Determination of the environmental impacts of gold mining within the scope of the circular economy: Applications of the new economic model of the European Union

Edip Avşar[1], Sevgi Akkoy[2] & Ramazan Kiliç[3]

[1] Bilecik Seyh Edebali University Vocational School, Environmental Protection Technologies Department, 11230 Bilecik, Türkiye

[2] Bilecik Seyh Edebali University, Graduate School Institute, Industrial Sustainability Department, 11230 Bilecik, Türkiye

[3] Bitlis Eren University Environmental Engineering Department, 13100 Bitlis, Türkiye Environmental Engineering, Bitlis, Türkiye

Correspondence: Bilecik Seyh Edebali University, Graduate School Institute, Industrial Sustainability Department, 11230 Bilecik, Türkiye. E-mail: akkoysevgi@gmail.com

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Abstract

Following the Industrial Revolution wastes generated in the production and consumption processes have emerged as disruptive elements to ecosystems and threats to the safety of future generations. Resources are finite, limiting the ability to sustain the cycle for a sustainable future. With increasing population and industrial development, the single-use lifestyle of “take, use, discard” has become a significant problem in direct economic strategies. The European Union has led the way in waste management with its circular economy strategy, aiming to 'do more with less' as a long-term approach to economic growth. Today, companies in various industries must set an example for environmental awareness, lifestyle, and consumption habits in society to shift positively. This study focuses on the gold mining sector. Its objective is to examine and evaluate the impact of cyanide used in the purification process on groundwater and surface water resources. A sample facility was selected for analysis. Monthly environmental reports from 2015-2016 were obtained for this facility, allowing the study to examine the effects of cyanide on water sources by comparing available analysis results with the relevant national legislation. As a result, it was found that the cyanide levels at the treatment plant outlet and waste storage facility did not exceed the committed limits, and continuous pollution was not observed in the monitoring wells drilled to assess groundwater contamination.

Keywords: direct economy, circular economy, gold mining, environmental impacts, cyanide, water pollution.

Determinação dos impactos ambientais da mineração de ouro no âmbito da economia circular: Aplicações do novo modelo econômico da União Europeia

Resumo

Após a Revolução Industrial, os resíduos gerados nos processos de produção e consumo surgiram como elementos disruptivos para os ecossistemas e ameaças à segurança das gerações futuras. Os recursos são finitos, limitando a capacidade de sustentar o ciclo atual para um futuro sustentável. Com o aumento da população e do desenvolvimento industrial, o estilo de vida de uso único de "pegar, usar, descartar" tornou-se um problema significativo nas estratégias econômicas diretas. A União Europeia liderou o caminho na gestão de resíduos com sua estratégia de economia circular, visando "fazer mais com menos" como uma abordagem de longo prazo para o crescimento econômico. Hoje, para que a conscientização ambiental, o estilo de vida e os hábitos de consumo na sociedade mudem positivamente, as empresas de vários setores devem dar o exemplo. Este estudo se concentra no setor de mineração de ouro. Seu objetivo é examinar e avaliar o impacto do cianeto usado no processo de purificação em recursos hídricos subterrâneos e superficiais. Uma instalação de amostra foi selecionada para análise. Relatórios ambientais mensais de 2015-2016 foram obtidos para esta instalação, permitindo que o estudo examinasse os efeitos do cianeto em fontes de água comparando os resultados de análise disponíveis com a legislação nacional relevante. Como resultado, verificou-se que os níveis de cianeto na saída da estação de tratamento e na instalação de armazenamento de resíduos não excederam os limites comprometidos, e não foi observada poluição contínua nos poços de monitoramento perfurados para avaliar a contaminação das águas subterrâneas.

Palavras-chave: economia direta, economia circular, mineração de ouro, impactos ambientais, cianeto, poluição da água

1. Introduction

The ongoing advancements in technology and urban population growth stemming from the Industrial Revolution. This trend has resulted in numerous negative environmental impacts, particularly the depletion of natural resources and the acceleration of climate change (Standart, 2018). Environmental pollution is not confined to production processes alone; the accumulation of waste at a rate surpassing the environment's capacity for self-renewal has brought pollution to the forefront of global concerns (Steffen et al., 2015).

The linear economy, characterized by a 'take-make-use-dispose' model, originated with the Industrial Revolution, shaping the global economy around this unidirectional system. This model operates on the assumption that natural resources are readily available, abundant, easily accessible, inexpensive, and free to waste, which has led to surpassing planetary limits in various areas. For many years, the linear economy has dominated global production. However, as the environmental and resource-related issues of this model have become increasingly apparent, the search for alternative frameworks has intensified (Sustainable Development Goals, 2021).

The United Nations' Sustainable Development Goals (SDGs) provide a roadmap for achieving this vision. Consequently, many industries are evolving, with innovative circular economy practices challenging traditional frameworks. Gold, a precious metal dating back over 7,000 years, has long held significant cultural and economic value. Throughout the life cycle of a mining project, from exploration to closure, environmental impacts occur (Kılıç 2018).

The study's objective is to evaluate the impact of cyanide, used in gold mining purification processes, on groundwater and surface water resources. A sample facility was chosen for analysis, and monthly environmental reports from 2015 to 2016 were reviewed to assess the effects of cyanide on water sources. The findings were contextualized within the circular economy framework and compared to national environmental regulations. Results indicate that cyanide concentrations at the treatment plant outlet and waste storage facility remained within regulatory limits, and no continuous pollution was detected in the observation wells monitoring groundwater.

2. Literature review

2.1 Circular economy model and waste management

Looking at the historical development of the circular economy, we see that the relationship between the economy and the environment is divided into two periods: before and after the 20th century thus, we can examine the relationship between the economy and the environment in two ways (Aldemir; Kaypak, 2008). Given the uncontrollably increasing resource consumption in the world, local municipalities, politicians, businesses, and non-governmental organizations are increasingly discussing solutions for limited resources (Leipold and PetitBoix, 2018). Countries around the world are now gradually abandoning the linear economy model and moving towards a circular economy business model. This shift has led to the concept of the circular economy.

The circular economy has become one of the most important topics on the agenda in public debates about new and more sustainable industrial paradigms and strategies in almost every field today. The linear economy model, which is an economic model in which raw materials are extracted and used in finished products through open production and returned to waste after consumption, is now being replaced by a circular economy model, which aims to transform the way resources are used and utilized. The idea behind the development of the circular economy is that businesses that traditionally adopted the build-use-dispose model now face increased responsibility. The new model was developed as a result of having the responsibility to maintain their values re-evaluate their production models and search for new ways of thinking to meet the needs not only of shareholders and close stakeholders but of all humanity (Gedik, 2020). In this context, waste management hierarchy is given in (Figure 1).

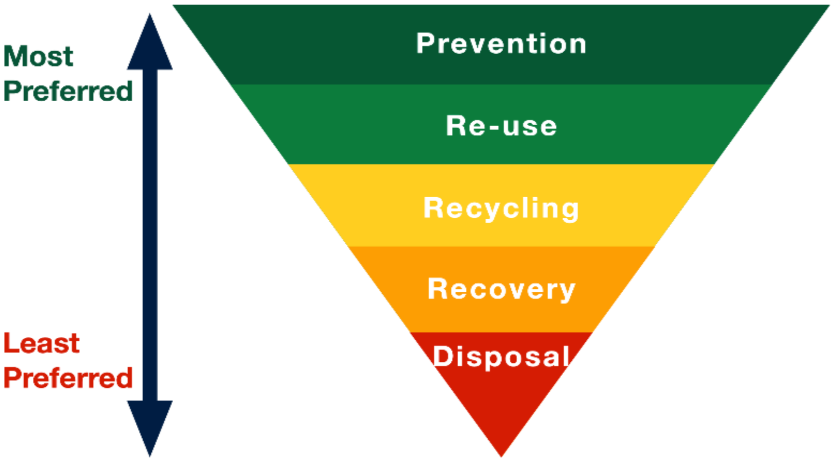

Figure 1. Waste management hierarchy. Source: Zero Waste (2022).

This shows us that the broadest concept of the circular economy will be given by the 5Rs. The 5Rs stand for "Refuse, Reduce, Reuse, Recycle, and Rot" and are defined as follows:

1. Refuse: It is a buy, use, throw away approach. In other words, it is necessary to think well before buying and reject if it is not needed.
2. Reduce: Reduce unnecessary consumption, which means living simply and simplifying everything. You should not burden yourself with things you use very little and do not need.
3. Reuse: Reuse what you have, i.e. avoid disposable and packaged products.
4. Recycle: Zero waste is central to this lifestyle. First of all, it is necessary to consider what you can recycle when buying things that you cannot refuse, reduce, or reuse.
5. Rot (Compost): This refers to the decomposition and nutrient cycling of organic materials, i.e., composting organic waste (Johnson, 2013).

With the same idea, our country's mining enterprises and cement industry are planning to increase their current potential to higher levels, especially with energy and different recovery techniques from waste.

The four principles of the circular economy are

- Waste is a product nutrient a nutrient for products countries can get more value from diversity when they share their strengths and have a larger pool of resources),
- Many countries can get more value from diversity when they share their strengths and have a larger pool of resources), countries can gain more value from diversity by sharing strengths and having access to a larger pool of resources
- Using energy from renewable sources,
- Thinking in terms of systems (people, places, and ideas)

The circular economy approach is given in (Figure 2).

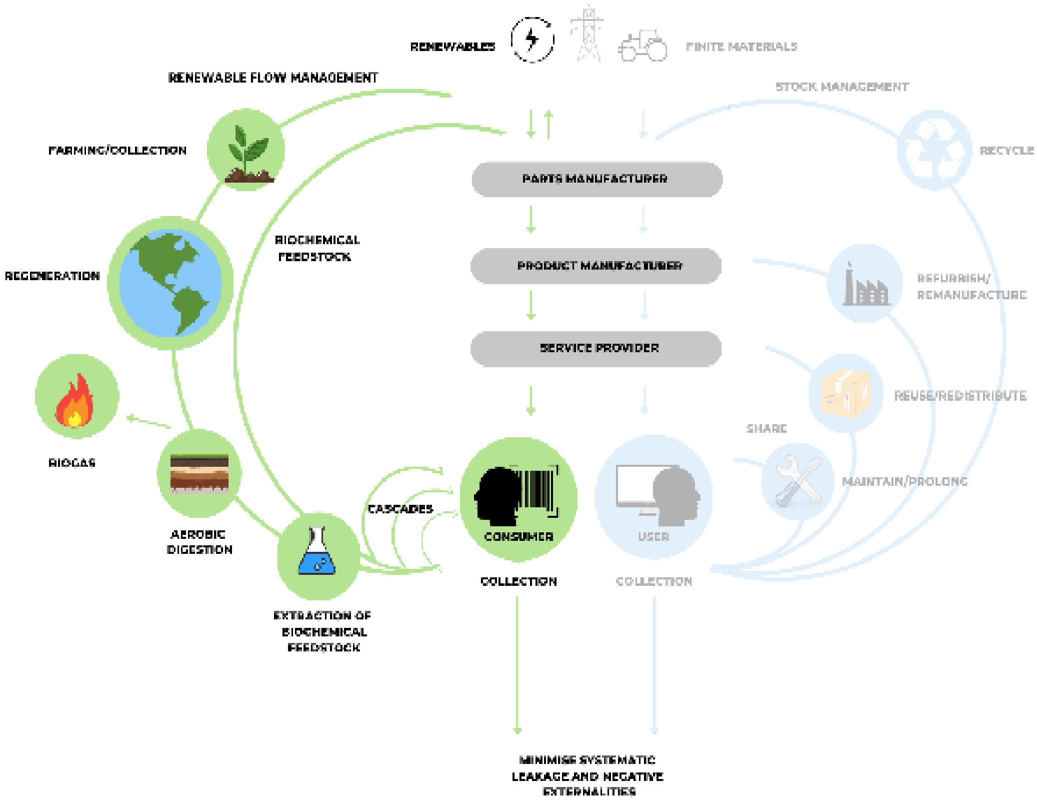

Figure 2. Circular economy approach. Source: Circularinnovationlab (2021).

Thanks to the circular economy, there is a need for increased cooperation between sectors in order to reduce the waste generated after the consumption process or during the production process and to ensure resource efficiency. Thanks to the circular economy model that requires this cooperation, resources can be kept in a continuous cycle and used for a long time, saving energy and reducing waste. In addition, minimized waste will also become recyclable (Balbay et al., 2021).

In its 2015 report “Closing the loop Closing the Loop - An EU Action Plan for a Circular Economy the European Commission defines the circular economy as the conservation of economic resources and the minimization of waste production. The transition to a circular economy is described as the foundation of “the EU's efforts to develop a sustainable, low-carbon, resource-efficient and competitive economy. This transition is key to a sustainable competitive advantage for Europe, as it enables resources to be reused to create value. It is a kind of technological revolution (Hobson; Lynch, 2016).

The mining sector is the sector that produces the most waste in our country. In this context, it is very important to integrate these wastes into the circular economy and to apply the best available technologies that produce less waste to the sector. Precious metal mining is one of the mining activities carried out intensively in our country and gold mining is a branch of it. It is important to reduce environmental impacts by examining mining activities according to the 5R technique. Gold is an important and precious raw material that is used by several manufacturing sectors. Sectoral usage areas of gold are given in (Figure 3).

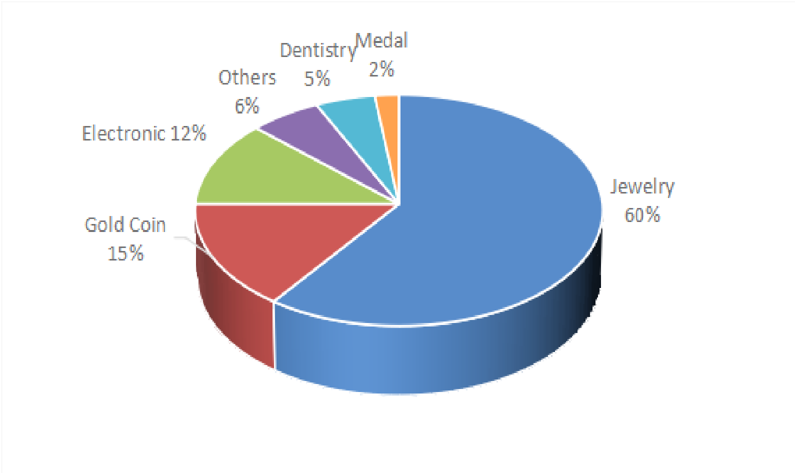

Figure 3. Sectoral usage areas of gold. Source: Authors (2024).

Today, 3,330 tons of gold are produced in the world, and around 38 tons in Türkiye. Mining activities cause the loss of biodiversity resources (Acosta et al., 2011). It is also known that the environment and human health are negatively affected by heavy metals in regions where mining activities take place (Franco-Hernández et al., 2010). Especially in the human body, cyanide prevents cells from using oxygen, creating hypoxia in tissues and causing a bluish discoloration of the skin. If the respiratory system cannot supply cells with oxygen and precautions are not taken rapid, deep breathing followed by convulsions, loss of consciousness, and suffocation can result.

The most obvious form of cyanide is HCN gas. If the concentration of HCN in the air reaches 250 ppm, death can occur within a few minutes (ELAW, 2010). It has been determined that these activities pollute not only the environment but also the waters and atmosphere in the region (Franco-Hernández, 2007). Gold mining is a much more polluting element for the natural environment than other mining. After the gold in the ore used in this mining is taken, approximately 99% of it is released into the environment as waste (Adler; Rascher, 2007). Therefore, it has very harmful effects on the area in the region.

In addition to metals such as arsenic, cadmium, chromium, lead, and mercury, which pose a risk to human health during gold mining, other metals are also present as food contaminants. Cyanide, which is also a focus of discussion in gold mining, is naturally found in fruit juices, seed-based jams, and nougat. The importance of these metals varies with the amounts of them in foods. These amounts should not exceed "the ADI (Acceptable Daily Intake) value determined by scientific methods. According to the TUBITAK Report by Prof. Dr. Fehim Üçışık, the ADI value of cyanide is 0.05 mg/kg. Given that the ADI value of cyanide is 0.05 mg/kg^{-1}, a 70 kg person can safely consume up to 3.5 mg of cyanide per day (70 x 0.05 = 3.5 mg). "If the cyanide concentration in the tailings dam is 1 mg/L (1 ppm), the statement in the TÜBİTAK Report is considered accurate (Karakaya, 2001).

2.2 Impact of gold mining on water quality

In the context of the study, the examined facility operates as an open pit. From the obtained ore, gold is produced in the processing plant by tank leaching method. This method is applied to high-grade (> 3 g Au/ton soil) but fine-grained gold ores and gold recovery are high (90-99%). For this purpose, the ore is passed through the crusher, ground in ball mills, and turned into flour. Then, it is fed to steel leach tanks for the gold dissolution process with cyanide (Ünal et al., 2016). The reaction taking place in the leach tanks is given in Equation 1 (Cyanide Compounds, 2019). The waste resulting from the ore processing step is first taken to the INCO SO_2/air chemical degradation unit. The process consists of the conversion of free and weak acid-soluble metal cyanide complex (WADCN) to cyanate using a copper-catalyzed SO_2/air mixture in a controlled pH environment (pH 8-9). The reactions are given in equations 2 and 3. Thanks to the reaction, all types of cyanide, including stable iron cyanide complexes, are removed from the solution (Mudder et al., 2001).

$$4Au + 8NaCN + O_2 + 2\,H_2O \rightarrow 4Na[Au(CN)_2] + 4NaOH \qquad (1)$$

Following this, the negligible amount of heavy metals in the ore content are stabilized by the ferric sulfate method and turned into insoluble compounds, and all of them are stored in the tailings pond. An average of 2000 tons of sodium cyanide is imported annually for mining activities in Türkiye (Gold Mining in the World and Türkiye, 2002). Cyanide is highly toxic to humans. The reference dose for non-carcinogenic chronic effects has been determined by the USEPA as 0.02 mg/kg/day^{-1} (Cyanide Compounds, 2019). The cyanide concentration allowed in tailings ponds on the EU side is 25 mg/L^{-1}. The maximum contaminant level (MCL) of cyanide allowed in drinking water by the USEPA is 0.2 mg/L^{-1} (URL 3). According to the Regulation on Water Intended for Human Consumption, the permitted cyanide concentration in drinking water is 0.05 mg/L as stated in Annex-1 (Itashy, 2005).

$$4CN^{-}\ Au + SO_2 + O_2 + H_2O \xrightarrow{Cu^{2+}\ Catalyst} OCN^{-} + SO_4^{2-} + 2H^{+} \qquad (2)$$

$$M(CN)_4^{-2} + 4SO_2 + 4O_2 + 4H_2O \xrightarrow{Cu^{2+}\ Catalyst} 4OCN^{-} + 4SO_4^{2-} + 4H^{+} + M^{+2} \qquad (3)$$

Source: Avşar; Kılıç, (2019).

3. Materials and Methods

The study aims to examine and evaluate the effects of cyanide used for purification purposes in gold mining, within the framework of the circular economy, an alternative economic model that has gained prominence over the last century. To utilize areas rich in gold, a vital mineral globally and in Türkiye, and to assess its environmental impacts, is found in Türkiye and to examine its environmental effects. A representative facility was selected for this study. Monthly environmental status reports for the sample facility for the years 2015-2016 were obtained, and the impact of cyanide used in mining on groundwater and surface water was analyzed based on current data and compared with national regulations.

3.1 Sampling points

All data in this study were sourced from environmental status reports prepared by the sample facility and shared with the public. As a result of the treatment "cyanide concentrations were monitored in the effluent from the chemical degradation facility and the recycled process water from the waste storage facility.

In addition, as stated in the EIA commitments of the sample facility, observation wells (GK) were opened before (GK-6, GK-20, GK-40) and after (GK-4, GK-5, GK-7, GK-8, GK-9, GK-11, GK-12, GK-21, GK-22, GK-23, GK-41) the waste storage area by the groundwater flow direction and the groundwater cyanide concentration was monitored and reported every month. Monitoring was extended beyond the facility boundaries, with observation wells established in nearby villages selected according to the groundwater flow direction, one before the facility (VILLAGE 1), one close after the facility (VILLAGE 2), and one far after the facility (VILLAGE 3) remover and the groundwater cyanide level was monitored and reported. The data obtained in the study covers 24 months from December 2014 to December 2016.

3.2 Measurement method

"For this study, total cyanide levels were measured spectrophotometrically (SM 4500 CN- E) after distillation pre-treatment (SM 4500 CN- C). The determination of weak acid-soluble cyanide was also made spectrophotometrically (SM 4500 CN-I) following the distillation pre-treatment (SM 4500 CN- C).

3.3 Statistical data

In the scope of the study, monthly averages of daily cyanide measurements at the treatment plant outlet are given in (Figure 4), and monthly averages of daily measurements in the water recycled from the waste pool to the plant for reuse are given in (Figure 5).

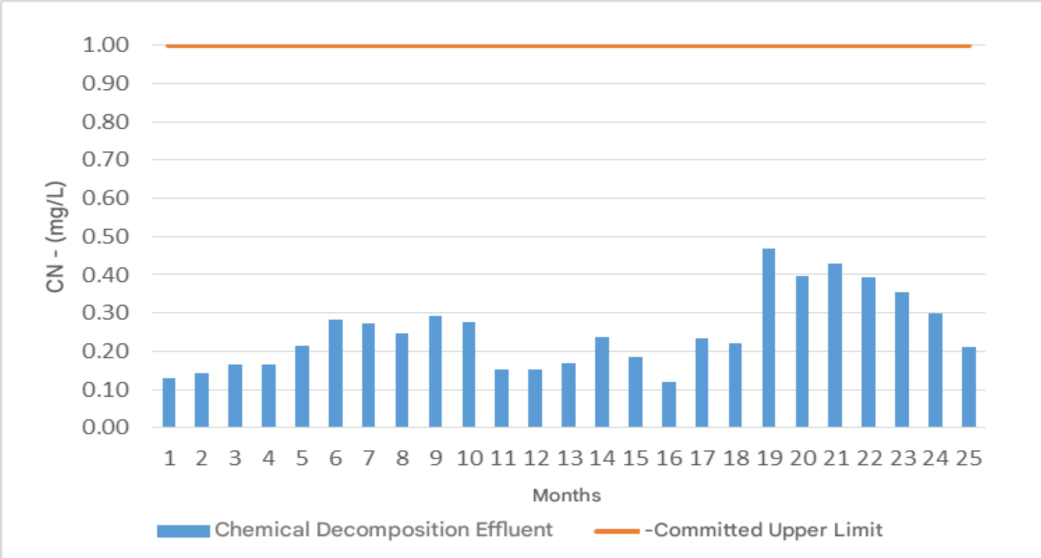

Figure 4. Monthly average cyanide concentrations in treatment unit effluent. Source: Authors (2024).

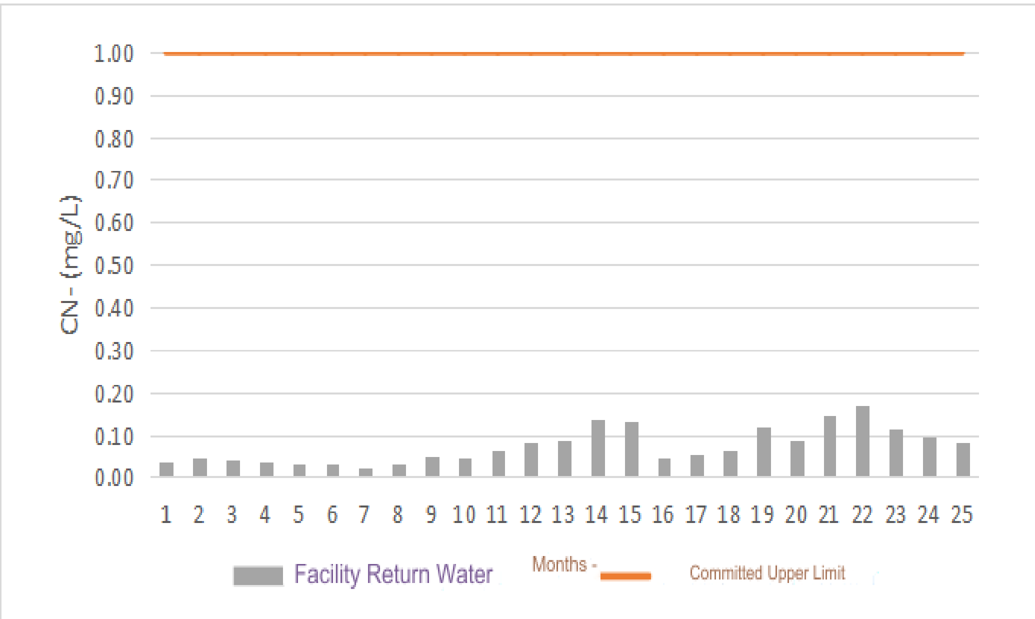

Figure 5. Data of monthly average cyanide concentrations in water supplied from the tailings pond for process use.

In the examined facility, the cyanide (CN) concentration entering the treatment plant is approximately 150 mg/L^{-1}. In the chemical degradation outlet water, the cyanide (CN) concentration entering the treatment plant is approximately 150 mg/L^{-1}. This demonstrates a cyanide removal efficiency of over 99%. Although no regulatory limit exists for cyanide discharge to the tailings pond the commitment of the sample facility under the EIA guidelines is that the cyanide concentration in treated water must not exceed 1 mg/L^{-1}. The values obtained are below the committed value. In the recycled water returned to the plant, the monthly maximum cyanide concentration is 0.17 mg/L^{-1}, with an average of 0.07 mg/L^{-1}. These values are again below the committed value of 1 mg/L^{-1}. Furthermore, these values are well below the EU-permitted cyanide concentration of 25 mg/L^{-1} for tailings ponds

Table 1. Total cyanide measurement results obtained every month in the observation wells opened during the study period

Parameter	Term	OW 4	OW 5	OW 6	OW 7S	OW 8D	OW 11	OW 12	OW 20	OW 21	OW 22	OW 23	OW 40	OW 41	VILLAGE 1	VILLAGE 2	VILLAGE 3
	14-Dec	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Jan	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Feb	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Mar	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Apr	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-May	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Jun	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Jul	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Aug	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	15-Sep	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	15-Oct	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total Cyanide (TCN)	15-Nov	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	15-Dec	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	16-Jan	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	16-Feb	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Mar	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Apr	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-May	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Jun	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Jul	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Aug	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Sep	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Oct	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Nov	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	16-Dec	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Source: Authors, 2024.

Table 2. Results of weak acid soluble cyanide measurements obtained on a monthly basis in the observation wells opened during the study period.

Parameter	**Term**	**OW 4**	**OW 5**	**OW 6**	**OW 7S**	**OW 8D**	**OW 11**	**OW 12**	**OW 20**	**OW 21**	**OW 22**	**OW 23**	**OW 40**	**OW 41**	**VILLAGE 1**	**VILLAGE 2**	**VILLAGE 3**
Weak Acid Soluble Cyanide (WADCN)	14-Dec	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Jan	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Feb	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Mar	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Apr	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-May	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Jun	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Jul	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Aug	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	15-Sep	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	15-Oct	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	15-Nov	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	15-Dec	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Source: Authors, 2024.

Parameter	Term	OW 4	OW 5	OW 6	OW 7S	OW 8D	OW 11	OW 12	OW 20	OW 21	OW 22	OW 23	OW 40	OW 41	VILLAGE 1	VILLAGE 2	VILLAGE 3
	16-Jan	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	16-Feb	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	16-Mar	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	16-Jul	-	0,002	0,002	-	0,002	0,002	0,002	0,002	0,002	-	-	-	-	-	-	-
	16-Jul	-	0,002	0,002	-	0,002	0,002	0,002	0,002	0,002	-	-	-	-	-	-	-
	16-Jul	-	0,002	0,002	-	0,002	0,002	0,002	0,002	0,002	0,002	-	-	-	-	-	-
	16-Jul	-	0,002	0,002	-	0,002	0,002	0,002	0,002	0,002	0,002	-	-	-	-	-	-
	16-Aug	-	0.002	0.002	-	0.002	0.002	-	0.002	0.002	0.002	-	-	-	-	-	-
	16-Sep	-	0.002	0.002	-	0.002	0.002	0.002	0.002	0.002	-	-	0.002	0.002	0.002	0.002	0.002
	16-Oct	-	0.005	0.005	-	0.005	0.005	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	16-Nov	-	0,004	0,004	-	0,004	0,004	-	0,004	0,004	0,004	0,004	0,004	0,004	-	0,004	0,004
	16-Dec	-	0,004	0,004	0,004	0,004	0,004	-	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0.004

Source: Authors, 2024.

In the examined facility the cyanide (CN) concentration entering the treatment plant is approximately 150 mg/L^{-1}. In the chemical degradation outlet water, the monthly peak value is 0.47 mg/L^{-1}, with an average of around 0.25 mg/L^{-1}. This demonstrates a cyanide removal efficiency of over 99%. Although no regulatory limit exists for cyanide discharge to the tailings pond "the sample facility is committed, under the EIA guidelines, to ensuring that the cyanide concentration in treated water does not exceed 1 mg/L^{-1}. The recorded values are below this committed threshold. In the recycled water returned to the plant, the monthly maximum cyanide concentration is 0.17 mg/L^{-1}, with an average of 0.07 mg/L^{-1}. These concentrations are again below the committed threshold of 1 mg/L^{-1}. Furthermore, these values are well below the EU-permitted cyanide concentration of 25 mg/L^{-1} for tailings ponds.

4. Conclusion and Evaluation

With the Industrial Revolution, the damage given to the environment has increased human beings have started to use the environment for their purposes. Now more resources are consumed the damage to the environment has increased This process has caused more deterioration of the deterioration of the natural environment and increased pollution. After the Second World War, underdeveloped and developing countries adopted the development approach by industrializing in their development efforts, which increased the pollution of the environment and resource consumption. It has been observed that the current problems. This cannot be solved with the continuation of the implementation of the linear economy approach together with the sustainable development approach.

Therefore, as a result of new searches, the aim is to reduce the amount of resources used in the economy with the circular economy through reuse, recycling, and reduction. For this system to change, not only the behaviors of producers but also those of consumers need to change. For this purpose, some countries have started to prefer recyclable or green products in public procurement processes. "Businesses may encounter some difficulties in the transition to the circular economy. The fact that businesses find the circular economy applications expensive and do not implement them, insufficient knowledge in the field of circular economy, lack of personnel, and lack of financial support mechanisms may result in few applications of the circular economy. However, initiatives by exemplary private sector enterprises in the field of circular economy can serve as models for others. One of these sectors is the gold mining sector.

Monthly monitoring results of total and weak acid-soluble cyanide concentrations in groundwater within the scope of the study are presented in (Tables 1 and 2). Weak cyanide compounds, defined as weak acid soluble, decompose in solution depending on pH and "convert into free cyanide species that are considered environmentally significant. Cadmium, copper, nickel, silver, and zinc cyanide compounds can be classified as weak cyanide compounds. Strong cyanide compounds are more stable and dissolve more slowly than weak acid-soluble species under normal conditions. "This highlights the environmental significance of weak acid-soluble species (Gold Miners, 2019).

According to the analysis results, the values obtained are below the 0.2 mg/L^{-1} MCL value allowed by the USEPA "in drinking water supplies. By the Regulation on Waters In the period of September-October-November 2015, the concentration of cyanide permitted in drinking water "according to the Regulation on Waters Intended for Human Consumption in all wells, including monitoring wells, was determined to be above 0.05 mg/L^{-1} as stated in Annex-1, but the level of weak acid soluble cyanide was low. The increase in the level of wells opened before the facility suggests that the situation may be due to an error in the analysis results or external factors. However, it also brings to mind "the necessity of operating such facilities under strict controls. Needs to be investigated. The reason for this situation needs to be investigated. The daily amount of cyanide entering the body of a 70 kg person who drinks drinking water with "a daily cyanide level of approximately 0.1 mg/L^{-1} results in an intake of around 0.028 mg/kg, and a constant cyanide concentration of this level may create chronic risks. However, when the entire measurement process is examined, this situation is not consistent.

As a result, the cyanide gold processing method was assessed by analyzing the results obtained from a sample facility where gold production with cyanide is carried out. It is seen that the values obtained are at low levels compared to the limit values. Cyanide is a toxic substance that has both acute and chronic effects to be highly controlled and production to be carried out within certain limits. To implement circular economy strategies in line with sustainable development goals in gold mine production, the public should be informed on this issue, especially with technical information such as the methods that individual gold miners should apply in terms of the characteristics of hazardous chemical substances (mercury, cyanide, acids, batteries, etc.). In addition, it is recommended that the Ministry of Energy and Natural Resources should provide training to minimize the environmental impacts arising from the activities of individual gold miners. Finally, it is recommended that a new mining law be enacted to minimize the negative environmental impacts in this sector which aligns fully with the sustainable development goals "and also contributes to the country's economy.

5. Availability of data and materials

This study was developed from the paper titled Investigation of the Effect of Cyanide Used in Gold Mining on Water Pollution, which was presented at the International Engineering and Science Symposium on June 22, 2019. All data used in the study were obtained using data from environmental status reports prepared by the sample facility and shared with the public. The data obtained in the study covers 24 months from December 2014 to December 2016.

6. Authors' Contributions

Edip Avşar: conceptualization, methodology study design, and research. *Sevgi Akkoy*: validation, writing, methodology, investigation, writing, and scientific reading. submission and publication. *Ramazan Kılıç*: coordination of the article, submission, publication methodology, and data collection.

7. Conflict of interest

The authors declare no conflict of interest.

8. Ethics Approval

Not applicable.

9. Reference

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