DOI: http://doi.org/10.21698/simi.2017.0028

CONTROL OF INORGANIC AND ORGANIC CONTAMINATION, ASSESSMENT OF WATER QUALITY IN HYDROPOWER LAKES ON JIU RIVER

Victorita Radulescu

University Politehnica of Bucharest, Splaiul Independentei 313, Faculty of Energy, Sector 6, Bucharest, vradul4@gmail.com, Romania

Abstract

In the last decades near the hydropower lakes, have developed numerous private companies and settlements that constantly uses water from these lakes. In many cases, the spills are not controlled and are not decontaminated properly or even at all. In the Jiu hydrographic basin, there are 225 localities with a population of more than 2,000 peoples. Only 32 of them are equipped with sewer systems and only 2 of them in accordance with Directive 91/271/EEC. As consequence of the pollution with organic and inorganic substances (nutrients) has appeared the eutrophication of the lakes. From the total 12-hydropower lakes with a surface over 50 ha, eight of them are clogged in the proportion of 60%, and 3 of them in a proportion of 80%. In the first part of the paper are analyzed the main punctual and diffuse sources of organic and inorganic pollution, with a decisive factor in the development of the aquatic vegetation. During 2010-2016, a systematic campaign of measurements was done. They were determined the protection zones that need to be tracked, the catchments zone for the human consumption, the zones for protected fish or of those species economically important, the natural protected areas, and the zones vulnerable to nitrate and nitrites. The obtained results are presented for the most affected hydropower lakes from the selected area. Finally, are mentioned some possibilities and measures necessary to be followed as to reduce the inorganic and organic pollution, some conclusions, acknowledgement and references.

Keywords: *environmental engineering, hydroelectric power generation pollution, water*

Introduction

The central objective of the Water Framework Directive is to achieve the "good status" for all the water bodies, both for the surface and for the underground. To solve this problem must determine the types of pollution: with organic matter, the nutrients pollution, the pollution from priority substances/dangerous and the morphological alterations. The river Jiu, unlike other rivers, lacks major tributaries and the sediments are transported almost uniformly throughout its entire course.

The hydro-energetic structure of the river Jiu consists mainly of the hydropower plants: Valea de Pesti, Motru, Tismana, Vadeni, Tg-Jiu, Turceni, Isalnita, and some smaller as Tismana Aval, Clocotis, Suseni, Valea lui Iovan, Izbiceni, Dumitra. Of these power plants for analysis are chosen Vadeni, Tg. Jiu and Izbiceni, currently clogged more than 80%. The vegetation that grew in excess in these lakes gets its necessary substances to develop from the current sediments.

The physical and chemical parameters influence both the nutritional values of the ecosystem changes, but also the induced modification of the anthropogenic activities of the natural river basin. These properties are the result of the interaction between water and minerals from the systems geochemical water-rocks and water-sediment. Have been identified structures of phosphorus and nitrogen. The analyzes were performed on samples taken at different times during the years 2010-2016.

Some observations

1. The substances dissolved in the water synthesize the tissues of the aquatic algae
2. Structural, the carbon is the main compound, after hydrogen and oxygen
3. Under natural conditions, the phosphorus is the main nutrient, which provides the synthesis of the new tissue, being classified before the nitrogen and the carbon. The phosphorus is called "the limiting factor." This chemical element is the main factor contributing to the vegetation development. It can influence the increase or decrease of the algal proliferations. First, is metabolized the nitrogen found in the air, and then those from the aquatic environment.

In Table 1 are presented the localities from the Jiu hydrographic basin and the level of the water decontamination. There are 214 municipalities with more than 2000 inhabitants which are not equipped with water decontamination stations. From the total eight stations, only two are realized in conformity with current legislation. In the Jiu basin does not exists localities < 2000 inhabitants equipped with collecting systems in a centralized form (Carpenter 1998).

Table 1. Actual Situation of the water decontamination – organic load

Dimension	Nr.	Waste water treatment	Organic load (i.e.)	Organic load collected		Cleaned Organic load	
				(i.e.)	(%)	(i.e.)	(%)
>150000	1	0	385000	331100	6	0	0
15000-150000	11	4	573567	408943	29	253268	44.2
10000-15000	9	1	110500	47698	16	10857	9.82
2000-10000	204	3	819696	11879	44	5076	0.61
Total	225	8	1888763	799620	42.2	269201	14.3

Table 2. Actual situation of the water decontamination of N and P

Localities	**CCO**	**BCO_5**	**Total Nitrogen**	**Total Phosphorus**
	t/year	t/year	t/year	t/year
> 100000	8061.4	3428.2	1836.4	868.7
10000-100000	1166	569.7	217.8	18.3
2000-10000	63.3	38.3	14,8	1.5
< 2000	-	-	-	-
Total	9290.7	4036.24	2069	888.5

Table 2 shows the quantities monitored by organic substances, expressed as CCO-Chemical Consumption of Oxygen and BOC_5- Biochemical Oxygen Consumption at 5 days at 20^0C, and the nutrients as total nitrogen and total phosphorus, measured in 2010, reported at different categories of human agglomeration. Table 3 shows the results obtained from the sediment samples, collected in 2016 from the three lakes under analysis. In Table 4 are mentioned the same parameters as in Table 2, but produced of the industrial capacities (Integrated Prevention Pollution Control IPPC), and in Table 5 another substances due to the local industry.

Table 3. The chemical sediment components

Parameter	Lake Vadeni	Lake Tg. Jiu	Lake Izbiceni
Humidity (105^0C) %	56.246	58.88	57.64
pH (upH)	6.78	6.66	7.16
Organics (%)	8.15	8.93	9.36
Inorganic (%)	92.75	96.17	93.68
NH_4^+ (mg/100g)	6.53	7.52	8.82
NH_4^+ (mg/l)	111.23	158.09	146.16
NO_3^- (mg/100g)	0.7	0.81	0.79
NO_3^- (mg/l)	6.25	7.87	6.12
PO_4^{3-} (mg/100g)	0.12	0.09	0.11
PO_4^{3-} (mg/l)	1.78	1.84	1.77
$N-NH_4^+ + N-NO_3^-$ (mg/100g)	5.63	5.97	6.83
$P-PO_4^{3-}$ (mg/100g)	0.05	0.053	0.058
$N_{dissolved}$ /$P_{dissolved}$	212.74	257.71	243.73

Table 4. Actual situation of the water decontamination

Type	**CCO**	**BCO_5**	**Total Nitrogen**	**Total Phosphorus**
	t/year	t/year	t/year	t/year
Industry IPPC	12933.1	2904.4	31.4	12.83
Industry Non-IPPC	1313.6	322	16.3	26
Total industry	14246.76	3226.3	47.7	38.8
Other sources	171	8.6	8.5	0.056

Table 5. Other parameters of the contamination, due to the industry

Type	Cu	Zn	Cd	Ni	Pb	Hg	Cr
	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year	kg/year
Industry IPPC	-	-	-	-	-	-	-
Industry Non-IPPC	0.9	1.9	-	-	0.1	-	0.1
Total industry	0.9	1.9	-	-	0.1	-	0.1
Other sources	0.1	0.1	-	-	0	-	1

In the Jiu River Basin, from the 39 significant industrial and agricultural local point sources of pollution, 17 have installations covered by the IPPC Directive. The improper waste management in localities is a local source of diffuse pollution, as same as the un-proper collection/disposal of the sludge from the wastewater treatment plants (Horrigan 2002).

Materials and Methods

During the measurements of 2010-2016, has been observed that if some species of cyano-bacteria grow, reducing the proliferation of the algae. They have an ability to proliferate rapidly due to the physic-chemical conditions mentioned above. Considering a small scale of time and space, after scientific experimentation, it was observed that the nitrogen deficiency is a limiting factor, but on a global scale for the Jiu basin, the phosphorus is responsible, triggering the biological nitrogen fixation. The cyano-bacteria are of a size and toxicity that opposes to the potential predators (herbivorous zooplankton) or of to other consumers. These bacteria dominate many algae, modifying the functionality of the food chain.

The development in the anoxic conditions in bodies of water removes all superior life forms, as the fresh water fish such as salmonids.

At the interface between water–sediment, anoxia maintains the reduction of iron compounds. The existence of cyanobacteria poses specific problems related to the toxins, which they secrete. A trend of intense phosphorus pollution is manifested in the waters where the flow rate is reduced, at the end of the hydroelectric lakes. They are considered sensitive areas. The data from the Table 2 demonstrate that the actual sediments from these hydropower lakes have the physical-chemical characteristics similar to each other.

The mineral nutrition is favorable in the light and depends on the temperature, the hydrodynamics, and other environmental conditions. The bioavailability of nutrients presented in the water, the gas dissolved or the minerals in solution are factors favorable to the proliferation of aquatic vegetation (micro-algae, macro algae, or floating macrophytes). The report of consumer/demand requirement is a function of the composition of the living organisms, Table 6 (Seteanu 2004).

The average composition of the aquatic vegetation, algae, and aquatic plants comprise the carbon as a major constituent, together with hydrogen and oxygen. It should be considered the silicon, which is ubiquitous in the water world, in the diatoms. Nitrogen is the following chemical element, then calcium, potassium, and phosphorus (0.08%), and ends the enumeration with magnesium, sulfur, and chlorine. These constituents, provide nutritional support necessary to proliferation of the aquatic vegetation in the absence of the polluting substances that inhibit the growth of these plants.

The upstream lakes are not contaminated anthropogenic than an insignificant extent and this correlated with the significant reserves of the essential nutrients from these ecosystems, explains the presence of such a large amounts of the aquatic macrophytes, Fig.1.

By the composition of the cells, the major component is carbon, because the proliferation of the bioavailability algae depends on it. As a result, the required algal mass can be satisfactory in water, where the chemical elements are present in different composition different from the cell concentrations (Seteanu 1998).

Table 6. Report of consumption/offer of substances in water

Element	Symbol	Consumption (vegetal) %	Water offer %	Consumption /offer (approx.)
Oxygen	O	80.5	89	1
Hydrogen	H	9.7	11	1
Carbon	C	6.5	0.0012	5.000
Silica	Si	1.3	0.00065	2.000
Azoth	N	0.7	0.000023	30.000
Calcium	Ca	0.4	0.0015	<1.000
Potassium	K	0.3	0.00023	1.300
Phosphor	P	0.08	0.000001	80.000
Magnesium	Mg	0.07	0.0004	<1.000
Sulfur	S	0.06	0.0004	<1.000
Chloride	Cl	0.06	0.0008	<1.000
Sodium	Na	0.04	0.0006	<1.000
Iron	Fe	0.02	0.00007	<1.000
Bore	B	0.001	0.00001	<1.000
Mangham	Mn	0.0007	0.0000015	<1.000
Zinc	Zn	0.0003	0.000001	<1.000
Copra	Cu	0.0001	0.000001	<1.000
Molybdenum	Mo	0.00005	0.0000003	<1.000
Cobalt	Co	0.000002	0.000000005	<1.000

Figure 1. Existent aquatic vegetation in analyzed lakes

If it is considered an average composition of the natural waters, is determined for each element the report required/offer, it appears that a ratio value 80,000. Phosphorus comes first ahead nitrogen (30,000) and carbon (5,000).

As shown in Table 6, the N/P ratio of the aquatic vegetation is 0.7/0.08 = 8.75, which means that the nutrient medium has a ratio N/P equal to this value, being thus in a perfect balance with the desired ratio of the vegetable medium (Walker 2006).

The lake Vadeni because it has features morphometric, hydraulic, and hydrological closer to a channel, the aquatic macrophytes are less developed. The tributary rivers Susita, Jiet bring additional amounts of nutrients used by these vegetable bodies.

Lake Vădeni records a value of pH of 7.7, slightly exceeding the limit of 7.5. Ammonia, nitrites, and nitrates do not exceed much the maximum permissible, but the heavy metals are often exceeded. The cadmium reaches values 11 times higher than the maximum permissible one, the lead almost twice, the zinc maximum is limited at 1000μg/l, and copper exceeds sporadically the limit of 100 mg/l. The lake is clogged in a proportion of 85%, meaning that there is a risk of the dam functioning. The hydroelectric power plant can operate only two hours per day. Nowadays a plan of rehabilitation intends to raise the dam and the lateral dikes to have a higher volume of water. The data resulting from the hydro-chemical analysis of samples taken in 2016, between August and November are presented in Table 7.

Table 7. Measurements in 2016

Parameter	Data	River Jiu	Vadeni	Tg. Jiu	Izbiceni
Temperature	06.08	12.0	14.0	15.5	15.0
^0C	01.11		9.3	6.8	6.2
pH (u.pH)	06.08	7.6	7.5	7.5	7.5
	01.11		7.3	7.3	7.2
Oxygen dissolved	06.08	8.28	9.04	8.74	8.44
mg O_2/l	01.11		9.20	10.53	7.93
Organic dissolved	06.08	9.10	9.10	12.40	12.09
mg $KMnO_4$/l	01.11		14.16	10.97	6.73
Nitrates	06.08	1.53	2.51	2.41	2.28
mg NO_3^-/l	01.11		1.15	1.90	3.03
Nitrites	06.08	0.040	0.014	0.026	0.013
mg NO_2^-/l	01.11		0.020	0.012	0.014
Ammonium	06.08	0.32	0.19	0.21	0.15
mg NH_4^+/l	01.11		0.28	0.31	0.24
Phosphates	06.08	0.012	0.014	0.012	0.010
mg PO_4^{3-}/l	01.11		0.016	0.010	0.030
Total Alkalinity	06.08	3.44	2.02	1.96	2.00
mval/l	01.11		2.40	2.20	5.52
Calcium	06.08	64.13	37.67	34.47	35.27
mg Ca^{2+}/l	01.11		49.70	40.88	70.54
Magnesium	06.08	9.73	6.81	8.07	7.78
mg Mg^{2+}/l	01.11		7.30	8.27	10.21
Bicarbonates	06.08	209.8	123.2	119.6	122.0
mg HCO_3^-/l	01.11		146.4	134.2	214.7

It was elected an interval between full ranges of developed vegetation until the period of regression. If this ratio is below the value of 8.75, there is a deficit of nitrogen relative to phosphorus. In this case, the nitrogen is the limiting factor. If the ratio is greater than the value of 8.75, the nitrogen induces a phosphorus deficiency. In this case, the limiting factor is the phosphorus. The chemical element phosphorus is the key to cellular metabolism compared to nitrogen and carbon.

Results and Discussion

The power supplies of the river Jiu and its tributaries and the cascade power plants (e.g. Vadeni, Tg. Jiu, Izbiceni) shows comparable values of pH, oxygenation, organic loading and phosphate concentrations. On the trophic level, the lakes are classified as mesotrophic to eutrophic lakes. This is primarily due to the large volume of wastewater discharged. Comparing the maximum values of some parameters, measured in 2010 and 2016, it was observed significant differences, such as:

- Permanganate consumption (KMnO4 mg/l)	7.9	14.85
- Dissolved oxygen (mg/1)	9.6	14.20
- Nitrates (mg/1)	1.5	5.20
- Phosphorus (mg/1)	<determination limit	0.038
- Chlorine (mg/1)	9.93	17.02

Due to the multiple utilization of water, a mismatch between resources and requirements, and due to the reuse of the watercourse, it requires the coordination of an activity of management of the water resources (Smith 1999). The setting sampling stations for the water analysis was performed taking into account the whole system approach, to identify the possible sources of nutrients that contribute to the proliferation of vegetation. It is important to know the chemical composition of water mainly from the accumulations upstream being the major source of water supply for the downstream HPPs (Hydro-Power Plants). Table 8 summarizes some measurements in 2015 which highlight how is affected the water structure.

Table 8. Measurements along the analyzed area

Station	pH	Ca^{+2} mg/1	NH_4^+ mg/1	NO_3- mg/1	PO_4^{-3} mg/1	CCOMn $mgKMnO_4/l$
Downstream Vadeni	7.85	43.25	<0.001	1.20	0.003	10.23
Preparation Plant Coroiești	7.60	55.18	0.060	2.60	0.250	68.00
Downstream discharge	7.03	40.28	0.013	1.20	0.032	15.80
Isalnita	7.98	99.39	0.056	3.70	0.210	20.85
Sugar Podari	7.85	46.69	0.009	4.65	0.067	18.40
Effluent Treatment Station	7.73	43.20	0.016	1.35	0.080	14.85

Downstream the dam Vaduri is an industrial effluent, row 2. The wastewater from the unit, although it passed through a water treatment plant, still inserts large amounts of ammonium nitrate, phosphorus, and organic substances. After the mixture with the water coming from the upstream, there is a certain reduction of the amounts of nutrients, as result of dilution, but the contribution from this industrial effluent remains substantially as a continuous process of additional nutrients for the downstream sector. Although there still are many places without sewage plants, after the rehabilitation of the treatment, plant in Tg. Jiu an improvement of the water composition appeared. There still is much sewage delivered directly into the watercourse. The water remains significant loaded with nitrogen, and phosphorus. In Fig.2 are presented the areas necessary to be protected as nature reserves, 2a) and areas needed to be protected from excessive intake of nutrients 2b).

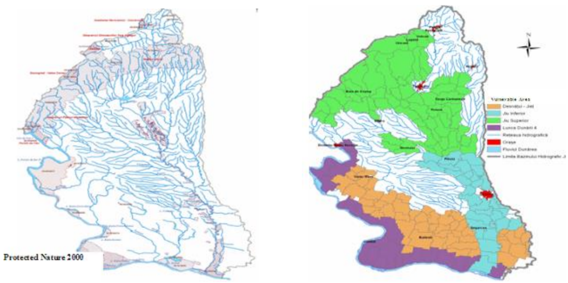

Figure. 2 Protected areas 2a) 2b)

High concentrations of nutrients in the water allow the development of populations of Cladophora in the downstream sector. During time have been evacuated significant amounts of toxic substances (phenols, cyanides etc.). The measures proved that they act as an inhibiting for the vegetation Cladophora, but with unexpected effects on human health.

Conclusions

Pollution by the emissions of organic matter and nutrients (nitrogen and phosphorus) is due to the wastewater from human agglomerations, industrial, and agricultural sources. Lack of or insufficient wastewater treatment leads to pollution of the surface waters that started to be degraded and consume oxygen. This causes a significant impact on the aquatic ecosystems by reducing the biodiversity, vegetation abundance, and lakes eutrophication (the nutrient enrichment and excessive algae growth). The fight against nitrates can solve the problem of lakes eutrophication. The nitrates are the target, but their presence contributes treating two undesirable pollution problems with phosphates:

- Nitrogen increases the report N/P; helps the appearance of nitrogen compounds
- Oxygen maintains the iron oxidation and at the interface, water-sediments is opposing to formation of the phosphorous associations.

Romania was identified as being a sensitive area to pollution with nutrients (total nitrogen and total phosphorus) based on Annex II to Directive 91/271/EEC.

Acknowledgements

I would like to thank my colleagues from the Hidroelectrica SA, who presented to me the problems appeared into these hydrographic river basin catchments and supported me in the realization of the measurements during 7 campaigns between 2010-2016.

References

Seteanu, I & Radulescu, V 2004, *'Numerical models in hydraulics and power engineering',* Bren Publisher, Bucharest, ISBN 973-99604-4-8.

Seteanu, I, Radulescu, V & all, 1998, 'Sisteme hidraulice, Fundamente si aplicatii, Editura Tehnica, Bucuresti ISBN 973-31-1412-X.

Carpenter, SR, Caraco, NF & Smith VH 1998, 'Non-point pollution of surface waters with phosphorus and nitrogen', *Ecological Applications,* vol. 8, pp. 559-568.

Horrigan, LR & Walker, P 2002, 'How sustainable agriculture can address the environmental and human health', *Environmental health perspectives*, vol.110, no. 5, pp. 445–456, doi:10.1289/ehp.02110445.

Smith, VH, Tilman, GD & Nekola JC 1999, 'Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems' *Environmental Pollution*, pp. 179–196, doi:10.1016/S0269-7491(99)00091-3.

Walker, IR 2006, '*Chironomid overview*', vo1.1, pp. 360-366, Elias, Encyclopaedia of Quaternary Science, Elsevier.

Directive 2009/31/CE regarding prevention and integrate control of environmental pollution (IPPC).

Directive 91/676/EEC regarding water protection against nitrates pollution.

Directive 91/271/EEC, concerning urban wastewater treatment.