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ECOLOGICAL ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF HEAVY METALS IN THE WASTE GENERATED BY THE METALLURGICAL INDUSTRY
(case study: Baku steel company)

The article primarily presents ecological analytical studies on the waste generated in the production areas of the Baku Steel Company. It was determined that during various steel casting and processing operations in several production areas of the enterprise, different types of waste are formed in gaseous-aerosol, liquid, and solid states, each with distinct compositions and properties. Based on our preliminary scientific research, the actual composition and concentration levels of harmful substances released into the atmosphere at different times in both the working and sanitary protection zones were identified. Additionally, the composition of industrial wastewater and solid wastes generated by the enterprise was analyzed. The gaseous emissions at Baku Steel Company were measured using a Drager Tubes LLG gas detector device, while the analyses of water samples taken before and after purification from various departments of the plant were conducted using the ICP-OES GBC Quantima device. The article also provides scientific explanations on the negative environmental and human health impacts caused by heavy metals present in the industrial waste formed in the production areas of this enterprise.

Keywords: ecological analytical assessments, steel casting, sanitary protection zone, working zone, industrial waste.

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Металлургиялық өндіріс қалдықтарындағы ауыр металдардың қоршаған ортаға әсерін экологиялық бағалау
(Бакудегі металлургиялық зауыт мысалында)

Мақалада негізінен Бакудегі металлургиялық зауыттың өндірістік цехтарында пайда болатын қалдықтардың экологиялық аналитикалық зерттеулері ұсынылған. Қорытынды бойынша, болатты құю және өңдеу процестерінің нәтижесінде кәсіпорынның бірнеше өндірістік учаскелерінде газ-аэрозольді, сұйық және қатты формадағы әртүрлі құрам мен қасиеттегі қалдықтар пайда болатыны анықталды. Алғашқы ғылыми зерттеулерімізге сәйкес, жұмыс аймақтарында және санитарлық-қорғау аймақтарында атмосфераға әртүрлі уақытта шығарылатын зиянды заттардың нақты құрамы мен концентрациясы анықталды. Сонымен қатар кәсіпорында пайда болатын өндірістік ағынды сулар мен қатты қалдықтардың құрамы талданды. Бакудегі металлургиялық зауытта газ тәрізді шығарындылар Drager Tubes LLG газанализаторы арқылы өлшенді, ал кәсіпорынның әртүрлі бөлімдерінде тазартудан бұрын және кейін алынған су үлгілерінің талдауы ICP-OES GBC Quantima аспабы арқылы жүргізілді. Мақалада сонымен қатар кәсіпорынның өндірістік қалдықтарындағы ауыр металдардың қоршаған ортаға және адам денсаулығына тигізетін теріс экологиялық әсері жөнінде ғылыми түсініктер берілген.

Түйін сөздер: экологиялық аналитикалық талдау, болатты құю, санитарлық-қорғау аймағы, жұмыс аймағы, өндірістік қалдықтар.

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**Экологическая оценка воздействия тяжёлых металлов
в отходах металлургической промышленности на окружающую среду
(на примере Бакинского металлургического завода)**

В статье в основном представлены экологические аналитические исследования отходов, образующихся в производственных цехах Бакинского металлургического завода. Установлено, что в результате различных процессов литья и обработки стали в нескольких производственных участках предприятия формируются отходы различного состава и свойств в газо-аэрозольной, жидкой и твердой формах. Согласно нашим предварительным научным исследованиям, были определены фактический состав и концентрации вредных веществ, выбрасываемых в атмосферу в различные периоды времени как в рабочих зонах, так и в санитарно-защитных зонах. Также был проведён анализ состава производственных сточных вод и твердых отходов, образующихся на предприятии. Газообразные выбросы на Бакинском металлургическом заводе были измерены с помощью газоанализатора Drager Tubes LLG, а анализы водных проб, взятых до и после очистки в различных отделах предприятия, были проведены с использованием прибора ICP-OES GBC Quantima. В статье также даны научные объяснения по поводу негативного экологического влияния тяжёлых металлов, содержащихся в промышленных отходах предприятия, в частности на окружающую среду и здоровье человека.

Ключевые слова: экологический аналитический анализ, литьё стали, санитарно-защитная зона, рабочая зона, промышленные отходы.

Introduction

According to the information and explanations provided in many technical sources [1–8], one of the main sectors of the metallurgical industry is the secondary steel melting production. As noted in these sources, the secondary steel melting process generates significantly more gaseous, liquid, and solid (slag) wastes compared to primary steel production facilities. Based on the explanations in scientific and technical literature [1–3] and the results of recent ecological research, it can be stated that, like all industrial enterprises, Baku Steel Company LLC creates various environmental problems due to the different types of pollutants it generates. Therefore, conducting ecological research in such production areas is considered one of the most urgent environmental issues today. Along with modern industrial development, the metallurgical industry is one of the main sectors impacting the environment. During the production of steel and other metallurgical products, various chemical substances especially heavy metals are released into the atmosphere, water bodies, and soil. These heavy metals (Pb, Cd, Cr, Ni, Zn, Cu, etc.) are toxic to living organisms and can cause serious ecological and health problems over time.

This article investigates the environmental assessment of heavy metals present in wastes generated by the metallurgical industry and their impact on the environment. The environmental effect of heavy metals is linked to their ability to accumulate and their resistance to degradation. These substances can accumulate in soil, be absorbed by plants, and eventually enter the human body through the food chain. Metals released into the atmosphere can enter the body through the respiratory system and cause serious health disorders. Therefore, the proper management of waste, as well as the improvement of filtration and purification systems, are essential measures.

The most commonly encountered heavy metals in the metallurgical industry are: Lead (Pb), Cadmium (Cd), Mercury (Hg), Chromium (Cr, especially Cr^{6+}), Nickel (Ni), Copper (Cu), Zinc (Zn), etc. These heavy metals mainly arise during the following industrial processes:

- Steel and iron melting (heating metals in furnaces);
- Casting and cooling of metals;
- Wear and cleaning of equipment;
- Surface treatment and painting of metals.

During these processes, heavy metals are released into the atmosphere in the form of gas-aerosols, enter wastewater in liquid form, and remain in the composition of solid wastes (slag, dust). The environmental impacts of heavy metals are diverse. When heavy metals enter the soil, they can persist for a long time without degrading and are absorbed by plants. Through this pathway, heavy metals enter the food chain and affect the health of humans and animals. They reduce soil fertility and weaken the activity of microorganisms. The discharge of waste-

water into water bodies leads to the contamination of aquatic and terrestrial ecosystems. Heavy metals accumulate in the bodies of fish and other aquatic organisms, which reduces biodiversity and can cause poisoning in humans. Heavy metal particles released into the atmosphere can enter the respiratory system, leading to chronic respiratory diseases, allergies, and various types of cancer. For example, the hexavalent form of chromium (Cr^{6+}) has a highly carcinogenic effect. The heavy metals present in the waste generated by the metallurgical industry pose a serious threat to both the environment and human health. The environmental assessment and monitoring of their impact are essential prerequisites for developing effective waste management strategies. The application of environmentally safe technologies is necessary to ensure environmental protection and the sustainability of industrial development. In some countries, the following conditions are considered essential to prevent environmental pollution:

- Technological discipline;
- Use of modern technologies;
- Implementation of technical modernization.

Thus, based on the explanations provided in scientific and technical literature [2–11], it can be scientifically justified that conducting ecological research in various directions at metallurgical industrial enterprises should be considered one of the key contemporary environmental requirements.

Materials and methods

As is well known, during environmental research at any industrial facility, the initial step involves collecting general information about the composition and characteristics of the raw materials accepted by the enterprise. In subsequent stages, it is essential to investigate the causes of environmental pollution that may arise during the preparation of these raw materials for processing and throughout the technological processes. Alongside this, it is also necessary to document the types of waste generated during the technological operations at the facility under investigation. Taking the above into consideration, the main objective of this environmental research was to determine the composition and environmental impact of all types of waste generated in the Electric Arc Steel Melting Furnace (EASMF) area section, which is considered one of the main production departments of the Baku Steel Company (BSC).

Initially, the actual concentrations of gaseous emissions formed in the working area of this production site were determined using the Dräger Tubes

LLG, a flexible and mobile gas detection device. Regular monitoring of gas emissions in the production area is crucial for both safety and environmental protection. The Dräger Tubes LLG gas detector is one of the flexible and portable devices used for this purpose. It is a portable gas analyzer specifically designed for the detection and measurement of various gases. Belonging to the Long Life Gas Detectors (LLG) series, this detector ensures high accuracy and ease of use in measuring gas emissions. The device operates with specially designed test tubes adapted for different gases such as carbon dioxide, methane, ammonia, heavy metals, and others. This detector is mainly used in industrial environments, particularly in high-risk zones, for monitoring gas leaks and protecting worker health.

Operating Principle of the Dräger Tubes LLG Gas Detector:

1. Test Tubes: The Dräger Tubes LLG gas detector operates using special test tubes. Each test tube is designed to measure the concentration of a specific gas. When used, the gas enters the tube and reacts with the chemical reagents inside, causing a visible color change.

2. Gas Concentration Measurement: The device determines the concentration of gas in the air using a calibrated method. The color change inside the test tube corresponds to the concentration of the target gas. A color scale printed on the tube allows the user to visually interpret the result and determine the gas concentration.

3. Safety and Portability: The portability of the device allows workers to use it easily in various locations. Its compact design and simple operation make it suitable for a wide range of environments. Measurements can be taken quickly, and results are available within a short time, ensuring timely detection and safety.

A long-term research study was conducted to determine the continuous and sustained presence of various inorganic substances with ecotoxic properties at elevated concentrations within the gas mixture. The concentrations of these specific ecotoxic substances in the air were measured using the device with the aid of glass indicator tubes. The analyses were repeated several times on different days, and the average values were calculated to improve accuracy.

The Dräger Tubes LLG gas detector offers an ideal solution for ensuring safety in industrial environments by accurately measuring and monitoring airborne gas emissions. Thanks to its portability and ease of use, the device helps minimize workplace

hazards and plays a crucial role in protecting the health of workers.

Results and discussion

The actual concentrations of inorganic substances with ecotoxic properties emitted into the ambient air from the Electric Arc Steel Melting Furnace (EASMF) area of the Baku Steel Company were determined, primarily in the working area, particularly near the electric arc furnace. The measurements were conducted using the aforementioned portable device, with flexible analyses carried out in a circular pattern at a 10-meter radius around the EASMF. The results are presented in Table 1.

Table 1 – Analysis Results of Ecotoxic Inorganic Substances Emitted into the Atmosphere from the Electric Arc Steel Melting Furnace (EASMF)

Names of Inorganic Substances with Ecotoxic Properties	Maximum Allowable Concentrations (MAC) of these substances mg/m³	Measured Concentrations in the Electric Arc Steel Melting Furnace (EASMF)
Hg	0.0003	0.5ppm (4.10 mg/m³)
Cu	0.002	1ppm (2.59 mg/m³)
Ni	0.001	1ppm (2.40 mg/m³)
Pb	0.0003	1ppm (8.47 mg/m³)
Zn	0.05	2ppm (5.34 mg/m³)

In addition to the aforementioned observations, it should be noted that in the working area of the Electric Arc Steel Melting Furnace (EASMF) of the production facility under investigation, the concentrations of inorganic gaseous emissions with ecotoxic properties were also measured at distances of 50, 100, 150, and 200 meters, as well as within the sanitary protection zones. The concentrations of these harmful substances in the ambient air at these locations were determined. The obtained results are presented in Table 2 and Figure.

Table 2 – Analysis Results of İnorganic Ecotoxic Substances in the Ambient Air Outside the Electric Arc Steel Melting Furnace (EASMF)

| Names of Inorganic Substances with Ecotoxic Properties	Measured concentrations outside the Electric Arc Steel Melting Furnace (EASMF)				
	50 m	100 m	150 m	200 m	Within the Sanitary protection Zone
Hg	0.05 ppm	0.006 ppm	0.004 ppm	0.003 ppm	0.1ppm
Cu	0.9 ppm	0.1 ppm	0.01 ppm	0.005 ppm	0.01ppm
Ni	0.9 ppm	0.1 ppm	0.01 ppm	0.005 ppm	0.01ppm
Pb	0.9 ppm	0.1 ppm	0.01 ppm	0.005 ppm	0.01ppm
Zn	1.5 ppm	1.3 ppm	0.9 ppm	0.1 ppm	0.1ppm
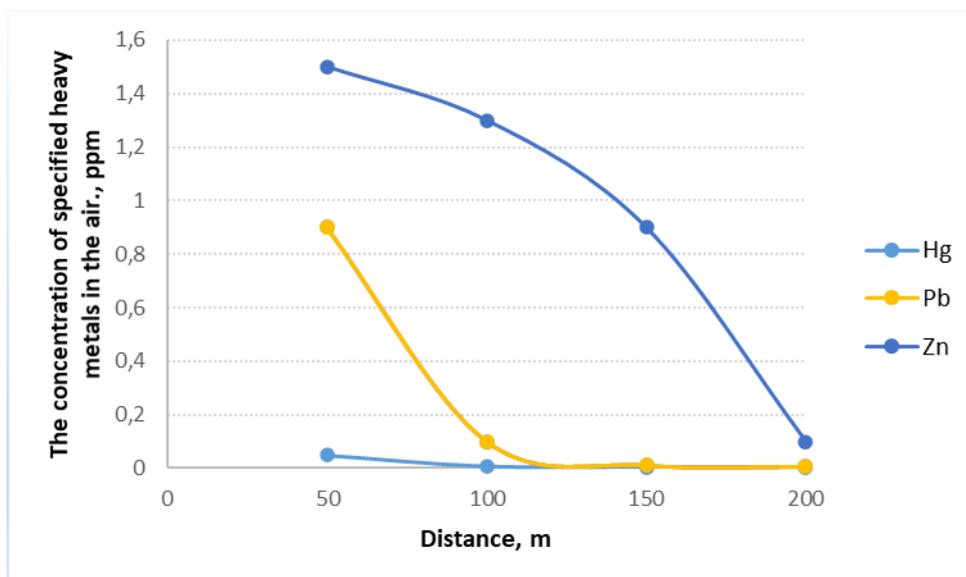
Figure – Ecotoxic Inorganic Substance Concentrations as a Function of Distance

Additionally, sampling and analysis of industrial wastewater generated primarily in the production areas of the Baku Steel Company, particularly in the Electric Arc Furnace Section (EAFS), have been carried out. Samples were taken from the water entering and exiting the cooling system of the EAFS (i.e., industrial wastewater samples). The analyses mainly focused on determining the concentrations of metal ions using established analytical chemical methods (such as photometric, photocolorimetric, and argentometric) techniques. During the analysis, it was found that the inlet water to the EAFS cooling system contained elevated levels of certain chemical parameters, particularly metal ions. This can be explained by the fact that a significant portion of the water entering the cooling system is recycled water, which results in higher concentrations of metals such as Cu, Mo, Mn, Al, Pb, Cr, Zn, and others. The concentrations of Cu, Mo, Mn, Al, Pb, Cr, Zn, and other metals were determined using the ICP-OES method with the GBC Quantima instrument. The average results of these analyses are presented in Table 3.

Table 3 – Determination of Heavy metals in İndustrial Wastewater Generated Mainly in the Production Areas of Baku Steel Company, Especially in the Electric Arc Furnace Section (EAFS)

Component Name	Unit of measurement	Inlet water to EAFS cooling system	Outlet water from EAFS cooling system
Na^+	mg/l	137.8	222.5
K^+	mg/l	3.2	3.1
Al^{3+}	mg/l	9.49	41.4
Fe	mg/l	79.5	225.2
Mn	mg/l	0.372	7.98
Cu	mg/l	54.4	93.6
Mo	mg/l	23.7	25.0
Zn	mg/l	0.525	1.8
Pb	mg/l	0.162	0.673
Ni	mg/l	2.88	2.1
Cr	mg/l	3.44	4.68

It is known from the literature that all steel alloys contain sulfur, carbon, phosphorus, heavy metals, and inorganic elements. It should be noted that during the high-temperature melting process of recycled steel equipment in the Electric Arc Steel Melting Furnace (EASMF) area, oxygenated, hydrogenated, and halogenated derivatives compounds of many elements are formed. Furthermore, it can be stated that many of the inorganic substances with ecotoxic properties listed in Table 1, even when undergoing various transformations during the process, lead to the formation of numerous harmful compounds.

Conclusion

Although the concentrations of ecotoxic substances formed in the Electric Arc Steel Melting Furnace (EASMF) area of the investigated facility which are emitted into the atmosphere and considered hazardous to both the environment and, primarily, human health tend to dilute over time and approach the Maximum Allowable Concentration

(MAC), each of these substances is still regarded as highly dangerous.

During the recycling process of steel equipment, cast iron, and even non-ferrous metals classified as scrap metal a variety of complex metallic compounds are formed as a result of the high-temperature decomposition of many components used in the process (such as coal, coke, ferromanganese, and ferrosilicomanganese). During the cooling of these alloys, a portion of the metals that have separated from the main alloy enters the composition of the cooling water, thereby generating industrial wastewater. In the Electric Arc Steel Melting Furnace (EASMF) area, the amount of ecotoxic and harmful substances in the water used for cooling steel alloys which is then reused increases significantly. For this reason, the application of multistage physical and chemical treatment methods to purify the recycled industrial wastewater can be considered essential in preventing the emergence of environmentally stressful conditions in the working zone of the facility.

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