About possibility the impact of exploitation of small hydropower plants on the degree of pollution of river water by heavy metals

Sukiasyan Astghik[1†], Baghdasaryan Marinka[2], Mayilyan Anton[2]

[1]Faculty of Chemical technology and Environmental engineering,

National Polytechnic University of Armenia, 105 Teryan Str., 0009 Yerevan, Armenia,

e-mail: sukiasyan.astghik@gmail.com

[2]Faculty of Electrical Engineering, National Polytechnic University of Armenia,

105 Teryan Str., 0009 Yerevan, Armenia,

ABSTRACT

The territory of Armenia is characterized by the domination of dry lands and many mountain rivers. To obtain and investigate the expensive and ecologically clean hydropower, a cascade of mountain rivers is used. Investigations have shown the difference in the chemical composition of the river water according to the content of heavy metals (HMs) in the upper and lower sections of the river. In that context, a quantitative determination of ions of some HM in a plant-indicator has been developed, allowing determining the spreading zones of the elements off the river bank. The concentration of the given HMs obviously decreases when moving far from the river bank. The analysis and comparison of these results show that the soil pollution has a protracted character.

Keywords: Small hydroelectric power station, Mountain river, Ecosystem, Heavy metals, Plant-indicator, River bank.

1. INTRODUCTION

The development of hydropower often leads to considerable changes in the management of natural regimes of water problems for the majority of rivers. It is well-known that hydropower plants strongly destroy the dynamic development of the ecosystem along the river flow [1]. At the same time, the change in the water quality [2, 3], sediment and flow at constructing dams has been mentioned [4].

The presence of a hydropower plant cascade introduces spatial and cumulative effects against the natural process of ecological recovery, however it leads to more damage in the ecological characteristics [5], and it can lead to the succession of the whole damage of the ecosystem.

At present, it is not possible to completely abandon the use of the river flow for power purposes, especially in a geographic region where rough mountain rivers dominate. Armenia is distinguished by a network of mountain rivers. The necessity of using alternative power sources is of a social and industrial interest. This facilitates the rapid development of small hydropower plants (HPP) constructed on the mountain rivers. The HPPs allow to produce low-cost electricity of water flows by using hydraulic turbines, generators and transformers, and deliver it to the by high-voltage wires. Such a power source is completely renewable. Despite the high cost of constructing such power plants, they fully compensate the expenses for a short period of time. It is particularly important to use the energy of water masses in the channel streams and the tidal movements as a power source.

That is why, hydropower plants are usually built on the rivers by erecting dams and reservoirs. For the efficient production of electricity at hydropower plants in Armenia, the factor of having a rather wide network structure of mountain rivers with great slopes plays an important. They are built immediately on the water source or near it, using the flow of water as an energy source [6]. The production efficiency of HPPs depends on the uninterrupted water supply throughout the year, the slope of the river, as well as the type of the relief.

The energy of small rivers has rather an important role in the reserves and scales of application. The reason for this is the high energy density of the water flow and the relative temporal stability of the flow regime of most rivers [7].

But the impact of small HPPs on the environment is unavoidable. Among the factors, contributing to the environmentally irreversible processes should particularly be mentioned the influence of small HPPs on the geochemical changes in the environment.

The quality and quantity of the water consumed changes for the worse. The surface water is used by people both globally for the irrigation of agricultural crops and for everyday needs [8]. Therefore the issue on building water facilities on the mountain rivers is very urgent and perspective now. In fact, technically, the contaminated water comes to the general consumer – the human, along a chain. The whole volume of the public consumption of water in small HPPs leads to restriction in the surface water in the national economy.

Maintenance of small HPP is accompanied not only by a change in the chemical composition of surface waters, but also violates the volume and direction of the rivers. It is shown that the construction of a hydropower plant changes the direction of the river, leading to a break in the natural dynamic balance [9]. It is obvious that hydrochemical factors play a decisive role in the proper formation of the overall environmental situation at developing hydroenergetics. A special attention should be paid to the quality of the used constituents and parts of the HPPs. They can significantly change the chemical composition of the water used, too [10].

It is well-known that the rivers in different regions have their own key elements due to their special background conditions. In the present work, the problem of estimating the possibility of ecological consequences, leading to the destruction of the river ecosystem and the change of typical ecological characteristics is investigated. Our goal has been to investigate the changes in the chemical composition of the river water caused by the operation of hydropower plants. That is why, in our investigations, the rate of some heavy metals (HM), existing to the river water in the river bank soil with their further accumulation in the plants-indicators has been assessed.

2. MATERIAL AND METHODS

2.1. The geographic description of location of the River Voghji

As an object for monitoring, the River near the town of Kapan, Armenia has been selected (Fig.1). The River Voghji is the left tributary of the River Araks. The river length on the territory of Armenia is 48km and the water catchment area – 933km^2, with 0.038% of average inclination and 2200m of average catchment area elevation.

Fugure 1. The location of the River Voghji with points in which the sampling of water (points 1, 2, 3, 4), and the study of migration of heavy metals by bank of the river (point 3) have taken place.

The River Voghji is a mountain river with typical seasonal water regime, depending on the spring snow melting and rain floods. The latter change was very slowly due to the prolonged melting of the snow and glaciers in Meghri and Zangezur, lasting from April to July. The soil cover is diverse, but it mainly consists of dark brown soils. The forest covers 18% of the River Voghji basin [11].

2.2. Sampling and database collection

As an indicator plant - *Urtica Dioica L.*, growing on the banks of the river and further into the depths along the normal has been used. The length of the ground is 300 m, the width of the section (normal to the waterfront) - 30 m. The gathering point of the nettle leaves were gridded $(5 \pm 0{,}5)$ X (50 ± 1) m oriented along the bank of the river. At a distance ≥ 500 m from the bank, additional 5 points of the gathering Urtica Dioica to determine the "background concentrations" of heavy metals in the leaves of the plant were randomly selected. The gathering of the plant was carried out in May before the blossoming period.

2.3. Determination of the HM concentration

Environmental monitoring of the river water condition by some heavy metals was carried out. The choice of these HMs was dictated by their participation in the process of adaptation of plants at the anthropogenic stress. [12]. HMs were measured by the atomic absorption flame spectroscopy. The concentration of ions of molybdenum, manganese, nickel and cobalt in the solution was determined on the AAS "Analyst - 800", and then calculated on the dry material. [13].

2.4. Statistical analysis

For all the biochemical measurements, a Student t-criteria: a minimum of all measured values for this removal (f = 4; P = 0.95); "background" values (when the number of degrees of freedom f = 13 and the probability level P = 0.95) have been determined. The data are presented as means of four biological replicates ± standard error (SE). The effects were considered significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

To understand the mechanism of possible changes in the composition of the river water caused by the work of a number of small HPPs on the River Voghji, it is necessary to choose the place for biological estimation of the cumulative capacity of the plant. The river water is used to a full extent for various needs of the town. That is why, the chemical condition of the water after using small HPPs was assessed before entering the town of Kapan. Our goal was to evaluate the water before it was used for different purposes.

According to the obtained results, we can assume that the operation of the small HPPs has probably caused a change in the chemical composition of the water. This fact may be related to both the direct operation of the small HPPs and the wear of its constituent parts. That is why, first, the major physical and chemical parameters of water sampling in the period of 2008-2013 were analyzed. Based on a great number of samples, the concentration changes of some HMs were measured. These metals were nickel, cobalt, manganese, and molybdenum which take an active part in the metabolism of the plants and regulate the physiological processes of growth and adaptation [12]. According to the results shown in Fig.1, the tendency of the contents of these HMs is maintained for 6 years.

The first two points are almost at the water intake source of Voghji and here, there are a rather limited number of small HPPs. Therefore, the results of the total concentration of HMs are not very different in their values, with a slight increase in the value in the second point of water sampling. Further, along the river, small HPPs are located. The third point of water sampling is almost in a suburb of the town of Kapan. The possible migration of these HMs from the water into the soil and subsequently their accumulation in the plant was studied in this very place. The change in the chemical composition of the river water directly affects the physiological characteristics of the plant, growing directly near the rivers. The results of comparison of quantitative changes in the content of the investigated transition of metals in water and plants are presented in Table 1.

Table 1. The heavy metal content in the leaves of the plant based on the dry substance, depending on the distance along the normal from the bank

Name of metal	**Concentration of metal in water [μg/g] (**)**	**Concentration of metal in plant removing by normal from the bank [μg/g]**	
		30 m (*)	**500 m (**)**
Nickel	1.350 ± 0.068	0.136 ± 0,004	0.062 ± 0.001
Cobalt	0.442 ± 0.022	0.146 ± 0.003	0.044 ± 0.002
Manganese	19.156 ± 0.957	0.328 ± 0.006	0.107 ± 0.003
Molybdenum	12.149 ± 0.607	0.420 ± 0.010	0.116 ± 0.005

(*) - the minimum of all the measured values for this removal (f = 4; P = 0.95);

(**) - "background" values (when the number of degrees of freedom f = 13 and the probability level P = 0.95).

It is known that soil is a natural filter at migration of chemical elements through it. That is why, in order to monitor the chemical composition of water, the method of phyto-indication was used. Plants are sensitive to the content of HMs and react to their toxicity. The latter depends on the dose and type of the ion during the whole period of time. HMs, in the period of the plant growth, participates in various metabolic processes to form various complexes of a low molecular weight.

To estimate the accumulation of rate HMs by plants, of the plant material – namely Urtica Dioica was performed twice. At a distance from the bank, along the normal of 30 m, the HM concentrations of the test decreased by almost one orders, except for the case with cobalt. In this case, the decrease in the concentration of the chemical element was 33%. There were significant changes in the concentration of manganese and molybdenum.

Then we carried out selection of the plant at a distance of 500m from the bank line along the normal. In this case, the concentration of heavy metals decreased almost three times.

Further, along the river, the main small HPPs are located before the entering Kapan. It is here, that the change in the chemical composition of a small watercourse can be due to the increasing intensification of the anthropogenic influence [14, 15].

It especially increases the water amount of those rivers that flow near the settlements. So here, sampling of the river water was carried out. Our assumptions were confirmed. In point number four the highest concentration of all the HMs (Figure 2) can be found.

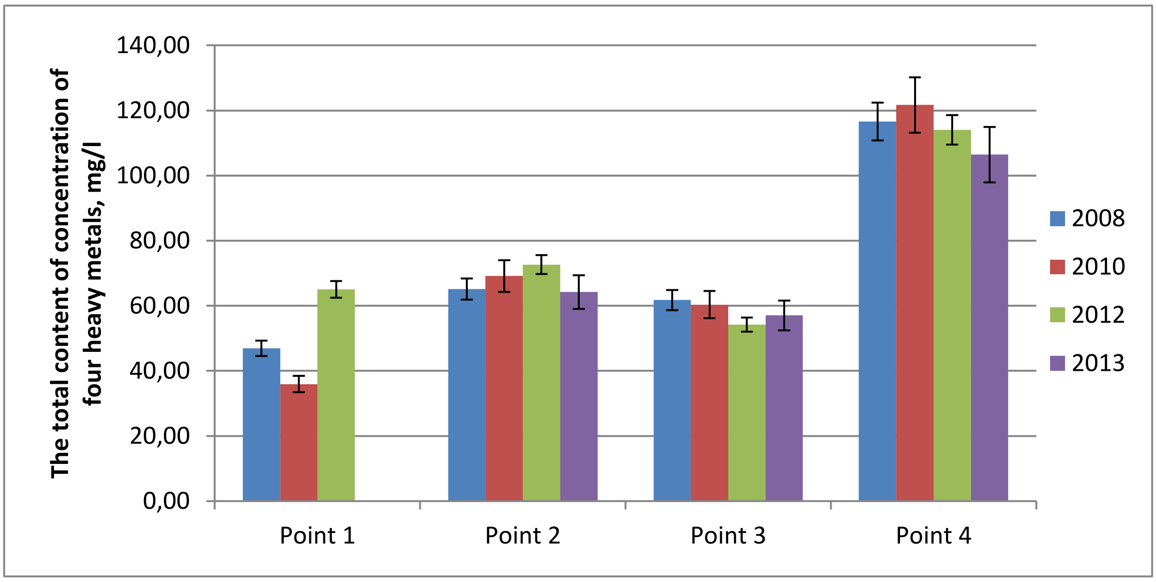

Figure 2. A change in the total content of some heavy metals (Ni, Co, Mn, Mo) in points where sampling of water in the period 2008-2013 was carried out.

4. CONCLUSION

The distance from the bank has been determined at which the changes in the concentration of HMs has been established. It is 500 meters from the bank where there is an obvious low concentration of HM content, allowing using the bank soils safely for various needs. By using a special plant-indicator, it is possible to limit the migration of HMs, using plants which absorb and accumulate the specific chemical elements. It immediately reduces the rate of migration of HMs and allows using the bank soil for the agricultural purposes during the operation of small HPPs.

5. CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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