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COMPREHENSIVE ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBONS AS ORGANIC POLLUTANTS IN THE ECOSYSTEM COMPONENTS OF LAKE ZIGH: A CHEMICAL AND ECOLOGICAL ASSESSMENT

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Abstract

The aim of this study was to characterize the current environmental state of Lake Zigh, located in the southwest of the Absheron Peninsula. In August and October 2020-2023, a total of 84 samples were collected from Zigh Lake water, bottom sediments, and the soil cover of nearby areas. According to visual observations and physicochemical analyses, the concentration of nutrients exceeds the permissible levels by 2-10 times, while oxygen levels are 5-20 times lower, indicating an intense eutrophication process in the lake. An analysis of heavy metal concentrations in water, bottom sediments, and coastal soil samples revealed the highest and most hazardous levels. The highest levels of polycyclic aromatic hydrocarbons (PAHs) were observed in the coastal soil compared to water and bottom sediments. The concentration of naphthalene in the soil exceeded the permissible limit by 9-12 times, anthracene by 32-166 times, and benzo(a)pyrene by 30-80 times. To determine the levels of PAHs in the atmospheric air around Lake Zigh, biomonitoring was conducted using moss transplants (Moss Sphagnum girgensohnii Russow), which also revealed high PAH concentrations in the atmosphere. Due to years of negative anthropogenic impact, the ecological balance of the lake has been severely disrupted, leading to the loss of its natural properties. Therefore, urgent action is required from government authorities to implement a comprehensive action plan for the improvement and rehabilitation of Lake Zigh's ecological condition

Keywords: *Lake Zigh, organic pollutants, naphthalene, anthracene, benzo(a)pyrene, bottom sediments, biomonitoring*

Introduction

Anthropogenic impact on lake basins has increased over the past 100 years, especially over the past 10 years. As a result of this impact, both the morphological characteristics and the hydrophysical and biochemical properties of many lakes have changed.

Most of the tested water quality indicators of the lakes in terms of physicochemical parameters, spatial distribution of some trace elements and organochlorine compounds are above the permissible limits for water and pose a danger to biota and humans, so there is an urgent need to develop monitoring, management and mitigation strategies to prevent further pollution by restricting the discharge of industrial and agricultural wastewater into these lakes [1].

Extreme plant and algal growth are common due to excessive anthropogenic eutrophication, with exacerbations from dreissenid establishment and lake mixing (e.g., coastal upwelling events and nearshore-offshore water exchanges), resulting in nuisance algal blooms on the coastal shores of urban lakes [2].

Investments in agricultural intensification to fulfill food and economic demands of countries, which has led to increased use of fertilizers and pesticides, poses environmental risks to water bodies in agricultural catchments. As a result, nutrient and pesticide emissions have worsened the trophic status of lakes, shifting it towards hypereutrophic conditions [3].

The overall water quality analysis of some lakes and their main feeder rivers is classified as unsuitable for domestic use and for aquatic life. Multivariate methods and water quality index (WQI) approaches were applied for hydrochemical analysis based on 44 water quality parameters in Lake Ziway, Ethiopian Rift. The results of the analysis showed how anthropogenic activities in the watershed such as soil erosion, agriculture, industrialization and urbanization have had a significant impact on the lake's water quality and ecological integrity [4].

In many lakes, the observed eutrophication index and algal blooms may be due to intense anthropogenic activities and land use patterns around the catchment, indicating a high probability of untreated wastewater entering the lake through active inputs. This wastewater entering the lakes should be treated immediately to prevent further deterioration of the overall lake. Immediate restoration of the lake is recommended as hypereutrophic condition may lead to irreversible imbalance in the lake ecosystem [5].

The input of suspended sediment into watersheds affects total phosphorus levels in lakes, which in turn is largely related to precipitation, as well as hydrodynamics affecting biogeochemical processes and the response of algae to nutrient inputs are critical to understanding how an expected increase in extreme events will influence nearshore water quality in large lakes [6].

Heavy metal contamination in surface water is widespread throughout the world as a result of numerous anthropogenic activities, this pollution also affects aquatic life as fish can accumulate heavy metals in their tissues making them vulnerable. In summer season, water quality deteriorates compared to winter and becomes unsuitable for drinking purposes. The risk assessment of fish toxicity increases in summer indicating acute impact on human health compared to winter [7].

To determine the potential ecological risks of heavy metals in the bottom water of lakes, the content, distribution and speciation of nine heavy metals (As, V, Cr, Co, Ni, Cu, Zn, Cd and Pb) in the bottom water and sediment of Chaohu Lake were studied, and it was found that industrial sources (16%) are no longer the largest source of heavy metal pollution; traffic sources (33.6%) and agricultural sources (23.4%) have become the main sources of pollution at present. This

study can provide some support and suggestions for the treatment of heavy metals in lakes [8].

Artificial neural networks offer a viable way to assess and understand the presence and concentration of heavy metals that may cause dangerous complications in the broader context of predicting water quality for ecosystem sustainability. The artificial neural network model is a good predictive tool that can be effectively used to determine the contamination of lakes with heavy metals as part of the efforts to protect the water balance of lakes and eliminate existing contamination [9].

In addition, the agricultural non-point source pollution forecast in highly urbanized areas was carried out based on the general socio-economic pathways using Lake Taihu as an example, and a localized parameter system was constructed to forecast the rural population and economy from 2020 to 2050. It was found that the overall pollution will decrease, but the rate of decline will gradually slow down, and the pollution caused by rural production and life will be difficult to completely avoid [10].

In the near future, the environmental situation of the Absheron lakes may deteriorate even further due to the planned intensive development of the oil industry on the peninsula and in the Azerbaijani sector of the Caspian Sea. The discharge of wastewater from mines, terminals, and other industrial facilities into these lakes could have a serious impact on their ecological state. Therefore, establishing continuous environmental monitoring of the lakes and implementing strict control over changing conditions is currently one of the most pressing environmental challenges**.**

Environmental experts also believe that the main cause of pollution in the Absheron lakes is the lack of a unified sewage system on the peninsula, leading to untreated wastewater from new residential developments and industrial enterprises being discharged directly into nearby lakes. The main goal of our research was to determine the current ecological state of Lake Zykh by assessing the level of pollution with heavy metals, polycyclic aromatic hydrocarbons, and other contaminants in natural waters, bottom sediments, and soils of the surrounding areas of the lake.

Experimental Part

In August and October of 2020–2023, 21 water samples were collected from 7 observation points, 21 sediment samples from 7 observation points, and 42 soil samples from 14 observation points in the area around the Lake Zigh (Fig. 1). Analyses were conducted based on various parameters.

During the field and laboratory studies, the following works were carried out:

- ✓ the location of solid waste at the bottom of the lake has been identified;
- ✓ sediment samples and lake water samples were collected to study the bottom deposits of the lake;
- ✓ soil samples were taken from the area surrounding the lake;
- ✓ an inventory of wastewater discharges around the lake was conducted, and ongoing monitoring continues. Wastewater and groundwater samples were collected, and atmospheric pollution and radiation levels were measured;
- ✓ water samples were taken from various depths across the lake. It was found that salinity increases from west to east.

Fig. 1. The location of observation stations on Lake Zigh

Lake Zigh Water Quality. Water quality parameters in Lake Zigh can vary significantly depending on the season. Water samples were collected from the lake area in August and October of 2021-2022 [11,12]. The salinity of the water ranges from 48.6 to 53.5 g/L, increasing from east to west. During winter and spring, salinity can decrease by half, depending on the lake's water level.

Since most lakes in the region are constantly exposed to: oily and iodized waters, rainwater runoff from contaminated soils, heavily polluted bottom sediments.

The level of petroleum pollution is extremely high. Pollution levels increase during warm months. The total hydrocarbon content in the lake ranges from 3,331 to 7,300 mg/L, increasing from west to east. On calm days, the lake's surface is completely covered with an oil slick.

Surface Waters Entering Lake Zigh. As previously mentioned, wastewater and rainwater enter Lake Zigh from five locations. However, these sources operate intermittently and temporarily. The inflow of water into the lake mainly occurs during the rainy season.

During field studies, wastewater from Zigh and nearby settlements was observed flowing into the lake. Since the wastewater travels long distances and passes through ponds before reaching the lake, its chemical composition may change. The salinity of the discharged water was measured at 34.5 g/L. The pollution levels of wastewater from petroleum products ranged between 18–578 mg/L. At the point of entry into the lake, the concentration was 144 mg/L [13].

Groundwater. The analysis of groundwater samples, collected from wells drilled in the area around Lake Zigh, shows that the groundwater enters from two sources:

1) domestic wastewater: This water has lower mineralization levels, ranging from 1.1 to 15.5 g/L;

2) groundwater: Groundwater from more distant areas have a higher level of mineralization, ranging from 27.9 to 50.2 g/L.

Since the groundwater is located close to the surface, oil contamination is observed in all the wells.

Water Contamination Analysis. Determination of physicochemical parameters in water samples taken from Lake Zigh. Determination of pH, electrical conductivity, temperature, amount of dry residue and dissolved oxygen in natural water samples taken from Lake Zigh was carried out using the device "Water Quality Meter" 850081 [14].

Determination of nitrates in natural water samples. The content of nitrate ions in water samples taken from Lake Zigh was determined using a spectrometric method. The methodology according to the international standard ISO 7890-3 is intended for determination of surface, ground and drinking waters [15, 16].

Determination of nitrites in natural water samples. A spectrometric method with the Griess reagent was used to determine nitrites in natural water samples taken from Lake Zigh [15, 16].

Determination of phosphates in natural water samples. A spectrometric method was used to determine phosphate ions in natural water samples taken from Lake Zigh [14].

Determination of ammonium ion in natural water samples. A spectrometric method using the Nessler reagent was used to determine ammonium ions in natural water samples taken from Lake Zigh [15, 16].

The amount of heavy metals in water, soil and bottom sediment samples was determined using atomic absorption spectrometry (AAS) [17-20].

Atomic absorption spectroscopy is the most widely used method for analyzing water from various sources [17-20]. Extraction methods are widely used to determine elements in collected water samples. Determination of heavy metals in samples collected from Lake Zigh was carried out using the ZEEnit 700 P device. Water, sediment, and soil samples from the surrounding area of the lake were analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) [21,22]. The combined use of AAS and GC-MS provides a comprehensive analysis of water pollution in Lake Zigh. While AAS focuses on heavy metals, GC-MS detects petroleum-related organic pollutants.

The liquid extraction method was used to prepare water samples from Lake Zigh [23-26]. Water samples (0.5 L) were extracted three times with 30 mL of dichloromethane, dried over anhydrous sodium sulfate, and concentrated on a rotary evaporator until the residual volume was 1 mL. Deuterated naphthalene and phenanthrene were used as internal standards. Similarly, bottom sediment and soil samples from coastal areas weighing 1.4 and 1.6 g were collected from the lake, extracted three times with 30 mL of dichloromethane, dried over anhydrous sodium sulfate, and concentrated on a rotary evaporator until the residual volume was 1 mL. Deuterated naphthalene and phenanthrene were used as internal standards. Determination of organic compounds in the samples was carried out on a chromatograph mass spectrometer (GC-MS, Agilent, USA) HP6890 in one-dimensional and two-dimensional modes. Ionization energy 70 eV. Capillary silicon column RTX-5MS (30 m), temperature conditions: 40°C (2 min.) - 20°C/min. - 300°C (10 min.).

Bottom Sediments Analysis. The thickness and volume of the contaminated bottom

sediments in the northern part of Lake Zigh have been determined. The thickness of polluted sediments gradually decreases from north to south - from 3.3 meters to 0.8-1.2 meters across the lake basin - before increasing again to 2.4 meters along the northern dam.

Based on mapping, the total volume of contaminated sediments was estimated at 490-360 m^3. Sediment samples were collected from various depths (1m, 2m, 3m) using a specialized submersion device. The highest contamination levels were observed at a depth of 1 meter. Oil pollution was visually apparent in the bottom sediments. Heavy metals in the samples were measured using atomic absorption spectrometry (AAS) with a ZEEnit 700 P spectrometer. Organic compounds were identified using a gas chromatography-mass spectrometry (GC-MS) system (Agilent, USA, HP6890).

21 bottom sediment samples were collected from 7 locations and analyzed for total petroleum hydrocarbons and PAHs. Heavy metals such as As, Cd, Co, Cu, Hg, Pb, Ni and Zn were detected in the bottom sediment samples [18-20, 27,28].

Soil Contamination Analysis. In the dry part of Lake Zigh, a natural soil layer is almost completely absent. This is due to the disposal of materials from demolished buildings, oil sludge, and solid waste in the area. Additionally, in many locations, the soil layer has been removed, making it difficult to distinguish between the natural and disturbed soil layers.

In the surveyed areas, the natural soil cover is absent. Soil samples were collected from various depths using drilling methods, revealing that pollution is more concentrated in the upper layers.

The study of surface and subsurface contamination in the coastal soils was conducted using various methods [29]. Excavations confirm that the area has been polluted at different times. The average thickness of the contamination layer across the entire study area is 1.44 meters. The total volume of oil-contaminated soil is estimated at 288 m^3 at an average depth.

A total of 42 soil samples were collected and analyzed to assess soil contamination at different depths. The analysis focused on determining the total petroleum hydrocarbons (TPH) and their fractional composition (TPH (C10-C40)), as well as benzene, toluene, ethylbenzene, xylene (BTEX), aromatic compounds, and polycyclic aromatic hydrocarbons (PAHs) [30].

Additionally, the concentrations of heavy metals, including arsenic (As), cadmium (Cd), cobalt (Co), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), and zinc (Zn), were measured in soil samples collected from various parts of the area [11, 12, 17, 18, 31, 32].

The heavy metal content in soil samples was determined using the atomic absorption spectroscopy (AAS) method. Soil samples were fused with lithium metaborate at a temperature of 400-500°C, then dissolved in hydrofluoric (HF) and perchloric ($HClO_4$) acids. A mixture of several acids was used for soil sample dissolution: $HNO_3 + H_2O_2$; $HNO_3 + HClO_4$; $HNO_3 + HCl$.

Waste Pollution in the Zigh Lake Area. For many years, the Zigh Lake region has been used as an illegal dumping ground for solid waste, significantly impacting the environmental condition of the lake. Since the second half of the 19th century until 2016, various types of waste have been dumped into the lake, including: liquid and solid oil sludge; construction and demolition debris; municipal solid waste; industrial waste; household and sewage wastewater. From 2016 onwards, after the territory came under the management of Tamiz Shahar OJSC,

unauthorized dumping has been partially controlled. Despite improved waste management efforts, illegal dumping continues in the southern part of Zigh settlement, where the lake is located. Environmental impact:

- oil sludge and industrial waste have led to severe soil and water contamination;
- heavy metals and hydrocarbons persist in lake sediments, posing a serious ecological threat;
- toxic waste affects groundwater quality, making it unsafe for consumption or use [27].

Additionally, during our parallel studies, we calculated the areas of oil-contaminated sites in the eastern part of the territories surrounding Lake Zigh (Fig. 2).

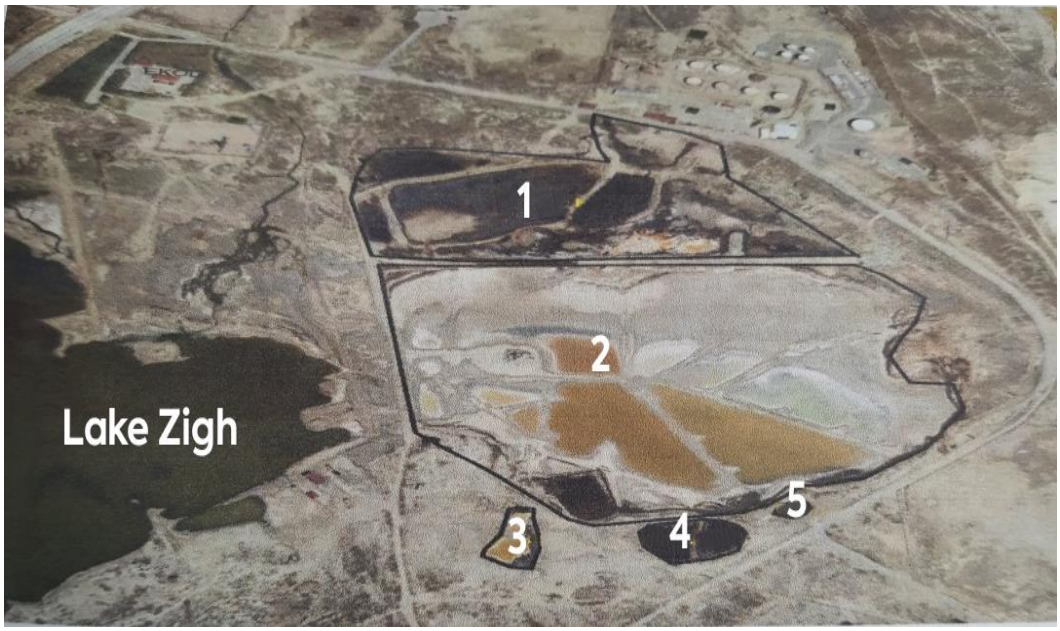

Fig. 2. Oil-contaminated areas in the eastern surroundings of Lake Zigh:

- area of oil-contaminated land: 1 - 9.0 ha; 4 - 0.5 ha; 5 - 0.1 ha;
- areas contaminated by formation waters: 2 - 19.7 ha; 3 - 0.3 ha

Radiation level. Radiation levels were measured in all samples (soil, air, water) collected during the field studies. In all samples, radiation levels were at or near the natural background level (7-18 μR/h) [33].

Results And Discussion

The Absheron Peninsula is located at the easternmost part of our republic and covers an area of approximately 2.000 km². Since a moderately hot semi-desert and dry steppe climate with arid summers forms here, the long-term average air temperature is 13.5–14.0°C, while the annual amount of atmospheric precipitation varies unevenly across the territory, ranging from approximately 150 to 300 mm. According to meteorological observations from 1991 to 2018, the average annual precipitation is 302 mm. The main evaporation on the Absheron Peninsula occurs

during the warm period of the year (April–October). The estimated potential annual evaporation is 1,200 mm.

The river network on the Absheron Peninsula is almost nonexistent. The channels of several small rivers flowing from the western outskirts of the peninsula dry up for most of the year, and during brief wet periods, mineralization levels exceed 1 g/kg [33].

Arid-denudation processes, ravines, depressions, erosion, suffosion processes, etc., which are characteristic of the region's arid climate, define the relief of the peninsula. In the lower parts of most valleys and depressions, salt marshes and saline lakes have formed.

There are about 800 natural lakes in our country, approximately 100 of which are located on the Absheron Peninsula. This area is the most lake-rich region of our republic. Lakes cover 2.5% of the peninsula's area, which accounts for 2.0% of the country and 0.35% of the world's total.

Every year, 41.5 million cubic meters of wastewater are discharged into these lakes. The environmental impact of these lakes includes soil degradation and salinization, flooding of additional areas due to rising water levels, emissions of hydrocarbons and other harmful substances into the atmosphere due to evaporation, as well as damage to settlements, enterprises, roads, and other communication lines.

Up to 3 million people live on the Absheron Peninsula, and more than 70% of the industrial potential of the Republic of Azerbaijan is concentrated in this area. Therefore, the protection and improvement of the environment in this region are of paramount importance for ensuring environmental security and the sustainable development of the country as a whole [33].

Lake Zigh is a lake with a large water surface area and a tense ecological situation among the lakes of Absheron. Lake Zigh is located in the southwest of the Absheron Peninsula, in Baku, the capital of Azerbaijan. Lake Zigh borders on the Surakhani and Yeni Guneshli mountain ranges in the north, on the Khatai district in the west, on the Caspian Sea in the south, and on the village of Hovsan in the east. Lake Zigh has a surface area of 20 hectares and a depth of 1.5 m. It is fed by domestic and industrial wastewater, as well as groundwater coming from the territory of the village of Zigh. The annual volume of domestic wastewater discharged into the lake is 1.826.000 cubic meters, industrial waste – 73.000 cubic meters. Since sewage systems have not been built in the residential areas of Zigh, the discharge of domestic wastewater into the lake and adjacent areas further worsens the environmental situation.

According to observations, the depths in open areas of the lake are 3.40-3.95 m, and the maximum depth is 4.20 m. The depth in the nearby parts of the lake varies between 0.50-1.70 m. The lake has an oval shape, a length of 10 km, stretched from the northwest to the southeast, the maximum width is 1.5-2.0 km. Currently, Lake Zigh is a closed basin into which groundwater from all nearby territories is directed. The area of the lake's water surface is 1,300 hectares, and its volume is 45 million cubic meters. Wastewater is discharged into Lake Zigh by household, commercial and other facilities, as well as private residential buildings built around the lake in the Surakhani, Khatai and Nizami districts of the city and not equipped with sewerage systems. Currently, 18 thousand m^3 of industrial and domestic water from 49 sources enters the lake daily.

One of the main sources of pollution of the lake is the discharge of oil field waters into the lake, which were formed during oil production in nearby areas, starting in the 1930s.

According to statistics, oil and mine waters have been discharged into the lake since 1929. 60% of this water was extracted directly during drilling, and the rest was used in mines and taken directly from the sea through water pipes. Since the 1970s, fecal, domestic and industrial wastewater has been discharged into the lake. Domestic and fecal waters were discharged into the lake without prior treatment, unsystematically, through open channels and depressions, which significantly worsened the sanitary condition of the area, and the bottom of the lake and the shoreline were covered with a layer of bitumen from oil products (Fig. 3). In hot weather, as a result of the evaporation of oil products, light fractions of oil are released into the atmosphere, causing a pungent odor.

Based on its water mineralization level, Lake Zigh belongs to the group of brackish lakes, with its water mineralization far exceeding the maximum permissible concentration. The lake's oxygen regime is completely disrupted. One of the main reasons for the low dissolved oxygen content in the lake's water is the acceleration of biological processes due to the oxidation of pollutants. As a result, the biochemical oxygen demand in Lake Zigh is several times higher than the norm.

Due to natural factors and the discharge of wastewater into the lake, the mineralization of Lake Zigh’s waters increases, along with the concentration of cations and anions in the water [27,33]. The levels of calcium, magnesium, and chlorides [31] significantly exceed sanitary standards, while sulfate concentrations are several times higher [32]. The concentrations of petroleum products and phenols, the lake's primary pollutants, also far exceed the maximum permissible limits [13, 30].

Synthetic detergents are also present in excess in the lake. The primary pollutants in the lake include heavy metals such as cadmium, arsenic, lead, mercury and nickel, with concentrations several times exceeding the permissible limits [27].

The salinity level and chemical composition of groundwater serve as indirect indicators confirming their origin. The low salinity in many wells in the area proves that groundwater is fed by domestic wastewater from the settlement of Zigh. Increased salinity (≥40 g/L) is characteristic of water found in the second aquifer from the surface. These waters flow into the lake from the Surakhany oil field. Wastewater and rainwater from the Zigh settlement enter Lake Zigh through surface water inflows. According to monitoring results, the volume of these waters ranges from approximately 1800-2000 m^3/day, depending on the season. On rainy days, the water discharge can increase to 2500-3000 m^3/day.

Considering these factors, we conducted an environmental monitoring study of the water, sediment, and soil cover in the area surrounding the lake to determine the current state of Lake Zigh [27]. The results of field and laboratory studies are presented below (Tab. 1,2).

Table 1. Analysis of water samples from Lake Zigh on 01.02.2023

Physical and chemical parameters	Unit	MPC	Lake Zigh
Smell	–		swamp
Color	–		yellowish
pH	–	6.5-8.5	8.0
Dissolved oxygen	mgO_2/L	≥4.0	0.4
Electrical conductivity	μCm/cm	–	70.3
Turbidity	FTU(NTU)	<5	20.4
Transparency	cm	>30	24
Hardness	mg/L	7.0	130.1
Calcium, Ca	mg/L	180	1825.0
Magnesium, Mg	mg/L	50	474.6
Chlorine ion, Cl^-	mg/L	350	40221.6
Sulfate ion, $SO4^{2-}$	mg/L	500	2357.2
Hydrocarbonate ion, HCO_3^-	mg/L	400	500.4
Synthetic surfactants, SSAM	mg/L	<0.5	1.86
Petroleum hydrocarbons	mg/L	0.05	0.23
Intestinal bacteria group (IBG)	unit/L	2 000	1 980 000
Escherichia coli (E. coli)	unit/L	1 000	1 560 000
Enterococci	unit/L	–	1 070 000

As can be seen from Tab. 1, the amount of dissolved oxygen in the lake water samples is 10 times less than the norm. It was found that the turbidity of the water was 4 times higher, the hardness was 18 times higher, the amount of chloride, sulfate, hydrocarbonate, calcium, magnesium ions was many times higher than the permissible concentration, the Intestinal bacteria group was 990 times higher, and E.coli was 1560 times higher. The amount of synthetic surfactants also exceeds the permissible concentration many times [13]. The water in the lake is very turbid and has a swampy smell. The oxygen regime of the lake water is disturbed. The oxygen concentration is 10 times lower than the sanitary norm.

Table 2. Physical and chemical parameters of water samples taken from Zigh lake

Physical and chemical parameters	Unit	Sampling stations (S)							MPC [13]
		S1	S2	S3	S4	S5	S6	S7	
pH			7.5	8.38	8.1	7.8	7.9	8.2	6.5-8.5
Dissolved oxygen	mgO_2/L	0.7	0.2	0.8	0.5	0.85	0.55	0.3	≥4.0
NO_3^-	mg/L	48.12	58.46	52.22	47.1	48.9	53.9	46.7	45.0
NO_2^-	mg/L	1.23	1.25	1.8	1.2	2.26	2.34	2.9	3.3
NH_4^+	mg/L	1.35	1.47	4.3	2.9	4.86	2.59	3.9	0.5
PO_4^{3-}	mg/L	4.88	4.72	5.36	8.2	7.51	6.7	6.4	3.8

Maximum permissible concentrations (MPC) for surface waters are taken from the document “Rules for the protection of surface waters from pollution by wastewater”, approved by

the State Committee for Ecology and Nature Management of the Republic of Azerbaijan by order No. 01 dated January 4, 1994.

As can be seen from Tab. 2, the amount of ammonium ions in the lake water samples exceeds the MPC by 2-10 times, and phosphate ions by 1.2-2.2 times [23-26]. The oxygen concentration is 5-20 times lower than the sanitary norm.

The water of Lake Zigh is characterized by a critically low concentration of dissolved oxygen (hypoxia), as well as significantly elevated levels of ammonium nitrogen (NH_4^+) and phosphates (PO_4^{3-}), indicating pronounced eutrophication and substantial input of organic and nutrient-rich substances into the aquatic system. These parameters reflect active organic matter decomposition processes and the predominance of anaerobic conditions in the water environment, accompanied by disturbances in the natural biogeochemical cycles of nitrogen and phosphorus. Although the pH values remain within the acceptable range and do not indicate extreme acid–base conditions, this is insufficient to sustain a stable ecosystem. The severe oxygen deficiency suppresses aerobic processes, inhibits the survival of aerobic organisms, and promotes the development of anaerobic microbial communities. This shift leads to the formation of toxic reduced compounds, such as hydrogen sulfide and ammonia, further deteriorating water quality. Overall, the observed hydrochemical conditions create an unfavorable environment characterized by high toxicity and low biological productivity. This results in a sharp decline in biodiversity, disruption of trophic interactions, and ultimately the near-complete disappearance of aquatic organisms. The findings indicate a profound degradation of the lake ecosystem and its transition into an ecologically critical state, where natural self-purification processes are severely impaired. As can be seen from Tab. 3, the amount of nitrogen, phosphorus and Al in the bottom sediments taken from the lake exceeds the permissible concentration; in particular, the amount of nitrogen exceeds the norm by 2.5-4.5 times, and the amount of phosphorus by 1.4-1.7 times. The content of calcium does not exceed the permissible concentrations [13, 25].

The amount of radiation in the bottom sediments taken from Lake Zigh is 14-23 μR/h [33].

Table 3. Amount of inorganic substances in the bottom sediments of Lake Zigh

Inorganic substances	Unit	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
Nitrogen	mg/kg gm	124	112	106	132	178	155	40
Phosphorus	mg/kg gm	38.46	42.18	44.32	46.7	45.9	43.9	27.2
Calcium	mg/kg gm	93.12	108.69	85.71	187	193	254	430
Aluminum	mg/kg gm	126.41	129.7	136.3	123	117	189	105

As can be seen from the table of results of the analysis of physical and chemical parameters of soil samples, the amount of total phosphorus in the soil samples around the lake exceeds the permissible concentration by 1.3-1.8 times, the amount of total nitrogen by 1.6-4 times, and the amount of total phosphate by 1.5-3.4 times (Tab. 4). Only the content of total iron does not exceed the permissible concentration [13].

Table 4. Physicochemical parameters of soil samples

Inorganic substances	Unit (gm-dry matter)	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
Total Phosphorus	mg/kg gm	37.96	34.25	37.20	50.14	43.5	40.2	27.2
Total Nitrogen	mg/kg gm	128	158	108	86	58.9	65	40
Total Iron	mg/kg gm	120.1	106.6	111.9	115.55	210	298	4000
Total Sulfate	mg/kg gm	214.5	247.25	262.0	257.38	221.9	334.7	160
Total Phosphate	mg/kg gm	257.4	160.4	113.8	178.2	175.8	187.3	76.8

As can be seen from Tab. 5, the amount of some heavy metals found in water samples taken from the lake exceeds the permissible concentration by many times [13]. The analysis of heavy metal concentrations in the lake water revealed significant spatial variation and indicated considerable anthropogenic impact on the aquatic environment. The measured concentrations were compared with the maximum permissible concentrations (MPC), allowing for an assessment of pollution levels and ecological risks.

Among the analyzed elements, mercury (Hg), cadmium (Cd), lead (Pb), and nickel (Ni) showed substantial exceedances of MPC values across all sampling stations. Mercury concentrations ranged from 0.9 to 2.5 μg/L, exceeding the guideline value (0.50 μg/L) by approximately 2–5 times. Given the high toxicity and bioaccumulative nature of mercury, its presence poses a serious threat to aquatic ecosystems. Cadmium concentrations varied between 3.6 and 16.3 μg/L, exceeding the MPC (1.0 μg/L) by up to 16 times. Such elevated levels are typically associated with industrial discharges and indicate strong technogenic pollution. Similarly, lead concentrations (41.2–57.5 μg/L) exceeded the permissible limit (30 μg/L) at all sampling points, suggesting persistent contamination, possibly from urban runoff or industrial sources.

Nickel was identified as one of the dominant pollutants, with concentrations ranging from 342 to 839.4 μg/L, which is 3-8 times higher than the MPC (100 μg/L). This indicates a significant and widespread source of contamination affecting the entire water body. In contrast, arsenic (As), copper (Cu), cobalt (Co), and zinc (Zn) remained within acceptable limits at all sampling stations. Arsenic concentrations (9.69-41.25 μg/L) did not exceed the MPC of 50 μg/L. Copper and zinc levels were also well below their respective thresholds (1000 μg/L), while cobalt concentrations were negligible compared to the permissible limit. Despite being within regulatory limits, the presence of these metals contributes to the overall chemical load of the system.

Spatial analysis showed that station S2 exhibited the highest overall contamination, particularly with respect to cadmium and nickel. Stations S4 and S5 also demonstrated elevated levels of lead and mercury, while station S3 was relatively less polluted, although still exceeding MPC values for several toxic elements. The combined presence of multiple heavy metals exceeding permissible limits suggests a cumulative toxic effect on the aquatic environment. Such conditions are known to disrupt physiological processes in aquatic organisms, inhibit reproduction, and lead to biodiversity loss. These findings are consistent with field observations indicating the absence of fish and other aquatic life in the lake.

Overall, the results demonstrate that the lake water is heavily contaminated with toxic

metals, primarily Hg, Cd, Pb, and Ni, reflecting strong anthropogenic pressure. The observed contamination levels, together with previously identified low dissolved oxygen concentrations and elevated nutrient levels, indicate a degraded and ecologically unstable system. The lake can therefore be classified as a highly polluted water body, unsuitable for sustaining aquatic life and requiring urgent environmental management and remediation measures. The maximum permissible concentrations (MPC) for lake water are taken from the document "Rules for the Protection of Surface Waters from Pollution by Wastewater", approved by the State Committee for Ecology and Nature Management of the Republic of Azerbaijan by order No. 01 dated January 4, 2011 [37].

Table 5. Amount of heavy metals in lake water samples

Metals	Unit	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
As	mkg/L	34.27	41.25	9.69	19	23	36	50
Hg	mkg/L	1.78	1.67	1.16	2.5	2.1	0.9	0.50
Cd	mkg/L	10.5	16.3	4.8	3.6	4.1	8.7	1.0
Cu	mkg/L	42.59	332.5	171.4	231	186	346	1000
Co	mkg/L	1.31	1.26	1.25	3.8	4.3	2.8	100
Pb	mkg/L	41.2	45.6	43.7	57.5	53	47	30
Ni	mkg/L	479.5	839.4	369.2	342	543	515	100
Zn	mkg/L	128.4	142.02	100.49	214	356	432	1000

The analysis of heavy metal concentrations in bottom sediments revealed selective contamination and spatial variability across the sampling stations. The obtained values were compared with established maximum permissible concentrations (MPC) to evaluate the degree of pollution and potential ecological risks. Among the analyzed elements, arsenic (As) and mercury (Hg) showed notable exceedances of MPC values. Arsenic concentrations ranged from 49 to 97.57 mg/kg, significantly exceeding the guideline value of 10 mg/kg by approximately 5-10 times at all sampling stations. This indicates substantial and long-term accumulation of arsenic in the sediments, which may be associated with both anthropogenic inputs and natural geochemical background. Mercury concentrations varied between 1.2 and 6.93 mg/kg, exceeding the MPC (2.1 mg/kg) at several stations, particularly S1, S4, and S5. Given the high toxicity and mobility of mercury, its accumulation in sediments represents a serious environmental concern, as it can be remobilized into the water column under changing redox or pH conditions. Zinc (Zn) concentrations ranged from 12.32 to 32 mg/kg and slightly exceeded the MPC value (23 mg/kg) at station S6, indicating localized contamination. However, in most sampling points, zinc levels remained within acceptable limits. In contrast, cadmium (Cd), chromium (Cr), copper (Cu), cobalt (Co), lead (Pb), and nickel (Ni) were all found to be below their respective MPC values. This suggests that, for these elements, the bottom sediments are not significantly contaminated and do not currently pose a major environmental risk. Spatial distribution analysis showed that station S3 had the highest arsenic concentration, while station S4 exhibited the maximum mercury content. The distribution of other metals was relatively uniform, indicating the absence of strong localized sources for most elements, except for minor zinc enrichment at S6. From an ecological perspective, bottom sediments act as both a sink and a potential secondary source of heavy metals. The elevated concentrations of arsenic and mercury suggest that the sediments

have accumulated contaminants over a prolonged period and may contribute to ongoing pollution of the water column through remobilization processes.

Although most metals were within permissible limits, the significant enrichment of arsenic and mercury highlights a potential ecological risk. These findings, in combination with previously observed heavy metal contamination in water and unfavorable physicochemical conditions, indicate a degraded aquatic system. The sediments thus play a critical role in maintaining the overall contamination level of the lake and may hinder natural recovery processes. Overall, the results demonstrate that bottom sediments are moderately to heavily contaminated with specific toxic elements, particularly arsenic and mercury, and represent an important factor in the persistence of environmental degradation in the lake ecosystem [28].

Table 6. Amount of heavy metals in bottom sediments

Metals	Unit	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
As	mg/kg	77.13	64.87	97.57	56	49	63	10.0
Cd	mg/kg	0.66	0.39	0.387	0.5	0.7	0.4	1.0
Cr	mg/kg	0.1	0.2	0.18	0.25	0.4	0.5	100
Cu	mg/kg	3.71	3.54	7.15	5.12	4.73	4.8	55
Co	mg/kg	1.23	1.28	1.35	0.9	0.8	0.75	5.0
Hg	mg/kg	5.19	3.03	1.8	6.93	4.5	1.2	2.1
Pb	mg/kg	0.81	0.59	1.56	1.8	1.9	1.3	32.0
Ni	mg/kg	0.48	0.532	0.44	0.8	0.6	0.79	85
Zn	mg/kg	15.86	14.08	12.32	17	23	32	23.0
Fe	mg/kg	101.9	108.52	110.7	84	82	78	40000

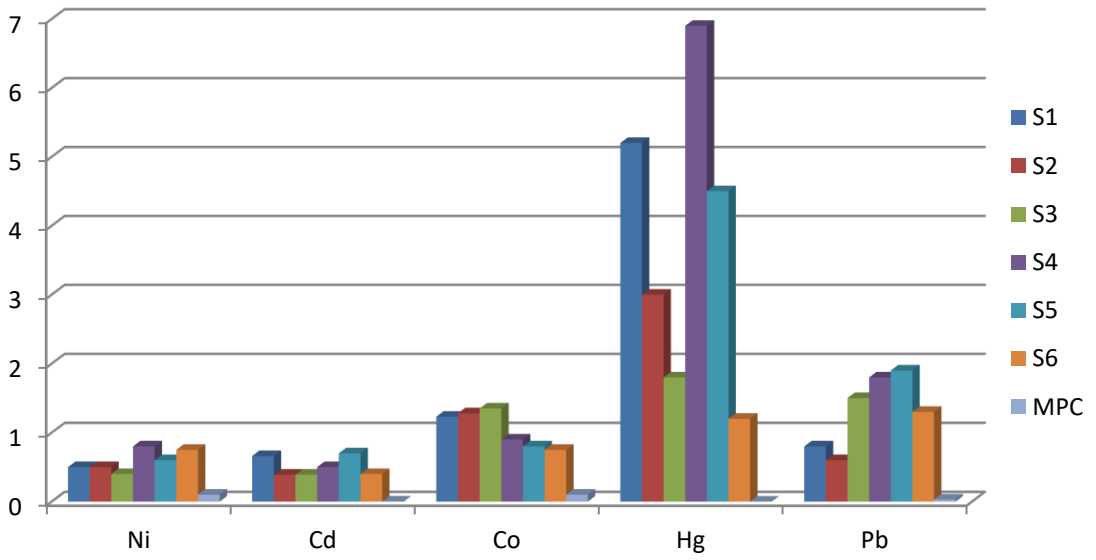

Fig. 4. The amount of some heavy metals in bottom sediments at different monitoring stations

The analysis of heavy metal concentrations in soil samples collected from the area surrounding Lake Zigh indicates generally low levels of contamination, with most elements remaining below their respective maximum permissible concentrations (MPC). The results suggest that, compared to water and bottom sediments, the surrounding soils are less impacted by heavy metal pollution. Arsenic (As) concentrations ranged from 5.9 to 9.27 mg/kg, which is below the MPC value of 10 mg/kg across all sampling stations. This indicates that arsenic contamination in soils is minimal and does not currently pose a significant environmental risk. Mercury (Hg) was detected at very low levels, with most values below the detection limit (<0.05 mg/kg) and a maximum recorded concentration of 0.3 mg/kg at station S6. All measured values are well below the MPC (2.1 mg/kg), suggesting negligible mercury contamination in the soil. Cadmium (Cd) concentrations were also generally low, mostly below detection limits or within a narrow range (up to 0.3 mg/kg), remaining below the MPC (1.0 mg/kg). Similarly, chromium (Cr), copper (Cu), cobalt (Co), lead (Pb), and nickel (Ni) were found at concentrations significantly below their respective permissible limits, indicating that these elements do not represent a major source of soil pollution in the study area. In contrast, zinc (Zn) showed relatively higher variability, with concentrations ranging from 14.0 to 33.9 mg/kg. Notably, the value at station S3 (33.9 mg/kg) and S6 (25 mg/kg) exceeded the MPC (23 mg/kg), indicating localized zinc enrichment in the soil. This may be associated with anthropogenic activities such as agricultural practices, atmospheric deposition, or industrial emissions. Spatially, slight variations were observed among sampling stations; however, no consistent pattern of widespread contamination was identified. The majority of heavy metals remained within acceptable limits, suggesting that the soils in the area are relatively less affected by direct pollution sources compared to the aquatic environment. From an environmental perspective, the soil acts as a partial sink for heavy metals, but in this case, it shows limited accumulation of toxic elements. The localized exceedance of zinc may warrant further investigation, although it does not currently indicate severe contamination. Overall, the findings demonstrate that the soils around Lake Zigh are largely uncontaminated by heavy metals, with the exception of minor zinc enrichment at certain locations. This contrasts with the heavily polluted conditions observed in the lake water and bottom sediments, highlighting that the primary environmental burden is concentrated within the aquatic system rather than the surrounding terrestrial environment [13,30].

Table 7. Amount of heavy metals in soil samples taken in the area of Lake Zigh

Metals	Unit	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
As	mg/kg	9.1	9.27	6.74	8.97	5.9	7.6	10.0
Hg	mg/kg	0.27	<0.05	<0.05	0.13	0.1	0.3	2.1
Cd	mg/kg	<0.5	<0.1	<0.05	0.24	0.1	0.3	1.0
Cr	mg/kg	<0.1	<0.1	<0.1	<0.1	0.2	0.24	100
Cu	mg/kg	2.25	1.45	2.29	1.84	2.1	2.8	55
Co	mg/kg	0.83	0.62	0.61	0.70	0.9	0.5	5.0
Pb	mg/kg	<0.1	<0.1	<0.1	<0.1	0.2	0.3	32
Ni	mg/kg	1.03	0.61	0.77	1.24	0.9	0.87	85
Zn	mg/kg	19.6	14.0	33.9	16.9	18	25	23

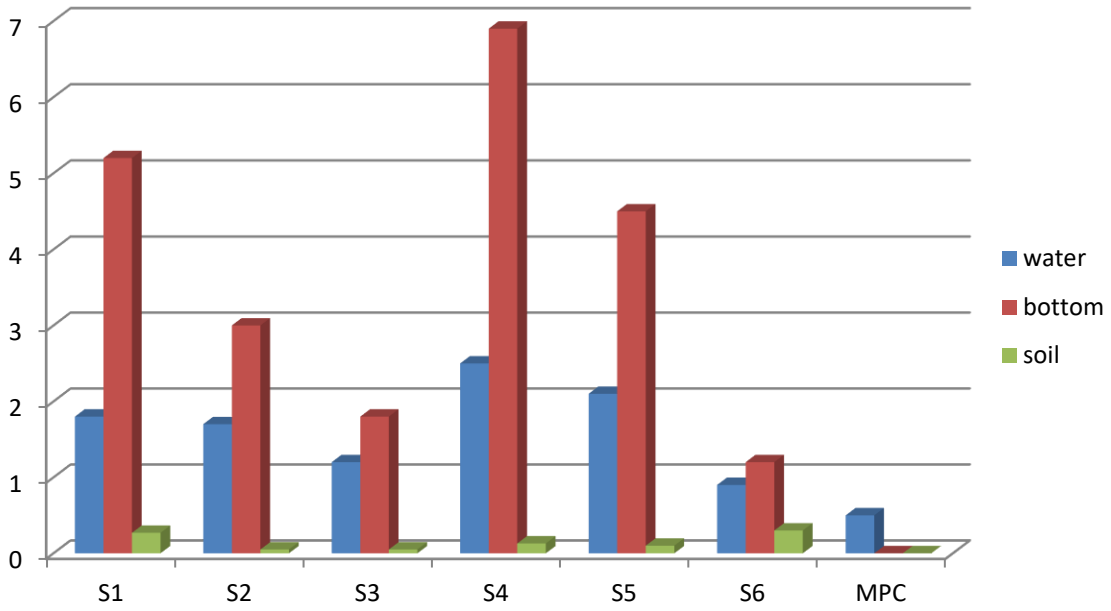

Fig. 5. Mercury content in water, bottom sediments and soil at various monitoring stations

A comparative analysis of the data indicates that heavy metal concentrations in 2023 increased by approximately 50% compared to 2020. Since the 2020 values were 1.5 times lower than the current levels, a clear upward trend in contamination is observed. This demonstrates a progressive deterioration of the environmental quality of the lake system over the studied period.

Based on the diagram in Fig.5, it can be said that the level of mercury pollution in the study area is very high, especially in the bottom sediments, where catastrophic levels of pollution were recorded.

The average statistical concentration of total hydrocarbons over the entire area is 37.428 mg/kg or 4.1%, and the maximum is 454.899 mg/kg or 45.5%. In 14 soil samples taken, the total hydrocarbon content exceeded 500 mg/kg. If we consider the composition of different types of hydrocarbons in the soil layer, we can conclude that the amount of heavy hydrocarbons (C_{21}-C_{40}) is higher. They account for about 70% of the total volume of petroleum hydrocarbons. Thus, the level of total hydrocarbon contamination of soils in the area is on average 78 times higher than the permissible contamination level (≤500 mg/kg), and in some places 900 times.

In addition, the content of PAHs in samples of water, bottom sediments and soil of the study area was investigated.

As can be seen from Tab. 8, in some water samples taken from the lake, the chrysene content exceeded the permissible concentration by 6 times, benzoprene by 20 times, phenanthrene by 33 times, and acenaphthalene by 1.7 times [13].

Table 8. The amount of PAHs in water samples taken from Lake Zigh

PAH	Unit	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
Naphthalene	mkg/L	0.01	<0.02	0.015	0.01	0.018	<0.02	0.02
Acenaphthylene	mkg/L	0.015	0.01	0.011	0.01	0.017	0.01	0.006
Anthracene	mkg/L	0.01	<0.02	0.01	0.01	0.015	<0.02	0.02
Fluoranthene	mkg/L	0.01	<0.02	0.01	0.01	0.018	<0.02	0.02
Fluorene	mkg/L	0.01	0.058	0.015	0.01	0.019	0.024	0.006
Phenanthrene	mkg/L	0.2	0.203	0.18	0.17	0.15	0.143	0.006
Benz[a]pyrene	mkg/L	0.001	<0.02	0.001	0.02	0.001	<0.02	0.001
Chrysene	mkg/L	0.0015	<0.02	0.001	0.001	0.0018	<0.02	0.003

As can be seen from Tab. 9, in the samples of bottom sediments taken from Lake Zigh, the amount of naphthalene exceeds the permissible concentration by 5-12 times, the amount of anthracene by 20-105 times, and the amount of benzoprene by 5-45 times. The amount of chrysene slightly exceeds the permissible concentration [13]. Soil samples collected around Lake Zigh contain high levels of PAHs, while the concentration of PAHs in the bottom sediments is tens and even hundreds of times higher. In general, the results of the analysis of the various presented soil and bottom sediment samples show that due to the significant excess of PAHs in their content, this area of Baku has a high environmental load [27].

Table 9. The amount of PAHs in bottom sediment samples taken from Lake Zigh

PAH	Unit	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
Naphthalene	mkg/kg	0.1	0.2	0.18	0.25	0.15	0.3	0.02
Acenaphthylene	mkg/kg	0.004	0.005	0.002	0.0046	0.004	0.003	0.006
Anthracene	mkg/kg	0.02	0.025	0.105	0.023	0.051	0.031	0.001
Fluoranthene	mkg/kg	0.02	0.025	0.004	0.028	0.005	0.031	0.02
Fluorene	mkg/kg	0.035	0.039	0.04	0.031	0.012	0.03	0.006
Phenanthrene	mkg/kg	0.0049	0.0041	0.005	0.004	0.005	0.004	0.006
Benz[a]pyrene	mkg/kg	0.005	0.035	0.04	0.03	0.045	0.006	0.001
Chrysene	mkg/kg	0.0035	0.0038	0.004	0.004	0.004	0.003	0.003

As seen in Tab. 10, the amount of naphthalene in soil samples taken around the lake exceeds the permissible concentration by 9-12 times, fluorene by 2-7 times, anthracene by 32-166 times, and benzo(a)pyrene by 30-80 times [13], classifying the area as a hazardous zone.

The concentration of polycyclic aromatic hydrocarbons (PAHs) in all samples is extremely high. The average PAH concentration in all collected samples was 28.1 mg/kg, with a maximum concentration of 45.13 mg/kg. High levels of benzene, toluene, ethylbenzene, and xylene were mainly observed in the deeper soil layers. The average concentration of benzene, toluene, ethylbenzene, and xylene in all collected samples was 94.4 mg/kg, while the maximum concentration reached 6.485 mg/kg.

Table 10. The amount of PAHs in soil samples taken around Lake Zigh

PAH	Unit	Sampling stations (S)						MPC [13]
		S1	S2	S3	S4	S5	S6	
Naphthalene	mkg/kg	0.046	0.09	0.18	0.25	0.15	0.3	0.02
Acenaphthylene	mkg/kg	0.004	0.004	0.004	0.0046	0.004	0.003	0.006
Anthracene	mkg/kg	0.166	0.032	0.166	0.023	0.051	0.031	0.001
Fluoranthene	mkg/kg	0.004	0.004	0.004	0.028	0.005	0.031	0.02
Fluorene	mkg/kg	0.0081	0.0083	0.04	0.031	0.012	0.03	0.006
Phenanthrene	mkg/kg	0.004	0.0043	0.005	0.0041	0.005	0.004	0.006
Benz[a]pyrene	mkg/kg	0.066	0.081	0.04	0.03	0.045	0.007	0.001
Chrysene	mkg/kg	0.003	0.0039	0.0045	0.0043	0.007	0.003	0.003

In addition, we conducted an analysis of standard PAHs (naphthalene, anthracene, phenanthrene, pyrene, etc.) using the GC-MS method [21,22], as well as an estimation of PAH concentrations in the soils and bottom sediments of Lake Zigh, which differ in levels of environmental load. The selection of these compounds for PAH monitoring is explained by the influence of aromatic hydrocarbons on the formation of benzo(a)pyrene.

Sample preparation was carried out using the liquid extraction method. The determination of organic compounds in the samples was performed using the "Pegasus HRT" chromatograph-mass spectrometer in both one-dimensional and two-dimensional gas chromatography modes (Fig. 6).

The error margin for the quantitative determination of PAHs in TIC mode is high (Sr = 20%), making it suitable only for qualitative identification of soil components. The content of the studied PAHs in the samples was determined by comparing the samples (Fig.7).

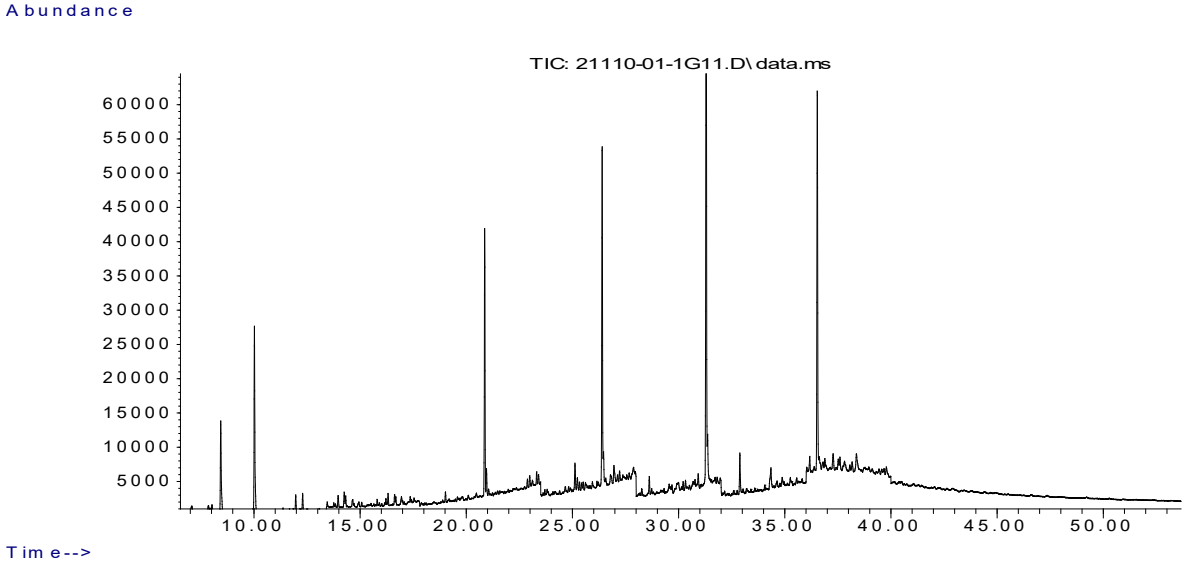

Fig. 6. Chromatogram of Lake Zigh's bottom sediments

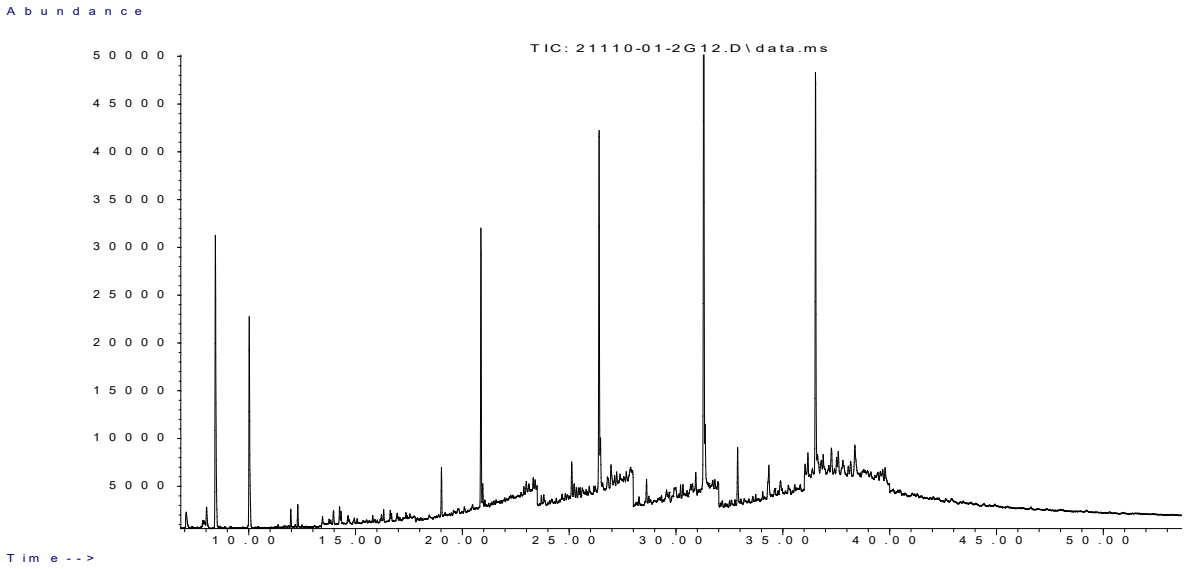

Fig. 7. Chromatogram of soil from the vicinity of Lake Zigh

Analysis of the samples using the GC-MS method [21,22] revealed that the concentrations of all detected compounds exceeded the maximum permissible levels by several times. The PAH content in the soil sampled from the shore of Lake Zigh expectedly increases, and in the bottom sediments, PAH concentrations are tens or even hundreds of times higher. Overall, the results of soil and bottom sediment analyses, presented in Tab. 9 and 10, indicate a significant increase in PAH levels in this area of Baku, which experiences high environmental stress.

The data obtained using the developed analytical methodology highlight the need to find accessible and effective methods for disposing of anthropogenic PAHs and, where possible, reducing their emissions into the environment.

In addition, we conducted an analysis of persistent organic pollutants in the atmospheric air of Lake Zigh [35]. To determine the concentration of toxic organic substances in the air, we carried out air biomonitoring using moss transplants (moss in pouches) Moss Sphagnum girgensohnii Russow. For this purpose, Sphagnum girgensohnii moss biomonitors were exposed for three months in various locations within this area.

It is important to note that this region of Baku is undergoing intensive construction, with active asphalt and bitumen production facilities, as well as oil refineries. The moss was collected from an environmentally clean bog in Central Russia and exposed in pouches. The exposure duration was three months.

Initially, the moss was cleaned of foreign particles after collection. The purified moss sample was then dried at 130°C for seven days. After drying, the moss was placed into pouches and positioned in the target analysis areas. Following the exposure period, the moss samples underwent extraction. The extraction process was performed in an ultrasonic bath using dichloromethane.

Qualitative analysis was conducted using the Agilent 6890N gas chromatograph with a mass-selective detector (Agilent 5975, GC-MS). Helium was used as the carrier gas, and the samples were introduced using an automatic sampler. The analysis was performed in scanning mode (SCAN). The spectral databases used were WILLEY and NIST libraries. Data processing and analysis were carried out using multivariate statistical analysis.

The results of the analysis revealed an increase in the number of polycyclic aromatic hydrocarbons—naphthalene, azulene, acenaphthene, chrysene, phenanthrene, anthracene, fluoranthene, pyrene, benzanthracene, benzo(a)pyrene, phenols, nitrobenzene, dibenzofuran, pyridine, phthalates, alkylbenzenes, toluene, styrene, xylene, benzene, ethanol, benzaldehyde, acetophenone, benzoic acid, formamides, furans, furfural, organic acids, etc. - in the atmospheric air of Lake Zigh [34-36]. As is well known, these organic compounds are toxic and can enter the environment during oil refining processes.

It should be noted that the use of *Sphagnum girgensohnii* as a biomonitor for polycyclic aromatic hydrocarbons (PAHs) represents a relatively new and actively developing area of research in environmental monitoring and ecological assessment. Currently, the available scientific literature provides a limited amount of data that would allow for a comprehensive quantitative evaluation of its sorption capacity, as well as the establishment of reliable correlations between PAH accumulation in moss and results obtained using alternative monitoring approaches (e.g., instrumental chemical-analytical methods). In the present study, the obtained results confirm the ability of *Sphagnum girgensohnii* to effectively accumulate pollutants, indicating its considerable potential as a bioindicator of environmental quality and PAH contamination levels. However, it should be emphasized that a more accurate and statistically robust quantitative assessment of the method requires further experimental studies, including larger sample sizes, extended time-series observations, and comparison with reference analytical techniques. Moreover, further advancement of this approach necessitates the development and implementation of standardized methodologies for sampling, sample preparation, and data interpretation. This would improve the comparability of results across different studies and ensure a more reliable assessment of the environmental status of the investigated areas.

In conclusion, it should be noted that the dire environmental condition of Lake Zigh has attracted the attention of the head of state, and on October 15, 2014, a decree titled "On Measures to Improve the Environmental Condition of Lake Zigh" was signed. In accordance with the presidential decree of February 21, 2021, the responsibility for addressing this issue was assigned to the Ministry of Ecology and Natural Resources.

The working group has thoroughly studied and analyzed the current state of the lake, the measures being undertaken, the location and amount of oil and other solid waste present, as well as other related issues. Based on the results of scientific research, the preparation of project documentation for the initial rehabilitation of the lake has begun. The findings from our monitoring of Lake Zigh’s environmental condition have been presented to specialists involved in the restoration project led by the Ministry of Ecology and Natural Resources.

The following schematic plan outlines the boundaries of the protected area designated for the improvement of Lake Zigh (Fig. 8).

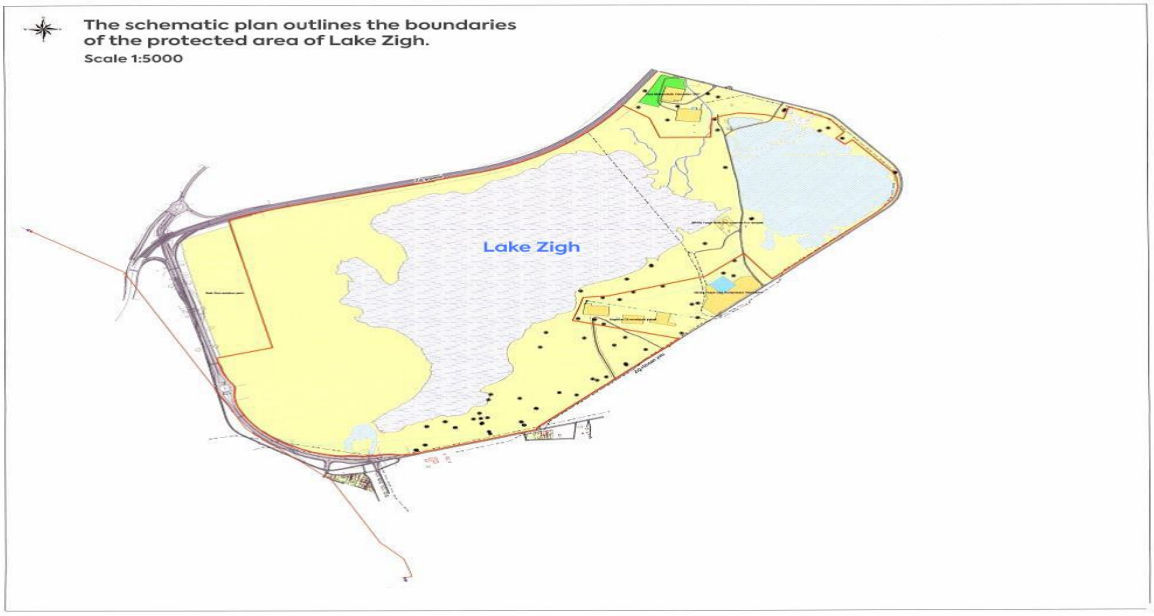

Fig. 8. Schematic plan outlines the boundaries of the protected area of Lake Zigh

According to experts, the project envisions reducing the water surface area of Lake Zigh from 120 hectares to 40 hectares, reclaiming the surrounding oil-contaminated land, and cleaning it from petroleum products and solid waste. Once these works are completed, a 100-hectare green belt will be established around the lake, with trees being planted.

In addition to this, the project also includes provisions for future opportunities for small and medium-sized businesses in this sector. On the western side of the lake, land will be allocated for the construction of social housing. However, first and foremost, it is necessary to prevent any further interference with the lake.

The restoration and improvement of the lake's surroundings will eliminate the existing unsanitary conditions. Beautification of the area and the creation of a cultural landscape will enhance its aesthetic appeal, making it one of the most attractive recreational spots within the city. This will lead to improved hygiene and public health. The construction of a resort and sanatorium complex will provide a foundation for people's well-being.

As a result, the number of waterborne diseases will decrease, and overall health standards will rise. New fish species can be introduced into the lake, helping to restore its ecosystem. Additionally, housing availability will improve, and new jobs will be created.

Conclusions

1. According to the results of the physicochemical analysis, the turbidity of Lake Zigh's water exceeds the standard by 4 times, the concentration of nutrients is 2-10 times above the permissible level, and the oxygen concentration is 5-20 times lower than normal, indicating a strong eutrophication process occurring in the lake.
2. The concentration of most heavy metals in the water, bottom sediments, and soil samples

taken from the lake greatly exceeds permissible levels, with the highest and most hazardous concentrations found in the bottom sediments: As: 1.540-1.940 times above the norm; Cd: 400-700 times above the norm; Pb: 50-80 times above the norm; Hg: 10.380-13.860 times above the norm (the most dangerous indicator).

3. The PAH (polycyclic aromatic hydrocarbon) concentrations in water samples collected from the Lake Zigh area are high, while in bottom sediments and soil samples, PAH levels exceed permissible concentrations by dozens and even hundreds of times: Naphthalene: 5-12 times (bottom sediments), 9-12 times (soil); Anthracene: 20–105 times (bottom sediments), 32-166 times (soil); Benzo(a)pyrene: 5-45 times (bottom sediments), 30–80 times (soil). Based on these analytical results, it can be concluded that this area of Baku experiences significant environmental pollution due to high PAH concentrations.
4. Based on our biomonitoring of the atmospheric air around Lake Zigh using moss transplants (Sphagnum girgensohnii Russow), we determined that there is an increase in polycyclic aromatic hydrocarbon (PAH) concentrations in the studied area.

The analysis of the current state of Lake Zigh has shown that years of anthropogenic impact have resulted in severe pollution, making the lake uninhabitable for aquatic organisms. The environmental situation of Lake Zigh can be assessed as extremely critical, necessitating urgent environmental remediation.

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