

Hydrochemical analysis of surface water flow from an abandoned iron ore mine

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Abstract

Purpose. The purpose of this research is to investigate the potential formation of contaminants in abandoned mining areas due to the interaction between rocks, water, and air, as well as their impact on surface water quality around the mine area.

Methods. Mineralogical analysis using an optical microscope and X-ray diffraction (XRD) on iron ore samples obtained from the stockpiles and chemical analysis of water obtained from the mining site and downstream river.

Findings. Iron ore at the study site is dominated by iron oxide minerals such as magnetite, hematite, and goethite. Additionally, quartz, birnessite, pyrite, and chalcopyrite minerals were also found. The mineral content indicates the presence of two sulfide minerals that have the potential to form acid mine drainage, namely; pyrite (FeS₂) and chalcopyrite (CuFeS₂). The pH measurement results of the water flowing from the iron ore stockpile have a pH of 2.9, while the void and surrounding river vary from 6.4 to 8.2.

Originality. Identifying iron ore minerals by combining polarized light microscopy and XRD can enhance the reliability of the observation results. Both methods showed the same results in identifying sulfide minerals, with chalcopyrite in the excavated iron ore stockpile and pyrite in the crushed iron ore stockpile. The formation of acid mine drainage at abandoned mine sites is only a local phenomenon, and after being diluted by other water flows, the water's pH returns to neutral.

Practical implications. This research activity was conducted during the rainy season when overflow occurred, with water spilling from the mine pit lake to the surrounding areas. The results show that the formation of acid mine drainage and the high concentration of total Fe that occurred in one of the stockpiles did not affect the change in water quality around the mine, and there is potential for water in the mine void to be used as a water source for the surrounding community.

Keywords: abandoned mine, iron ore, XRD, acid mine drainage, pit lake

1. Introduction

Iron ore mining has developed into a very important industry worldwide. Iron ore is the main raw material for the steel industry, which has various uses and contributes significantly to economic growth [1]. However, iron ore mining can have significant environmental impacts like other mining activities. In many cases, mining activities create mine voids and leave behind significant mining waste [2], [3]. The exposure of iron ore deposits and rock waste further facilitates the interaction between water, rocks, and air, which can lead to the formation of contaminants.

The mining process generates waste rock and tailings in large quantities, which are then piled on the surface, causing damage to the land surface. The waste rocks and tailing that are discarded are often very unstable and will eventually become a source of pollution [4]. The waste rock and tailings contain heavy metals, minerals, and other toxic substances [5], [6]. They generally exhibit hazardous properties such as extreme pH, high metal concentrations, and a lack of organic matter [7]. The pollution load in areas near iron ore mines can manifest as high contamination of surface soil in the form of increased heavy metal concentrations [8] and water quality around mine areas [9].

The interaction of surface water and groundwater with waste rock can cause the dissolution of chemical elements from the rock into the water. Changes in the chemical composition of water can identify the sources of dissolved elements in the water and represent the geochemical relationship between water and rocks [10]. Furthermore, significant amounts of sulfide minerals, especially pyrite, which function as acid-generating phases, are usually present in these iron ore materials. Acid mine drainage results from sulfide minerals being exposed to air and coming into contact with water [11], [12]. The rate of sulfide oxidation can be regulated by temperature, dissolved oxygen content, pH, ferrous iron chemical activity, oxidizing microbial species, and mineralogy [2], [13]. Pyrite texture (particle size, porosity, and surface area), pyrite crystallography, and trace element substitution are the mineralogical features that affect pyrite oxidation rates, which are the primary causes of acid mine drainage [14]. This has the potential to cause contamination of surface water and groundwater, ultimately resulting in the loss of biodiversity and posing health risks to humans and aquatic life [4]. Therefore, it is essential to manage and reduce this impact to minimize damage to the environment and

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surrounding communities. However, in reality, many abandoned mining sites contain water that is of sufficient quality and quantity to be regarded as a water supply source [15].

This study was conducted at a deserted mining location in the Tanjung region of South Sulawesi Province, Indonesia. The change in governmental regulations resulted in the termination of mining activities at this location. The mining site was ultimately left abandoned, lacking appropriate closure procedures, leading to mine voids, stockpiles, and neglected rock waste. In the rainy season, surface runoff from the abandoned mine flow into rivers to the sea, moving through agricultural land, plantations, and residential areas, raising significant concerns within the local community. Consequently, this study was carried out to determine the possible emergence of pollution within the mine area and its effects on the adjacent regions, especially concerning the quality of surface water flow.

2. Methods

Research area is located in Tanjung area, Bontocani-Bone, South Sulawesi Province, Indonesia at coordinates $5^{\circ}1'24.58''$ South Latitude and $120^{\circ}4'11.72''$ East Longitude. The research area is located in the Tanjung region, Bontocani-Bone, South Sulawesi Province, Indonesia, at coordinates $5^{\circ}1'24.58''$ South Latitude and $120^{\circ}4'11.72''$ East Longitude. This location is a former mining operation situated in a hilly area, with excavation depths ranging from fifty to seventyfive meters. The prominent objects in this area are the mining void, and two stockpiles of material from the excavation and crushed iron ore. At the end of the void, a small river forms, flowing its water into the Bulukbuluk River downstream.

Research activities in this area include field observations, rock and water sampling, and chemical analysis in the laboratory of the rock and water samples. Figure 1 shows the research location and sampling points. Field observations were conducted to describe the geometric shapes and situational conditions of former mining sites and surface geological objects, as well as to determine sample collection locations that can represent the research objectives. Based on the field observation results, the rock sample collection locations were determined at two stockpiles.



Figure 1. Research area and sampling location

The first stockpile is a heap of excavated material, while the second stockpile is a heap of crushed material. Sampling at each stockpile is taken at three positions, namely the top, middle, and bottom of the stockpile. Next, water sampling was conducted at 10 locations spread across the void (W-01 and W-02), stockpile (W-10), and along the Bulukbuluk River flow at certain distances from the void (W-03 to W-09).

Analysis in the laboratory involves using a polarizing microscope and XRD, instruments frequently employed to enhance the data acquired through chemical methods [11], [16]. The polarizing microscope (Nikon-Eclipse LV100POL) serves to identify the classification and texture of minerals. The material collected from the field is processed into thin sections. The subsequent step involved identifying the material's mineral content and chemical elements through XRD analysis using a diffractometer (Shimadzu Maxima X-7000) on rock samples that were crushed to a size of 200 mesh. The specifications for XRD scanning are outlined below: Voltage: 40 kV, Current: 30 mA, Scanning Range: 5-70° 20. Scan Step: 0.02°, Scan Time: 2°/minute. Analysis of XRD data utilizing the PDX-2 database from the Mineral Data Institute (MDI) in conjunction with the experimental version of MATCH! 3.9 software. This analysis employs a figure of Merit (FoM) of 0.6 to enhance the precision of mineral phase selection.

Water sample conditions are evaluated by measuring physical properties in the field and assessing chemical composition in the laboratory. Total dissolved solids (TDS), pH, electrical conductivity (E_c), and turbidity are some of the physical qualities of water tested in the field. Chemical composition was determined for eight primary elements, which included four cations and four anions. The cationic elements are Na⁺, K⁺, Ca²⁺, and Mg²⁺; the anionic elements are Cl⁻, HCO₃⁻, CO₃²⁻, and SO₄²⁻. Furthermore, the concentrations of four other minor elements, namely total Fe, S, SiO₂, and P, are measured. Bar charts and trilinear diagrams represent the major elemental makeup.

3. Results and discussion

3.1. Climate and geological condition

The mining method uses an open pit mining system that leaves the mine void filled with water. Water spills from the void into the river during the rainy season as surface run-off, while water is stored in the mine void during the dry season and flows downstream as groundwater flows.

According to meteorological and climatological data from Bone Regency for 2014-2023, the average temperature is 28.5°C, with a minimum of 20.9°C and a maximum of 37.9°C. The region exhibits a tropical climate characterrized by two distinct seasons: the dry season from July to October, featuring precipitation below 200 mm per month, and the rainy season from November to June, marked by rainfall exceeding 200 mm per month. The average monthly precipitation in Figure 2 varies from 69.80 to 340.9 mm. Water in the void will overflow and flow into the downstream river only from November to June, coinciding with the rainy season.

The iron ore deposit in the Tanjung region of Bone Regency, South Sulawesi, comprises lump ore linked to igneous intrusions, predominantly granodiorite and pegmatite-granodiorite [17]. Iron ore mineral deposits can be found in various geological contexts. These deposits may exist in sedimentary, metamorphic, and igneous rock formations.



Figure 2. Average monthly rainfall in the research area 2014-2023

There are about 300 minerals that contain iron, but there are five primary sources of iron ore minerals, namely magnetite (Fe₃O₄), hematite (Fe₂O₃), goethite (Fe₂O₃H₂O), siderite (FeCO₃), and pyrite (FeS₂). Magnetite, hematite, and goethite are usually found in large quantities that can be mined economically [1].

The mineralogical analysis of the ore revealed that magnetite is the predominant phase, succeeded by hematite and goethite. Pyrite is found in small quantities as inclusions inside magnetite and as a filler material for cracks. The occurrence of garnet in the accompanying host rock indicates that the ore deposit type comprises iron-rich skarn [18]. Despite the presence of sulfide minerals in limited quantities inside the iron ore, prolonged exposure of these minerals to the atmosphere may exacerbate the production of acid mine drainage. There isn't any mining going on right now. Mining lakes and exposed material stockpiles from iron ore excavation and processing have developed in this region. This makes it easier for water, rock, and air to interact, which may alter the makeup of runoff water that enters the surrounding areas.

3.2. Mineral composition

Analysis with a polarizing microscope was conducted on two thin sections representing material taken from the stockpile of excavated boulders (SP-1) and crushed iron ore (SP-2). The mineral composition of sample SP-1 is shown in Figure 3, indicating the presence of magnetite (mag), hematite (hem), and goethite (goe) as the main iron oxide minerals, and the sulfide mineral chalcopyrite (ccp). In addition, quartz minerals (qrz) were also found in the form of gangue minerals. The grains of chalcopyrite mineral show weathering edge forms where their boundaries have been replaced by goethite.

The microscopic appearance of sample SP-02 is shown in Figure 4. In the image, the presence of the minerals magnetite (Fe₃O₄), goethite (FeO(OH)), hematite (Fe₂O₃), quartz (SiO₂), and pyrite (FeS₂) is also visible. The sulfide minerals identified in this section are only Pyrite in trace amounts in the sample, and no other sulfide minerals were found.

The results of the microscope analysis of the excavated iron ore sample (SP-1) and the crushed iron ore sample (SP-2) have relatively similar mineral compositions. Both contain the minerals magnetite, hematite, goethite, and quartz. The difference is seen in the excavated boulder, consisting of a large amount of chalcopyrite, and in the crushed material, consisting of a small amount of pyrite. However, both of these sulfide minerals have the potential to trigger the formation of acid mine drainage.



Figure 3. Photomicrograph of a polished section of a sample of excavated iron ore material (SP-1): (a) magnetite (mag), goethite (goe), chalcopyrite (ccp) and quartz (qrz); (b) goethite (goe), magnetite (mag), hematite (hem), and chalcopyrite (ccp)



Figure 4. Photomicrograph of the polished incision of a sample of crushed iron ore material (SP2): (a) goethite (goe), magnetite (mag), pyrite (pyr), and quartz (qrz); (b) goethite (goe), magnetite (mag), hematite (hem), pyrit (pyr), and quartz (qrz)

3.3. X-ray diffraction analysis

The XRD method is intended to identify minerals that are not visible under a microscope. Interpretation of the XRD graph (Fig. 5) for rock samples from excavation intact rock revealed existing oxide minerals, sulfide minerals, and gangue minerals. The oxide minerals are hematite (3.54, 2.69, 2.20, and 1.69 Å), goethite (4.16, 2.28, 1.83, and 1.69 Å), magnetite (2.96, 2.52, 2.42, 1.61, and 1.48 Å), and birnessite (7.12 and 3.54 Å). The sulfide mineral identified in this graph is chalcopyrite (1.59 and 1.45 Å), while the interfering minerals are quartz (3.35 and 1.97 Å).



Figure 5. Difraktogram of sample SP-1

The XRD analysis of samples taken from crushed material stockpile of SP-2 reveals a pattern illustrated in Figure 6. The oxide minerals found include hematite (3.68, 2.53, 2.29, 1.84, and 1.69 Å), goethite (4.22 and 2.45 Å), magne-tite (2.97, 2.10, and 1.48 Å), and birnessite (7.10 Å). The sulfide mineral is pyrite (2.70 and 2.21 Å), while the gangue mineral is quartz (3.34 and 1.60 Å). The diffractogram of this sample (SP-1) is shown in Figure 6. The three samples obtained from this stockpile show similar XRD patterns.



The XRD analysis of rock samples from SP-1 and SP-2 shows various oxide, sulfide, and gangue minerals. In the SP-1 sample, the identified oxide minerals include hematite, goethite, magnetite, and birnessite. Chalcopyrite is the present sulfide mineral, and quartz is the gangue mineral. The XRD patterns for these samples show a consistent mineral composition. In the SP-2 sample, similar oxide minerals were found, with hematite, goethite, magnetite, and birnessite once again being the most prominent. However, pyrite sulfide minerals were observed in SP-2, while quartz was present as a gangue mineral. If compared to the results of the polarizing microscope analysis, this XRD analysis found birnessite.

3.4. Physical properties of water

Mining activities typically involve heavy metals, minerals, and various toxic substances that can present considerable health hazards to both humans and aquatic ecosystems. The evaluation of water quality and pollution levels in surface and groundwater is conducted through the analysis of the physicochemical parameters of these water sources [3], [5].

During the dry season, water accumulates in mine pit lakes and percolates as groundwater discharges into rivers in minimal volumes but with potentially elevated chemical concentrations. During the rainy season, pit lakes discharge substantial amounts of water into rivers with low chemical concentrations. Stockpiles adjacent to the pit lake may also influence the water quality in the mining vicinity. Rainwater accumulating on the pile will traverse the topo-graphic pathways and amalgamate with water from the mine pit lake. This research examines the condition of water that overflows from the mine void and disperses into the adjacent sections of the mine. The selection of surface water sampling sites is based on the correlation between water flow and entities that may contribute to environmental contamination.

The first sample site is at the center of the void (W-01), whereas W-02 is positioned at the void's exit, the nearest point to the crushed iron ore stockpile. Water from both locations will converge at W-03. The W-04 point is situated at the junction of water flow from W-03 and W-10, which is the effluent from the stockpile of uncrushed mining material (SP-1). The water proceeds to locations W-05 to W-09, following the distribution illustrated in Figure 1.

The physical properties of water were measured for pH and turbidity parameters. Data from W-01 to W-10, presented in Table 1, show that the pH levels at measurement points W-01 to W-09 are neutral, with values between 6.2 and 8.2. On the other hand, at point W-10, the pH value indicates acidic conditions, recorded at 2.9.

properties	of surface runo
pН	Turbidity
(-)	(NTU)
7.4	0.0
7.5	1.7
7.3	6.0
6.2	1.4
7.1	3.7
7.7	0.5
7.8	0.4
8.0	21.4
8.2	16.4
2.9	0.4
	properties (pH (-) 7.4 7.5 7.3 6.2 7.1 7.7 7.8 8.0 8.2 2.9

W-10 is the only exception, as the water flowing from the stockpile shows the lowest acidity level. The pH of the water at W-04 increased to 6.2 after coming into contact with the water flow from the void. The water then flows downstream to the main river, with a pH increase of 8.2.

In addition, for the turbidity values, a range from 0 at W-01 to 21.4 at W-08 was obtained. The data in Table 1 shows that high turbidity values of 16.4 and 21.4 NTU occurred at points W-09 and W-08, respectively. Both measurement points are located on the main line with a more significant flow rate. The main river flow carries sediment particles or eroded material.

3.5. Chemical composition of water

Chemical analysis of surface water was conducted on ten samples from the mining site and its surroundings. The study encompasses eight primary elements of four cations: sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), and magnesium (Mg²⁺), and four anions: chloride (Cl⁻), bicarbonate (HCO₃⁻), carbonate (CO₃²⁻), and sulfate (SO₄²⁻). Table 2 and Figure 7 display the chemical composition of the main elements in water. In addition, measurements of 4 other chemical elements or compounds that are likely to be abundant in water at iron ore mines were also conducted, namely Fe total, SiO₂, S, and P.

Table 2. Chemical properties of major elements in water samples

Sample	Cation (meq/litre)			Anion (meq/litre)				
	K^+	Na^+	Ca ²⁺	Mg^{2+}	Cl-	CO3 ²⁻	HCO3 ⁻	SO4 ²⁻
W-01	0.56	2.63	2.00	5.97	37.88	0.20	1.50	2.27
W-02	0.59	2.59	2.47	4.53	62.89	0.10	1.29	2.39
W-03	0.10	1.43	4.12	5.97	80.49	0.50	0.95	3.19
W-04	0.52	2.17	2.00	6.18	133.32	0.70	2.64	4.45
W-05	0.14	1.76	3.91	8.45	42.76	0.50	0.85	5.72
W-06	0.06	2.10	5.36	3.30	35.22	1.39	0.70	1.84
W-07	0.08	1.95	2.47	2.47	47.79	1.29	0.95	1.44
W-08	0.08	1.37	1.65	2.27	37.88	2.29	0.75	0.50
W-09	0.08	1.41	1.24	7.42	45.28	2.99	0.90	0.13
W-10	0.02	1.69	2.00	6.39	52.82	1.49	1.05	35.81

Chloride ions (Cl⁻) are the dominant element in the water from the 10 sampling locations previously described. The lowest concentration was in W-06, with a value of 35.22 meq/liter, and the highest was in W-04, with a value of 133.32 meq/liter. The concentration values of all elements were relatively the same for samples W-01 to W-10. A somewhat different condition was found at W-10 with a significantly higher sulfate concentration than other sampling points. The sulfate concentration in samples W-01 to W-09 varied from 0.13 meq/liter at W-09 to 5.72 meq/liter at W-05, while at W-10, it was 35.81 meq/liter.



tions in surface runoff

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The plotting of water chemical data into a trilinear diagram is shown in Figure 8. Samples W-01, W-03, W-04, W-05, W-09, and W-10 belong to the magnesium type in the cation phase, while samples W-02, W-06, W-07, and W-08 are of the non-dominant type. In the anion phase, all samples are in the chlorine phase. The parallelogram diagram shows that the obtained water sample falls within the calciummagnesium-sulfate facies. The trilinear piper diagram illustrates discrepancies between water samples from W-10 and those from other collection points. The combination of water from the pile with runoff from the void demonstrates an elevation in chloride levels at W-04 and sulfate levels at W-05.



Figure 8. Plotting water sample into Piper trilinear diagram

In addition to these main elements, the concentration of other essential elements and compounds that need to be considered in iron ore, such as Fe content, gangue (SiO_2) , and contaminants like P and S, is also measured. The results of measuring the concentration of these compounds or chemical elements typically associated are recorded in Table 3.

Table 3. The composition of elements and chemical compounds related to water in iron ore mines

ID	Fe total	S	SiO ₂	Р
	ppm	ppm	ppm	ppm
W-01	2.02	0.044	28.16	0.083
W-02	1.63	0.044	28.89	0.050
W-03	0.11	0.042	28.21	0.036
W-04	0.17	0.047	27.69	0.041
W-05	0.13	0.048	30.70	0.031
W-06	0.38	0.041	33.36	0.039
W-07	0.25	0.032	30.95	0.047
W-08	1.89	0.045	31.25	0.101
W-09	0.43	0.045	33.23	0.120
W-10	120.14	0.048	107.91	0.120

The S and P elements concentrations are relatively the same for all samples, with S values ranging from 0.32 to 0.48 ppm and P values ranging from 0.031 to 0.12 ppm. A striking difference occurs in the concentrations of total Fe and SiO₂. The total Fe content in samples W-01 to W-09 varies from 0.11-2.02 ppm, while in W-10, it is 120.14 ppm. In addition, the SiO₂ concentration in samples W-01 to W-09 ranges from 27.69-33.36 ppm, while in W-10 it is 107.9 ppm. This indicates that the increase in chemical concentration from water runoff passing through the iron ore stockpile can be diluted along the river flow, thus not significantly contributing to environmental pollution around the mine.

Studies on the impact of active iron ore mines on the surrounding environmental conditions have identified that they cause heavy metal contamination in the soil [8] and reduce the quality of surface and groundwater [9]. The extraction and processing of iron ore can negatively impact the environment through the continuous excess of metals into water bodies and soil. This can be triggered by the process of mineral dissolution and geomorphic processes. Concerns about these conditions are always present around the mines, especially in those that have been abandoned with residual materials scattered on the surface. However, from this study, it is significantly observed that there is the formation of acid mine drainage with a pH of 2.9 and total Fe above 120 ppm locally, but after mixing with other water bodies, it has returned to neutral due to the dilution process.

This research activity was conducted during the rainy season to observe the relationship of surface runoff from the mine to the surrounding area. From the research results, it appears that water quality is not affected significantly by the mine in the surrounding area. This is similar to many abandoned mines that have water meeting the quality and quantity criteria for a potential supply source for the city [15]. To confirm this, research needs to continue with intensive monitoring of changes in water quality in the mine pit lake during the dry season. This is to study the changes in water conditions within the void due to interactions with surrounding rocks and the process of increasing dissolved substance concentration due to evaporation. This research needs to pay attention to changes in water quality parameters with depth to conclude whether the accumulation of water in the mine void can be used as a raw water source for community activities around the mine.

4. Conclusions

Mineralogical analysis through ore microscopy and XRD has identified notable environmental concerns. Iron ore deposits, obtained through direct excavation or crushed materials, include sulfide minerals like pyrite (FeS_2) and chalcopyrite ($CuFeS_2$). These minerals may generate acid mine drainage, posing a significant threat to the ecosystem surrounding former mining sites.

Indications of acid mine drainage formation were found at the observation point of the water channel flowing from the excavated iron ore stockpile, with a water pH value of 2.9 and a total Fe content of around 120 ppm. Meanwhile, the voids from the former mining site yielded water with a neutral pH. The mixing of this acid mine water with water from the mine pit lake in the tributary resulted in water with a pH of 7.03 (neutral). Therefore, the formation of acid mine drainage at the stockpile of mine excavation material does not cause an environmental impact in the surrounding area. The voids left by mining can be used as a water source for the surrounding community.

Author contributions

Conceptualization: MR; Data curation: MR, SF; Formal analysis: MR, SF, AS, NH; Funding acquisition: MR; Investigation: MR, SF, AS, NH; Methodology: MR, SF; Project administration: MR, NH; Resources: SF, AS; Software: MR, AS; Supervision: MR; Validation: MR, SF; Visualization: AS, NH; Writing – original draft: MR; Writing – review & editing: MR, SF. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interests

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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Гідрохімічний аналіз поверхневого стоку води із покинутої залізорудної шахти

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Мета. Дослідження можливого утворення забруднювачів у покинутих гірничих районах внаслідок взаємодії порід, води та повітря, а також їхній вплив на якість поверхневих вод у зоні гірничого відводу.

Методика. Мінералогічний аналіз залізорудних зразків із відвалів за допомогою оптичного мікроскопа та рентгенівської дифракції (XRD), а також хімічний аналіз води, відібраної з району видобування та річки нижче за течією. Дослідження проводилися в дощовий сезон, коли спостерігався перелив води з кар'єрного озера у прилеглі території.

Результати. Визначено, що залізна руда на досліджуваній ділянці містить, переважно, оксидні мінерали заліза, зокрема, магнетит, гематит і гетит, а також виявлені кварц, бірнесит, пірит і халькопірит. Встановлено, що наявність двох сульфідних мінералів – піриту (FeS₂) та халькопіриту (CuFeS₂) – вказує на потенційну можливість утворення кислотного дренажу шахт. Вимірювання рН води, що стікає із залізорудного відвалу, показали значення 2.9, тоді як у водовідстійнику та навколишніх річках pH змінювався в діапазоні 6.4-8.2. Встановлено, що утворення кислотного дренажу та висока концентрація загального Fe в одному з відвалів не спричинили значних змін якості води у довкіллі.

Наукова новизна. Науково доведено, що формування кислотного дренажу шахт на покинутих гірничих об'єктах має лише локальний характер і після розбавлення іншими водними потоками рівень pH повертається до нейтрального.

Практична значимість. Проведені дослідження вказують на потенційну можливість використання води з кар'єрного озера як джерела водопостачання для місцевого населення.

Ключові слова: покинута шахта, залізна руда, рентгенівська дифракція, кислотний дренаж шахт, кар'єрне озеро

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