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RESEARCH ON WATER QUALITY INDICATORS AT THE ROVINARI POWER PLANT

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Abstract: *Indicators of: pH, temperature, conductivity, filtered residue at 105°C, suspended matter, ammonium, chemical oxygen consumption-CCOCr, chlorides, biochemical oxygen consumption - CBO5, sulfates, extractable substances with organic solvents, petroleum products, total iron, calcium, magnesium, sulfides and hydrogen sulfide. The excesses recorded in the sulfate and ammonium indicators in the phreatic waters within the unit premises and in the area of the slag and ash deposits are mainly due to natural causes and to a small extent to anthropogenic action. In accordance with the specialized literature, but also with the studies and research carried out, it is found that the exceedances recorded in the Oltenia area of the specified indicators are due to:*

- for ammonium (NH4+) - the primary conditions in the Pliocene basin for the formation of aquifer sand deposits;

- for sulfates (SO42-) - washing by underground waters of lignite layers in which sulfides frequently appear, especially in the form of pyrite.

Keywords: *water quality, primary energy resources, water pollution, environment*

1. Introduction

The energy sector, through the conversion of primary energy resources, has important effects, direct or indirect, on a local, regional or global scale on environmental components. [1, 2, 3]

Rovinari power plant is located in the industrial area in the south-western part of the town of Rovinari, Gorj County, and has been operational since August 18th, 1976. So far, it has gone through several stages of modernization and compliance in terms of environmental protection. The slag and ash deposits are located 2 ÷ 5 km away from the power plant and occupy an area of 478.9 ha.

Rovinari power plant is designed as a basic power plant of the National Energy System - SEN. According to the way of location, the thermal power plant is "*at the mouth of the mine*", unique in the country, which offers the possibility of direct energy utilization of the large quantities of lignite from the quarries included in the company, ensuring a minimum distance of transport of the coal from source. This also implies minimal costs for the transport of coal, Rovinari power plant being the only power plant exempted from railway transport costs. The power plant is an energy transformer of large proportions. It takes the chemically bound latent energy of fossil fuels and first converts it into the heat contained in a gas. Then this heat is given to the working environment itself (water), which on this occasion changes its state of aggregation (steam). The energy of the working environment is transformed by the steam turbine into mechanical energy, and this is then transformed by the generator into electrical energy. [4, 5, 6]

The techniques/ technologies implemented can be found in the BAT list. Law no. is applied. 278/2013 regarding industrial emissions, [7] is fully respected at Rovinari power plant.

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2. Water pollution from Rovinari Power Plant

2.1. Pollution prevention installations and equipment

Water supply and discharge of waste and rainwater is regulated by Water Management Authorizations no. 204/11.09.2020 valid until 30.09.2024, issued by the Romanian Waters National Administration. [8, 9, 10, 11]

The potable water supply is carried out through two hydrogeological boreholes located within the premises of the unit, in the northern area of the cooling towers, having the following technical characteristics:
- P_1 executed in 1986: H = 110 m, N_{hs} =12 m, N_{hd} =18.6 m, D_n=250 mm, Q_{expl} = 8.5 l/s;
- P_2 executed in 1986: H=110 m, N_{hs}=13.5 m, N_{hd}= 19.3 m, D_n=250mm, Q_{expl}= 9.0 l/s.

A sanitary protection zone is established around the wells. Authorized water volumes and flows:
- maximum daily flow: 128.3 m^3/day;
- average daily flow: 114.7 m^3/day;
- maximum hourly flow rate: 5.35 m^3/h.

The operation is permanent, 365 days/year, 24 hours/day.

2.2. Water treatment facilities and transport

The monoblock transfer station is composed of:
- distribution basin;
- spray room with aerated water basin 2.62 x 2.75m.
- pump station: 2(1+1) electric pumps Lotru 100 Q=30 m^3/h, H=12 mCA, P=3 kW, n= 1500 rpm for pumping under pressure aerated water in the rapid filters and 2 (1 +1) electric pumps Lotru 100 Q=30m^3/h, H=10mCA, P=3kW, n=1500 rpm for washing fast filters;
- quick filters – 2 containers type RF1;
- drip chlorination installation with sodium hypochlorite;
- water intake and storage installations: metal pipes with D_n 100 mm in length of 150 m and stored in a semi-buried reinforced concrete tank with V=300 m^3;
- the water distribution network: consists of networks of metal pipes du Dn=1" - 6" and PEID pipes D_n=200-75 mm in length of 4 km;
- pumping station equipped with 3 (2+1) electric pumps type SADU 100, Q=60 m^3/h, H=70 mCA, P=22 kW.

The water taken from the boreholes is transported through a metal pipe with D_n=350 mm, 1500 m long and stored in 3 concrete tanks each with a volume of 1000 m^3, the water is used as make-up water for the boilers.

The surface source, Jiu River, is captured by means of Rovinari barrage catchment, with a maximum flow of 64 m^3/s and is under the administration of A.N. Romanian Waters -A.B.A. Jiu Craiova.

Water treatment facilities consist of:
- Sand separator - composed of 7 stilling chambers equipped with upstream and downstream shut-off valves, wash valves and cofferdams having: L= 42.50 m, l = 7.50 m, H=5.0 m for decanting and retaining suspensions
- Site house equipped with:

- 4 rotary screens type 4210-20 CSR with Q= 4 m^3/h;
- 4 rotary screens type RSR with Q= 14 m^3/s.

- Sieve washing pumps: 4 CVAV type CSR pumps, 4 ACV-150-32 type pumps, CV 100-15 D electric pumps for emptying downstream and upstream compartments.

The raw water chemical treatment station is designed for a flow rate of 2600 m^3/s and consists of:
- Pre-treatment plant composed of: 3 pre-heaters from 20°C to 25°C of the water taken from the underground source, 8 filters with a mineral filter layer (quartz sand with 0.6 - 2 mm granulation, H= 1.2 m).
- The demineralization plant has a maximum capacity of 720 m^3/h composed of: six demineralization lines with the following filtration steps:

- the cationic step, consisting of two filters with strongly acidic cationite;
- the anionic stage, consisting of a filter with a weak basic anionite and a filter with a strong basic anionite;
- the finishing step, consisting of mixed bed filters.

Regeneration of ion filters is carried out in equipment with hydrochloric acid solution (7 ÷ 8%) for H-cationic filters and with sodium hydroxide solution (3 ÷ 4%) for anionic filters.

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In the chemical treatment facility there are also the related households of chemical reagents for regeneration. Dosing of chemical reagents is carried out through a consumption vessel-ejector system.

- Coagulation plant:

The conditioning of the supply water of the steam boilers is carried out with a dosing installation of ammonia solution (2%) and hydrazine. It consists of dosing and storage vessels.

- Condensate treatment plant:

The main condensate resulting from the 330 MW energy block is prepared in a chemical treatment facility included in the thermal circuit between the stage I and stage II condensate pumps. The main condensate treatment plant consists of two filtration stages:
- the H-cationic stage, with 4 filters with strongly acidic cationic mass;
- finishing stage, with 4 mixed bed filters, with external regeneration.

2.3. Waste water evacuation systems

The sewage network of industrial and rainwater is composed of a network of underground canals and auxiliary constructions (drainages, visitation houses, fuel oil separators, spillways, etc.) with a length of approximately 5 km. The secondary channels are made of prefabricated plain concrete tubes with D_n= 200-600 mm. Waste water is discharged into Jiu River through 5 main collectors as follows:

- **collector A** - made of reinforced concrete with a rectangular section of 2x1.4 (m) ensures the transport and evacuation of technological and rainwater waste water from the NW area of the plant site, water from the following processes:

- periodic washing of the skimmers;
- accidental losses from the ferrication and chlorination station;
- washing of accidental spills resulting from the handling, transport and feeding of reactive storage tanks
- washing of the area by rainwater.

The technological waters from the stage II water softening and demineralization station are collected by means of a concrete pipe with D_n=400 mm and neutralized in a homogenization basin located near the deferrization station. After neutralization, the waters are discharged into the washing chamber of the sandblaster through a pipe made of pre-compressed reinforced concrete with D_n=400 mm. Rainwater from the railway in the area also drains into this sewer.

The water from the washing of the rotating sieves is pumped out into the washing channel of the sandblaster, through a metal pipe with D_n=350mm.

- **collector B** – discharge into Jiu River, made up of sections of collectors with diameters between 200-800 mm, ensures the transport and evacuation of technological waste water and rainwater from the area of the cooling towers, taking the following waters:

- rainwater and drains from the solid fuel repair workshop that are released from concrete pipes D_n=300 mm,
- rainwater from the dammed surface of the 5000 cubic meter fuel tank, made of a concrete pipe D_n=300mm,
- the waters from the emptying of the basins of cooling towers no. 1, 2, 3, 4 and 5, made of a PREMO pipe D_n=600 mm,
- rainwater from the hydrogen production station and the storage of CO_2 cylinders, concrete pipe D_n=300 mm,
- rainwater and drains at the PSI ramp - concrete pipes D_n=300 mm,
- rainwater and drainage from the fire pump station - concrete pipes D_n=300 mm
- water from the emptying of the suction basins of the hot water pumps towers stage I and stage II, -concrete pipes D_n=300 mm,
- rainwater and runoff from the chemical foam preparation station - concrete pipes D_n= 300 mm
- drainage from regional roads

The evacuation into Jiu River is done through a circular channel, with prefabricated vaults, and for the last 50.0 m through an open channel.

- **collector C** - made up of collection sections with diameters of 300-1000 mm, evacuates into collector F the technological waste water and rainwater from:

- rainwater from the fuel oil unloading ramp;
- rainwater from the dammed surface of the 10,000m^3 fuel tank;
- conventionally clean waters from the emptying of the fuel pump station, after passing through the fuel oil separator;
- rainwater and drains from the back platform of the stage I boiler;
- rainwater and discharges from the compressor station;

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- rainwater from the railway related to the coal deposit;
- rainwater and discharges from the chemical water treatment station, stage I;
- rainwater from the centralized mechanical workshop;
- rainwater, drains and drains from the operating and administrative block;
- rainwater and drains from the laboratory body;
- rainwater from the non-family block;
- rainwater and the emptying of the hot and cold water channels from the engine room area stage I;
- rainwater from the drains from the neighbouring roads and entrance platforms to the thermal power plant;
- rainwater from the area of the wet desulfurization installation of combustion gases related to energy block no. 3.

- **collector F**-ensures the transport and evacuation of hot technological water, resulting from the process of cooling the condensers through 6 channels of reinforced concrete. When discharging into Jiu River, the channels are equipped with an energy dissipater, fixed and mobile berms;
- **collector CM**-evacuation to the domestic wastewater treatment plant; domestic wastewater is collected and treated in the unit's treatment plant and then discharged to the Bagger station and used as make-up water in the dense sludge preparation circuit.

2.4. The quality conditions of discharged wastewater

Characterization of the operation of the plant from the point of view of compliance with the quality conditions for discharged wastewater:
- the maximum allowed concentrations established by the water management authorization no. 204/11.09.2019 and NTPA 001/2002;
- in the summer months, the temperature of the cooling water frequently recorded values between 33-35ºC due to the prolonged drought (low easement flow and high temperature of the water taken from the Jiu river);
- during periods of flooding, exceedances of the suspension indicator are recorded both for the raw water taken and for the technological waste water discharged.

Through the subscription contract regarding the delivery of water management products and services, in 2021 the amount of 991,259.53 lei was settled, representing the value of the service of receiving discharged substances into surface waters for the quantities of pollutants provided in Table 1.

Table 1. The quantities of pollutants provided for in the 2021 subscription contract

No.	Pollutant	Amount of pollutant [t]
1	Suspensions	851.69
2	Fixed residual	618.29
3	Thermal load (ΔT^0C)	96.8
4	CNO_2	57.38
5	Petroleum product	0
6	Extractable substances with organic solvents	0

3. Investigation of water quality indicators

Monitoring the quality of wastewater discharged from the territory of Rovinari Power Plant is carried out in the environmental protection laboratory by daily determination of the following indicators: pH, temperature, conductivity, residue filtered at 105°C, suspended matter, ammonium, chemical consumption of oxygen-CCOCr, chlorides, biochemical oxygen consumption - CBO_5, sulphates, substances extractable with organic solvents, petroleum products, total iron, calcium, magnesium, sulphides and hydrogen sulphide. The indicators mentioned in the water management authorization were determined monthly with RENAR accredited laboratories: S.C. ICIA Cluj-Napoca and S.C. GIVAROLI IMPEX SRL Bucharest.

Sampling is carried out from the points established in the water management authorization: water intake, discharge of industrial and cooling waste water (at the confluence with Jiu River) - collectors A, B, F+C. Household wastewater is collected in the unit's treatment plant where it is treated and re-introduced into the dense sludge preparation circuit which is discharged into Gârla slag and ash deposit.

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Table 2. Average annual values of water quality indicators for 2021

No.	Indicator	M.U.	Jiu raw water sampling	Collector F+C	Collector A	Collector B
1	pH	pH	7.55	7.69	7.85	7.78
2	Temperature	(^{0}C)	10.75	19.33	11.42	15.04
3	Suspended matter	mg/dm^3	21.37	19.75	20.33	19.95
4	Ammonium (NH_4^+)	mg/dm^3	0.117	0.098	0.106	0.090
5	Sulphates SO_4^{2-}	mg/dm^3	18.45	18.367	17.96	17.27
6	Extractable substances with organic solvents	mg/dm^3	<20	<20	<20	<20
7	Petroleum products	mg/dm^3	0.58	1.525	0.51	1.03
8	Chloride	mg/dm^3	6.517	6.287	6.198	6.234
9	Residue filtered at 105^{o}C	mg/dm^3	133.83	133.167	135.667	136.333
10	Calcium	mg/dm^3	29.74	29.07	29.99	25.82
11	Total ionic iron (Fe^{2+},Fe^{3+})	mg/dm^3	0.053	0.055	0.056	0.052
12	Mercury	µg/ dm^3	<0.2	<0.2	<0.2	<0.1
13	Magnesium	mg/dm^3	3.360	3.339	2.653	3,573
14	Chemical oxygen consumption (CCOCr)	mgO_2/dm^3	9.77	9.22	10.263	8.98
15	Biochemical oxygen consumption (CBO_5)	mgO_2/dm^3	3.223	2.84	3.27	2.80

Table 3. Discharges into final effluents and/or into sewage networks, treatment plants, natural receivers raw water

No.	Indicator	M.U.	Concentration measured			MAC NTPA-001/2002 [10]	Volume of water taken annually [thousand m^3]
			Min.	Avg.	Max.		
1	pH	-	6.60	7.55	7.90	6.5-8.5	248.329,62
2	Temperature	^{0}C	6.00	10.75	21	Max.35^{o}C	
3	Suspended matter	mg/dm^3	7.2	21.37	75	60	
4	Ammonium (NH_4^+)	mg/dm^3	<0.064	0.117	0.228	2	
5	Sulphates SO_4^{2-}	mg/dm^3	11.10	18.45	28.10	600	
6	Extractable substances with organic solvents	mg/dm^3	<20	<20	<20	20	
7	Petroleum products	mg/dm^3	<0.05	0.58	0.74	5	
8	Chloride	mg/dm^3	<5	6.517	7.437	500	
9	Residue filtered at 105^{o}C	mg/dm^3	91	133.83	173.00	2000	
10	Calcium	mg/dm^3	20	29.74	48.88	300	
11	Total ionic iron (Fe^{2+},Fe^{3+})	mg/dm^3	0.035	0.053	0.081	5	
12	Mercury	µg/ dm^3	<0.2	<0.2	<0.2	50	
13	Magnesium	mg/dm^3	0.99	3.360	6.55	100	
14	Chemical oxygen consumption (CCOCr)	mgO_2/dm^3	5.02	9.77	16.90	125	
15	Biochemical oxygen consumption (CBO_5)	mgO_2/dm^3	1.57	3.223	4.30	25	

Table 4. F+C collector (cooling water mixture)

No.	Indicator	M.U.	Concentration measured			MAC NTPA-001/2002 [10]	Volume of water taken annually [thousand m^3]
			Min.	Avg.	Max.		
1	pH	-	7.0	7.69	7.9	6.5-8.5	235.256,40
2	Temperature	^{0}C	13	19.33	29	Max.35ºC	
3	Suspended matter	mg/dm^3	10	19.75	37	60	
4	Ammonium (NH_4^+)	mg/dm^3	<0.064	0.098	0.214	1	
5	Sulphates SO_4^{2-}	mg/dm^3	11.10	18.367	28.90	50	
6	Extractable substances with organic solvents	mg/dm^3	<20	<20	<20	20	
7	Petroleum products	mg/dm^3	<0.05	1.525	2.32	5 (no iridescent)	
8	Chloride	mg/dm^3	<5	6.287	6.729	30	
9	Residue filtered at 105ºC	mg/dm^3	94.00	133.17	169	500	
10	Calcium	mg/dm^3	20.0	29.07	40.0	100	
11	Total ionic iron (Fe^{2+},Fe^{3+})	mg/dm^3	0.038	0.055	0.078	0,5	
12	Mercury	µg/ dm^3	<0.2	<0.2	<0.2	50	
13	Magnesium	mg/dm^3	<5	3.339	6.10	50	
14	Chemical oxygen consumption (CCOCr)	mgO_2/dm^3	2.83	9.22	14.20	20	
15	Biochemical oxygen consumption (CBO_5)	mgO_2/dm^3	1.2	2.84	3.9	10	

Table 5. Collector A

No.	Indicator	M.U.	Concentration measured			MAC NTPA-001/2002 [10]	Volume of water taken annually [thousand m^3]
			Min.	Avg.	Max.		
1	pH	-	7.5	7.85	8.2	6.5-8.5	936
2	Temperature	^{0}C	6.5	11.42	21.0	Max. 35ºC	
3	Suspended matter	mg/ dm^3	11.00	20.33	46.00	60	
4	Ammonium (NH_4^+)	mg/ dm^3	<0.064	0.106	0,24	1	
5	Sulphates SO_4^{2-}	mg/dm^3	10.80	17.96	25.60	50	
6	Extractable substances with organic solvents	mg/dm^3	<20	<20	<20	20	
7	Petroleum products	mg/dm^3	<0.05	0.51	0.54	5 (no iridescent)	
8	Chloride	mg/dm^3	<5	6.198	7.083	30	
9	Residue filtered at 105ºC	mg/dm^3	88.00	135.67	166.00	500	
10	Calcium	mg/dm^3	20.00	29.99	38.00	100	
11	Total ionic iron (Fe^{2+},Fe^{3+})	mg/dm^3	0.035	0.056	0.088	0,5	
12	Mercury	µg/ dm^3	<0.2	<0.2	<0.2	50	
13	Magnesium	mg/dm^3	1.24	2.653	6.27	50	
14	Chemical oxygen consumption (CCOCr)	mgO_2/dm^3	6.30	10.263	15.00	20	
15	Biochemical oxygen consumption (CBO_5)	mgO_2/dm^3	1.80	3.27	5.70	10	

Table 6. Collector B

No.	Indicator	M.U.	Concentration measured			MAC Water Management Authorization no. 204/ 11.09.2019	Volume of water taken annually [thousand m^3]
			Min.	Avg.	Max.		
1	pH	-	7.50	7.78	8.00	6,5-8,5	312
2	Temperature	^{0}C	8.00	15.04	25.5	Max. 35ºC	
3	Suspended matter	mg/dm^3	6.00	19.95	81	60	
4	Ammonium (NH_4^+)	mg/dm^3	<0.064	0.090	0.143	1	
5	Sulphates SO_4^{2-}	mg/dm^3	11.50	17.27	22.20	50	
6	Extractable substances with organic solvents	mg/dm^3	<20	<20	<20	20	
7	Petroleum products	mg/dm^3	<0.05	1.03	0.11	5 (no iridescent)	
8	Chloride	mg/dm^3	<5	6.234	7.437	30	
9	Residue filtered at 105ºC	mg/dm^3	90.00	136.33	168	500	
10	Calcium	mg/dm^3	19.00	25.82	37	100	
11	Total ionic iron (Fe^{2+},Fe^{3+})	mg/dm^3	0.03	0.052	0.08	0,5	
12	Mercury	μg/dm^3	<0.2	<0,2	<0.2	50	
13	Magnesium	mg/dm^3	<5	3.573	4.99	50	
14	Chemical oxygen consumption (CCOCr)	mgO_2/dm^3	5.63	8.98	12.30	20	
15	Biochemical oxygen consumption (CBO_5)	mgO_2/dm^3	1.40	2.80	4.80	10	

4. Conclusions

Characterization of the operation of the plant from the point of view of compliance with the quality conditions for discharged wastewater:

- the maximum allowed concentrations established by the water management authorization no. 204/11.09.2019 and NTPA 001/2002 in the summer months, the temperature of the cooling water frequently recorded values between 33-35ºC due to the prolonged drought (low easement flow and high temperature of the water taken from Jiu river);
- during periods of flooding, exceedances of the suspension indicator are recorded both for the raw water taken and for the technological waste water discharged.

It is estimated that the deposits of slag and ash influence the groundwater in its immediate vicinity. With the distance from the deposit, the waters undergo a natural purification so that the phreatic water in the neighbouring inhabited areas does not undergo changes in the quality indicators.

Rovinari Electrocentrale branch monitors the quality of underground water in 3 (three) points, one upstream and two downstream of Gârla and Cicani-Beterega slag and ash deposits: 1.-Virt area; 2.- Moi area (Ciovică fountain); 3.- Moi area (Straja fountain).

Rovinari Power Plant operates on the basis of environmental authorizations, and the first Environmental Authorization can be found in 1999.

Rovinari power plant holds administrative documents issued by the competent authorities for environmental protection, Integrated Environmental Authorization with annual visa, Water Management Authorization, which regulate aspects regarding the environmental factor of water, the method of supply (capture, drilling), the method of use, treatment, evacuation, monitoring, in compliance with normative acts, HG no. 188/2002, Annex 3, NTPA-001/2002, with subsequent amendments and additions.

The safety and health of the population depends on ensuring the energy security of the country. It is definitely recommended to capitalize on an efficient solid fuel (lignite) supply system, production, transport, distribution and supply, which ensures the continuous supply of all consumers in conditions of accessibility, availability and bearable prices, taking into account the evolution of quality the surrounding environment.

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In 2021, Rovinari power plant produced the amount of 4698347 MWh of electrical energy, consuming the amount of 6982,606 thousand tons of lignite at the lower calorific value of 1596 Kcal/Kg, corresponding to a total number of 18,880 hours of operation.

Rovinari power plant was supplied with coal from Roșia de Jiu (37%), Pinoasa (30%) and Tismana (32%) quarries.

The coal production schedule from Roșia de Jiu, Pinoasa and Tismana quarries was in close correlation with the coal requirement of Rovinari power plant.

The production of electricity by Rovinari power plant was 4,731,741 MWh through the operation of the 3 active blocks: block no. 3 (27.0 %), block no. 4 (36.8%) and block no. 6 (36.2 %), which operated throughout 2021.

The monitoring of the level of pollutant emissions at Rovinari thermal power plant is carried out according to the provisions of the integrated environmental authorization no. 7/25.09.2018.

Rovinari thermal power plant contributes to the energy security of the population, and the modernization stages take into account the protection of the environment, including the human factor.

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