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Environmental risks from thermal power plants that use coal as raw material for a long time – a case study from Kosovo

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Abstract. Air and water pollution, along with heavy metal contamination, constitute some of the most pressing environmental issues affecting Kosovo. In recent years, the overall environmental situation in the region has deteriorated due to increased construction, traffic, and industrial pollution. This includes emissions from power plants and household heating during winter. Integrating sustainability into strategic energy planning is imperative for security policies and is well within the reach of emerging economies like Kosovo. The outdated technology and lack of effective regulations for air emissions from the two thermal power plants - Kosova A and Kosova B - have led to significantly higher stack emissions compared to coal plants in Western Europe. The specific impacts on vulnerable populations, such as children, the elderly, and those living close to the Obiliq power plants, have not been adequately studied. The construction of the new coal power plant - Kosovo C, represents a step forward in the energy sector but raises concerns about carbon dioxide emissions as a greenhouse gas pollutant. Currently, most energy production in Kosovo relies heavily on water usage across various power plants. Efforts are being made to reduce the environmental impact of Kosova A and Kosova B by decreasing dust, sulfur dioxide (SO_2), and nitrogen oxides (NO_x) emissions. It is crucial to shift towards producing green energy through sources like solar, water, and wind power to significantly mitigate these environmental challenges.

Key words: environmental pollution, power plants, emissions, green energy.

Introduction

In recent decades, humanity has grappled with escalating environmental pollution, evident in the alarming reduction of biodiversity and climate change. To safeguard life on Earth, it is crucial to pinpoint the sources of pollution and implement preventive measures. This pollution arises from both human activities and natural processes in the atmosphere, hydrosphere, and lithosphere. Adhering to legal provisions and instituting comprehensive monitoring of environmental pollution from all sources is imperative.

The energy sector in Kosovo in general, and the electricity sector in particular, is one of the main pillars of supporting economic development in Kosovo (Pristina Institute for Political Studies, 2022). Thermal power plants are complex energy systems composed of multiple interconnected technological and operational units whose purpose is to convert the energy of natural energy sources into thermal and electrical energy. General data show a continuous increase in the need for electricity production in Kosovo and this increase in production conditions a wide range of environmental impacts both at the local, regional and global levels (Communication from the Commission to the European Parliament, 2022).

The aim of each thermal power plant is to reduce the emission of pollutants without inhibiting the economic development of the country. This means keeping the environmental pollution under control as a result of the activities from

KEK's (Energy Corporation of Kosovo) operation, so that the concentration of pollutants is in compliance with the permitted international environmental norms (AQM in Kosovo, 2019).

All substances with high concentrations in the air, water and soil have negative impacts on the surrounding plant and animal world (Manisalidis et al., 2020). As a result of KEK's operating activities, air pollution stems from the emission of different gases in the air from the thermal power plants Kosova A and Kosova B, water pollution associated with technological water discharges, soil pollution and degradation caused by surface mining activities and underground of the whole area (Techene, 2017). Every energy corporation based on the use of coal must create mechanisms for regular control of all activities through internal audits and inspections, as well as reporting, documentation, information and efficient communication with the competent authorities and other actors acting in the protection of the environment (Hirzel et al., 2016).

The biggest concern are the levels of dust particles (PM_{10}, $PM_{2.5}$), nitrous gases (NO_x), sulfur dioxide (SO_2), carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOC), heavy metals as well as the components of industrial waters used in power plants (WHO Guideline, 2021). Thermal power plants in the process of producing electricity generate huge amounts waste materials, which end up in the environment, resulting in increasing pollution. It is especially expressed in thermal power plants with poor quality coal (lignite), which is the most consumed in thermal power plants in Obiliq, near the capital of Kosovo (Pristina), which produces about 97% of the total amount of electricity in Kosovo (Prishtina Institute for Political Studies, 2022). Ozone is a principal component of smog and can result in respiratory health and other environmental effects (Kim et al., 2020). Particulate matter (PM) includes dust and smaller particles with a maximum particle diameter of 10 microns (PM_{10}). In addition to PM_{10} emission standards, there are standards for $PM_{2.5}$, extremely small particles, that have a diameter less than 2.5 micrometers across. Based on current evidence $PM_{2.5}$ is thought to be the air pollutant which has the greatest impact on human health (EPA, 2025). Both short and long-term exposure to $PM_{2.5}$ increases the risk of mortality from lung and heart diseases (Prishtina Institute for Political Studies, 2022).

Coal-fired power plants are the biggest category of mercury emitters. Mercury is very volatile and can travel around in the atmosphere, repeatedly being deposited and re-emitted into the atmosphere. Mercury is deposited in lakes and rivers by rain, snow and surface runoff. While mercury is a pollutant with global consequences, the local impacts of mercury emissions from power plants also remain a serious concern (Singh et al., 2023). Ingested mercury can damage the nervous system, especially in children and fetuses (Environmental Impacts of Power Plants, 2023).

Coal power plants use water from lakes, rivers, municipal water utilities, or groundwater aquifers (Union of concerned Scientists, 2017). Surface water is often used for plant cooling, and groundwater is often used for plant processes. Power plants must discharge or dispose of process water someplace. Discharge locations range from streams or lakes to local municipal sewer systems that eventually discharge into streams or lakes. To handle the discharge, surface waters or sewer treatment systems must be able to absorb water that has been altered by the addition of heat, acids, or salts (Austin et al., 2017). Many of the physical and chemical substances in high concentrations in the water cause turbidity, reduce water plants' ability for photosynthesis, affect trophic chains, make difficulties for some species to find food, through sediments destroy feeding and spawn territories, as well as fill bottom of rivers and lakes, change flow of rivers, absorb and transport bacteria, pesticides or other hazardous substances on the surface of solid participles and eutrophication (Shah et al., 2023). Eutrophication is an increase in the concentration of chemical nutrients in an ecosystem to an extent that increases in the primary productivity of the ecosystem. Depending on the degree of eutrophication, subsequent negative environmental effects such as anoxia (oxygen depletion) and severe reductions in water quality may occur, affecting fish and other animal populations (Zaļoksnis, 2021).

Heated technological water, as a result of the cooling processes in thermal power plants, which is discharged into rivers or lakes without being treated beforehand, reduces the solubility of oxygen in the water and thus reduces the oxygen concentration. In this way the living species they become more susceptible to various diseases and later die (Wałkuska & Wilczek, 2010). Heated water generated by power plants or manufacturing plants may be controlled with cooling ponds, cooling towers, cogeneration etc. Industries and thermal power plants generate wastewater with high concentrations of conventional pollutants such as: ions of the metals, heavy metals, volatile organic compounds, total nitrogen including ammonia, phosphorus etc. Some industries have been successful at redesigning their manufacturing processes to reduce or eliminate pollutants, through a process called pollution prevention (Rodrigues Eugenio et al., 2018).

Soil contamination or soil pollution is caused by the presence of human-made chemicals or other alteration in the natural soil environment. Chemical pollution such as heavy metals from coal combustion residues in thermal power plants, migrate downstream through surface and underground channels (Altikulaç et al., 2022).

The aim of the present study is to: 1) Analyze the physicochemical properties of surface and groundwater affected by the thermal power plants Kosova A and Kosova B; 2) Evaluate the concentrations of major air pollutants and selected heavy metals in relation to the environmental impact of coal combustion; 3) Compare the obtained results with the applicable environmental quality standards and assess the potential risk to water, soil air quality, ecosystems, and human health in the surrounding areas.

Materials and methods

Study area

The map (Fig. 1) shows that the area of the Kosova A and Kosova B power plants is surrounded by urban and rural settlements, agricultural land, rivers and disposal sites. The close proximity of these industrial facilities to populated areas and natural resources increases the environmental impact of air, water, and soil pollution on nearby communities.

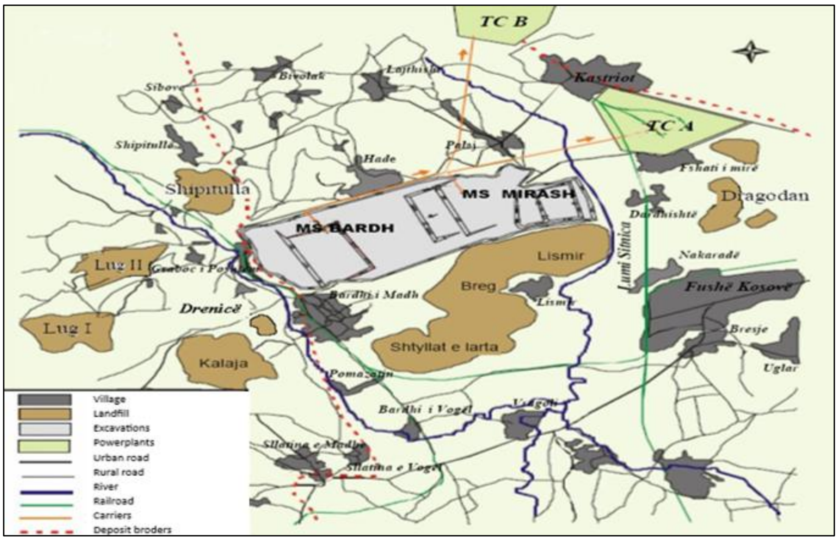

Fig 1. The spatial extent of the two termal power plants Kosova A (TC A) and Kosova B (TC B) near Pristina.

Sampling and analytical procedure

The physicochemical data presented in this study were obtained from official environmental monitoring reports conducted by the INKOS Institute, a licensed institution specialized in environmental and industrial analyses in Kosovo. The analyzed results refer to surface water and groundwater samples collected from several monitoring points associated with the thermal power plants Kosova A and Kosova B, including ash landfill discharge areas, industrial wastewater channels, and surrounding aquatic systems. Average annual values, reported in the official monitoring documentation, were used for interpretation and comparative assessment. Additional technical and contextual information regarding the energy sector and thermoelectric infrastructure in Kosovo was obtained from institutional reports and publications related to the Kosovo energy sector.

Air pollutants were measured using air quality monitoring instruments such as particulate matter sensors for $PM_{2.5}$ and PM_{10}, UV fluorescence analyzers for SO_2, chemiluminescence analyzers for NO_2, and NDIR analyzers for CO.

Water samples were analyzed using advanced laboratory methods, including atomic spectroscopy and other analytical techniques, to accurately determine heavy metal concentrations in environmental samples. In addition, water quality was assessed through laboratory analyses using instruments such as pH meters, dissolved oxygen meters, and spectrophotometric methods.

For all water flows coming out of the industrial area, KEK has engaged the external contractor Institute “INKOS” JSC to monitor air, water and soil pollution. KEK's contractor determines the quality of the discharged water by analyzing the physical-chemical parameters and carrying out bacteriological analyses, according to the permissible environmental standards established by the Law No. 04/L-147 for Kosovo Waters, and according to the Law No. 08/L-025 on protection of air from pollution.

In some points KEK also monitored the receivers (Sitnica River and Drenica River) in order to verify their quality and assess the damages (eventual pollution) that can be caused by its activities (Kabashi et al., 2016). The Sitnica River is the main catchment for the discharge of surface water from the Kosova A and Kosova B power plants.

The sampling points included both surface and underground waters influenced by thermoscentral activities and ash residues. In all waters discharged from Termocentrals (TC) Kosova A and Kosova B, weekly analyzes are performed at 12 sampling sites where 14 parameters are determined, monthly analyzes at 12 sampling sites where 24 parameters are determined and periodic (seasonal) analyzes at 12 sampling sites and 35 determined parameters (Fig. 2).

The analyzed physicochemical parameters included temperature, pH, electrical conductivity, turbidity, dissolved oxygen, suspended solids, chlorides, sulphates, nitrates, nitrites, phosphates, ammonium ions, total organic carbon, biological oxygen demand (BOD_5), chemical oxygen demand (COD), phenols, bicarbonates, and selected heavy metals such as iron (Fe), copper (Cu), cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), zinc (Zn), mercury (Hg), aluminum (Al), manganese (Mn), bromine (Br), and fluoride (F).

The obtained values were compared with permissible limit values (Table 1), presented in the monitoring reports and with applicable environmental quality standards for water assessment. The interpretation of results focused on identifying the influence of thermoelectric activities on the physicochemical quality of surface and groundwater resources in the surrounding areas (“INKOS” Institute, SH.A, 2023). The Table 2 presents the World Health Organization air quality guideline values for major air pollutants, including $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, CO, Cd, Pb, and Hg. The guidelines define permissible concentration limits based on different averaging periods in order to protect human health and environmental quality.

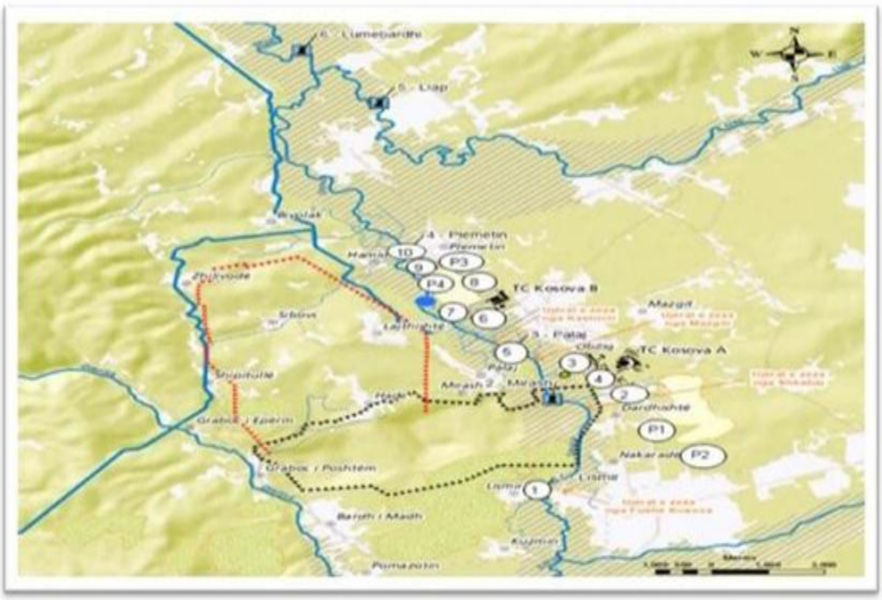

Fig. 2. Map of sampling sites in the thermal power plants Kosova A and Kosova B.

Table 1. Water quality and dissolved oxygen content in water.

Water Quality	Amount of Dissolved Oxygen (mg/l)
Excellent	8.0 – 9.0
Slightly	6.7 – 8.0
Moderately Polluted	4.5 – 6.0
Highly Polluted	<4.5

Table 2. World Health Organization air quality guidelines.

Air pollutant	Averaging time	WHO guideline value	Reference
$PM_{2.5}$	Annual mean	10 μg/m³	Recommended 2021 WHO AQG Air quality guidelines, compared to Global update - 2005
	24-hour mean	25 μg/m³	
PM_{10}	Annual mean	20 μg/m³	WHO (2000). Air Quality Guidelines for Europe – Second edition
	24-hour mean	50 μg/m³	
Ozone (O_3)	8-hour mean	100 μg/m³	
Nitrogen dioxide (NO_2)	Annual mean	40 μg/m³	
	1-hour mean	200 μg/m³	
Sulphur Dioxide (SO_2)	24-hour mean	20 μg/m³	
	10-minute mean	500 μg/m³	
Cadmium (Cd)	Annual mean	5 ng/m³	WHO (2000). Air Quality Guidelines for Europe – Second edition
Carbon Monoxide (CO)	1-hour	30 mg/m³	
	8 hours	10 mg/m³	
Lead (Pb)	Annual mean	0.5 μg/m³	
Mercury (Hg)	Annual mean	1 μg/m³	

Results and Discussion

Fig. 3 and Table 3 present the air emission limit values for dust, NO_x, and SO_2 during the 2021-2023 in accordance with EU environmental standards. The data show that the dust emission limit remained constant at 50 mg/Nm³ through-out the observed period, whereas the NO_x emission limits were gradually reduced from 500 mg/Nm³ in 2021 to 200 mg/Nm³ in 2023, indicating stricter environmental regulations. Meanwhile, the SO_2 emission limits remained unchanged at 400 mg/Nm³ during all three years.

In TC Kosova A in 2023 was produced 7.51% more electricity than in the previous year 2022 for the same time, which affects the increase in the emission of gases in the air (Table 4). The specific emissions in 2023 from TC Kosova A compared to 2022 were as follows: Dust -9.5% (↓), SO_2 +7.581% (↑), NO_x -15.8% (↓), and CO_2 +10.19% (↑) (Table 5).

In TC Kosova B the specific emissions in 2023 compared to 2022 were as follows: Dust -11.89% (↓), SO_2 -13.447% (↓), NO_x -30.909% (↓), and the specific emission of CO_2 was -4.4% (↓) (Table 5).

Table 3. Air Emission Limit Values in accordance with the EU Industrial Directive.

Polluter (VKE)	Year 2021	Year 2022	Year 2023
Dust (mg/Nm³)	**50**	**50**	**50**
NO_x (mg/Nm³)	**500**	**300**	**200**
SO_2 (mg/Nm³)	**400**	**400**	**400**

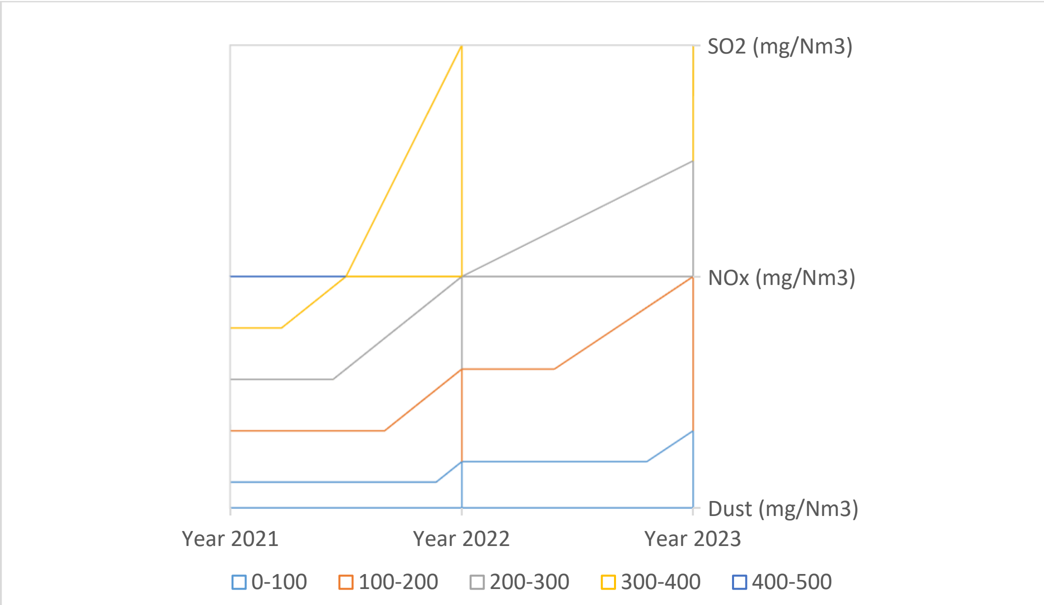

Fig. 3. Air emission limit values according to the EU.

Table 4. Average annual total and specific emissions for 2023 measured and calculated for the Kosova A and Kosova B Thermal Power Plants.

TC	Energy production, MWh	Pollutants	t/year	mg/Nm³	kg/MWh
TC-A	2240648	Dust	412.11	39.10	0.214
		SO_2	5452.1	441.20	2.520
		NO_x	7810.6	622.12	3.540
		CO_2	2830469	244.05	1251.21
TC-B	3359902	Dust	4569.1	302.25	1.222
		SO_2	8555	469.10	2.512
		NO_x	11274	614.5	3.355
		CO_2	3514489	195.51	1065.78

Table 5. Average specific emissions for TCA and TCB in 2023 and their difference in (%) compared to 2022.

TC Kosova	**Electric energy**			**Dust (mg/Nm³)**			**SO_2 (mg/Nm³)**			**NO_x (mg/Nm³)**			**CO_2 (mg/Nm³)**		
	Comparison by years in (%)														
	2023	**2022**	**%**	**2023**	**2022**	**%**	**2023**	**2022**	**%**	**2023**	**2022**	**%**	**2023**	**2022**	**%**
TC-A	2240648	2084002	7.51	40.18	44	-9.50	451.21	417	7.581	625.21	724	-15.801	245.55	273.44	10.19
TC-B	3359902	3641962	-7.74	305.64	342	-11.89	468.06	531	-13.447	613.4	803	-30.909	196.59	205.65	-4.4
EU* criteria				**50**			**400**			**500**			**-**		

EU* - Current emissions [(mg/Nm³) 6 (%)O_2 dry] and limits according to the European Commission

The physicochemical analyses of discharged surface and groundwater from Thermal Power Plant Kosova A indicate considerable deteriora-tion of water quality in several sampling points affected by industrial activities and ash disposal processes. Elevated turbidity and suspended solids were observed, particularly in the ash dump discharge area, suggesting intensive contamination by fly ash particles, coal residues, and sediment transport from disposal sites. The measured suspended materials exceeded the permissible limit values in several locations, reflecting a significant anthropogenic impact on the aquatic environment (Table 6).

The pH values were generally within acceptable ranges; however, electrical conductivity showed increased concentrations in some sampling points, indicating high mineralization and the presence of dissolved inorganic substances originating from industrial effluents. Dissolved oxygen concentrations were low in multiple samples, suggesting reduced self-purification capacity of the receiving waters and increased organic and chemical pollution load. In addition, elevated values of $KMnO_4$ consumption, BOD_5 and COD demonstrate substantial organic and oxidizable contamination associated with thermoelectric activities.

Phenols and nitrite concentrations approach or exceed permissible values in certain sampling points, indicating contamination related to coal combustion by-products and industrial wastewater discharge. Although most heavy metals such as cadmium, lead, mercury, and chromium remained below regulatory thresholds, increased concentrations of nickel, zinc, bromine, and aluminum were detected in some locations, suggesting localized contamination from ash disposal and technological processes.

Overall, the results demonstrate that the discharged waters from TC Kosova A exert significant pressure on surrounding surface and groundwater systems. The most critical indicators of pollution include high suspended solids, elevated conductivity, low dissolved oxygen, and increased concentrations of industrial pollutants, highlighting the necessity for improved wastewater treatment and environmental monitoring.

The physicochemical characterization of discharged waters from Thermal Power Plant Kosova B reveals notable alterations in water quality associated with thermoelectric operations and ash landfill discharges. Several sampling points exhibited highly alkaline conditions, with pH values reaching up to 10-11, significantly exceeding permissible standards (Table 7). Such alkalinity is commonly associated with fly ash deposition and the presence of alkaline compounds released during coal combustion processes.

Electrical conductivity values were elevated in several locations, indicating increased concentrations of dissolved salts and inorganic ions in the discharged waters. Furthermore, turbidity and suspended solids concentrations were substantially increased near ash disposal areas, reflecting the influence of industrial sediment and ash particles on surrounding water bodies. These findings indicate continuous transport of particulate matter from ash landfills into nearby aquatic systems.

Dissolved oxygen concentrations were below recommended levels in multiple sampling points, suggesting deterioration of ecological conditions and increased pollution stress within the receiving waters. Elevated BOD_5, COD, and $KMnO_4$ consumption values further confirm the presence of significant organic and chemical contamination related to industrial wastewater discharge.

Among inorganic pollutants, nitrite concentrations approached critical values in several samples, while phenols occasionally exceeded permissible limits, indicating contamination associated with coal-derived industrial effluents. Heavy metal analysis showed that cadmium, mercury, lead, and chromium generally remained below regulatory limits; however, increased concentrations of nickel, zinc, bromine, and aluminum were identified in selected sampling points, suggesting localized industrial influence and potential accumulation risks.

The findings of the present study are generally consistent with previous studies conducted in the Western Balkans and other regions where lignite-fired thermal power plants are the primary source of electricity. Although particulate matter (dust) emissions from Kosova A and Kosova B were below the current EU emission limit values, sulfur dioxide (SO_2) and nitrogen oxides (NO_x) remained above the recommended thresholds. Similar observations have been reported for coal-fired power plants in the Western Balkans, where aging combustion technologies and limited emission-control systems contribute to elevated gaseous emissions. These findings suggest that, despite improvements in dust control, additional measures are still required to reduce SO_2 and NO_x emissions and comply with European environmental standards (Kittner et al., 2018).

Table 6. Physico-chemical analyzes of discharged surface and underground waters from TC Kosova A.

	Average annual values in TC Kosova A sampling points								
	Sampling points							Subtoxic waters	
	Parameter	Measure unit	TCA (Lismir-Sitnicë)	TCA (The stream at Dardhish Bridge)	TC-A (waters)	Gasification (the main well)	TCA (Palaj Sitnicë)	TCA (the west ash dump)	Permissible limit values
			VM-1	**VM-2**	**VM-3**	**VM-4**	**VM-5**	**P 2**	**VKL**
1	Smell	-	w/o	w/o	w/o	w/o	w/o	faintly	w/o
2	Color	-	faintly	faintly	faintly	faintly	w/o	faintly	w/o
3	Temperature	(°C)	14.358	14.1583	16.6833	18.4333	14.7416	14.7	
4	Turbulence [NTU]	(mg/l)	23.457	30.0714	24.62	122.151	27.4	273.033	
5	pH value	-	7.7541	7.85083	8.3025	8.6175	7.3925	7.95	6.5÷9.0
6	Electrical Conductivity	(mS/cm)	631.50	765.775	550.75	573.275	562.858	2149.32	1500
7	Consumption of $KMnO_4$	(mg/l)	32.819	38.76	16.025	19.563	50.498	246.706	
8	Dissolved oxygen	(mg/l)	1.9800	3.3510	5.6500	8.7525	3.88916	5.40220	>4.5
9	Chlorides	(mg/l)	35.083	69.6666	30.8542	35.8958	30.4375	95.666	250
10	Nitrates, NO_3-N	(mg/l)	4.7166	2.62391	1.55025	1.10908	1.34358	2.557	20
11	Nitrites, NO_2-N	(mg/l)	0.6793	1.3411	0.4916	0.497	0.6013	6.7	0.6
12	Phenols	(mg/l)	0.0035	0.00533	0.00208	0.00908	0.00358	0.018	0.010
13	Sulphates	(mg/l)	42.191	56.525	28.0708	30.0833	34.1916	13.666	400
14	Phosphates	(mg/l)	4.0083	4.98	0.82417	0.92083	3.9758	4.6	
15	Suspended materials	(mg/l)	31.083	35.5	33.1458	125.5	31.916	550.333	35
16	BOD_5	(mg/l)	12.226	6.96833	5.97083	4.325	10.411	42.903	25
17	COD	(mg/l)	25.35	25.2166	20.65	25.558	23.383	74.433	125
18	Solidity [°dH]	(mg/l)	16.348	19.157	13.0529	12.12	14.9685	34.44	
19	phenolphthalein alkalinity [mval/l]	(mval/l)	0	0	0	0.4	0	0	
20	m-alkalinity [mval/l]	(mval/l)	5.3714	5.7	5.54286	3.357	5.08571	29	
21	Bicarbonates	(mg/l)	361.69	340.55	316.683	155.9	319.333	2562.33	
22	Ammonium ion, NH_4	(mg/l)	0.1308	0.22104	0.11063	0.165	0.04687	0.143	10
23	Total carbon	(mg/l)	13.771	15.9716	7.30083	9.961	12.7908	60.3	15
24	Iron (Fe)	(mg/l)	0.04	0.03	0.02	0.06	0.05	0.131	2
25	Copper (Cu)	(mg/l)	0.02	0.00866	0.005	0.013	0.013	0.024	0.5
26	Cadmium (Cd)	(mg/l)	< VKL	< VKL	< VKL	< VKL	< VKL	< VKL	0.02
27	Leaden (Pb)	(mg/l)	< VKL	< VKL	< VKL	< VKL	< VKL	< VKL	0.5
28	Nickel (Ni)	(mg/l)	0.0516	0.06033	0.02133	0.04533	0.04933	0.08566	0.5
29	Chromium (Cr)	(mg/l)	0.0166	< VKL	< VKL	< VKL	< VKL	< VKL	1
30	Zinc (Zn)	(mg/l)	0.3266	0.36333	0.04333	0.06333	0.37333	0.61	1
31	Mercury (Hg)	(mg/l)	< VKL	< VKL	< VKL	< VKL	< VKL	< VKL	0.01
32	Bromine (Br)	(mg/l)	4.3	7.9	28.6	22	4.4	1.4	
33	Aluminum (Al)	(mg/l)	0.19	0.14	0.18	0.12	0.19	0.15	
34	Manganese (Mn)	(mg/l)	0.009	0.014	0	0.034	0.01	0.11	
35	Fluoride (F)	(mg/l)	0.33	0.35	0.12	0	0.28	0	

VKL: Permissible limit value

Table 7. Physico-chemical analyzes of discharged surface and underground waters from TC Kosova B.

	Average annual values in TC Kosova B sampling points												
	Sampling points										Subtoxic waters		Permissible limit values
	Parameter	Mea-sure unit	**TCB** (Palaj Sitnicë)	**TCB** (base collection)	**TCB** (Techno-logical waters)	**TCB** (east landfill)	**Gasifica-tion** (the main well)	**TCB** (Pleme-tinë Sitnicë)	**Mirash** (the ash dump)		**TCB** (the east ash dump)		
			VM-5	**VM-6**	**VM-7**	**VM-8**	**VM-9**	**VM-10**	**VM-11**	**VM-12**	**P 3**	**P 4**	**VKL**
1	Smell	-	w/o	w/o	faintly	w/o	w/o	w/o	w/o	w/o	w/o	faintly	w/o
2	Color	-	faintly	w/o	faintly	w/o	w/o	w/o	w/o	w/o	w/o	faintly	w/o
3	Temperature	(˚C)	12.8	15.5	23.2	13.6	14.1	12.7	13.6	14.5	14.5	15.0	30
4	Electrical Conductivity	(mS/cm)	326.5	79.4	333.8	276.9	187.1	244.3	1063.1	1656.5	33.9	1309.2	1500
5	pH value	-	7.9	8.7	10.0	8.1	8.4	8.0	11.0	8.0	8.1	7.9	6.5-9
6	Chlorides	(mg/l)	42.6	23.4	21.3	49.4	37.2	37.0	231.4	54.4	35.0	218.5	250
7	Nitrates, NO_3-N	(mg/l)	3.81	1.5	1.7	3.6	3.2	6.1	13.0	3.9	1.3	16.7	20
8	Nitrites, NO_2-N	(mg/l)	0.332	0.052	0.085	0.024	0.041	0.327	0.403	0.139	0.032	0.530	0.6
9	Ammonium ion NH_4	(mg/l)	0.14	0.30	0.16	0.14	0.11	0.13	0.15	0.41	0.20	0.15	10
10	Dissolved oxygen	(mg/l)	2.140	4.75	3.97	4.31	8.55	3.87	5.46	5.03	3.42	2.30	>4.5
11	Sulphates	(mg/l)	40.4	14.9	48.9	74.8	42.7	43.4	210.7	214.3	153.0	353.3	400
12	Suspended materials	(mg/l)	45.1	14.0	167.7	25.8	33.8	29.8	9.7	20.4	62.0	103.3	35-60
13	Phenols	(mg/l)	0.005	0.002	0.010	0.003	0.004	0.006	0.011	0.005	0.005	0.009	0.01
14	Total organic carbon	(mg/l)	11.9	6.4	22.7	13.5	6.9	11.3	29.6	30.3	27.2	30.8	-
15	BOD5	(mg/l)	11.1	1.5	7.6	5.3	3.4	10.3	1.0	3.5	15.5	29.1	125
16	COD	(mg/l)	26.1	6.7	23.4	17.5	18.6	26.3	18.8	30.9	19.3	116.7	25
17	Phosphates	(mg/l)	5.0	1.3	1.5	1.6	1.6	4.6	1.9	2.1	4.9	4.2	10
18	H.$KMnO_4$	(mg/l)	27.1	14.8	67.4	25.7	15.6	28.2	55.5	59.0	49.9	0.0	-
19	Bicarbonates	(mval/l	365.1	99.6	47.4	363.0	208.5	323.1	18.3	364.2	240.0	212.6	-
20	Iron (Fe)	(mval/l	0.038	0.018	0.015	0.015	0.015	0.038	0.018	0.033	0.040	1.015	2
21	Copper (Cu)	(mg/l)	0.013	0.010	0.014	0.011	0.009	0.018	0.013	0.031	0.045	0.348	10
22	Cadmium (Cd)	(mg/l)	0.000	0.000	0.025	0.000	0.042	0.000	0.000	0.000	0.000	0.013	0.02
23	Leaden (Pb)	(mg/l)	0.011	0.021	0.002	0	0.013	0.021	0.062	0.033	0.011	0.018	0.5
24	Nickel (Ni)	(mg/l)	0.048	0.042	0.05	0.024	0.041	0.044	0.028	0.051	0.064	0.059	0.5
25	Chromium (Cr)	(mg/l)	0.000	0.000	0.002	0.000	0.000	0.000	0.02	0.03	0.12	0.03	0.5
26	Zinc (Zn)	(mg/l)	0. 31	0.04	0.16	0.22	0.04	0.36	0. 42	0.33	0.62	0.32	1
27	Mercury (Hg)	(mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
28	Arsenic (As)	(mg/l)	-	-	-	-	-	-	-	-	-	-	0.1
29	Bromine (Br)	(mg/l)	4.4	25.5	5.3	2.3	9.4	4.1	2.7	2.5	2.6	5.2	2
30	Aluminum (Al)	(mg/l)	0.186	0.18	0.15	0.117	0.098	0.183	0.159	0.24	0.14	0.166	0.01
31	Manganese (Mn)	(mg/l)	0.01	0.006	0.004	0.012	0.005	0.011	0.029	0.036	0.062	0.054	2
32	Fluoride (F)	(mg/l)	0.28	0.12	0.15	0.2	0.09	0.25	1.05	1.09	0.52	0.34	10

The results of the water quality assessment are also in agreement with previous investigations reporting that coal combustion residues and ash disposal sites may influence nearby surface water, groundwater, and soils. In the present study, most heavy metals remained below the permissible limits; however, localized increases in nickel, zinc, aluminum, and bromine were detected at selected sampling locations (Demaku et al., 2019). Similar enrichment of nickel and zinc around coal-fired power plants has been documented in Serbia, where these metals were associated with ash disposal areas and prevailing wind directions. Therefore, the contamination observed in the present study appears to be localized rather than widespread but still warrants continuous environmental monitoring (Ćujić et al., 2016). The obtained results indicate deterioration of several important water quality parameters, particularly in areas located near ash disposal sites and industrial discharge channels.

Elevated turbidity, high concentrations of suspended solids, increased electrical conductivity, and reduced dissolved oxygen levels were among the most significant indicators of environmental pressure identified during the analysis. In addition, increased concentrations of phenols, nitrites, and selected inorganic compounds suggest the influence of coal combustion residues and industrial wastewater discharges associated with thermoelectric production processes.

Although the majority of analyzed heavy metals remained below the permissible limit values, certain elements such as nickel, zinc, aluminum, and bromine showed increased concentrations in specific sampling locations, indicating localized industrial contamination and the potential for long-term environmental accumulation. Particularly concerning were the highly alkaline pH values detected in some discharge areas of TC Kosova B, reflecting the impact of ash landfill leachates and alkaline industrial effluents.

The rivers flowing through Kosova A Power Plant and Kosova B Power Plant, which receive discharged industrial wastewater from these facilities are so heavily polluted that aquatic flora and fauna are severely threatened; consequently, they are often described as "Dead Rivers".

Comparative evaluation of the two thermal power plants suggests that TC Kosova A exhibits more pronounced contamination related to suspended materials and particulate pollution, whereas TC Kosova B is characterized by stronger alkaline influence and elevated mineralization in several monitoring points. These findings are consistent with the operational characteristics and waste management practices of lignite-based thermoelectric facilities.

The main causes of environmental pollution from industrial activities include the incomplete implementation of laws and regulations aimed at controlling emissions and waste generated from coal combustion, as well as the weak enforcement of existing environmental standards. Another significant factor is the continued reliance on outdated and less efficient technologies, many of which have been in use for over 70 years despite having an operational lifespan of approximately 40 years, resulting in increased emissions and waste production. Furthermore, although Kosovo receives considerable support from the European Union for the development of renewable energy, political challenges have delayed the approval and implementtation of projects that promote cleaner and more sustainable environmental practices. The proposed new coal-fired power plant in Kosovo (Kosova C) could improve the energy sector system; however, it would not adequately address broader concerns related to carbon dioxide emissions as a greenhouse gas pollutant.

Conclusions

The physicochemical assessment of surface and groundwater affected by the thermal power plants Kosova A and Kosova B demonstrates a measurable impact of thermoelectric activities on the surrounding aquatic environment.

Overall, the study confirms that thermoelectric activities represent a significant source of physicochemical alteration of nearby water resources. Continuous environmental monitoring, improved wastewater treatment systems, and stricter implementation of environmental protection measures remain essential for minimizing the ecological impact of thermal power generation in Kosovo.

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