POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)
URL: http://dergipark.org.tr/politeknik

Effect of sodium cyanide and jin chan chemicals on gold gain from ore

Sodyum siyanür ve jin chan kimyasallarının cevherden altın kazanımına etkisi

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To cite to this article: Yılmaz H. ve Sayın Z. E., “Effect of sodium cyanide and Jin Chan chemicals on gold gain from ore”, ***Journal of Polytechnic***, 27(4): 1387-1397, (2024).

Bu makaleye şu şekilde atıfta bulunabilirsiniz: Yılmaz H. ve Sayın Z. E., “Effect of sodium cyanide and Jin Chan chemicals on gold gain from ore”, ***Politeknik Dergisi***, 27(4): 1387-1397, (2024).

Erişim linki (To link to this article): http://dergipark.org.tr/politeknik/archive

DOI: 10.2339/politeknik.1259655

Effect of Sodium Cyanide and Jin Chan Chemicals on Gold Gain from Ore

Highlights

- *Leaching tests with Jin Chan and Sodium Cyanide solvent reagents*
- *Determination of characteristic properties of ores with different structures*
- *Toxicity and chemical degradation tests.*

Graphical Abstract

Comparative experimental processes of sodium cyanide and Jin Chan gold solvent reagents.

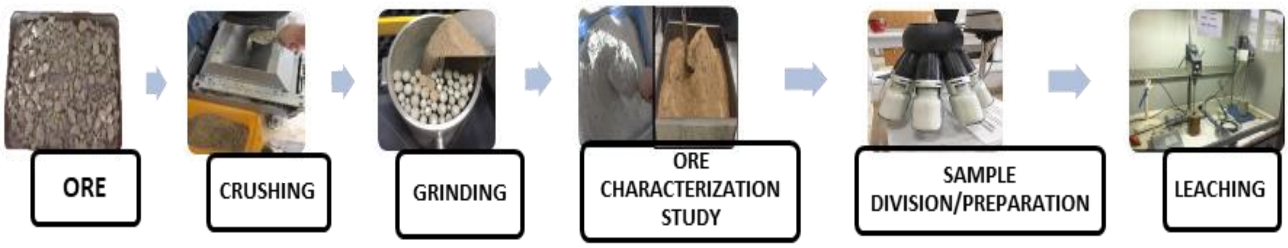

Figure: Experimental processes.

Aim

Jin Chan and Comparative experimental processes of Sodium cyanide gold solvent reagents.

Design & Methodology

A comparison experiment of gold dissolving chemicals was carried out on two different ores with different characteristics.

Originality

Investigation of the effect of solvents with different chemical composition on gold recovery by hydrometallurgical method in two different ore samples.

Findings

Optimum results were obtained for both chemicals and ores and chemical consumptions were calculated. Its effect on different ore deposits was evaluated.

Conclusion

Optimum results were achieved by leaching Kaymaz and Ovacık ores.

Declaration of Ethical Standards

The author of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Effect of Sodium Cyanide and Jin Chan Chemicals on Gold Gain from Ore

Research Article

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(Geliş/Received : 03.03.2023 ; Kabul/Accepted : 11.06.2023 ; Erken Görünüm/Early View : 01.09.2023)

ABSTRACT

In this article, experiments were carried out on samples taken from two different gold mines located in İzmir Province, Dikili District Çukuralan Locality and Eskişehir Province Sivrihisar District Kaymaz Site. Jin Chan, a new chemical approach with sodium cyanide (NaCN), comparatively evaluated leaching kinetics, gold recovery efficiencies and chemical consumption in the course of leaching. In the study using hydrometallurgical methods; the leaching studies with Çukuralan ore, the optimum parameters were observed at a 40% solid/liquid ratio and 300 mg/l Jin Chan concentration, and gold was recovered with a yield of 90.89%. Hereby, Jin Chan consumption was 0.72 kg/t. In NaCN, on the other hand, the optimum parameters were achieved at a solid/liquid ratio of 40% and a concentration of 300 mg/l NaCN, and gold was obtained with a yield of 91.98%. NaCN consumption was 0.31 kg/t. In the leaching studies with Kaymaz ore, the optimum parameters were reached at 40% solid/liquid ratio and 300 mg/l Jin Chan concentration, and gold was recovered with an 81.55% yield. Jin Chan chemical consumption is seen at 1.27 kg/t. In NaCN, on the other hand, the optimum parameters were achieved at a solid/liquid ratio of 40% and a concentration of 300 mg/l NaCN, and gold recovery was achieved with a yield of 82.86%. NaCN consumption is calculated at 0.95 kg/t.

Keywords: Jin chan, sodium cyanide, leaching, gold, mining.

Sodyum Siyanür ve Jin Chan Kimyasallarının Cevherden Altın Kazanımına Etkisi

ÖZ

Bu makalede İzmir İli Dikili İlçesi Çukuralan Mevkii ve Eskişehir İli Sivrihisar İlçesi Kaymaz Mevkiinde bulunan iki farklı altın madeninden alınan numuneler üzerinde, sodyum siyanür (NaCN) ile yeni bir kimyasal yaklaşımıyla Jin Chan, karşılaştırmalı olarak liç kinetiği, altın kazanma verimleri ve liç esnasında kimyasal tüketimi değerlendirilmiştir. Hidrometalurjik yöntemin kullanıldığı çalışmalarda; Çukuralan cevheriyle yapılan liç çalışmalarında en iyi sonuçlara %40 katı/sıvı oranında, 300 mg/l Jin Chan konsantrasyonunda ulaşılarak %90,89 verimle altın kazanılmıştır. Jin Chan tüketimi 0,72 kg/t olarak hesaplanmıştır. NaCN kullanımı ile elde edilen en iyi sonuçlara ise %40 katı/sıvı oranında, 300 mg/l NaCN konsantrasyonunda ulaşılarak %91,98 verimle altın kazanılmıştır. NaCN tüketimi 0,31 kg/t olarak hesaplanmıştır. Kaymaz cevheriyle yapılan liç çalışmalarında en iyi sonuçlara %40 katı/sıvı oranında, 300 mg/l Jin Chan konsantrasyonunda ulaşılarak %81,55 verimle altın kazanılmıştır. Jin Chan tüketimi 1,27 kg/t olarak hesaplanmıştır. NaCN kullanımı ile elde edilen en iyi sonuçlara %40 katı/sıvı oranında, 300 mg/l NaCN konsantrasyonunda ulaşılarak %82,86 verimle altın kazanılmıştır. NaCN tüketimi 0,95 kg/t olarak hesaplanmıştır.

Anahtar Kelimeler: Jin chan, sodyum siyanür, liç, altın, maden.

1. INTRODUCTION

Gold, a precious metal, has been a symbol of power and wealth in societies since its discovery. The rapid increase in gold prices in recent years has increased interest in gold mining all over the world. However, the gold requirement of our area, which has significant gold potential, is approximately 200 tons annually and 20% of the need is met from the gold mines operating in our country, while the remaining 80% is imported from abroad. World gold production is approximately 3500 tons per year according to the data for 2021 [1].

Hydrometallurgical processes have been developed because of gain low valuable metal concentrations from ore. Since the physical separation methods are not sufficient for metal gain from low grade ores, the use of hydrometallurgical methods has been effective in the gain of valuable metals [2, 3].

Hydrometallurgical processes are based on the principle of gaining the desired metal from different types of ores, concentrates and waste products with aqueous solutions containing different chemical reagents [3]. In hydrometallurgy, there are two main steps to obtaining the valuable metal. The first step known as leaching; It is a series of processes applied to selectively dissolve the

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valuable metal or metals in the ore in a suitable solution and selectively recover from the solution. In the second step, the valuable metal is recovered from the leaching liquid by cementation or precipitation by controlling the operating conditions and variables [4].

Considering mineralogical properties, grain size and grade of gold in the enrichment of gold ores; enrichment by density (3-5%), flotation (10-14%), amalgamation and chemical mining (cyanide leaching, 83-85%) methods are used. Since the grades and grain sizes of the gold deposits produced today are very low, gold is recovered with cyanide using the chemical mining method, the most among these methods [5, 6, 7].

Many alternative chemical enrichment systems are studied in gold recovery from ore such as. Some of the chemicals; thiosulfate ($S_2O_3^{-2}$), thiourea ($CS(NH_2)_2$), iodine/iodide, ammonia, liquid mercury, bioleaching, alpha-cyclodextrin, and aqua regia (HCl+HNO_3) [8]. Difficulties in testing these chemicals include cost, toxic chemicals in post-leaching waste, long time requirement, and gold recovery efficiency [9, 10, 11]. For a long time, cyanide has become the preferred leaching chemical in gold mining due to its high gold recovery, well-known leaching mechanism, durability, easy accessibility and relatively low cost [12]. Despite the wide application of cyanide leaching in the world; low heap leaching efficiencies, highly toxic and environmental restrictions are general drawbacks [12, 13]. There are also studies aimed at reducing the use of cyanide by making studies to eliminate these problems [14]. Chemicals are evaluated in terms of the environment and human health, and safe and unsafe doses are determined by the science of toxicology. The collapse of the wall separating the waste cyanide dams in the establishments where cyanide is used creates the danger of cyanide spreading outside. Risk analyzes used in occupational health and safety are carried out in order to be prepared by evaluating the incidents caused by the spread of cyanide sludge. In the risk assessment, there are evaluations about the damage to be caused by the main hazard, the probability of its occurrence, the frequency of accidents, and the number of employees [15]. Such disasters are characterized as major impact accidents, and disaster management is needed. In the disaster management cycle, it consists of risk and mitigation, preparedness, response, and recovery processes [16, 17].

Cyanide, which is preferred in gold production, is used in a safe dose and the amount of cyanide in the waste and liquid parts after production is in an amount that will not harm the environment or human health [18]. In addition, approximately 4% of the cyanide compounds used in our country are used in gold production, while the rest are used in many fields such as synthetic yarn, nylon, plastic and metal plating [19].

In cyanide leaching methods, the dissolution kinetics of gold; grain size, mineralogy, liberation size, solid/liquid ratio, free cyanide and dissolved oxygen concentration in solution, ambient temperature, other soluble metals in the ore, cyanide consumers such as sulfur minerals, etc. affects [20, 21, 22, 23]. Since the mineralogy of the ore is not a parameter that can be altered, the free cyanide and oxygen concentrations are mostly adjusted in the system at high rates in order to keep the efficiency at the highest possible level in gold production facilities [24, 25]. The "Elsner Equation" for the dissolution of gold is given in Equation 1 [26].

$4\ Au\ (s) + 8\ NaCN\ (liquid) + O_2\ (g) + 2H_2O(I) \rightarrow 4Na\ [Au\ (CN_2)](aq) + 4NaOH\ (liquid)$ (Equation 1)

However, in gold leaching, the pH change of the cyanide solution and the relationship of the cyanide compounds are important. With the change in pH value, the amount of HCN and CN^- ions in the environment changes.

Therefore, the solution medium is kept at a basic level to avoid from the formation of HCN gas. Thus, as the pH increases, the amount of HCN in the environment decreases, while the amount of CN^- ions increases. With this situation, the leaching efficiency is increased while HCN loses its toxic effect. In order to reduce cyanide loss in leaching, the optimum pH value should be at least 10 [27].

In recent years, a new generation of solvent chemicals has been developed. Of these products, Jin Chan was evaluated within the scope of the study. It has been stated that the replacement of cyanide with a new generation solvent chemical should be evaluated due to comparable gold gains and much lower environmental pollution. Unlike other non-cyanide solvent reagents, new generation solvents are used in some gold production plants around the world [28]. The applications of these solvent chemicals in the gold mining industry are increasing, but detailed statistical data are not available at this stage. Studies have shown that cyanide and Jin Chan have insignificant differences in gold gains at the same concentration and operating parameters. Jin Chan Gold Dressing Agent, Guangxi Senhe High Technology Co., Ltd. It is declared that the product produced by our company is an environmentally friendly patented product that can be used in gold recovery studies instead of NaCN. However, for the product specified as a direct replacement for sodium cyanide in gold production, without changing the original process and equipment, low toxicity, environmental protection, and high recovery, It is stated that it has advantages such as good stability, convenient use, fast recycling, low dosage, low cost and convenient storage [29]. It is seen that it makes a double bond and forms a triple structure with oxygen (Fig. 1).

In 2016, Jin Chan and cyanide comparison experiments were conducted at Gold Fields Ghana Limited in South Africa. As a result of the comparison, it was stated that the leaching kinetics of Jin Chan chemical was slower than NaCN. While the 97% gold recovery of the solvent was in 48 h of leaching time with Jin Chan, the same recovery was found over 24 h using NaCN [30].

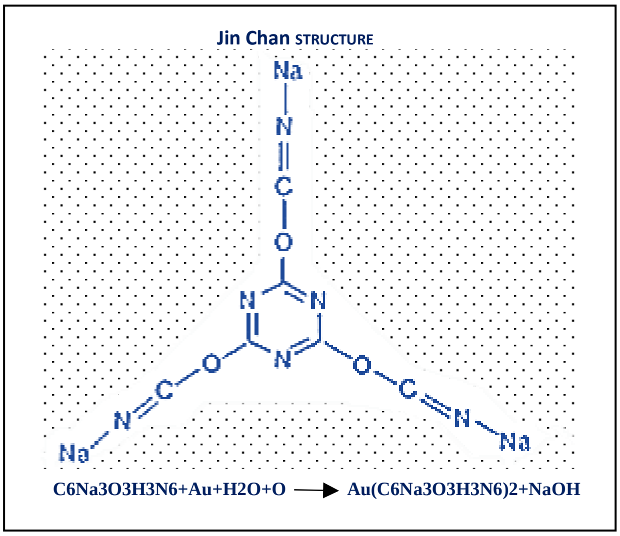

Fig. 1. Jin Chan Chemical Bond Structure [29]

In this study, using Jin Chan and NaCN chemicals in gold recovery comparatively, the effectiveness of Jin Chan in gold recovery was evaluated. The parameters applied on two different mineralogical properties of ores taken from Çukuralan and Kaymaz operations and the effect of ore properties on leaching and thus gold recovery were investigated.

2. MATERIAL and METHOD

Ore samples are obtained from Koza Gold Works. These two mineral deposits are separated from each other by their chemical content. Therefore, the kinetics of two gold ores with different mineralogical properties and different gold recovery chemicals were chosen to be studied.

Breaking within the scope of work, identical samples were prepared in a jar sample divider to be used in grinding, size reduction, blending and leaching studies. In the characterization studies, chemical and mineralogical analyses, particle size distribution, X-Ray diffraction (XRD) spectroscopy, scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) analyses were performed.

Mineralogical analyzes of the ores were made in the Laboratory of Technology Application Research Center (TUAM) at Afyon Kocatepe University (2θ=2˚-70˚) X-ray analyzes were tested using Shimadzu 6000 model Bruker D8 Advance X-ray diffractometers, and mineral identifications were tested using JCPDS (1993) cards.

Quartz, dolomite and lizardite characteristic in the X-ray diffraction pattern of Kaymaz gold ore peaks can be seen in Fig. 2. Characteristic quartz, albite, sanidine, ankerite, clinochlor and calcite peaks were detected in the X-ray diffraction pattern of Çukuralan gold ore (Fig. 3).

In The Institute of Mineral Research and Exploration (MTA) analysis laboratories, images and Microchemical (EDS) analysis of the samples were performed with the FEI INSPECT F50 Scanning Electron Microscope (SEM).

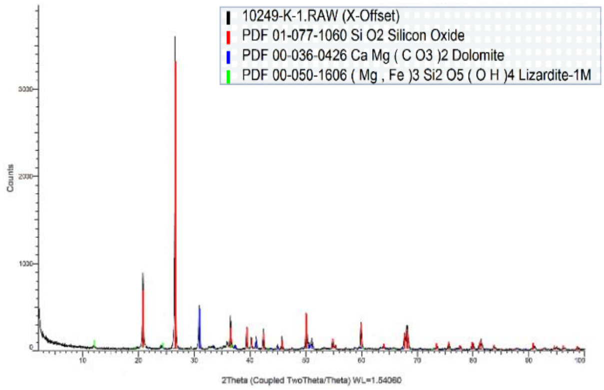

Fig. 2. Kaymaz ore feed commodities XRD analysis

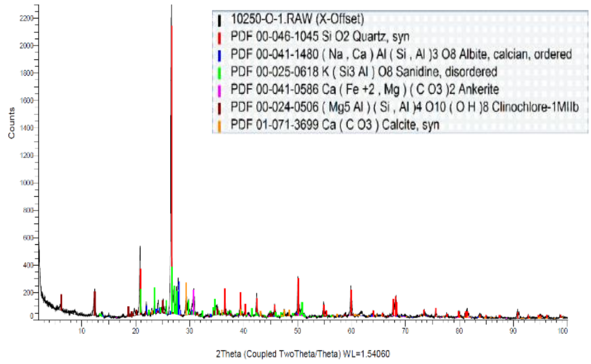

Fig. 3. Çukuralan ore feed commodities XRD results.

The semblance obtained by examining the Kaymaz ore sample on the SEM device is given in Fig. 4. The EDS analyses of the ore is given in Fig. 5. It is understood from the images that the gold grain size is concentrated between 200-400 nm. In the EDS analysis, there are Al, As, Si, O, Fe, Ca, Ni peaks, along with Au and Ag peaks. It is clear that the grain described is gold.

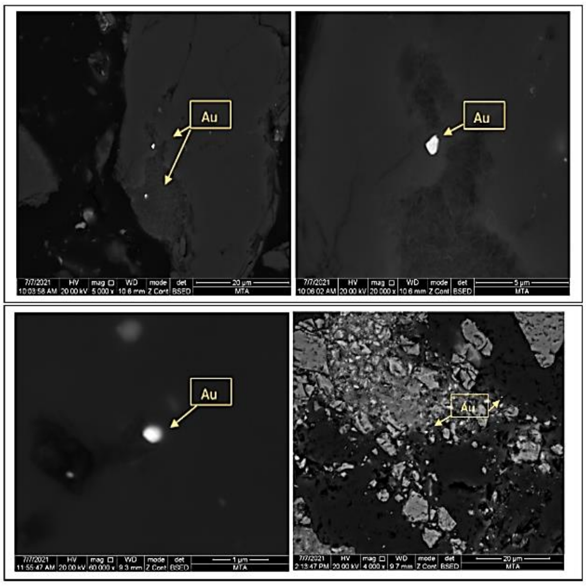

Fig. 4. SEM images of the Kaymaz ore samples

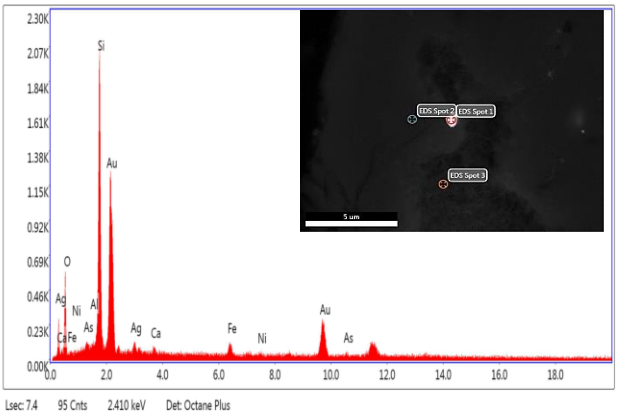

Fig. 5. EDS analysis of Kaymaz ore sample

The images obtained by examining the Çukuralan ore sample in the SEM device are given in Fig. 6. In Fig. 7, the EDS analysis of Çukuralan ore is given. As seen from the EDS, Al, Si, S, P, O, Fe, C, Ni, Mg peaks are available. In addition to gold and silver, peaks of Th, Ca, Si, Mg, Al, Mn, Fe, O, C, K, Y, P, Co, Hf, Zr, Ni, U were also detected in other samples. The carbon peak comes from the carbon coating. Not available in ore content.

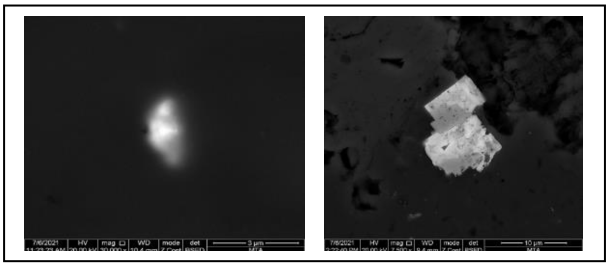

Fig. 6. SEM image of the Çukuralan ore samples

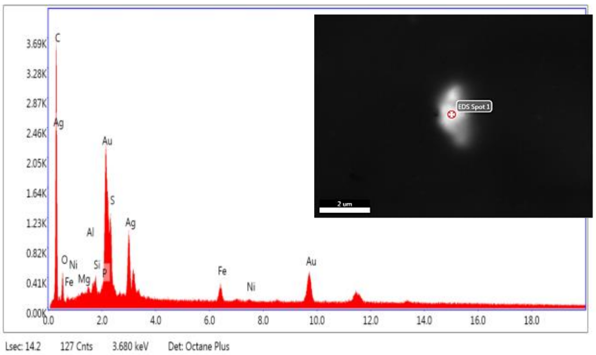

Fig. 7. EDS analysis of Çukuralan ore sample

Chemical analyses of the leaching liquids taken at the 2nd, 4th and 8th hours were made on the Atomic Absorption Spectroscopy (AAS) device. Gold and silver gains and chemical consumption were compared with the data obtained.

Chemical analysis of the samples was performed in Koza Gold Enterprises Chemistry Laboratory (liquid analysis) and Acme Analytical Laboratory (solid analysis). Feed grades of gold, silver and other minerals are given in Table 1. According to these data, it was determined that Kaymaz ore sample has 5.35 g/t Au and Çukuralan ore sample has 4.74 g/t Au grade.

Table 1. Acme analytical laboratory feed materials chemical analysis results

Minerals	Feed materials Çukuralan	Feed materials Kaymaz	Minerals	Feed materials Çukuralan	Feed materials Kaymaz
Au g/t	4.743	5.354	K %	0.14	0.03
Ag g/t	1.3	3.7	Na %	0.017	0.013
Cu g/t	34.3	16.9	Ca %	3.8	3.37
Sb g/t	1.2	56.2	Hg g/t	0.04	0.94
Zn g/t	86	30	La g/t	18	0
Mo g/t	3.3	7.3	Cd g/t	0.6	0.3
Th g/t	8.3	0.9	Mg %	1.32	2.63
Co g/t	11.3	69	S %	0.46	0.39
Mn g/t	583	301	Ti %	0	0
Fe %	2.56	4.99	Al %	1.14	0.09
As g/t	14	3970	V g/t	40	19
Pb g/t	37.4	48.8	Bi g/t	0.2	2.8
Ni g/t	42.4	1372.8	W g/t	0.2	9.8
Sr g/t	93	152	P %	0.0059	0.004
Cr g/t	47	222	Sc g/t	4.5	3.1
U g/t	1.5	11.5	Ba g/t	130	691

Samples were taken from both facilities at the mill entrance. The sample was first fed into a laboratory type jaw crusher and crushed to a particle size of less than approximately 1-1.2 mm. They were then fed into a rod mill, where the entire sample was ground to a particle size of less than 75 microns.

Parameters affecting process leaching has been established based on the parameters currently used in the facilities (Table 2). Parameters considered in leaching studies are chemical type and concentration, solid/liquid % ratio, leaching time, oxygen amount, pulp, mixing speed (HEIDOLPH RZR 2021 Model Mechanical Mixer), ambient temperature, pH value.

Table 2. Leach test parameters

Working Parameters of Çukuralan and Kaymaz Ore	Value
Pulp Ratios (%)	30/40/45
Chemical Concentrations (mg/l)	300/400/500
Mixing Speed (dev/dk)	660
Leach Time (sa)	2/4/8
pH	10.5-11
Grain size (µ)	75
Temperature ^{0}C	20-25
Oxygen (mg/l)	20-30

3. RESEARCH FINDINGS and DISCUSSION

Leaching studies were carried out with Jin Chan and NaCN at the determined parameters.

The results of leaching studies carried out with Çukuralan ore at a 30% solid/liquid ratio at 300, 400 and 500 mg/l concentrations are given in Figures 8, 9 and 10.

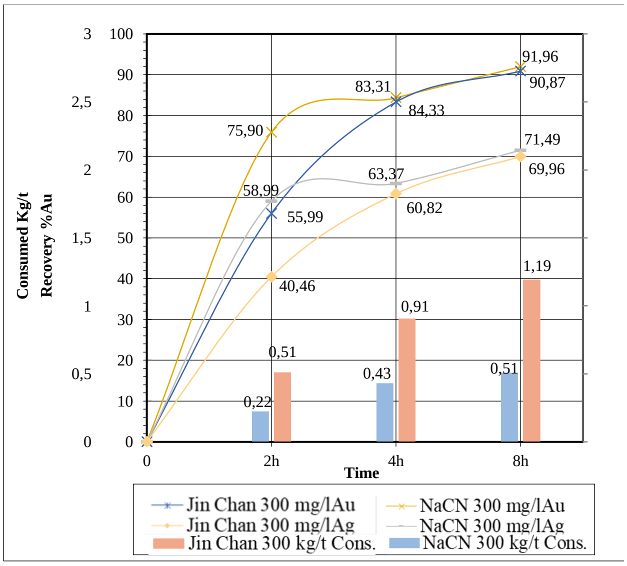

Fig. 8. Graph of Au-Ag recovery and chemical consumption in Çukuralan ore at 30% pulp and 300 mg/l concentration

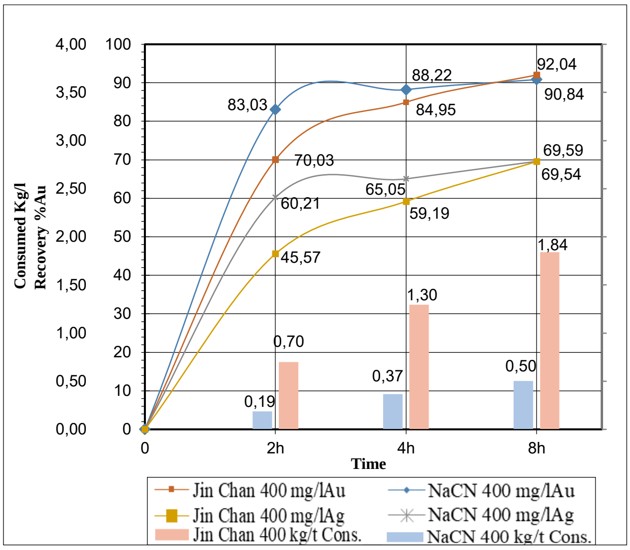

Fig. 9. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 30% pulp and 400 mg/l concentration

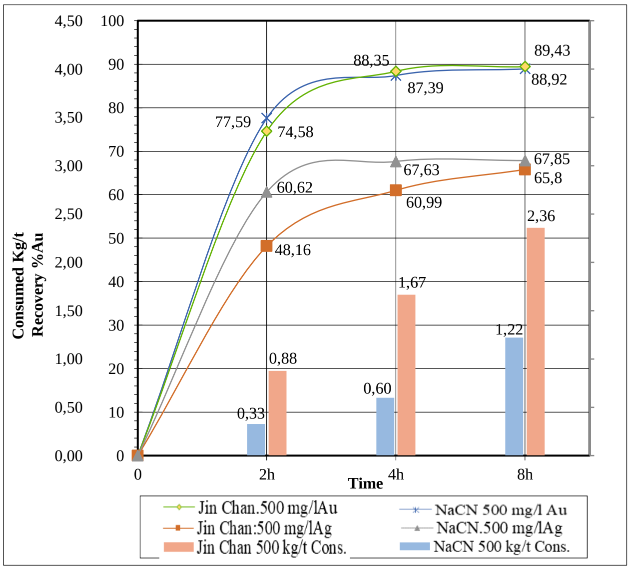

Fig. 10. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 30% pulp and 500 mg/l concentration

When the gold and silver gains of NaCN and Jin Chan chemicals were examined, it was seen that the increase in the concentration did not change the gain when the 8th hour chemical was taken into account. In general, it is seen that cyanide is more effective in gold recovery at 300 mg/l chemical concentration, while Jin Chan's gold recovery is slightly higher at 400 mg/l and 500 mg/l concentrations. However, consumption of Jin Chan after leaching was higher relative to NaCN.

The results obtained by leaching Çukuralan ore at a 40% solid/liquid ratio and chemical concentrations of 300, 400 and 500 mg/l are given in Figs 11, 12 and 13.

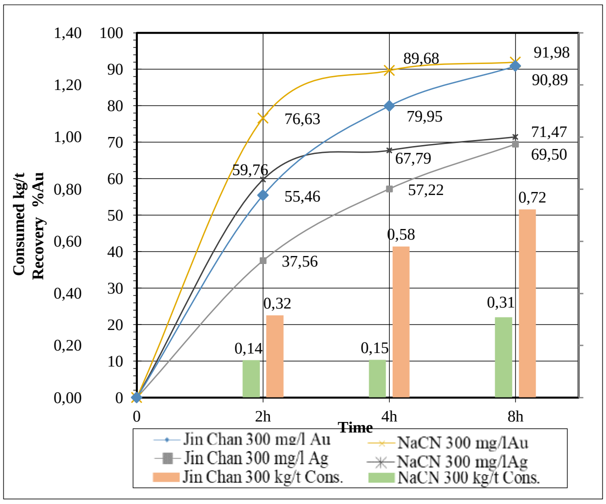

Fig. 11. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 40% pulp and 300 mg/l concentration

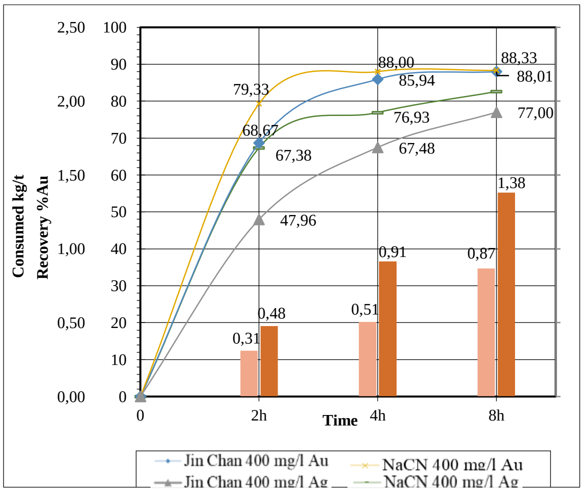

Fig. 12. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 40% pulp and 400 mg/l concentration

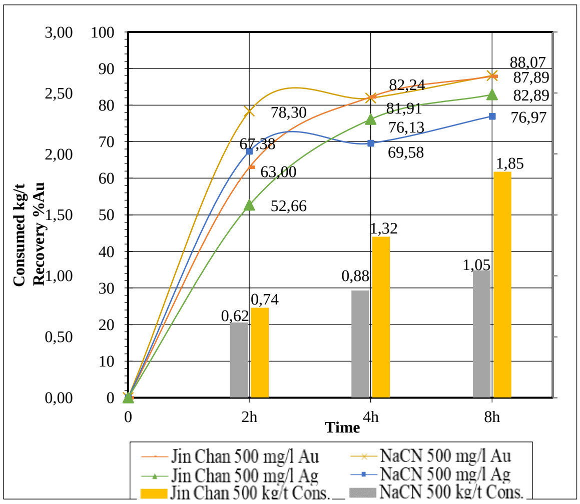

Fig. 13. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 40% pulp and 500 mg/l concentration

The increase in the concentrations of NaCN and Jin Chan chemicals in these parameters was reflected in a decrease in leaching yield. When this situation is examined in terms of chemical consumption, it is seen that the increase in concentration does not increase the efficiency. On the other hand, it decreases it, and as a result, it only causes an increase in the amount of consumption.

The results obtained from the leaching study carried out with Çukuralan ore at 45% solid/liquid ratio and chemical concentrations of 300, 400 and 500 mg/l are given in Figs.14, 15 and 16.

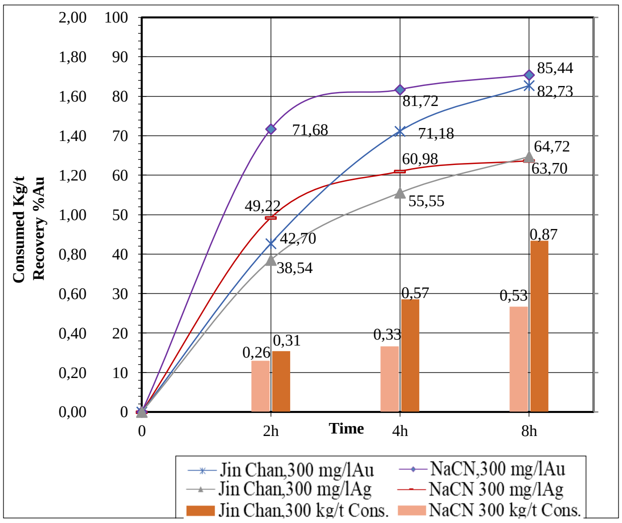

Fig. 14. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 45% pulp and 300 mg/l concentration

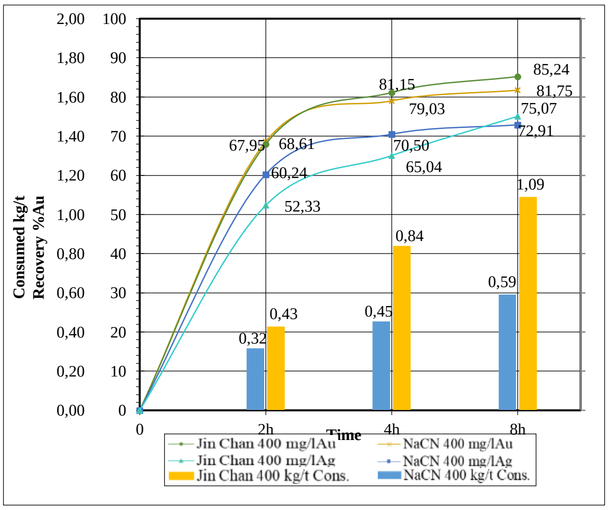

Fig. 15. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 45% pulp and 400 mg/l concentration

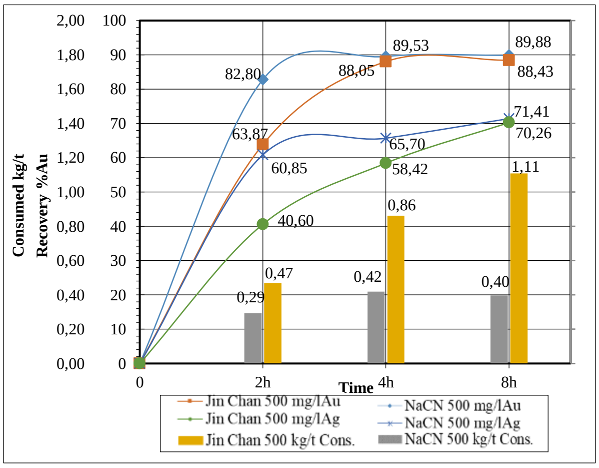

Fig. 16. Au-Ag recovery and chemical consumption graph in Çukuralan ore at 45% pulp and 500 mg/l concentration

At a chemical concentration of 500 mg/l at a 45% solid/liquid ratio, the gold-silver gains are the same for both chemicals, but are relatively higher than 300 mg/l. This difference significantly increased the consumption of Jin Chan chemicals (Fig. 16). Consumption of Jin Chan chemical in leaching reaches high levels compared to cyanide in all parameters. Are given in Figs. 17, 18 and 19.

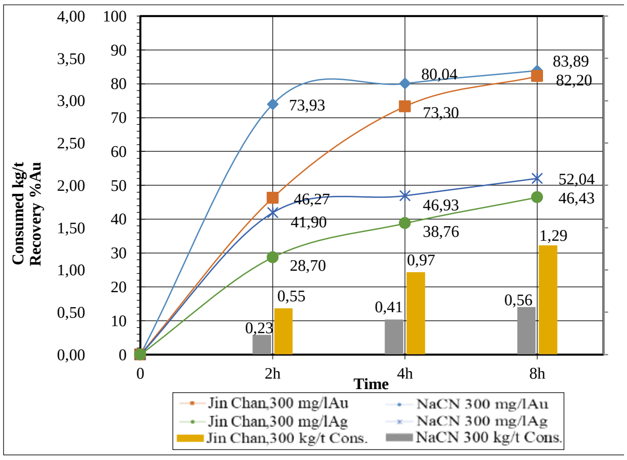

Fig. 17. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 30% pulp and 300 mg/l concentration

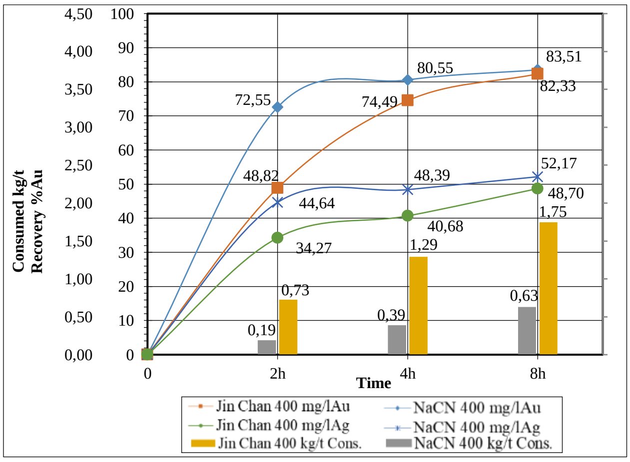

Fig. 18. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 30% pulp and 400 mg/l concentration

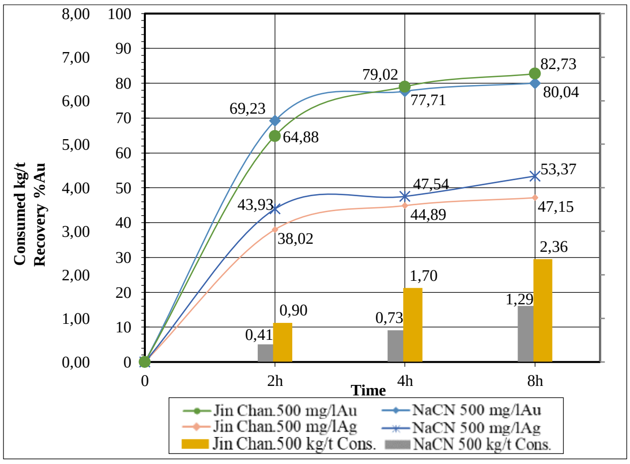

Fig. 19. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 30% pulp and 500 mg/l concentration

From the leaching studies with 30% solid/liquid ratio made with slip ore, it was observed that the leaching yields did not change even though the concentration value increased. As the concentration value increased, the NaCN consumption remained relatively the same, while the consumption of Jin Chan chemical was quite high, such as Figs. 20, 21 and 22. From the leaching studies, it was observed that the leaching yields did not change even though the concentration value increased. The results obtained with the leaching of Kaymaz ore at 40% solid/liquid ratio at 300, 400 and 500 mg/l chemical concentrations are given in Figs. 20, 21 and 22. From the leaching studies, it was observed that the leaching yields did not change even though the concentration value increased.

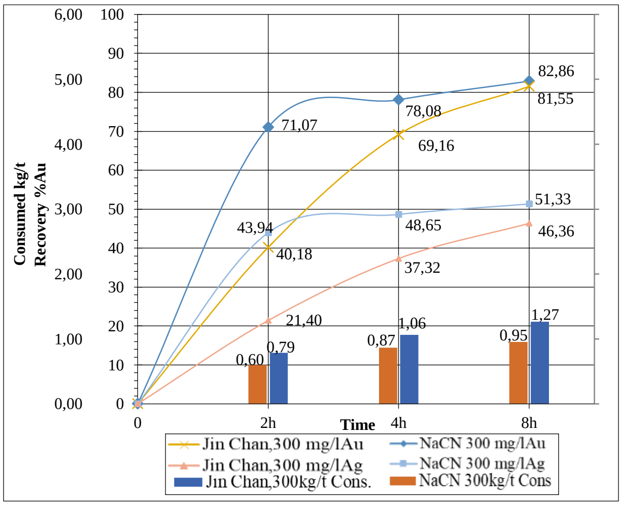

Fig. 20. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 40% pulp and 300 mg/l concentration

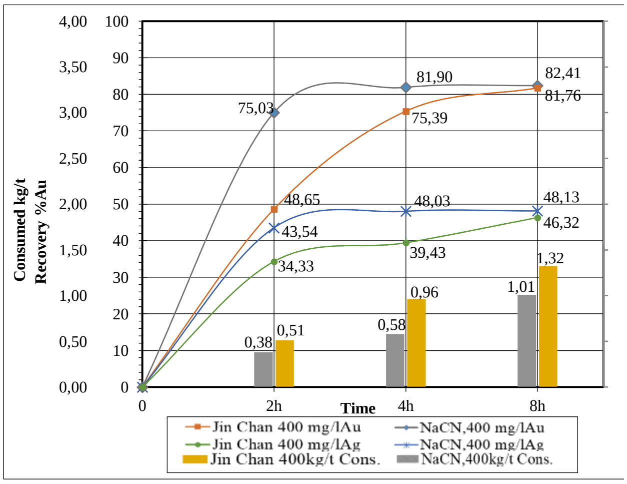

Fig. 21. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 40% pulp and 400 mg/l concentration

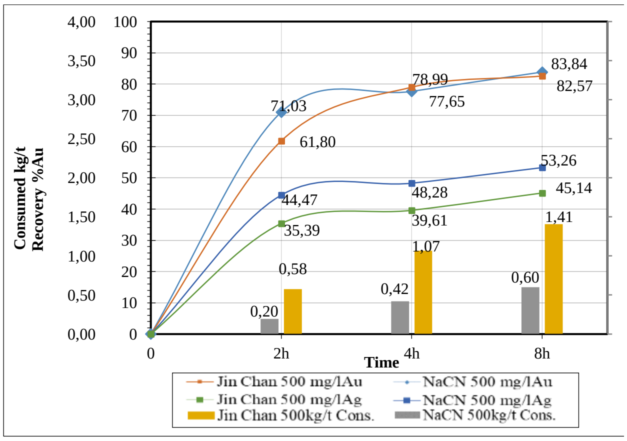

Fig. 22. Gold/silver recovery and chemical consumption graph in Kaymaz ore at 40% pulp and 500 mg/l concentration

The results obtained with the leaching studies carried out with the Kaymaz ore at a 45% solid/liquid ratio and chemical concentrations of 300, 400 and 500 mg/l are given in Figs. 23, 24 and 25. From the leaching studies, it was observed that the leaching efficiency increased as the concentration value increased.

As a result of the leaching studies with Çukuralan and Kaymaz ores, it was determined that the best results were obtained at 40% solid/liquid ratio, 300 mg/l NaCN and Jin Chan concentrations, which have low chemical content and a relatively higher solid/liquid ratio.

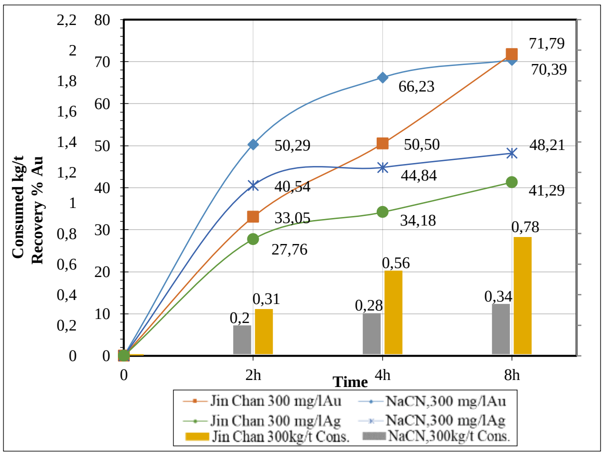

Fig. 23. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 45% pulp and 300 mg/l concentration

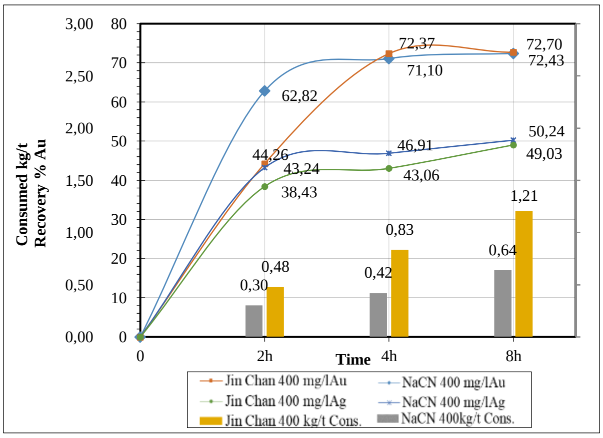

Fig. 24. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 45% pulp and 400 mg/l concentration

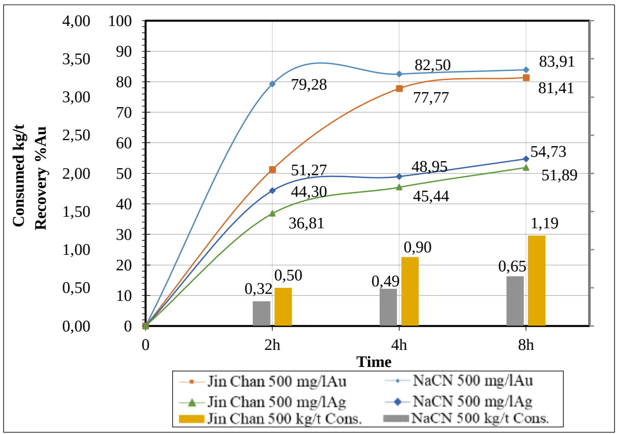

Fig. 25. Au-Ag recovery and chemical consumption graph in Kaymaz ore at 45% pulp and 500 mg/l concentration

3.1. Toxicity Assay

It is emphasized by the manufacturer of Jin Chan chemical that the chemical is environmentally friendly and non-toxic in the experimental studies conducted in the Far East. In this study, the toxicity and degradation/detox tests of Jin Chan chemical and NaCN were compared.

Toxicity analyses were performed on NaCN and Jin Chan chemicals by the Microtox Method at the Scientific and Technological Research Council of Turkey (TUBITAK) Marmara Research Center. Both samples were stated to be "quite toxic". EC_{50} concentration and toxicity class values are prepared and given in Table 3.

Table 3. Acute toxicity test analysis result

Sample Name / End. Serv. No.	pH (Adjusted)	EC_{50} (%) (15 min)	Toxicity Grade (class)	***Conclusion/ Explanation
NaCN Chemical	8.321	0.3401	4	Quite Very Toxic
Jin Chan Chemical	8.374	0.6755	4	Quite Very Toxic

According to the results given in the table; in the tests performed by absorbing the pH into the water phase, the concentration ratio (EC_{50}) that inhibited 50% of the bacteria was 0.3401 in the 15th minute NaCN test, while the EC_{50} dose value of Jin Chan chemical was 0.6755. When the result of the analysis was examined, it was concluded that cyanide is approximately twice as toxic as Jin Chan chemical.

3.2. Chemical Degradation / Detox Test.

Detox studies were also carried out to reduce the free cyanide released after leaching below legal limits and to precipitate metal ions. In the study, CN_{Wad} compounds were decomposed at three different sodium metabisulfite values in the presence of SO_2 gas. In the test performed at Koza Gold Enterprises Kaymaz Laboratory, metal cyanide ratios were compared by using sodium metabisulfite ($Na_2S_2O_5$) and copper sulfate ($CuSO_4$) at certain rates after 8 hours of leaching at 45% solid/liquid ratio and 300 mg/l concentration (Table 4).

Table 4. Kaymaz ore detox test parameters

Parameter	Value
Sodium metabisulphite ($Na_2S_2O_5$) (l/h)	200, 300, 400
pH	9.5 – 9.8
Time (Min.)	40
Copper Sulphate ($CuSO_4$) (l/h)	70
Oxygen (bar)	0.5
mixer (rpm/min.)	640

After comparison, as seen in Figure 26, Jin Chan solvent reagent was found to be more difficult to degrade than sodium cyanide.

These tests carried out in the laboratory environment do not reflect the facility, but we can gain insigt his from them. Since there is a continuous flow in the facility and a fixed sample is studied in the laboratory environment, there may be deviations in comparison with the facility data.

When the toxicity results are evaluated together with the studies and analyzes, it is seen that both chemicals are very toxic, but Jin Chan is less toxic than cyanide at lethal doses.

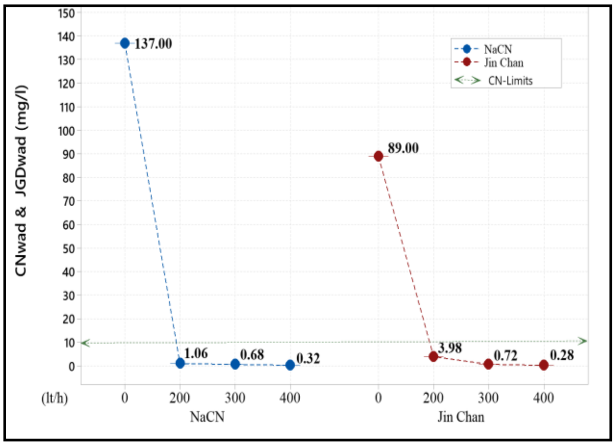

Fig. 26. Test plot of detoxification of free cyanide to weak cyanide compounds

According to the findings obtained from the studies, it was seen that the amount of Jin Chan chemical used in production is higher, but it can be degraded more difficultly than cyanide.

4. CONCLUSIONS

Mixing leaching was applied to Çukuralan and Kaymaz ores using the hydrometallurgical method in a mechanical mixer. In Jin Chan leaching studies with Çukuralan ore, the optimum parameters were achieved with 40% solids ratio and 300 mg/l chemical amount, and gold recovery was 90.89%. Here, Jin Chan's consumption was 0.73 kg/t. In the study with NaCN, the best parameters were achieved with 40% solid/liquid ratio and a 300 mg/l chemical amount, and the gold recovery rate was 91.89%. NaCN consumption was calculated at 0.31 kg/t.

In Jin Chan leaching studies with Kaymaz ore, the optimum parameters were reached and 40% solid/liquid ratio, 300 mg/l chemical amount, with 81.55% yield. Gold has been earned. Jin Chan's consumption was 1.27 kg/t.

In leaching with NaCN, the best parameters were achieved with 40% solid/liquid ratio and 300 mg/l chemical amount, and gold recovery was achieved with a yield of 82.86%. NaCN consumption is calculated at 0.95 kg/t.

Accepted leaching results are those obtained at the end of the 8th hour, and it is highly likely that the yield will be above 90% at the end of the 12th hour.

The cost calculation results based on Jin Chan and NaCN consumption amounts are given in Tables 5 and 6.

Table 5. Çukuralan ore, NaCN and Jin Chan cost table by consumption

Chemical	Ore Tenor (g/t)	%Recovery	Consumption (kg/t) in Optimum (40,300mg/l) Parameters	*Chemical Ton Price ($)
NaCN	4.743	% 91.89	0.31	2645
Jin Chan	4.743	% 90.89	0.72	2740

**Taken from February 2022 data.*

Table 6. Cost table of Kaymaz ore, NaCN and Jin Chan by consumption

Chemical	Ore Tenor (g/t)	%Recovery	Consumption (kg/t) in Optimum (40,300mg/l) Parameters	*Chemical Ton Price ($)
NaCN	5.354	% 82.86	0.95	2645
Jin Chan	5.354	% 81.55	1.27	2740

**Taken from February 2022 data.*

According to the optimum results, the cost of Jin Chan chemical is higher than the cost of NaCN when the gold recovery and chemical consumption of Çukuralan and Kaymaz ores are taken into account.

In the detox experiment conducted to reduce the free cyanide released under legal limits, the presence of oxygen in the formula structure of Jin Chan chemical adversely affected the SO_2/air detoxification process. This is thought to be due to the complex structure formed after the leaching process, which cannot consume oxygen.

Therefore, the presence of oxygen causes cyanide to be retained during the decomposition process, making it a more stable structure.

ACKNOWLEDGMENT

I would like to thank the BAPK unit for providing financial support with the project number 20.FEN.BİL.40 in the realization of the research work.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Hakan YILMAZ: Performed the experiments and analyse the results. Wrote the manuscript.

Zehra Ebru SAYIN: Performed the experiments and analyse the results. Wrote the manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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