the level of Cu or Cd accumulation, but concentration of Zn in enzymes, nucleus and organelles of the combined use of all three metals increased.

In response to the toxic effects of cadmium the organism reacts by compensatory-adaptive manifestations, primarily by physiological reactions, such as mucousity of gill tissue, the increase of lysozyme and cortisol in the blood, but the level of accumulation of Cd and metallothionein (MT) in different periods of metal exposure (5 days and 15 days) are statistically different [17].

Conclusions: The system of wastewater HPS-2 Almaty includes two reservoirs for ash accumulation, pipes of flood gates and the Kukuzek reservoir. The comparison of three water samples of the above mentioned objects (the reservoir for ash accumulation, the pipe and the Kukuzek reservoir) showed that physic-chemical parameters such as acidity, conductivity, dissolved oxygen and BOD$_5$ are within the normalized values for open water sources. At the same time electrical conductivity in the Kukuzek reservoir increased, due to the presence of a great number of metal salts. Thus, the aluminum content exceeded the normalized value 2.8 times while the concentration of other metals was within normal limits. However, compared to the storage reservoir aluminum content - 3.3 times, cadmium - 35 times, cobalt - 2 times, manganese - 41 times, copper - 1.2 times, lead - 51 times and zinc - 10 times decreased, but there is significant increase of iron in 1.8 times.

In the HPS-2 reservoir for ash accumulation there are considerable changes in water quality according to hydrological and chemical parameters. There is a dissolved oxygen and BOD$_5$ reduction, aluminum, cadmium and manganese concentration increases compared to standard values. Approximately similar changes are observed in water of flood gates (dumping site of the settler in the reservoir). In the Kukuzek reservoir there is exceeding of standard indicators of acidity, BOD$_5$ and aluminum. However, there is a significant decrease on investigated chemical elements, compared to the reservoir for ash accumulation. This is probably due to the level of their accumulation in living organisms that testifies to morphological changes in the liver and gills of fish living in the Kukuzek reservoir.

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