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RESEARCH ARTICLE

Evaluation of Environmental Impacts of Gold Mine Operation in Terms of Sustainable Environment

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ABSTRACT

In this study, the waste storage facility (WST), where the process wastes generated during the mining activities of the gold mine operation, which is of great importance, are stored, is planned to be built in an environmentally viable way. Within the scope of the WST construction, experiments and tests were carried out to ensure impermeability by the environmental legislation, and after the completion of the works, it was aimed to reintroduce the waste storage areas to nature. The water and wastewater management, air pollution, noise pollution, soil pollution, and chemicals management stages of the facility were carried out by regulations and standards, and the control and measurement results were evaluated from an environmental point of view.

Contents

1. Introduction

With the increase in the population of the world, developing technology, and industrialization, natural resources, and mines were needed and the extraction, processing, storage, and use of these resources have become a sector. This sector is the whole of the techniques and methods related to the exploration, location, extraction, and operation of underground resources, gathered under the name of mining, and enables the use of especially raw mines, ores, industrial raw materials, coal and petroleum, precious or semi-precious metals. Minerals extracted from underground vary according to their intended use; especially fuel, energy in many fields of industry, raw materials, coatings, etc., used in different

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fields. Mineral reserves for countries are especially important for coal, chrome, gold, silver, gold, copper, zinc, iron, and boron industries, and development. Especially gold is considered to be the first metal that humanity has benefited from, which has a wide area of use for countries and gives information about the power of the country's economies.

Gold is used in a wide range of industrial areas due to its superior electrical conductivity, ease to form, and corrosion resistance, in space vehicles, medical industrial and medical fields, optical lasers, and electronic instruments due to its high reflectivity. In addition to its industrial use, gold, which is seen as an investment tool, has also been a power for people. For these reasons, gold mining has become indispensable for countries every day [1].

While 53% of the world's gold production was made in the USA, Canada, Australia, and S. Africa, this rate increased and the production increase was 13 times in the USA, 18 times in Australia, and 3.5 times in Canada compared to 1980. In addition, Turkey ranks fifth in the world's gold demand along with India, the USA, Saudi Arabia, and China [2, 3]. While Australia, America, and Canada rank first in gold production, Turkey ranks 22nd with 40 tons of gold production. Some of the gold mines operating in Turkey are Artvin; Cerrahtepe, Balıkesir; Çoraklık, Kubaşlar, Kızıltepe, İvrindi Canakkale; Lapseki, Kirazlı, Akbaba Erzincan; Çöpler, Eskişehir; Kaymaz, Sivrihisar, Gümüşhane; Mescitli, Mastra, Izmir; in Ovacık, some mines will be operational and out of operation [3]. In addition to the benefits of these enterprises, which contribute greatly to the country's economy, the negative effects on the environment should be controlled. The wastes generated during ore preparation and extraction in these enterprises should be managed in terms of EIA and Regulations. While mining wastes are environmentally harmful, physical and chemical treatments are applied to extract valuable minerals from soil and rock in large quantities during processing. While the process water wastes generated during the process are also stored in the waste collection dams, waste management is applied [4–6]. In general, the damages caused by mining wastes to the ecological balance; Water pollution, visual pollution, deterioration in the land structure and erosion risk as a result, negative effects on living life, increase in carbon emissions, dusting, and noise, also heap leaching wastes and process wastes are wastes that need to be managed [7, 8]. Economic recovery can be achieved by taking many measures such as ensuring a sustainable environment, efficient use of resources, and minimizing waste [9]. The research has determined that the global greenhouse gas (GHG) emissions arising from gold mining exceed the standard values of the annual values of the country's emission intensity and bring an additional burden to the country's economy. Gold production costs were increased to an average of $13 per ounce in Finland and $ 275/ oz in South Africa [10]. Mine waste storage facilities should be designed to store the high sludge contained in the mine wastes in a controlled and planned manner, and they should be built in full capacity dimensions by making the necessary calculations and testing [11].

In the dry storage method of mining process wastes, the moisture content of the aqueous wastes is reduced to the natural moisture of the material and storage is carried out, and the use of machinery and equipment is required to transport the material to the storage area and to obtain the form with the desired consistency [12]. One of the storage methods of mine wastes is the paste technology method, in which the ore preparation plant residues are dewatered by filtration and stored in a viscous manner with the added binder material [13, 14]. Gold mining heavy metal wastes mix with water and reach plants, animals, and indirectly people in nature, creating a great risk [15]. As a result of this pollution, metal toxicity in the air, soil, and water increases and can accumulate in food chains permanently [16]. In particular, the most common pollution parameter is arsenic-containing waste, which is considered potential environmental pollution [17]. In one study, high metal concentrations were found in plant roots in samples taken from the surrounding vegetation in experiments to investigate the effects of mining wastes. The study proved that the Pb concentrations in the air biomass exceeded the reference ranges and that the toxicity from the plants would also affect human health and contributed to the future ecotoxicological risk assessments of the measures to be taken as an improvement [18].

2. Environmental Assessment of Gold Mining

Gold production facilities are required to obtain operating permits, prepare a comprehensive environmental impact assessment report, and conduct feasibility assessments. The land use of the enterprise and any waste generated during the operation should be carefully evaluated in terms of human health and the environment, and the measures and studies regarding the protection of water, soil, air, and natural life should be carried out within the scope of regulations [2]. Environmental precautions during the operations are carried out until the ore is mined and turned into gold; It should be taken under the headings of water and wastewater management, air management, waste management, noise management, soil pollution management, and chemicals management.

2.1. Water and wastewater management

As a result of the activities of certain units in the mine sites, wastewater is generated. Water savings can be achieved by eliminating the wastewater from these units or by returning them to the system. For wastewater originating from the vehicle washing unit, a disposal pool, a waste leachate pool, a preliminary settling pool, a concrete plant water pool, and a settling pool should be included in the system. Different wastewaters come out of different units, especially in the facilities. For example, wastewater generated in mine sites with a vehicle wash unit can be stored in an impermeable pool and settling can be applied and sludge should be sent to the mud pool. Wastewater with low pH and high metal concentrations that may arise from rust storage areas should be taken into a sealed bottom collection pool, collected with rain water, and analyzed periodically. In open pit and underground gold mine operations, groundwater discharge should be done under the water control of the enterprise in activities below the groundwater level. The waters to be discharged during the activities are collected in the underground operation settling basin, where suspended solids are removed and the resulting sludge should be sent to the sedimentation unit. Putty filler is prepared in the concrete plant for use in the underground operation of the gold mine.

Wastewater coming out of the operation should be stored in the impermeable pool in the concrete plant unit and sent to the pre-settlement pool by a pump. The sludge formed in the pools is sent to the settling pools for environmental pollution control. The water from the final settling basin must be sent via a pipeline to the WST. The sludge settling from the final settling basin should be drawn by a pump and sent to the WST [19, 20]. Storage areas should be irrigated periodically with a sprinkler to prevent dusting. In addition, germination studies should be carried out in vegetable soil storage areas and other landscaping areas.

2.2. Air control management

When the waste storage areas are finished, the vegetation should be laid, and germination and tree planting should be done. The facility should completely close crushing, screening, milling units, and conveyors. Dust caused by the work should be minimized by giving regular training including internal subcontractors in the business. The dusting that will occur during the loading and unloading processes should be reduced to a minimum by reducing the loading and unloading level. Loading and unloading areas should be kept moist by watering regularly. All mine access roads should be irrigated. Concrete and gravel coating should be done on the roads inside the facility [21].

2.3. Solid waste management

Domestic wastes originating from the mine site, industrial wastes, and packaging wastes, these wastes should be separated according to their types and kept in separate containers, and dangerous and non-hazardous wastes should be stored in temporary storage areas by authorized employees daily.

2.4. Noise control and management

According to the provisions of the noise management regulation, air shock, vibration, and noise measurements should be made in the blasting carried out within the facility with a fixed noise measuring device for 24 hours within the scope of the facility activity.

2.5. Waste storage facilities

Waste storage facilities are facilities consisting of impermeable layers and coating structures. Although the purposes of the impermeable systems and design criteria vary from area to area, in General; Dust and erosion control wastes with the potential to form acid, ensuring chemical stability (with control of oxygen and/or water ingress), control of pollutant component release (controlling leakage), and It is made to provide a growth environment for plant growth [22]. The precious metals extracted from the mines are taken and the remaining solids are sent to WST for final storage. The wastes generated in the ore enrichment facilities are sent to WST with the help of pumps. To keep the water consumption at a minimum level in the water collection pool placed on the bottom during the construction of the WST, the water in the process waste coming from the ore enrichment facility is recovered again.

3. Material and Methods

Structures were built where gold mine Gümüşhane (Mastra Koza) wastes are stored and controlled.4.5-hectare WST structure where 550.000m^3 of waste will be stored. In the construction of the slope and ridge excavations, fillings, slope surface preparation, drainage systems, floor clay filling, paving systems, and bonding channel processes are applied. In Figure 1 (a,b,c), images are given of the area of WST construction and after the geo membrane laying and bonding channel construction. base fill compression graph is given in Figure 2 [23].

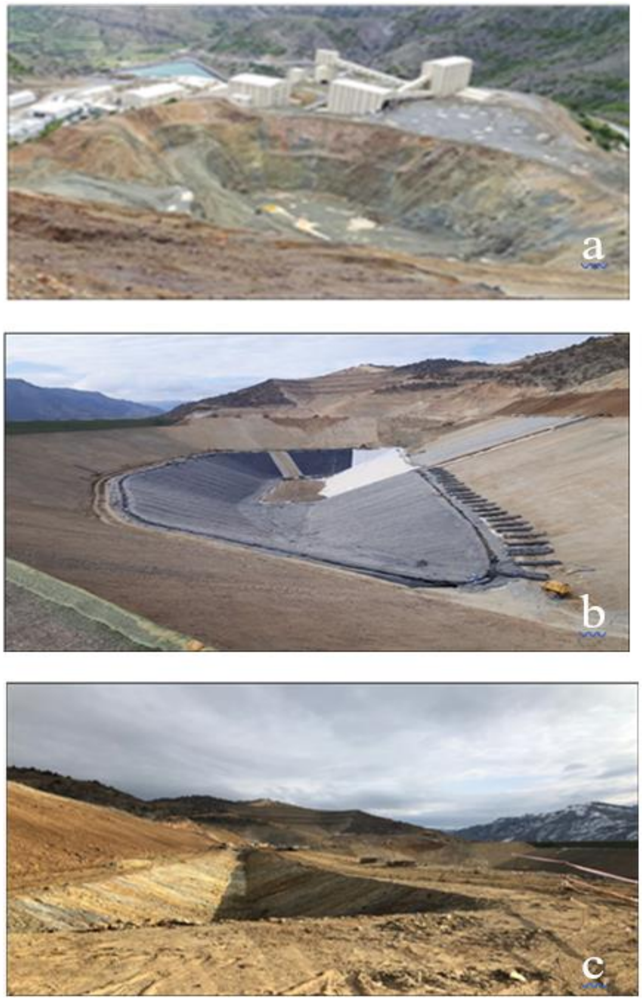

Figure 1 (a) Land view before WST construction (b) geo membrane laying (c) channel construction [23]

Figure 2 Base fill compression

Tests are carried out for the impermeability of the floor and safety measures are carried out. One of them is the air test, in which the tightness of the air duct between the geo membrane seams is checked for a certain period by pressure. The place where the air test was performed is given in Figure 3 [23].

Figure 3 Air-tested floor [23]

4. Results and Discussion

Due to the activities carried out at the project site, air quality, noise and vibration, blasting measurements, and observation wells measurements were made in terms of human and environmental health.

4.1. Air quality

Air pollution occurs when pollutants in the air, which adversely affect human health and nature, reach an amount and density above normal. These pollutants are generally emitted from sources such as traffic, industry, vegetation, and dust formation on surfaces by the effect of wind and heating. The shares of these sources of air pollution vary according to the pollutants they emit. The dust generated in the production of WST is controlled in terms of humans and the environment. Measurements are made with the collapsed dust collection chamber and are shown in Figure 4 [23].

Figure 4 Collapsed dust container

4.2. Noise and vibration

24-hour measurement can be taken with the noise and vibration device in the Mastra gold mine. In addition to the fixed measurements taken, measurements were taken with a mobile vibration device during the blasting at the mine site. The average values of the measured results are shown in Table 1 as noise and vibration results.

Table 1 Annual average of noise and vibration results in Sep 2017-2018

Day L. dB(A)	Even. L. dB(A)	Day Leq	Evening Leq	LA_{10}	LA_{90}	Daily vib. ($m\ ms^{-1}$)
65	55	50,2	49,2	51,1	47,7	0,466

Noise values cannot exceed the noise limit values in Table 4 of Annex VIII of the Regulation (limit values are 65 dBA in the daytime, 60 dBA in the evening, L 55 dBA at night for the areas where commercial buildings and noise-sensitive uses are located together and where residences are densely located).

4.3. Blasting measurement results

It is subject to the noise limit values specified in the Environmental Noise Evaluation and Management Regulation dated 07.03.2008 and numbered 26809. As a result of the measurements, it was observed that the vibration criteria did not exceed the allowable vibration values in Annex VIII Table 6 of the regulation. During blasting in WST, the vibration velocity is at most 19 mm/second. Vibration limit values are shown in Table 2 and. The blast measurement results made in WST are shown in Figure 5.

Table 2 Vibration limit values

Vibration frequency (Hz)	Maximum Permissible Vibration Rate (Peak Value -mm/s)
1	5
4-10	19
30-100	50

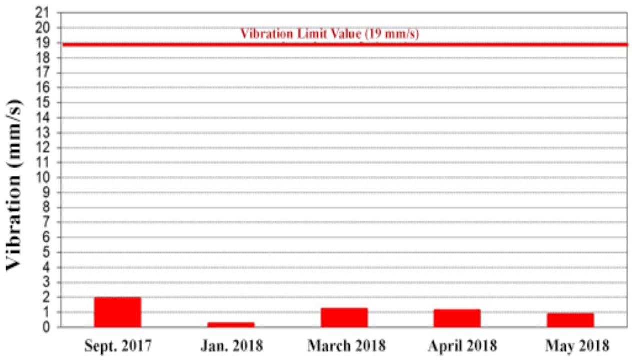

Figure 5 Blast measurement [23]

4.4. Observation wells

According to the Water Pollution Control Regulation (WPCR) and surface water Quality Management Regulation (SWQMR), which entered into force after being published in the Official Gazette dated 31.12.2004 and numbered 25687 in Turkey, observations opened at least one upstream point of the facility to determine the effects on surface and groundwater. Samples were taken according to the flow direction of the groundwater from at least two points determined in the wells and on the surface. In the project area, the observation well named GK-2 is located upstream, and the Observation Well GK-1 and the observation well named GK-3 are located downstream. The observation wells drilled are for monitoring purposes and measurements are made before WST becomes operational. Observation well measurements are taken as a reference for the WST to be monitored. The graph of the observation wells shows the pH analysis graph of the observation wells in Figure 6, the oxygen graph of the observation wells in Figure 7, and the conductivity graph of the observation wells in Figure 8 [23].

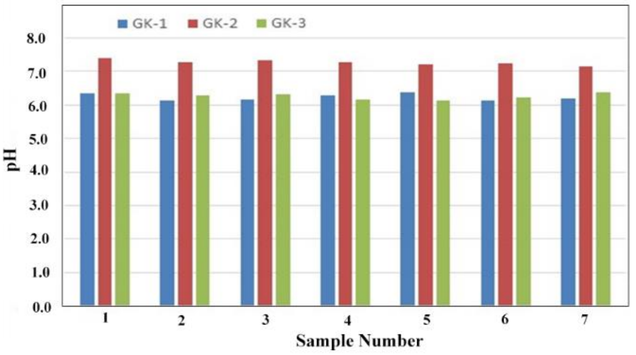

Figure 6 Observation wells pH values graph

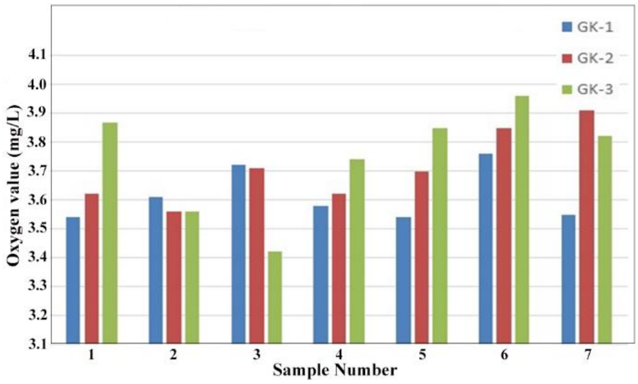

Figure 7 Observation wells oxygen values graph

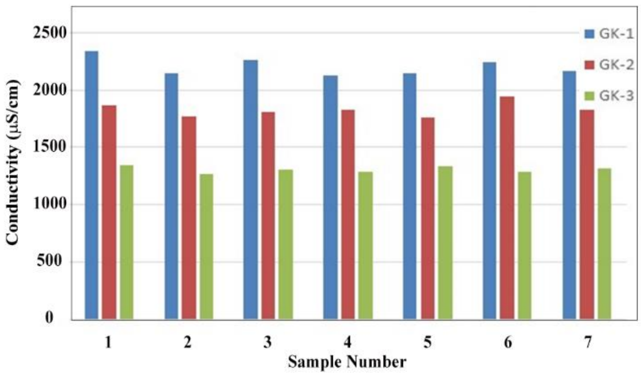

Figure 8 Observation wells conductivity values graph

5. Conclusion

It has been observed that all required field and laboratory tests are applied in Mastra WST to prevent any leakage from the area where the process wastewater is stored to nature. The compression ratio of the filling material used in the project is required to be 85%, and results above this value were obtained in the compression test results.

For the area required for WST, degraded land was used without the need for excavation, filling, blasting, loading, and unloading. The observation wells drilled in the 500,000 m^3 Mastra WST are for monitoring purposes. The pH, conductivity, and oxygen values of the underground water resources of the mine site were obtained in the pancake wells. Rehabilitation is required as a result of the open pit activities of the mines. If the mines need WST instead of performing open pit rehabilitation, the open pit area can be converted to WST by calculating the benefit/cost ratio. The reorganization of the open pit area as WST is a great ecological problem, as it will ensure that virgin land is not used, and will eliminate many environmental risk sources such as pollution of groundwater, air pollution caused by various climatic factors, pollution of surface water resources and agricultural soil as a result of erosion and surface runoff. considered as a benefit. Depending on the development of technology, mine process wastes should be evaluated within the Zero Waste Project. The mines in the regularly stored waste should be recovered and systems that will not require regular storage should be developed. Since WSTs are important engineering structures, they are important in their design, construction, operation, durability, permeability, etc. These are the structures that must be followed with great care by the regulations until the tests, closure, and post-closure monitoring.

Declaration of Conflict of Interest

Authors declare that they have no conflict of interest with any person, institution, or company.

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