The benefits of using Aachen High Shear Reactors in gold tailings reprocessing from laboratory and plant evaluations

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The use of Aachen High Shear Reactors has been widely implemented in the gold industry and is gaining substantial traction in tailings reprocessing. The Aachen High Shear Reactor is a highly efficient oxygen mass transfer and shear device. The findings from two tailings reprocessing sites utilising Aachen technology are discussed. For both sites, extensive laboratory testwork was conducted using the Aachen reactor. These results were subsequently compared to the actual plant performance over a period of time. Site A achieved a 2.82% increase in gold recovery from 41.55% to 44.37% after implementing Aachen pre-oxidation, with testwork showing that a 2.35% improvement was possible. Site B achieved a gold recovery improvement of 6.13% from 34.94% to 41.08% with a reduction in cyanide consumption of ~33% after increasing the installed Aachen reactors from two to three. The laboratory testwork conducted indicated a benefit of 3.23% in gold recovery and a reduction of 4% in cyanide consumption. From these observations, it is evident that the combination of shear and highly efficient oxygen mass transfer achieved through the use of the Aachen reactor assists in the improved reprocessing economics of gold tailings material. It is also clear that any benefits observed during testwork are typically exceeded on an industrial scale.

Keywords: Gold, tailings, oxygen, shear, cyanide

INTRODUCTION

As the exploration and discovery of new gold reserves become increasingly rare and costly, mining companies are shifting their focus towards reprocessing existing tailings dams (Singo and Kramers, 2021). Tailings dams contain significant amounts of gold and other valuable minerals that were not fully extracted during initial processing (Chingwaru *et al.*, 2023). This trend is particularly notable in regions with a long history of gold mining, such as South Africa, where the landscape is dotted with numerous abandoned tailings dams (Rösner and Van Schalkwyk, 2000). Reprocessing these tailings not only presents a more cost-effective alternative to traditional exploration and mining but also aligns with environmental sustainability goals by mitigating the need for additional land disruption and waste generation (Burger, 2024). Consequently, mining companies are investing in advanced technologies and techniques to extract gold and other minerals from tailings more efficiently. A recent example of this is the Mogale Tailings Retreatment Project, where R2.5 billion will be invested in retreating nine different tailings dumps in the West Rand area of South Africa (Creamer, 2023; Tassel, 2024).

Extracting the remaining gold from the tailings material can be complex, and sometimes requires pre-treatment methods to increase gold recovery and reduce reagent consumption (Mutimutema *et al.*, 2022). One technology that has gained traction in the gold processing industry, specifically tailings retreatment, is the Aachen High Shear Reactor. The Aachen is a specialised device used in the mining industry to enhance the extraction of precious metals, particularly gold, from ores (Flatman *et al.*, 2015). It operates by efficiently introducing oxygen into the solution or slurry whilst also enacting shear forces on the particles (Lotz *et al.*, 2015).

The high shear environment promotes the polishing of tailings particles, ensuring surfaces are clean and ready for cyanidation. As higher throughput rates linked to tailings reprocessing also require higher oxygen masses to be introduced into slurry, the Aachen reactor's highly efficient oxygen mass transfer ensures less oxygen is required than would typically be needed with conventional oxygenation devices. This combination makes the Aachen reactor a highly suitable device for tailings reprocessing.

In this paper, the author evaluates the implementation of Aachen High Shear Reactors on two South African gold tailings retreatment plants, referred to as Site A and Site B. For both sites, testwork was initially conducted to evaluate the potential benefits linked with the introduction of Aachen technology. After implementation on industrial scale, the plant data were evaluated to determine if the laboratory benefits were realised.

Site A:
This site is a gold tailings reprocessing site located in the North West province of South Africa. The specific stream evaluated treats an average of 23 000 tpd at a grade of 0.29 g/t. A total of 4 x REA 450 Aachen units were installed in the pre-oxidation tank in 2020 (Figure 1). These units are supplied by 2 x Warman 14/12 pumps (2 x REA 450s per pump) with 400 kW motors.

Figure 1. Site A: Plant Aachen installation pictures.

Site B:
This site is a gold tailings reprocessing site located in the Lowveld region of South Africa. The site treats an average of 2500 tpd at a grade of 1.50 g/t. The process plant originally employed 2 x Aachen REA 450 units installed in the first leach tank (2013) as well as in the cyanide INCO detox tank (2017). An additional Aachen REA 450 unit was installed in 2022 in the second leach tank. The first leach tank was subsequently converted to a pre-oxidation tank with the Aachen unit. Each Aachen unit is supplied by a Warman 8/6 pump with a 200 kW motor. The Aachen units installed at Site B are shown in Figure 2.

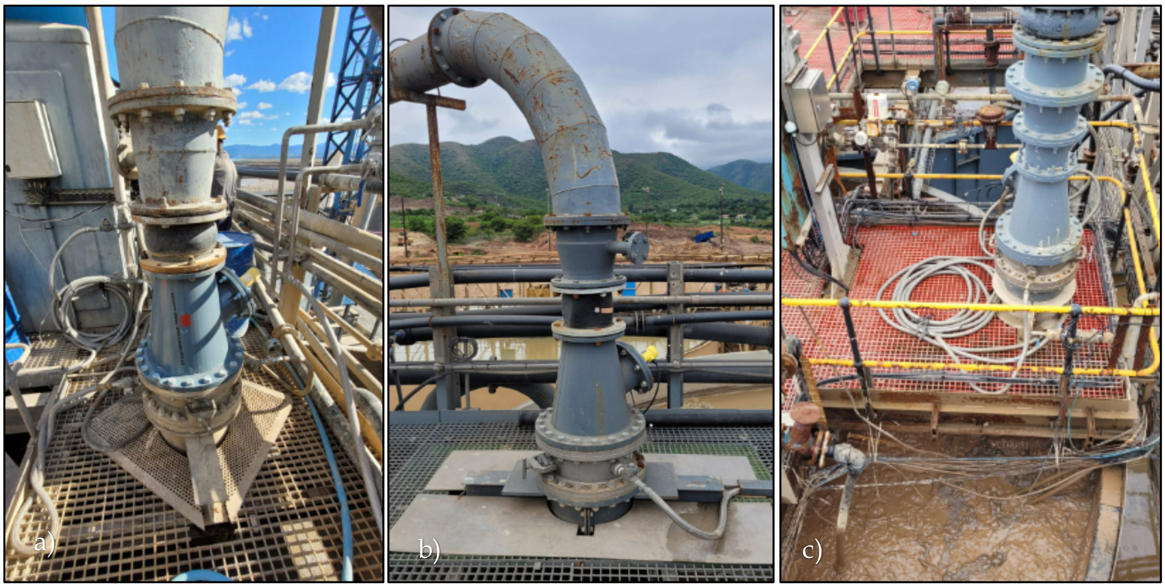

Figure 2. Site B Aachen installation picture: a) Aachen pre-oxidation reactor, b) Aachen assisted leach reactor, c) Aachen INCO detox reactor.

METHODOLOGY

Site A

Sample receipt and preparation:

A total of 25 gold-bearing tailings samples were received for the testwork campaign. These samples were drilled from various tailings dams to be treated through Site A's process plant. The samples had varied head grades and chemical compositions.

Basecase laboratory testwork

The samples received were subjected to basecase leach testwork, simulating the plant conditions prevailing during the testwork campaign. The conditions used are found in Table I. All the leach tests were performed as bottle roll tests using the specified conditions. The final leach products were filtered, dried and submitted for gold analysis. Solutions were further analysed for CN^- using the Mintek Cynoprobe.

Table I. Site A basecase leach conditions

Parameter	**Value**
Grind	'As received'
Solids (%)	45
pH	10.5
Pre-oxidation with oxygen sparging (hours)	1.5
Dissolved oxygen levels during pre-oxidation (ppm)	9 - 11
NaCN addition (kg/t)	0.33
Carbon addition (g/l)	20
Leach duration (hours)	11

Aachen laboratory testwork

The samples were also subjected to laboratory Aachen testwork. These results were compared to the basecase leach results to observe if any benefit could be achieved in terms of leach kinetics, gold recovery and reagent consumption. An Aachen laboratory rig as shown in Figure 3 was used to conduct the testwork. Each solid sample was re-suspended at a pH of 10.5 and a solids concentration of 50%.

The slurry sample was then added to the tank and pumped through the Aachen for 2-passes. This means the entire volume of slurry passed through the Aachen unit twice, simulating what would be achievable, but also still economically viable for a full-scale Aachen installation considering the low gold tenor. After Aachen pre-oxidation, the samples were subjected to bottle roll leach tests mimicking the basecase leach test conditions.

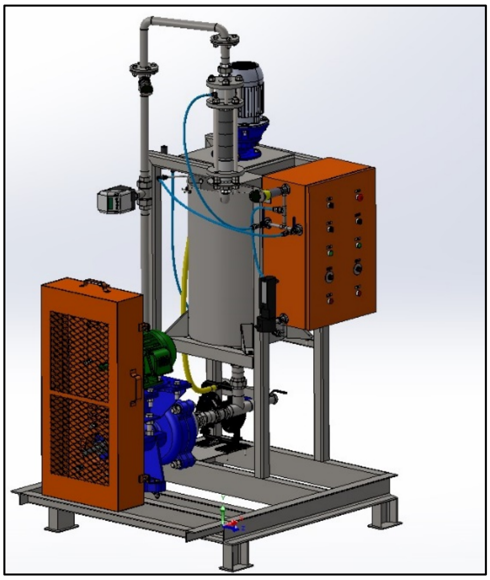

Figure 3. Aachen laboratory rig.

Plant evaluation
Plant data spanning a period of one year and six months was received from Site A. During this period, the Aachen units had varying utilisation rates whilst also being offline for certain periods due to oxygen supply-related issues. The data were analysed to evaluate whether the Aachen units were beneficial in the client's gold dissolution. As the gold dissolution was strongly linked to the tailings head grade, a period was carefully selected where the head grade remained constant at approximately 0.3 g/t, while Aachen utilisation varied from 100% to 0% and then to 50%. This period, spanning from 13 April 2021 to 29 December 2021, allowed for isolating the effects of Aachen units on dissolution rates, minimising the interference of head grade fluctuations for a clearer analysis.

Site B
Sample receipt and preparation
A total of 10 gold-bearing tailings samples were received for the testwork campaign. These samples were a mixture of drilled tailings dam samples, and samples taken from direct feed sources to the process plant. The samples had varied head grades and chemical compositions.

Aachen laboratory testwork:
Aachen optimisation testwork was conducted to evaluate different Aachen configurations. These results were compared to the basecase leach results to observe if any benefit could be achieved in terms of leach kinetics, gold recovery and reagent consumption. An Aachen laboratory rig as shown in Figure 3 was used to conduct the testwork. Each solid sample was re-suspended at a pH of 10.5 and a solids concentration of 50%. The slurry sample was then added to the tank and pumped through the Aachen reactor for the following configurations:

- 3-pass Aachen Assisted Leaching (AAL) (basecase)
- 3-pass Aachen Pre-oxidation + 3-pass AAL

For the AAL tests, NaCN is added inside the Aachen tank and passed through the reactor together with oxygen but in the absence of activated carbon. Typically, 70% of the NaCN is added during the Aachen test whilst the remaining 30% is added during the bottle roll leach. After the Aachen simulation, the samples were subjected to bottle roll leach tests mimicking the basecase leach test conditions. The final leach products were filtered, dried and submitted for gold analysis. Solutions were further analysed for CN^- using the Mintek Cynoprobe.

Table II. Site B leach conditions

Parameter	Value
Grind (p80 - µm)	75
Solids (%)	50
pH	10.5
Oxygen sparging after each Aachen step (hours)	2
NaCN addition (kg/t)	0.5
Carbon addition (g/l)	20
Leach duration (hours)	24

Plant evaluation:
Plant data before and after adding an additional Aachen reactor to the process were evaluated. The data before implementation were over a period of 11 months (July 2021 – May 2022), whilst the data after installation were over a period of 10 months (June 2022 – March 2023). These periods were selected based on similar tonnages treated throughout the duration, as throughput was considered to have the most significant influence on gold recovery.

RESULTS AND DISCUSSION

Site A

Laboratory result
From the 25 samples evaluated, 16 samples had an improved gold dissolution when compared to the basecase tests. The highest gold dissolution increase was 13.66%, whilst the average increase for all samples evaluated was 2.35%. This equates to a gold dissolution increase from 47.29% to 49.64%. The samples had an average gold head grade of 0.43 g/t. A summary of the results is shown in Figure 4.

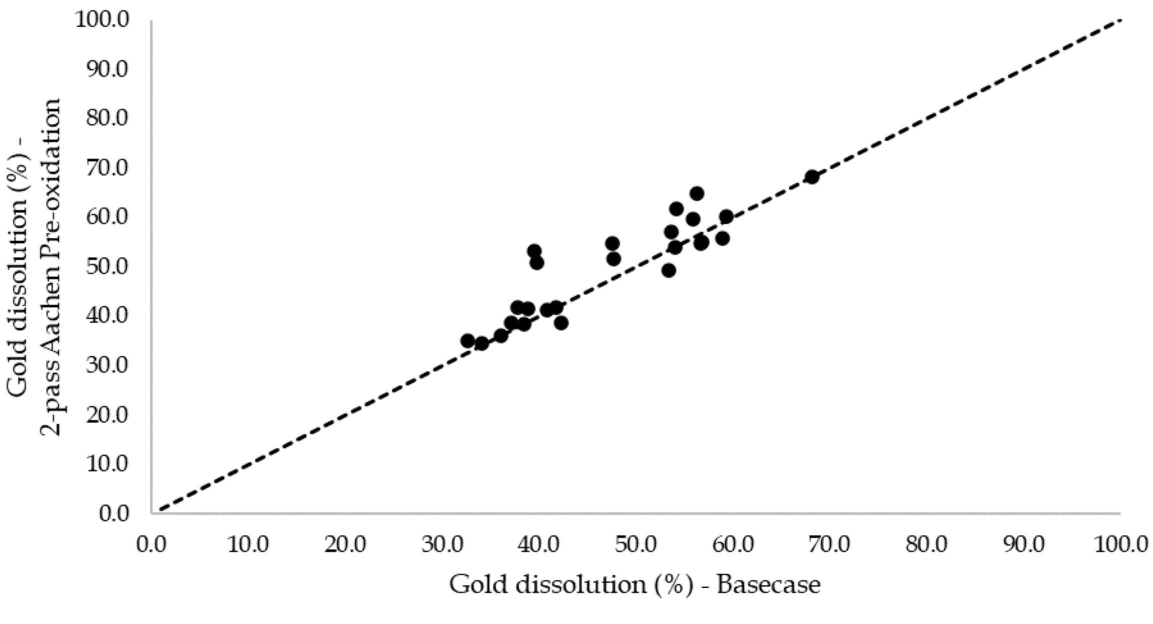

Figure 4. Site A testwork results – comparison of basecase vs. Aachen results.

Plant evaluatio:

The following periods were evaluated, representing Aachen utilisation figures of 100%, 0% and 50% respectively:

- Period 1: 13 April 2021 – 20 July 2021 (99 days). Average daily throughput of 25 890 tpd at a gold head grade of 0.3 g/t.
- Period 2: 21 July 2021 – 30 August 2021 (41 days). Average daily throughput of 24 654 tpd at a gold head grade of 0.3 g/t.
- Period 1: 31 August 2021 – 29 December 2021 (121 days). Average daily throughput of 21 065 tpd at a grade of 0.3 g/t.

A summary of the findings is given in Table III.

Table III. Site A plant evaluation – average data for each period

Period	Aachen utilisation	Aachen runtime	DO achieved (ppm)	Gold head grade (g/t)	Gold residue grade (g/t)	Gold dissolution	Change in dissolution
1	100%	90%	20.57	0.30	0.17	43.74%	+2.19%
2	0%	0%	17.02	0.30	0.18	41.55%	
3	50%	84%	22.80	0.30	0.16	45.00%	+3.45%
Average Aachen benefit							**2.82%**

From the data reviewed, it is evident that the implementation of Aachen technology increased the gold dissolution by 2.82% on average, even considering that Period 3 only had a 50% utilisation rate. This trend can be further seen in Figure 5, showing a cumulative summation (CUSUM) analysis done using the Aachen runtime, gold dissolution and gold head grade data for the three periods. The head grade can be seen to remain more or less constant, whilst the gold dissolution followed the trend of the Aachen runtime.

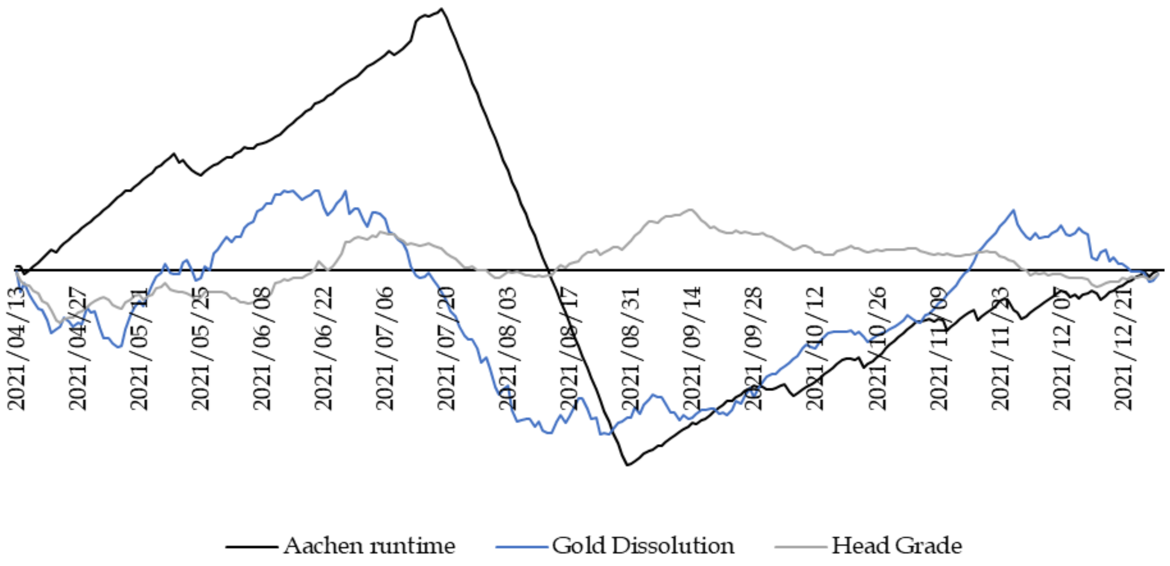

Figure 5. Site A CUSUM analysis – Aachen runtime, gold dissolution and gold head grade.

A comparison between the laboratory testwork and the plant scale implementation can be found in Table IV. The plant results slightly outperformed the results found during laboratory testwork.

Table IV. Site A – Laboratory testwork vs. plant evaluation results comparison

	Gold dissolution (%) improvement after Aachen implementation
Laboratory Testwork	2.35
Plant Evaluation	2.82

Site B

Laboratory results

From the 10 samples evaluated, seven samples showed improved gold dissolution after the addition of a 3-pass Aachen pre-oxidation step. On average, a 3.23% increase in gold dissolution was seen for all samples evaluated. This relates to a gold dissolution increase from 33.55% to 36.78%. Almost all of the samples showed a decrease in NaCN consumption after the addition of the Aachen pre-oxidation. This reduction was in the order of ~11% or 0.05 kg/t on average for all samples. The results are illustrated in Figure 6 and 7.

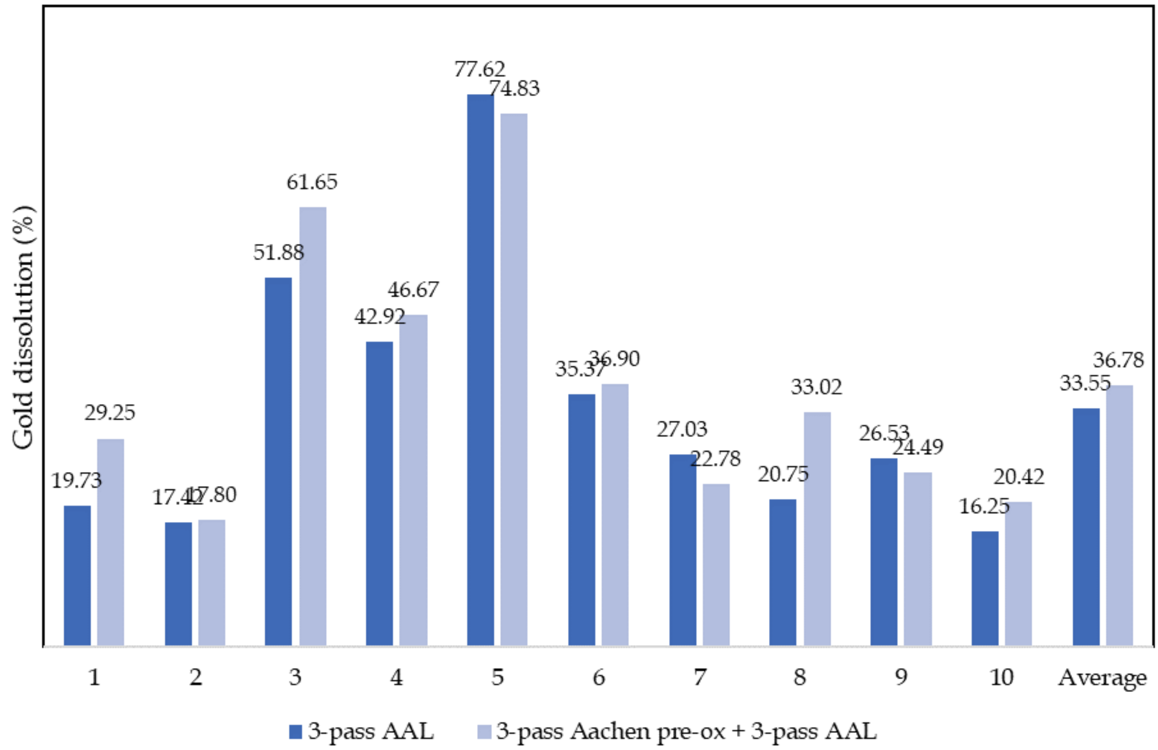

Figure 6. Site B - gold dissolution (%) results comparison.

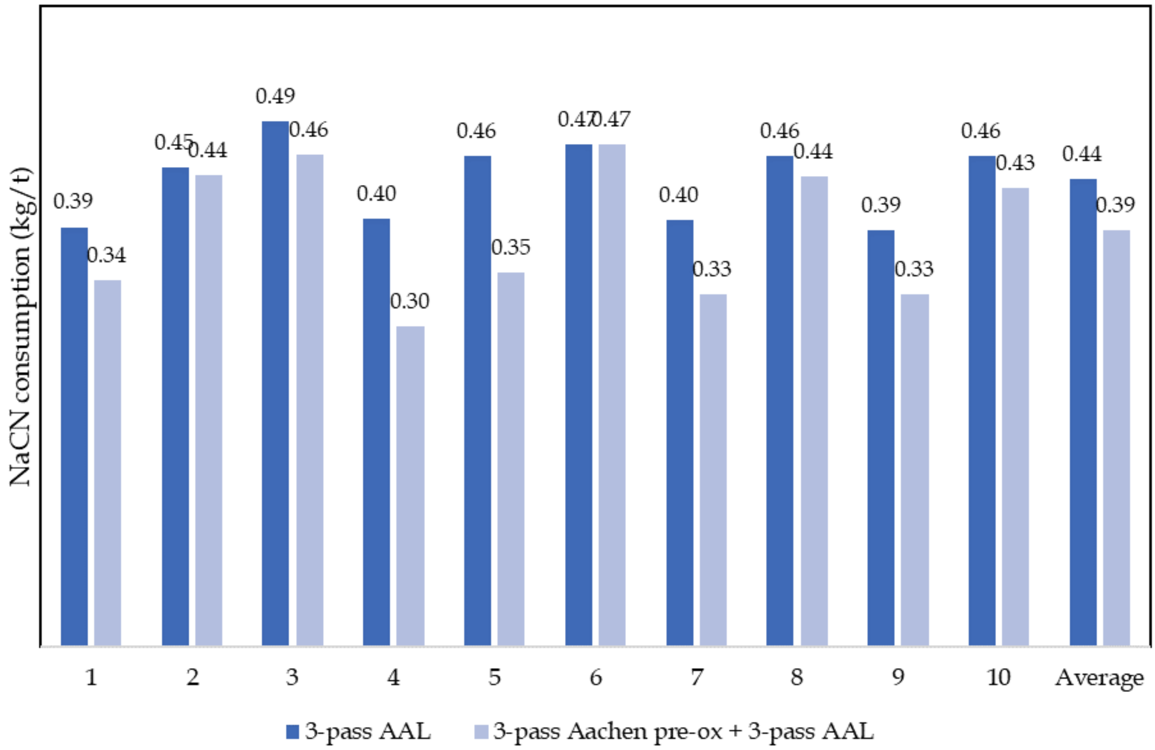

Figure 7. Site B - NaCN consumption (kg/t) results comparison

Plant evaluation:
The site already had an Aachen reactor installed and implemented a 3-pass AAL configuration. After testwork illustrated possible benefits with the addition of another unit for pre-oxidation, the change was implemented in June 2022. The original Aachen unit was used for pre-oxidation, whilst a new unit was installed on the first leach tank for AAL. The additional Aachen unit assisted in improving the gold dissolution by 6.13% from 34.94% to 41.08% whilst reducing NaCN consumption by 33% or 0.36 kg/t. A summary of the results is given in Table V.

Table V. Site B - plant evaluation before and after Aachen installation (averaged over the period)

Parameter	**July '21 - May '22** ***Before the additional Aachen installation***	**June '22 - March '23** ***After the additional Aachen installation***
Tonnes treated/month (t)	75122	76645
Recovery (%)	34.94	41.08
NaCN consumption (kg/t)	1.09	0.73

A comparison between the laboratory testwork and the plant scale implementation can be found in Table VI. The plant results greatly outperformed the results found during laboratory testwork for both gold dissolution and NaCN consumption.

Table VI. Site B - laboratory testwork vs. plant evaluation results comparison

	Gold dissolution (%) improvement after Aachen implementation	NaCN (kg/t) reduction after Aachen implementation
Laboratory Testwork	3.23	0.05
Plant Evaluation	6.13	0.36

CONCLUSION

The results obtained from both Site A and Site B demonstrate the efficacy of Aachen technology in enhancing gold dissolution rates and reducing NaCN consumption in gold tailings reprocessing.

At Site A, laboratory tests revealed a notable increase in gold dissolution. An average improvement of 2.35% across samples was observed, while plant-scale implementation showed a consistent increase in gold dissolution, averaging 2.82%. This trend was corroborated by CUSUM analysis, illustrating a direct correlation between Aachen runtime and gold dissolution rates, reaffirming the technology's effectiveness in real-world applications.

Similarly, at Site B, the addition of a 3-pass Aachen pre-oxidation step resulted in significant improvements in gold dissolution rates, with an average increase of 3.23% across samples. Plant-scale evaluation further validated these findings, with the installation of an additional Aachen unit leading to a substantial enhancement in gold dissolution by 6.13% and a reduction in NaCN consumption by 0.36 kg/t.

The improvement in gold dissolution observed after Aachen implementation for both Site A and B is likely linked to two factors:

1) The polishing of the tailings particle surfaces, reducing the film boundary layer and rendering the gold leach amenable.
2) Increased dissolved oxygen levels in the slurry ensuring that adequate levels of oxygen were available for both gold leaching and any other side reactions that might occur.

Furthermore, the reduction in NaCN consumption at Site B could be credited to the introduction of the Aachen pre-oxidation step, aiding the oxidation of certain cyanide consuming species.

Overall, the findings presented in this study underscore the value of Aachen technology as a reliable and efficient solution for enhancing gold recovery and reducing cyanide consumption in gold leaching operations. It further shows that results generated through laboratory scale testwork are duplicated and even improved during full-scale implementation.

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