Natrium Cyanide Replacement with Environmentally Friendly Polymerized Cyanide GOLDIX for Leaching of Gold Ore from Sumbawa Indonesia

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Abstract. Indonesia possesses abundant mineral resources, particularly gold ore. Leaching with sodium cyanide (NaCN) is commonly employed to extract gold in a cost-effective manner. However, due to its toxicity, NaCN poses environmental risks and requires detoxification before tailings can be safely disposed of. GOLDIX, a polymerized form of NaCN, emerges as an eco-friendly alternative with superior degradability, CN-, and a reduced environmental impact. This study utilizes several samples to compare the performance of NaCN and GOLDIX in gold ore leaching and detoxification. Tests were conducted using agitation leach with equal dosages of both reagents, and detoxification was evaluated through a blanking method as baseline, oxidation method for filtrate, and INCO for slurry. The results indicated that GOLDIX exhibited similar or even superior leaching performance compared to NaCN, particularly regarding gold and silver recovery. One type of GOLDIX achieved a gold recovery rate of 77.51%, surpassing NaCN's 70.09%. In the detoxification test, the same GOLDIX series also reduced free cyanide by approximately 90% in 90 minutes, while NaCN only achieved a 22.5% reduction. These results suggest that this type of GOLDIX is effective for gold leaching and represents a more environmentally responsible choice with potential cost-saving benefits in detoxification.

1 Introduction

Florrea GOLDIX is a newly patented reagent developed as a cyanide-free alternative for gold leaching, designed to maintain operational efficiency while addressing environmental and safety concerns associated with cyanidation. Its consumption rate is reported to be comparable to sodium cyanide on specific ore types, indicating minimal need for process redesign or increased reagent dosage. The reagent exhibits a high gold leaching rate and shorter leaching time, which suggests improved kinetics that could enhance throughput in leach circuits. A critical advantage is its reduced sensitivity to interfering metals such as arsenic (As), antimony (Sb), and sulfides, which are often present in refractory ores and known to hinder cyanide leaching by forming passivating layers or complexing with cyanide [1].

Operationally, GOLDIX mimics cyanide in application, allowing existing infrastructure to be utilized with minimal modification. The optimal leaching environment is in the alkaline pH range of 10 – 12, maintained using lime, mirroring conventional cyanidation pH control and supporting compatibility with standard practice [2]. Beyond performance metrics, the reagent promises significant economic and environmental benefits, including reduced costs associated with risk management, transport, and inventory due to its low toxicity. Importantly, it eliminates the need for post-leaching detoxification processes, thereby lowering tailings treatment costs and minimizing environmental liabilities. Collectively, these features position GOLDIX as a viable and cost-effective cyanide substitute, particularly suitable for operations under increasing regulatory and social pressure to reduce cyanide use.

Florrea GOLDIX is described as a synthetically engineered, cyanide-like polymeric compound, primarily based on carbonized sodium cyanurate ($Na_3C_6N_6H_3O_3$). It belongs to a class of polymeric cyanates formed through the high-temperature reaction of urea, alkalis (such as caustic soda), and other reactants. This synthesis process yields a grey-yellow solid that is alkaline and readily water-soluble, making it compatible with aqueous gold leaching processes. Mechanistically, GOLDIX functions similarly to cyanide by forming stable gold-ligand complexes, but with a different ligand structure that imparts greater selectivity and potential resistance to interference from detrimental ions like sulfides or arsenic.

The reaction pathway of GOLDIX in gold extraction mirrors cyanide in terms of stoichiometry and oxidant requirements. The gold dissolution equation for GOLDIX is represented as [2]:

$$4Au + 8Na_3C_6N_6H_3O_3 + O_2 + 2H_2O \rightarrow 4Na_5Au(C_6N_6H_3O_3)_2 + 4NaOH \quad (1)$$

which can be compared to the classical cyanidation reaction [1]:

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$4Au + 8NaCN + O_2 + 2H_2O \rightarrow 4Au(CN)_2^- + 4NaOH$ (2)

Both reactions depend on molecular oxygen as the oxidant and produce sodium hydroxide as a by-product, maintaining an alkaline environment throughout the leaching process [2]. However, in the case of GOLDIX, the resulting gold complex involves a larger and potentially more stable chelated structure based on the polymeric cyanurate ligand.

Florrea GOLDIX represents a promising advancement in this field. GOLDIX is a cyanide-free, polymeric leaching agent based on carbonized sodium cyanurate ($Na_3C_6N_6H_3O_3$), engineered to mimic the complexing behaviour of cyanide with gold while significantly reducing toxicity [1]. The leaching operates optimally in alkaline conditions (pH 10 – 12), like conventional cyanidation [3], enabling its use with minimal modifications to existing process circuits. The reagent demonstrates enhanced gold dissolution kinetics and reduced sensitivity to sulphides, arsenic, and antimony, common inhibitors in refractory ores. Moreover, the lower acute toxicity of GOLDIX (LD_{50} ~430 mg/kg) compared to NaCN (LD_{50} ~1 – 2 mg/kg) substantially reduces health and environmental risks, eliminating the need for multistage detoxification and complex tailings treatment [1].

In addition to safety and environmental benefits, GOLDIX exhibits strong metallurgical performance. Its polymeric NCN^- species form stable, selective gold complexes, offering effective recovery even from complex or low-grade ores. Waste solutions resulting from GOLDIX leaching are naturally photodegradable and non-toxic, allowing for simplified effluent treatment and reduced environmental liabilities.

2 Materials and methods

2.1 Sample and reagents

Gold ore from Sumbawa, Indonesia, was characterized as high-grade oxide ore or high concentration of Au with p80 75 µm particle size distribution. Four reagents were tested: NaCN, GOLDIX 570 (GD570), GOLDIX 571 (GD571), and GOLDIX 575 (GD575). Reagents were dosed at 1.5 kg/ton equal to 1000 ppm NaCN and for detoxification test maintain start from equal to 200 ppm CN on NaCN.

Table 1. Head Grade

Head Grade (ppm)		
Au	Ag	Cu
1.55	19.25	67.25

2.2 Leaching method

Leaching tests were conducted on high-grade oxide gold ore using a solid concentration of 40% (w/w) in all experiments. Four different cyanide-based reagents were evaluated: sodium cyanide (NaCN), GOLDIX 570 (GD570), GOLDIX 571 (GD571), and GOLDIX 575 (GD575). Each test maintained a fixed cyanide dosage of 1.5 kg/ton, equivalent to approximately 1000 ppm free cyanide for NaCN [4], and adjusted accordingly for each GOLDIX type to ensure comparable leaching solution oxidative strength. The pulp pH was controlled at 10.5 throughout the duration of the test using lime to maintain alkaline conditions and minimize the formation of toxic hydrogen cyanide gas. Dissolved oxygen (D.O.) levels were sustained at approximately 11 mg/L using hydrogen peroxide (H_2O_2) as an oxidizing agent to enhance gold dissolution kinetics [2].

Each leaching test was conducted under continuous agitation for 24 hours to simulate dynamic leaching conditions. Solution samples were collected at 2, 4, 8, 12, and 24 hours to monitor leaching kinetics over time. After 24 hours, final residue and solution samples were analysed to determine gold (Au), silver (Ag), and copper (Cu) recoveries using standard fire assay and atomic absorption spectroscopy (AAS) methods [1]. The test aimed to evaluate and compare the leaching performance and reagent efficiencies of the different cyanide-based lixiviants under controlled and consistent conditions focusing on kinetics and overall final recovery from the leaching [4].

Table 2. Leaching Test Parameter

Test Parameter							
Cyanide type	Cyanide / Goldix	Lime	Peroxide	pH	%Solid	D.O.	Leaching Time
	kg/ton	kg/ton	kg/ton			mg/L	ppm
NaCN	1.5	Adjusted	Adjusted	10.5	40.0	11.0	24
GD570	1.5	Adjusted	Adjusted	10.5	40.0	11.0	24
GD571	1.5	Adjusted	Adjusted	10.5	40.0	11.0	24
GD575	1.5	Adjusted	Adjusted	10.5	40.0	11.0	24

2.3 Detoxification Methods

Cyanide detoxification in gold processing was evaluated using two primary methods: the oxidation method with hydrogen peroxide and the INCO method involving sodium metabisulphite (SMBS) and copper sulphate. The cyanide destruction test under a blanking scheme was conducted to evaluate the baseline behaviour of free cyanide in various filtrate solutions without the addition of detoxification reagents. Each test used 200 mL of filtrate adjusted to pH 10.7 to prevent volatilization of hydrogen cyanide, with an initial cyanide concentration ranging from 38 to 200 ppm depending on the cyanide type (NaCN, GD570, GD571, GD575). A consistent reagent dosage of 0.0400 grams was applied to each solution.

Table 3. Detoxification Test Blank Filtrate

Filtrate - Blanking Scheme				
Cyanide Type	Filtrate Volume	pH	Cyanide Initial	Reagent
	ml		ppm	gram
NaCN	200	10.7	200,0	0.04
GD 570	200	10.7	63,0	0.04
GD 571	200	10.7	70,0	0.04
GD 575	200	10.7	38,0	0.04

A blanking scheme was conducted on gold tailing slurry to establish the baseline behaviour of cyanide without the addition of detoxification reagents. The test utilized 300 mL of cyanide solution mixed with solids to achieve a 25% solid concentration, resulting in a total slurry volume of approximately 338.5 mL at pH 10.5.

Four cyanide types, NaCN, GD570, GD571, and GD575, were tested with initial concentrations ranging from 38 to 200 ppm, and a fixed reagent dosage of 0.060 grams.

Table 4. Detoxification Test Blank Slurry

Tailing Slurry - Blanking Scheme						
Reagent Type	Filtrate Volume	Slurry Volume	pH	%Solid	Cyanide Initial	Reagent
	ml	ml		%	ppm	gram
NaCN	300	338.5	10.5	25.0	200.0	0.06
GD 570	300	338.5	10.5	25.0	63.0	0.06
GD 571	300	338.5	10.5	25.0	70.0	0.06
GD 575	300	338.5	10.5	25.0	38.0	0.06

The Cyanide Detoxification tests using peroxide as detoxification reagent which can be applied for detoxification in gold processing [5] were performed using 200 mL of solution at pH 10.7, with four cyanide types, NaCN, GD570, GD571, and GD575, at initial concentrations ranging from 38 to 200 ppm, and a fixed cyanide reagent dosage of 0.040 grams. Hydrogen peroxide was applied at three stoichiometric levels relative to the cyanide content to assess [6].

Table 5. Detoxification Oxidation Test Filtrate

Filtrate - Oxidation Scheme							
Reagent Type	Filtrate Volume	pH	Cyanide Initial	Cyanide Reagent	Peroxide Stokio Dosage		
	ml		ppm	gram	Dosage 1	Dosage 2	Dosage 3
NaCN	200	10.7	200	0.04	0.25x	0.5x	1.0x
GD 570	200	10.7	63	0.04	0.25x	0.5x	1.0x
GD 571	200	10.7	70	0.04	0.25x	0.5x	1.0x
GD 575	200	10.7	38	0.04	0.25x	0.5x	1.0x

Cyanide detoxification tests were conducted on gold tailing slurry using the INCO method, which applies sodium metabisulphite (SMBS) as alkali sulfate-based reduction and copper sulphate ($CuSO_4$) as catalyst agents under controlled alkaline conditions [4]. Four cyanide sources, NaCN, GD570, GD571, and GD575, were evaluated at initial concentrations ranging from 38 to 200 ppm. The experiments were performed using a slurry with 25% solids at pH 10.7, with a fixed filtrate volume of 200 mL and total slurry volume of 169.2 mL. Copper sulphate was maintained at 40 g/t across all tests, while SMBS was dosed at three stoichiometric levels (0.1x, 0.25x, and 0.5x).

Table 6. Detoxification INCO Test

Tailing Slurry - INCO Scheme										
Reagent Type	Filtrate Volume	Slurry Volume	pH	%Solid	Cyanide Initial	Cyanide reagent	Sodium Metabisulphite Stokio Dosage			Copper Sulphate
	ml	ml		%	ppm	gram	Dosage 1	Dosage 2	Dosage 3	g/t
NaCN	200	169.2	10.7	25	200	0.04	0.1x	0.25x	0.5x	40
GD 570	200	169.2	10.7	25	63	0.04	0.1x	0.25x	0.5x	40
GD 571	200	169.2	10.7	25	70	0.04	0.1x	0.25x	0.5x	40
GD 575	200	169.2	10.7	25	38	0.04	0.1x	0.25x	0.5x	40

3 Results

3.1 Leaching

Based on result Fig. 1. Gold leaching kinetics were evaluated by comparing the performance of four reagents, sodium cyanide (NaCN), GOLDIX 570, GOLDIX 571, and GOLDIX 575, over a 24-hour period, with sampling intervals at 0, 2, 4, 8, 12, and 24 hours. Recovery percentages were determined by measuring Au concentration in the leach solution and calculating the total dissolved Au against the initial gold content.

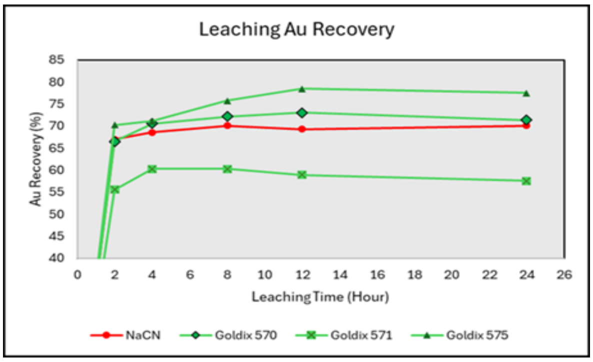

Fig. 1. Leaching Kinetics of Au Recovery

All lixiviants exhibited rapid initial Au dissolution, followed by a reduced leaching rate after the first two hours and subsequent stabilization, which is characteristic of leaching kinetics. This decrease in leaching rate is not related to mineral liberation issues, as the ore was well ground, homogeneous, and adequately liberated prior to testing. The NaCN system reached 66.94% Au recovery at 2 hours and stabilized at approximately 70.09%, while GOLDIX 570 showed comparable performance, increasing from 66.49% to 71.36% at 24 hours. GOLDIX 571 exhibited slower kinetics, reaching 57.70% at 24 hours, whereas GOLDIX 575 achieved the highest final recovery of 77.51%, outperforming NaCN by more than 7%.

These results indicate that GOLDIX 575 has the most favourable leaching kinetics, with both rapid dissolution and high overall recovery. GOLDIX 570 performs similarly to NaCN, while GOLDIX 571 is significantly less efficient under the same leaching conditions. This suggests GOLDIX 575 as a strong alternative to conventional cyanide in gold hydrometallurgy, particularly when high recovery and environmental considerations are prioritized.

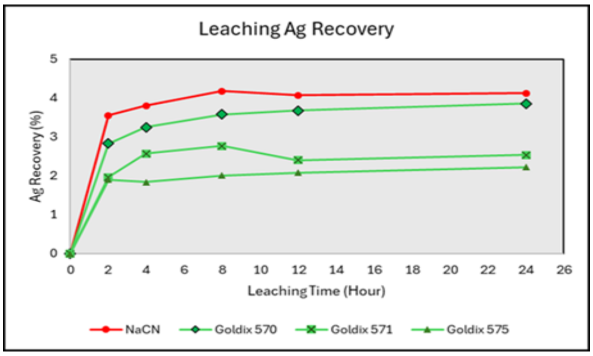

Fig. 2. Leaching Kinetics of Ag Recovery

Silver leaching kinetics on Fig. 2. were evaluated for four lixiviants, NaCN, GOLDIX 570, GOLDIX 571, and GOLDIX 575, over a 24-hour period, with sampling intervals at 0, 2, 4, 8, 12, and 24 hours. The silver recovery performance was assessed by determining Ag concentration in the leach solution and calculating recovery percentages relative to the total silver content.

Among the tested reagents, NaCN showed the highest silver recovery, starting at 3.55% at 2 hours and peaking at 4.17% at 8 hours, before slightly declining to 4.12% at 24 hours, indicating relatively stable silver dissolution. GOLDIX 570 exhibited moderate leaching performance, reaching a maximum recovery of 4.20% at 12 hours, but slightly decreasing to 3.86% at 24 hours. GOLDIX 571 displayed the lowest recovery efficiency, initiating at 1.96% and reaching only 2.53% at 24 hours, suggesting limited silver complexation capability. GOLDIX 575, although better than GOLDIX 571, remained less effective than NaCN and GOLDIX 570, with a gradual increase from 1.90% to 2.22% over the 24-hour period.

Overall, silver recovery was significantly lower than gold recovery across all lixiviants, which is expected given the variable solubility of silver arising from its diverse mineral associations and its sensitivity to leaching conditions. In the preg-robbing ore tested, silver dissolution may be further constrained by re-adsorption onto reactive or carbonaceous phases, as well as by the formation of passivating surface species. Across all tested lixiviants, silver extraction remained below 5%, with only minor variations of approximately 1 – 2%, indicating limited suitability for silver extraction under the tested conditions. The observed leaching kinetics suggest that effective silver dissolution may require enhanced or specifically tailored reagent formulations.

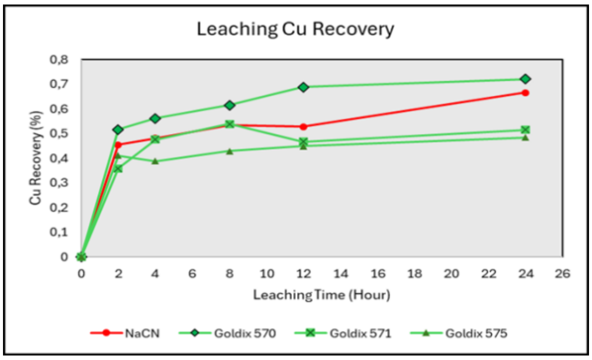

Fig. 3. Leaching Kinetics of Cu Recovery

Based on Fig. 3. Among all tested reagents, GOLDIX 570 consistently demonstrated the highest Cu recovery, beginning at 0.52% at 2 hours and reaching 0.72% at 24 hours, indicating efficient complexation and dissolution of copper species. NaCN also showed progressive Cu recovery, starting from 0.45% at 2 hours and increasing to 0.67% at 24 hours, suggesting moderate but consistent leaching capability. GOLDIX 571 and 575 exhibited slightly lower recoveries, reaching only 0.51% and 0.48% respectively at the end of the test, although both reagents showed steady leaching progress over time.

Copper recovery was consistently very low (<1%) across all tested lixiviants, with only negligible differences observed. The kinetic behaviour indicates slow and limited Cu dissolution for all reagents, likely due to the low copper content and the poor leachability of copper-bearing minerals under the tested conditions. As a result, no meaningful distinction in copper leaching performance can be established among the reagents. Consequently, while GOLDIX-based lixiviants may still be considered as potential alternatives to cyanide in systems where copper solubilization is of interest, reagent selectivity and economic factors must also be carefully evaluated. The discussion is therefore more appropriately focused on gold extraction, noting that all reagents produced low and comparable recoveries for silver and copper.

3.2 Detoxification Test

Cyanide detoxification in gold processing was evaluated using two primary methods: the oxidation method with hydrogen peroxide and the INCO method involving sodium metabisulphite (SMBS) and copper sulphate.

Cyanide destruction in the blanking filtrate was monitored over a 90-minute period. The performance of detoxification reagents GD570, GD571, and GD575 was compared against a control sample containing NaCN only, serving as an untreated blank without detoxification. The control (NaCN) exhibited minimal natural cyanide degradation, with CN Free decreasing gradually from 200 ppm to 155 ppm. In contrast, all detoxification reagents significantly enhanced cyanide reduction. GD575 showed the highest efficiency, reducing CN Free from 38 ppm to 20 ppm within the first 30 minutes and maintaining this level throughout. GD570 and GD571 also improved cyanide degradation, with CN Free decreasing from 63 to 45 ppm and 70 to 50 ppm, respectively. These results demonstrate that the application of detoxification reagents, particularly GD575, is highly effective in promoting rapid and sustained cyanide destruction in filtrate, outperforming the untreated control.

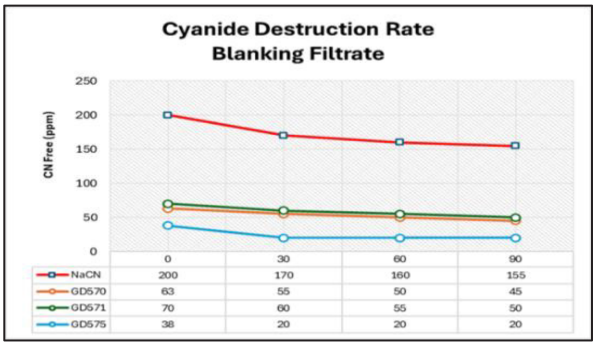

Fig. 4. CN Destruction rate on blanking filtrate

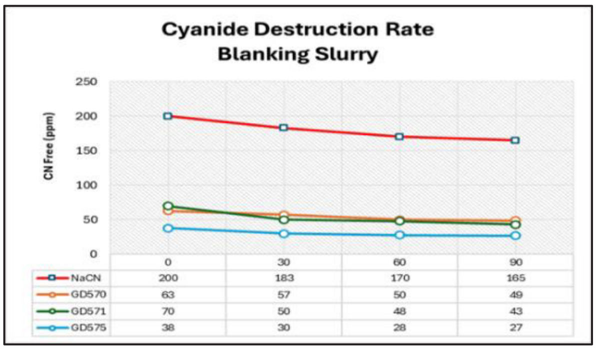

Fig. 5. CN Destruction rate on blanking slurry

The performance of detoxification reagents GD570, GD571, and GD575 was assessed in comparison with a NaCN control representing an untreated system. The control sample showed only limited natural cyanide degradation, as free cyanide decreased slowly from 200 ppm to 165 ppm, whereas all tested reagents significantly enhanced cyanide reduction. GD575 was the most effective, reducing cyanide levels from 38 ppm to 27 ppm, followed by GD571 and GD570, which reduced cyanide from 70 to 43 ppm and 63 to 49 ppm, respectively. These results demonstrate that the application of detoxification reagents enhances cyanide destruction in slurry tailings, with GD575 showing superior and consistent performance, indicating its potential as the most efficient option for cyanide detoxification under these conditions.

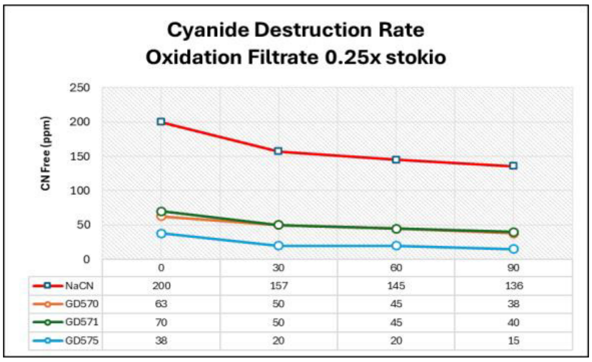

Fig. 6. CN Destruction rate on Peroxide 0.25x stokio

The graph Fig. 6. illustrates the cyanide destruction rate in oxidation filtrate using 0.25× stoichiometric dosage of hydrogen peroxide as the oxidizing agent, comparing the performance of different detoxification reagents (GD570, GD571, and GD575) against a control sample (NaCN). The control exhibited a gradual reduction in free cyanide from 200 ppm to 136 ppm over 90 minutes, reflecting limited natural oxidation. In contrast, the addition of detoxification reagents significantly enhanced cyanide degradation. GD575 showed the highest efficiency, reducing cyanide from 38 ppm to 15 ppm, followed by GD570 and GD571, which achieved reductions from 63 to 38 ppm and 70 to 40 ppm, respectively. These results indicate that even with a low oxidant dosage, detoxification reagents, especially GD575, significantly improve cyanide destruction efficiency compared to untreated conditions, demonstrating their potential for effective cyanide management in oxidative environments

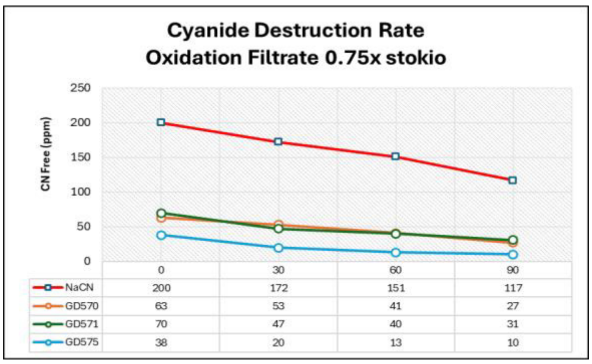

Fig. 7. CN Destruction rate on Peroxide 0.75x stokio

The cyanide destruction rate in oxidation filtrate using 0.75× stoichiometric dosage of hydrogen peroxide shown on Fig. 7. the control showed a gradual reduction in free cyanide from 200 ppm to 117 ppm over 90 minutes, indicating limited oxidation in the absence of detoxification agents. In contrast, all detox reagents significantly enhanced cyanide degradation. GD575 demonstrated the highest efficiency, with a rapid decrease from 38 ppm to just 10 ppm. GD571 and GD570 also showed substantial reductions, from 70 to 31 ppm and 63 to 27 ppm, respectively. These results confirm that increasing the oxidant dosage improves cyanide destruction and that the addition of detoxification or oxidation reagents [7], especially GD575, the cyanide reduction greatly accelerates cyanide degradation, making them highly effective for oxidative treatment of cyanide-containing solutions.

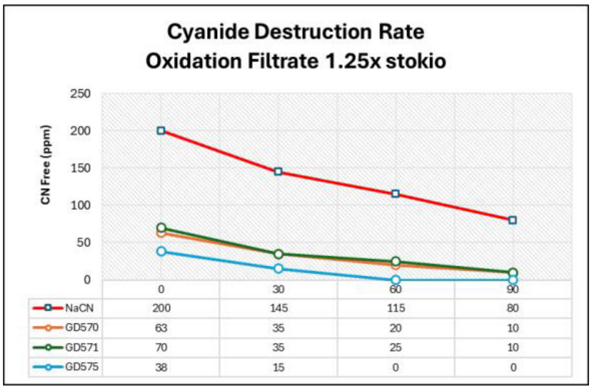

Fig. 8. CN Destruction rate on Peroxide 1.25x stokio

The cyanide destruction rate in oxidation filtrate treated with 1.25× stoichiometric (stokio) dosage of hydrogen peroxide that shown on Fig. 8. comparing the performance of detoxification reagents (GD570, GD571, GD575) to a NaCN. The control (NaCN) exhibited moderate cyanide degradation, decreasing from 200 ppm to 80 ppm over 90 minutes. In contrast, the use of detox reagents significantly accelerated cyanide destruction. GD575 showed the highest efficiency, reducing cyanide levels from 38 ppm to 0 ppm within 60 minutes, and maintaining complete removal thereafter. GD570 and GD571 also achieved full or near-complete degradation by the end of the test, reducing from 63 and 70 ppm to 10 ppm, respectively. These results demonstrate that at a 1.25× stoichiometric peroxide dosage, all detox reagents become highly effective, with GD575 achieving the fastest and most complete cyanide elimination. This confirms the synergistic benefit of combining optimized oxidant dosing with suitable detox reagents for effective cyanide treatment.

On Fig. 9. show Cyanide destruction rate in the INCO method using 0.1× stoichiometric dosage of sodium metabisulfite (SMBS) combined with 40 g/t $CuSO_4$, comparing various detoxification reagents (GD570, GD571, GD575) with a control (NaCN). The control exhibited limited natural degradation, with cyanide levels decreasing from 200 ppm to 140 ppm over 90 minutes. In contrast, all detox reagents significantly accelerated cyanide destruction. GD575 demonstrated the most effective performance, rapidly reducing CN Free from 38 ppm to 0.5 ppm, achieving near-complete detoxification within 60 minutes. GD571 also showed strong performance, decreasing from 70 ppm to 10.8 ppm, while GD570 achieved a reduction from 63 ppm to 27 ppm. These results confirm that even at low SMBS dosage, the INCO method is highly effective when combined with appropriate detox reagents, especially GD575, which achieved nearly complete cyanide destruction. This highlights the synergistic benefit of combining Cu-catalysed oxidation with tailored reagent formulations for efficient cyanide detoxification.

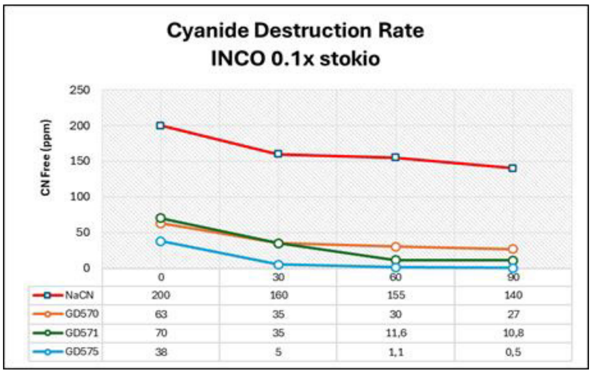

Fig. 9. CN Destruction rate on SMBS 0.1X stokio

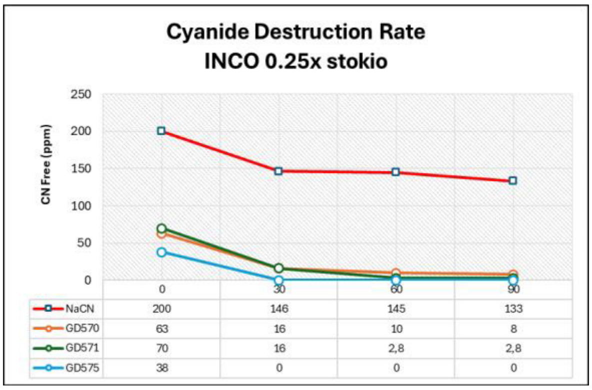

Fig. 10. CN Destruction rate on SMBS 0.25X stokio

The graph Fig. 10. presents the cyanide destruction rate using the INCO method with a 0.25× stoichiometric dosage of sodium metabisulfite (SMBS) and 40 g/t $CuSO_4$, comparing the detoxification performance of GD570, GD571, and GD575 against a control (NaCN). The control showed limited cyanide degradation from 200 ppm to 133 ppm over 90 minutes. In contrast, all detox reagents achieved significantly greater reductions. GD575 demonstrated exceptional efficiency, eliminating cyanide (0 ppm) within 30 minutes and maintaining zero levels throughout the test. GD570 and GD571 both reduced cyanide from over 60 ppm to 8 ppm and 2.8 ppm, respectively, by the end of 90 minutes. These results show that increasing the SMBS dosage to 0.25× stokio in the INCO process dramatically enhances cyanide destruction when combined with detox reagents, especially GD575, which achieved total cyanide removal in the shortest time. This underscores the importance of both reagent selection and adequate oxidant dosing for effective cyanide detoxification in industrial processes.

The graph Fig. 11. illustrates the cyanide destruction rate using the INCO method with a 0.5× stoichiometric dosage of sodium metabisulfite (SMBS) and 40 g/t $CuSO_4$, comparing the performance of detoxification reagents GD570, GD571, and GD575 to a control (NaCN). The control showed limited cyanide reduction from 200 ppm to 118 ppm after 90 minutes. In stark contrast, all detox reagents demonstrated high efficiency in cyanide removal. GD575 achieved complete cyanide destruction (0 ppm) within 30 minutes and maintained zero levels throughout the test. GD571 showed similarly rapid effectiveness, reaching 0 ppm by 60 minutes. GD570 also performed well, reducing cyanide from 63 ppm to just 0.5 ppm. These results indicate that increasing the SMBS dosage to 0.5× in the INCO process significantly enhances detoxification performance, with GD575 and GD571 achieving complete cyanide removal. This demonstrates the powerful synergy between optimized oxidant dosing and effective reagent selection, particularly GD575, for rapid and total cyanide detoxification

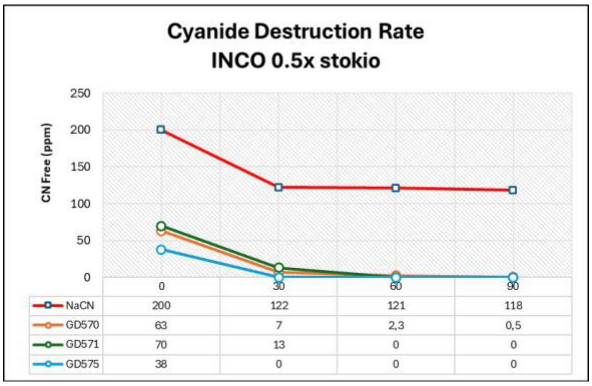

Fig. 11. CN Destruction rate on SMBS 0.5X stokio

4 Conclusion

Overall, GOLDIX 575 as the most effective reagent for gold recovery, with enhanced kinetics and final yield, while GOLDIX 570 shows balanced performance across all three metals, including copper. GOLDIX 571 was the least effective in all categories. These results support the application of GOLDIX reagents, particularly 575 and 570, as promising alternatives to sodium cyanide in gold hydrometallurgy, especially where environmental concerns, reagent selectivity, or operational safety are prioritized.

Cyanide destruction improves with increasing peroxide dosage. GD575 consistently outperformed other reagents across all conditions, achieving complete cyanide removal at the highest peroxide dose. Thus, GD575, especially at or above 0.75× stoichiometric peroxide, is the most effective reagent for cyanide detoxification in oxidation filtrates.

Increasing the stoichiometric dosage of SMBS in the INCO process significantly enhances cyanide detoxification, particularly when combined with effective detox reagents. GD575 consistently outperformed other reagents, achieving complete or near-complete destruction across all conditions. GD571 also showed excellent performance at higher dosages.

These findings highlight GD575 as the most robust and reliable reagent for cyanide removal under varying SMBS conditions in the INCO method.

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