

# International Journal of Applied Engineering Research (IJAER)

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**Area of Interest** : Electrical Power Systems, Renewable Energy Sources, Embedded Systems

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**Area of Interest** : Mechanical Engineering - Cad/Cam, Product Design, Rapid Prototyping, Finite Element Analysis

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**Area of Interest** : Power Quality, Electromagnetic Compatibility

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**Area of Interest** : Heterogeneous Catalysis And Development Of Novel Catalytic Green Processes. Catalytic Conversion Of Natural Gas And Light Alkanes Into Intermediates, Fuels And Chemicals Of Higher Added Value. Conversion Of Renewable Biomass For The Production Of Bulk Chemicals, Electrochemical Sensors

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**Area of Interest** : ICT, software engineering

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**Area of Interest** : Encompass Network Centric Data Management, Data

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**Area of Interest** : Electrical discharge machining, machining, micro/nano machining, nanofluid

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**Area of Interest** : Image processing, Computer Network

**Dr. Ch. Swapna Priya**, Assistant Professor, Department Computer Science And Engineering, Vignan's institute of Information Technology, Visakhapatnam, Andhra Pradesh, India.

**Area of Interest** : Image processing, Pattern recognition deep learning, machine learning

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**Area of Interest** : Theory of computation, Computer Networks, Advanced Computer Architecture, Operating Systems, Computer Programming, Network Security, Object Oriented Analysis and Design and Data Base Management System

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**Area of Interest** : Computer Engineering & Information Technology, Software Engineering, Genetic Algorithms and Cloud Computing

**Dr. Ghassan Fadhil Smaisim**, Associate Professor, Department of Mechanical Engineering, University of Kufa, Faculty of Engineering, Kufa, P.O. Box: 21, Najaf Government.

**Area of Interest** : Enhancement Heat Transfer, Renewable Energy, Fluid Mechanics, Thermal Nanofluid Flow, Power Generation, Solar Energy, CFD.

**Dr. Darshankumar Chandrakant Dalwadi**, Associate Professor, Department of Electronics and Communication Department, Birla Vishvakarma Mahavidyalaya Engineering College, Post Box No. 20

**Area of Interest** : Digital Communication, Wireless Communication and M Tech Information Theory and Coding

—

**Jong-Wook Lee**, Electrical & Computer Engineering, Ajou University, Worldcupro 206, Yeongtong-gu. 16499, Geonggi-do, **South Korea**

Area of Interest: I Device structure and materials for sub-0.5V voltage operation, I Scaling-down enabling technology, I Low-power, high-speed devices and circuits.

**Mohd Hafiz bin Jali**, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Melaka, **Malaysia**

Area of Interest: Control system, Signal Processing, Rehabilitation, Human assist technology. Pattern Recognition, Robotic.

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Area of interest: mechanics of materials, experimental mechanics, mechanical testing, structural analysis of MEMS.

**Rajeev Ahuja**, Physics Department, Uppsala University, Box 530, 751 21 Uppsala, **Sweden**

Area of interest: Computational Materials Science, Electronic Materials, Spintronics, High pressure, Dynamics.

**Shigeru Aoki**, Department of Mechanical Engineering, Tokyo Metropolitan College of Technology, Shinagawa-ku, Tokyo 140-0011, **Japan**

Area of Interest: Random vibration, Seismic response of mechanical system, Approximate analysis of nonlinear vibration.

**G.Q. Chen**, Department of Mechanics and Engineering science, Peking University, Beijing 100871, **China**

Area of Interest: CFD (Computational fluid dynamics), energy and resources engineering, and systems ecology.

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Area of Interest: Energy, Thermal & Fluid Engineering.

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Area of Interest: Structural Health Monitoring and Management, Structural System Identification and Life Prediction, Forensic Engineering.

**B.T.F. Chung**, Department of Mechanical Engineering, University of Akron, Akron, Ohio 44325, **USA**  
Area of interest: Heat Transfer with Phase Changes, Optimum Design of Extended Surfaces, Radiative Heat Transfer System.

**Marcelo J.S. De Lemos**, Departamento de Energia - IEME, Instituto Tecnológico de Aeronáutica - ITA, 12228-900 Sao Jose dos Campos S.P. - **Brazil**  
Area of interest: Turbulence Modeling, Porous Media, Combustion in Porous Media, Numerical Methods, Finite Volume.

**Dimitris Drikakis**, Head of Aerospace Sciences Department, Cranfield University, School of Engineering, Cranfield, MK43 0AL, **United Kingdom**  
Area of Interest: Computational Fluid Dynamics, Aerodynamics, Turbulence Gas dynamics, Computational Nanotechnology.

**A.S. Al-Harthy**, Department of Civil, Surveying and Environmental Engineering, University of Newcastle, Callaghan, NSW 2308 **Australia**  
Area of interest: Concrete material and durability, Recycling construction materials, reliability assessment of structures.

**S.Z. Kassab**, Mechanical Engineering Department, Faculty of Engineering, Alexandria University, Alexandria, 21544 **Egypt**  
Area of Interest : Experimental Fluid Mechanics, Lubrication, Energy, Environment and Pollution.

**Bashar El-Khasawneh**, Chairman, Industrial Engineering Department, JUST, P.O. Box 3030, Irbid 22110 **Jordan**  
Area of Interest: Design process and manufacturing-related sciences and processes, advanced and parallel kinematics machine tools.

**Kazuhiko Kudo**, Laboratory of Micro-Energy Systems, Division of Human Mechanical Systems and Design, Graduate School of Engineering, Hokkaido University, **Japan**  
Area of interest: Radiative heat transfer analysis, transient analysis on surface tension.

**Carlos Mario Morales Bautista**, Calzada Olmeca 105. Cerrada Chiltepec No. 1. Fraccionamiento la Venta. Villa Parrilla II. C.P. 86280. Villahermosa, Centro, Tabasco, **Mexico**

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Area of Interest: Nanomagnetism, Superconductivity.

**Huihe QIU**, Department of Mechanical Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon **Hong Kong**

Area of Interest: Transport phenomena in microscale multiphase flows, micro sensors and actuators, optical diagnostics and instrumentation.

**S.A. Soliman**, Electrical Engineering Department, University of Qatar, P. O. Box 2713 Doha **Qatar**

**Area of Interest:** Applications of State Estimation to Electric Power Systems, Fuzzy and Neural System Applications to Electric Power Systems.

**Dimitri V. Val**, Dept. of Structural Engineering, Faculty of Civil and Environmental Engineering, Technion - Israel Institute of Technology, Haifa 32000, **Israel**

Area of Interest: structural safety and reliability; analysis, design, and assessment of reinforced concrete and steel structures.

**Guo-Xiang Wang**, Department of Mechanical Engineering, The University of Akron, Akron OH 44325-3903 **USA**

Area of Interest: Heat and Mass Transfer, Materials Processing, Solidification Theory and Application.

**Samir Mekid**, Mechanical Engineering Department, King Fahd University of Petroleum and Minerals PO Box 155, Dhahran, 31261, **Saudi Arabia**

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Area of Interest: Polymer Processing and Rheology, Biobased Polymer Composite, Microwave Processing of Polymer.

**V.R. Mudinepalli**, Department of Physics, National Taiwan Normal University, Taipei, 11677, **Taiwan.**

**Damodar Maity**, Civil Engineering Department Indian Institute of Technology, Kharagpur, West Bengal, **India**

Area of Interest: Damage Assessment of Structures; Seismic Resistant of Structures; Fluid-Structure Interaction; Sloshing; Concrete Gravity Dam.

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Area of Interest: biomedical engg; computational fluid dynamics and numerical heat transfer.

**Mohammad Luqman**, Chemical Engineering Department King Saud University Chemical Engineering Department, Riyadh, **Saudi Arabia**

Area of Interest: Polymer Nanocomposites, Polymer/Plastic, Ionomers, Nanocomposites.

**Mohammad Valipour**, Department of Irrigation and Drainage Engineering, College of Abureyhan, University of Tehran, Pakdasht, Tehran, **Iran**

Area of Interest: Surface and pressurized irrigation, Drainage engineering, Fluid mechanics, Heat transfer in soil media.

**Najm Obaid Salim Alghazali**, Department of Civil Engineering, Babylon University, Hilla, Babylon, **Iraq**

Area of Interest: Hydraulic Structures, Hydraulics, Engineering Hydrology, Groundwater Hydrology, Dams Engineering.

**Sushant K. Singh**, Earth and Environmental Studies Department, Montclair State University, Montclair, 07043, New Jersey, **USA**

Area of Interest: Environmental pollution, Environmental management, Environmental toxicology, Environmental policy.

**Hongseok Choi**, Department of Mechanical Engineering, Clemson University, 205 Fluor Daniel Bldg. Clemson, SC 29634 **USA**

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Area of Interest : Fluids Engineering, Multiphase flow, CFD (Computational Fluid Dynamics).

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Area of Interest : Computer and network security, it management, digital forensics, cryptocurrency, blockchain

**Marlen Bissaliye**, Al-Farabi Kazakh National University, Almaty, Kazakhstan, Senior Lecturer

Area of Interest : Computer and network security, it management, digital forensics, cryptocurrency, blockchain

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# The Effect of Ag<sup>+</sup> ION Existence in the Cyanidation Process of Tailing of Cijiwa Gold Ore Process on Gold Recovery

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## Abstract

Tailings still contain gold that allows to be extracted again. Some tailings contain silver which can affect the effectiveness of leaching. The purpose of this research is to examine the effect of Ag<sup>+</sup> ion existence on cyanidation process of gold ore processing to Au recovery. The test is done by adding silver nitrate (AgNO<sub>3</sub>) to the leaching process. The experiment was conducted five times. The feed capacity was 200 kg with the addition of AgNO<sub>3</sub> of 0 g, 1 g, 2 g, 3 g, and 4 g. The leachate solution was circulated through the activated carbon for 24 hours. Au content in activated carbon was analyzed using atomic absorption spectrophotometry (AAS) method. The results showed that Au recovery in addition of AgNO<sub>3</sub> 0 g, 1 g, 2 g, 3 g, and 4 g respectively was 9.62%; 8.99%; 8.91%; 7.30%; and 6.41%. The Ag<sup>+</sup> ion contained in the tailings decreases the Au recovery because the Ag<sup>+</sup> ions can be bound by cyanide ions which interfere with the binding of Au<sup>+</sup> ions by the cyanide ion.

**Keywords:** silver ion, recovery Au, cyanidation, tailing, spectrophotometry method

## INTRODUCTION

Most of the people of Kertajaya village, Simpenan subdistrict, Sukabumi regency, West Java have profession as miner and processor of gold ore. One of the ways that people use to process gold ore is by cyanidation process. Each treatment will produce solid and liquid waste. The more gold ore being processed, the greater the solid waste or tailings produced. Research shows that the Au recovery of Cijiwa gold ore reaches 13 - 36% so there is still quite a lot of Au contained in tailings[1]. Au content in tailings can reach 4.41 ppm[2]. Au content in tailings of this size is still economical and interesting to be reprocessed. Tailings processing has two advantages: reducing environmental pollution and increasing employer profits.

In the cyanidation process, people prefer the heap leaching method rather than vat leaching and agitated leaching. This selection is based on economic considerations and ease of operation[3]. In general, Leaching uses a cyanide solution[1], however, studies show that microorganisms may replace the cyanide solution[4]. Tailings processing requires better

handling of ore processing. This is because the Au content in the tailings is lower than in the ore. In addition to the lower Au content, tailings also still have the potential to contain dominant impurities such as Ag and S[1].

The improvement of Au recovery has been sought by previous researchers. These efforts include seeking optimal operating conditions, increasing the dissolved oxygen in the concentrate, and reducing the amount of impurity miner[5]. One way to increase dissolved oxygen is by adding hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>)[6]. Mineral impurities should be minimized before the tailings are dissolved into the cyanide solution. This is due to the ability of the cyanide solution to bind the impurities which will interfere the binding of Au<sup>+</sup> and CN<sup>-</sup> ions. Mineral impurities have potential to disturb the binding reaction of Au<sup>+</sup> ions by CN<sup>-</sup> ions. The reduction of impurity minerals from gold ores has also been investigated. Methods to reduce impurity minerals are adjusted for the type of impurity minerals. The manganese (Mn) element is reduced by FeS and H<sub>2</sub>SO<sub>4</sub>[7]. While the element of arsenic is reduced by nanosorbent Fe<sub>3</sub>O<sub>4</sub>@SiO<sub>2</sub>@TiO<sub>2</sub>[8].

The dominant impurity miner contained in Cijiwa gold ore is sulphide minerals, such as pyrite (FeS<sub>2</sub>), chalcopyrite (CuFeS<sub>2</sub>), sphalerite (ZnS), arsenopyrite (FeAsS), covellite (CuS), and calcalk (Cu<sub>2</sub>S)[1]. Previous research has shown that the addition of AgNO<sub>3</sub> to the concentrate is capable of binding the S<sup>2-</sup> ion thereby reducing the thiosulfate ion and thiocyanate ion formed to prevent the disturbance of the oxygen supply[1]. Although the study showed that the addition of AgNO<sub>3</sub> was able to improve the Au recovery on ore processing, it has not known yet to have any effect when it was done to treat tailings which certainly contained different elements with ores.

## MATERIALS AND METHODS

### Tools and Materials

The materials used are tailings, technical NaCN (PT Insoclay Acidatama Indonesia), limestone (CaO), AgNO<sub>3</sub> p.a. (Merck), pH meter, water, and activated carbon from coconut shell (Kyodo Yushi), HCl p.a. 37% (Merck), and HNO<sub>3</sub> p.a. (Merck). While the tools used are scales, pumps, sprinklers,

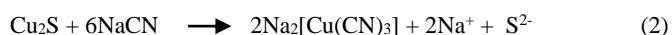
buckets, gauze, stirrer, paralon pipes, waterproof tarp from high density polyethylene material, and analytic balance.

out for 24 hours[9]. The flow of concentrate circulation is shown in Figure 1.

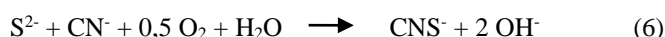
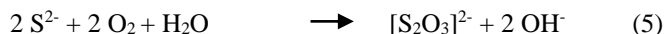
### The Research Procedure

The first step is weighing of 200 kg of tailings for 5 times. At each weighing, sampling and analyzing Au content in tailings was performed using the AAS method. The second step is to put 200 kg of tailings in the processing tub. The third step is the addition of silver nitrate (AgNO<sub>3</sub>), 400 grams of sodium cyanide (NaCN), 50 grams of chalk (CaO), and 99 liters of water into the tailings. Cyanide needs range from 0.5 to 5 kg per ton of feed[3]. The processing tub is in the form of waterproof solid (high density polyethylene) to prevent air pollutant infiltration against the soil. To facilitate the circulation of the concentrate stream, a slope of 3° to 6° is formed on the bottom of the tub. The variables used in this study were AgNO<sub>3</sub> concentration of 0 gram, 1 gram, 2 gram, 3 gram, and 4 gram that added to 200 kg tailings. The addition of CaO to the tailings is given in solution form. CaO solution used for conditioning the pH of the concentrate around 11-12 for optimal Au recovery[9]. The addition of Ag<sup>+</sup> ion in AgNO<sub>3</sub> form aims to test the effect of Ag<sup>+</sup> ion on Au recovery. After the addition of AgNO<sub>3</sub>, NaCN solution is sprayed through sprinkler. The rich solution (concentrate) is expected to contain many Au + ions bound by CN<sup>-</sup> so that Au recovery can be optimal.

In the leaching process, dissolution of metal minerals will occur. The oxidation reaction of Au metal can be seen in (1)[10]. Furthermore, the oxidation reaction of impurities minerals can be seen in (2), (3) and (4)[3].



In equations (2) and (3) the S<sup>2-</sup> ion is formed. This ion can react with oxygen to form thiosulfate ions as in (5). Additionally S<sup>2-</sup> ions could react with CN<sup>-</sup> ions and oxygen to form thiocyanate ions as in equation (6).



After leaching process that takes about 30 minutes, the concentrate is circulated and passed through the activated carbon in the column (CIC). The circulation process is carried

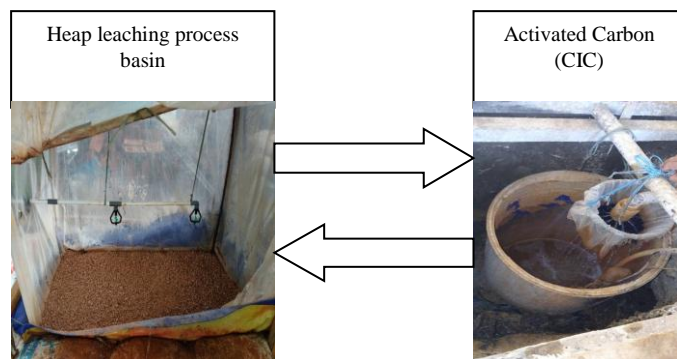


Figure 1. The flow of concentrate circulation

To determine the Au content in tailings (feed) and concentrate, AAS analysis was performed on the sample. AAS test was done at Geotek LIPI laboratory, Bandung, West Java, Indonesia. The next step was to burn the activated carbon to produce the bullion as presented in Figure 2. Bullion contains Au, Ag, and other metals.



Figure 2. Bullion result in gold extraction from tailings waste by heap leaching method and silver nitrate material assistance.

### Au Recovery

Au mass conservation laws is applied to the cyanidation process. The incoming Au mass must be equal to the Au mass out plus the accumulated Au mass. Au recovery is obtained from equation (7)[3].

$$\text{Au Recovery} = \frac{\text{AuMass(consentrate)}}{\text{AuMass(tailing / feed)}} \times 100\% \quad (7)$$

## RESULT AND DISCUSSION

This study studied the effect of  $Ag^+$  ion existence on feed to Au recovery on re-processing of tailings using cyanidation process.

### Au Concentration in Feed and Concentrate

Au content in tailings (feeds) is 3.63 ppm average. The feed mass per test is 200 kg so the Au mass is about 0.726 g contained in 200 kg of rock. While Au content in concentrates or rich solutions is presented in Table 1.

**Table 1:** Au concentration in concentrate

Test	Au Concentration (ppm)	
	Feed	Concentrate
1	3.63	0.71
2	3.45	0.62
3	3.28	0.60
4	4.06	0.64
5	4.08	0.55

To calculate the Au weight contained in the concentrate, the density of the concentrate is calculated as presented in Table 2.

**Table 2:** Concentrate density

Test	Concentrate Density (g/mL)
1	1.00
2	1.00
3	0.98
4	0.94
5	0.96

Based on Table 1 and Table 2, the Au mass contained in concentrates is presented in Table 3.

**Table 3:** Au mass in concentrate

Test	Au mass in concentrate (g)
1	0.0699
2	0.0620
3	0.0584
4	0.0593
5	0.0523

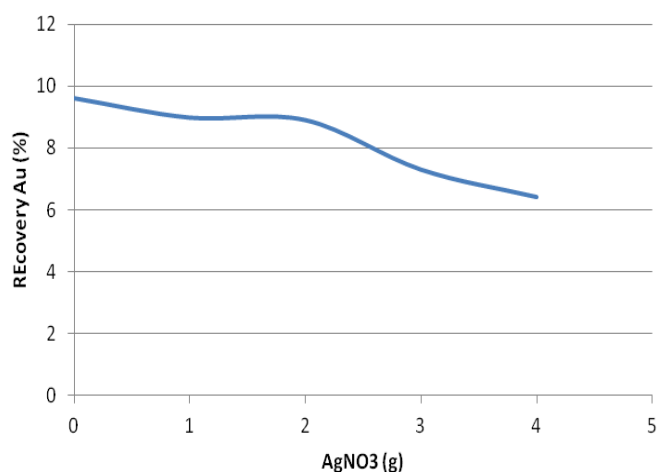
### Au Recovery

Based on equations (2), Table 1, and Table 3, the Au recovery is obtained as presented in Table 4.

**Table 4:** Au recovery

Test	Addition of $AgNO_3$ (g)	Recovery (%)
1	0	9.62
2	1	8.99
3	2	8.91
4	3	7.30
5	4	6.41

The effect of  $AgNO_3$  concentration into concentrate on Au recovery is presented in Figure 3.



**Figure 3.** Effect of  $AgNO_3$  concentration on heap leaching process with cyanide solution to Au recovery from tailings waste in Kertajaya village

In Figure 3 we can see the effect of adding  $AgNO_3$  to 200 kg of tailings (feed) to Au recovery. Figure 3 shows that the greater the addition of  $AgNO_3$ , the smaller the Au recovery. The largest Au Recovery of 9.62% was achieved under conditions without the addition of  $AgNO_3$ . This trend is in contrast when compared with the addition of  $AgNO_3$  in the processing of gold ore which can improve the recovery of Au [1]. This is probably due to the tailings feed, the sulphide mineral content is not as much in the ore so that  $Ag^+$  ions reacting with the  $S^{2-}$  ion forming less  $Ag_2S$  precipitate than in ore processing[11]. Furthermore, the excessive  $Ag^+$  ion in the concentrate has a great opportunity to react with the  $CN^-$  ion, thereby minimizing the chance of  $Au^+$  ions to be bound to  $CN^-$  ions.

## CONCLUSION

The presence of  $\text{Ag}^+$  ions in the tailings disrupts the cyanidation process because it minimizes the chance of  $\text{Au}^+$  ions to be bound to  $\text{CN}^-$  ions. The results showed that the addition of  $\text{AgNO}_3$  of 1 to 4 g into 200 kg feed in the form of tailings has decreased the Au recovery from 9.62% to 6.41%. Recovery Au can be improved by performing physical pretreatment, such as a tool that uses the concept of gravitational concentration.

## ACKNOWLEDGMENTS

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