

Operational Challenges at Olkaria IAU Power Plant Due to Shared Infrastructure and Hot ReInjection System Failures.

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ABSTRACT

Kenya electricity generating company operates five major geothermal power plants and fifteen wellhead units with a combined capacity of 799 MW. Within the Olkaria geothermal field, Olkaria I additional unit (IAU) power plant is located in the east production field. It shares steam gathering and hot reInjection infrastructure with Olkaria II power plant. This interconnection includes common steam lines, separator stations, and reInjection systems, allowing for flexible steam supply, minimal venting and improved plant availability. Despite these benefits, challenges arise from the shared infrastructure, particularly related to unbalanced mass flow during hot reInjection. The most significant issue occurs when a unit or several units are shut down for maintenance or emergencies, disrupting steam line continuity. Such interruptions reduce brine available for reInjection, causing wells to overheat and pressures to exceed inflow capacity. This imbalance often leads to separator flooding and brine carryover, which can trip units due to high scrubber levels and introduce silica scaling complications. These disruptions compromise reInjection efficiency and plant stability. The effects are amplified by the interconnected nature of the steam field, where a change in one plant's status directly impacts the other. As such, understanding and managing mass flow distribution is critical for sustainable field performance. This paper examines the implications of hot reInjection challenges on power plant operations with a focus on mass flow imbalance and infrastructure interconnectivity at Olkaria.

1. INTRODUCTION

Olkaria IAU geothermal power plant has in recent years faced persistent operational challenges linked to brine carryover and hot reInjection system failures. These issues directly affect plant performance, reliability, and maintenance demands. Brine carryover has emerged as a major contributor to scaling and deposition within critical steam path components, including Pressure Letdown Station (PLDS) control valves, main steam pipelines, scrubbers, and turbine blades. The accumulation of scale restricts steam flow and creates localized high-stress zones, increasing the risk of stress corrosion cracking (SCC) on turbine blades (MHI, Olkaria II Unit I, RCA Report, Sept.2023Rev.1). Hot reInjection system failures worsen the problem by disrupting proper brine disposal, thereby increasing the likelihood of brine entrainment in the steam. Over time, this reduces turbine efficiency, heightens corrosion risks, and results in costly unplanned outages. SCC from combined chemical attack and mechanical stress further threatens turbine integrity, potentially leading to premature blade replacement. To mitigate these risks, continuous condition monitoring is essential. Key monitoring tools include clogging ratio trends, detailed steam chemistry analyses, turbine chest pressure measurements, generator output tracking, scrubber level, and other operational indicators. These provide early warning of scaling, corrosion, and mechanical degradation, enabling timely corrective action.

2. BACKGROUND AND CONTEXT.

Currently in Olkaria geothermal field we have two major power plants sharing steam field infrastructure of both steam and brine, that is Olkaria II and Olkaria I Additional units IV and V. In between the two plants we have a pressure let down station (PLDS) that regulates and monitors pressures and flows. Olkaria II steam field operates at 5bars while that of Olkaria I additional units at 10bar pressures respectively. The main separator station shared between these two plants is SN3 with a number of six production and two reInjection wells. The production wells are OW724,730A,730B,732,732A and 732B while reInjection wells are OW703 and 718. In the event that either OW-703 or OW-718 fails to admit brine from SN3 pool, both Olkaria II and OIAU power plants will be affected. In Olkaria II field the brine system is common, meaning all brine is interconnected then reInjected to the wells with respect to their re-injectivity. These reInjection wells are R2, R3, OW-3, OW-34, and OW708. This shared phenomenon of steam and brine system affects the sister plant whenever there is a shedload, shutdown or tripping of either hence calls for some operations to balance it.

Olkaria IAU and II power plants interconnection of steam lines, pressure Letdown station and separator stations.

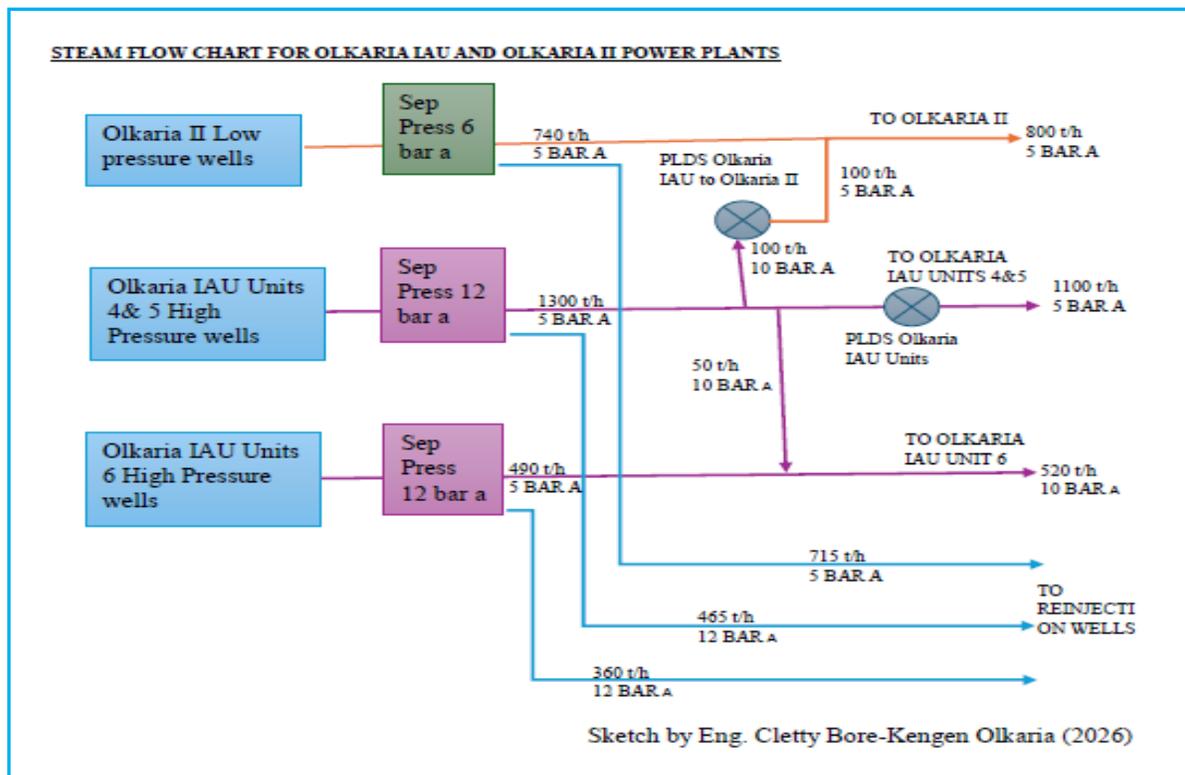


Figure 1: Olkaria II and Olkaria I Additional Unit steam field Interconnections

3. HOT REINJECTION SYSTEM DYNAMICS.

The reinjection system is in place to serve two main purposes i.e. environmental pollution prevention and recharge of the reservoir to ensure sustainability of the resource. These hot reinjection wells are normally drilled to a depth of between 2000m and 3000m. At times depleted production wells are also utilized for reinjection. Olkaria II power plant with installed capacity of 105MW, has more than twelve separator stations, twenty production, eight hot reinjection and four cold reinjection wells. The total mass flow for steam and brine is estimated at 1240t/hr and 600t/hr respectively. Any slight disturbance to this system might cause serious trips and damage to steam lines and power plants as a whole hence close monitoring and controlling is highly recommended. Olkaria IAU power plant has an installed capacity of 220MW with nine separator stations and thirty-six production, eight hot and three cold reinjection wells. The total mass flow of steam is 2100t/hr and brine mass flow of 800t/hr. Failure of hot reinjection wells to admit brine due to scaling or imbalanced mass flow will cause separator flooding and consequently brine carryover into the main steam line.

4. BRINE CARRYOVER CHALLENGES

4.1. Mechanisms of Brine Carryover

Brine carryover is a common feature in these steam fields due to varying pressures of both production and reinjection wells. At times reinjection wells get clogged or build up pressures due to less brine reinjection as a result of load shed or shutdown of production wells (Catherine N. Leech, Modelling the Geochemical Effects of the Geothermal Fluid Injection in the Olkaria Geothermal Field, UNU-GTP, Report 2016, Number 24). As a result of this the brine gets entrained into the steam phase towards the power plant causing scaling in PLDS valves, steam pipelines, scrubbers, turbine blade deposition and efficiency loss. At Olkaria IAU, brine carryover is primarily driven by failures in the hot reinjection system. The most affected well, OW-13, is designed to receive brine from separator stations in the Olkaria East production field but is not operating optimally. Consequently, brine is often diverted to the pond, with the dumping valve partially opened to minimize steam losses. Separator Station SE3 is the most affected, frequently experiencing brine entrainment into the main steam line (Kengen Plant Chemistry CDPS Report, July 2025). This results in downstream scaling and performance issues in PLDS valves and venturi systems. Although SE1 and SE2, also supply steam to OIAU Units 4 and 5, they are less severely impacted. The cyclic nature of wells feeding SE3 means brine cannot always be fully eliminated to the pond, causing carryover into the steam line. This underscores the importance of reliable reinjection capacity to ensure good steam quality and protection of plant components.

4.2. Effects of Brine Carryover on Plant Equipment

Brine carryover introduces multiple risks to plant equipment. Scaling is a primary effect, observed in PLDS valves, steam pipelines, and scrubbers, where salts and silica deposits restrict flow and increase pressure losses. In turbines, deposition on blades reduces aerodynamic efficiency and output. Additionally, corrosive species in brine accelerate material degradation and increase SCC risks, particularly in turbine blades and other high-stress components (MHI RCA Report, Olkaria II Unit I blade damage, Sept. 2023). Over time, these issues compromise equipment lifespan, elevate maintenance needs, and heighten the likelihood of forced outages, making brine carryover a critical operational challenge.



OIAU Scrubber unit 4 inner surface scaling

Olkaria IAU unit 4 Turbine 1st Stage Top Diaphragm blade scale, Dec.2024

Figure 2: Olkaria IAU Unit 4 Demister internal surface and Turbine 1st stage top Diaphragm blade scales.

4.3. Condition Monitoring and Diagnostic Tools.

Table 1. Showing pictures of scales collected from OIAU 1st and 2nd stages of stationary Turbine blade

Image	Description	Remarks
	Olkaria IAU unit 4 2 nd stage Top diaphragm	Light to dark grey, loosely cemented fragments that form a continuous colloidal material, signs of vesicles, signifying non-coherent aggregation, possible layering could indicate event deposition. Nonmagnetic, slight effervescence on addition of 0.1N HCl
	SE3	Massive solid deposit, light to dark grey in color, strong cementation, glass like layers longitudinally forming layers within the coherent matrix.

a) Steam Chemistry and Scaling Indices

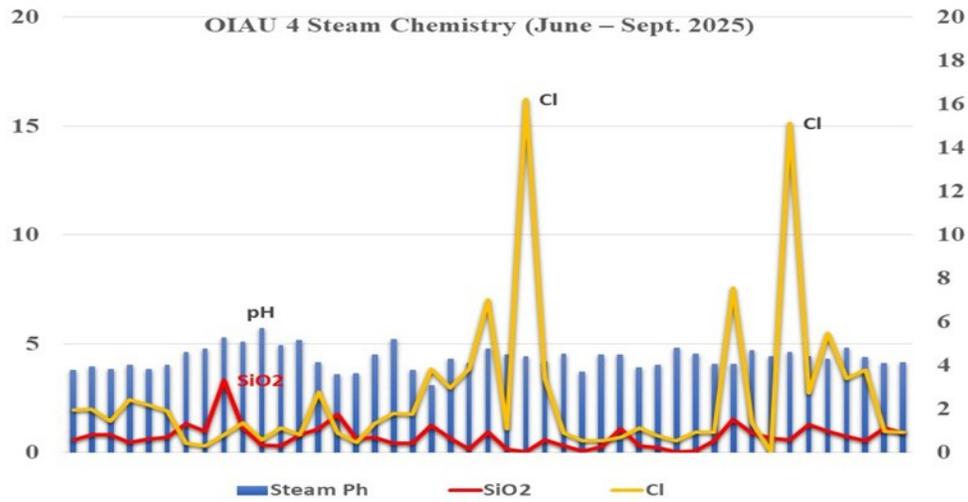


Fig. 3. A graphical representation of OIAU 4 steam Chemistry after the scrubber

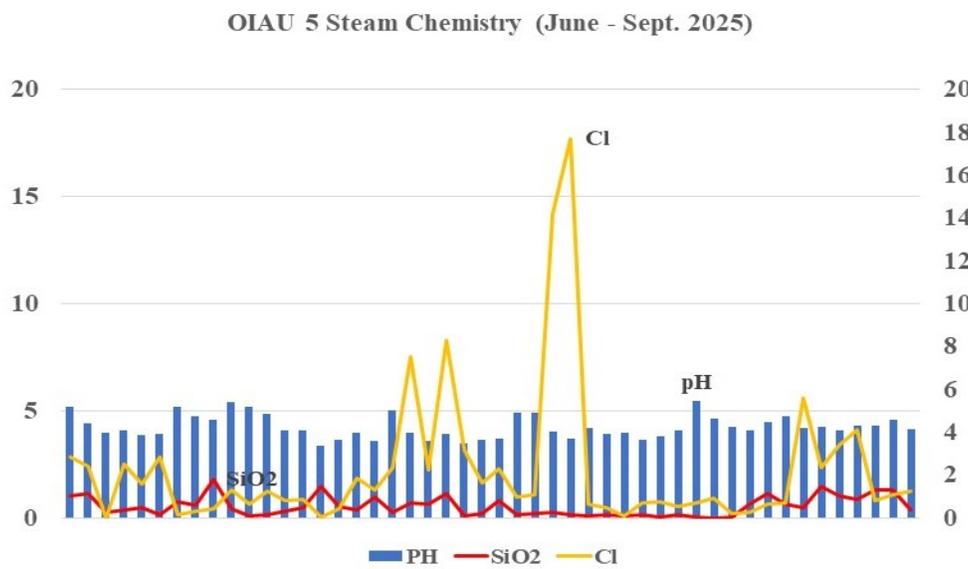


Fig. 4. A graphical representation of OIAU Unit 5 steam Chemistry after the scrubber

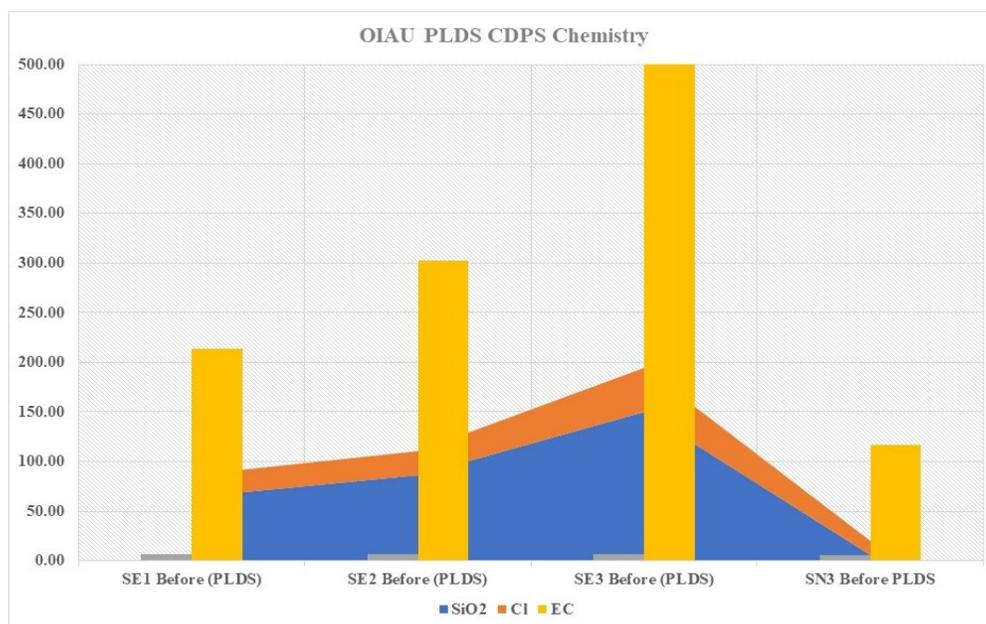


Fig. 5. A graphical representation of OIAU Main Steam line Condensate Drain pots at the PLDS and Control valves.

Figure 3 and 4 represents steam chemistry data for OIAU unit 4 and 5 respectively. The data shows elevated chloride concentrations against the 1.0 ppm threshold recommended for a steam turbine. The silica concentration fluctuates and at times surpasses the 1.0 ppm threshold as well. Silica and Chloride ions are non-volatile species and partitions majorly in the liquid phase. Therefore, for these species to be found in the steam, it means they are mechanically transported as part of the brine carryover.

Figure 5 represents main steam lines SE1, SE2, SE3 and SN3 condensate drain pots steam chemistry at the PLDS and control valves. At this point, we get a clear picture of separation efficiency or inefficiency based on the CDPS Chemistry data. Since this point is before the steam scrubbers, much of this brine will be eliminated at the scrubbers. However, the high solute content at this point is what affects the plants performance and availability. Since this is at a pressure letdown station, steam field pressure is reduced incidentally from 10 bars to 5 bars and this brings about thermodynamic changes and operational hazards. Flashing happens and accelerated scaling occur right on the control valves and the main steam line orifices.



A picture of PLDS Control valve after only 45 days in operation after cleaning



Scaling inside the SE3 main steam line pipe after the PLDS Control Valve-Unit 4

Figure 6. Olkaria IAU Pressure Let down Control valve and SE3 Main steam pipe at PLDS scales.

4.4. XRF-Scales Elemental Analysis

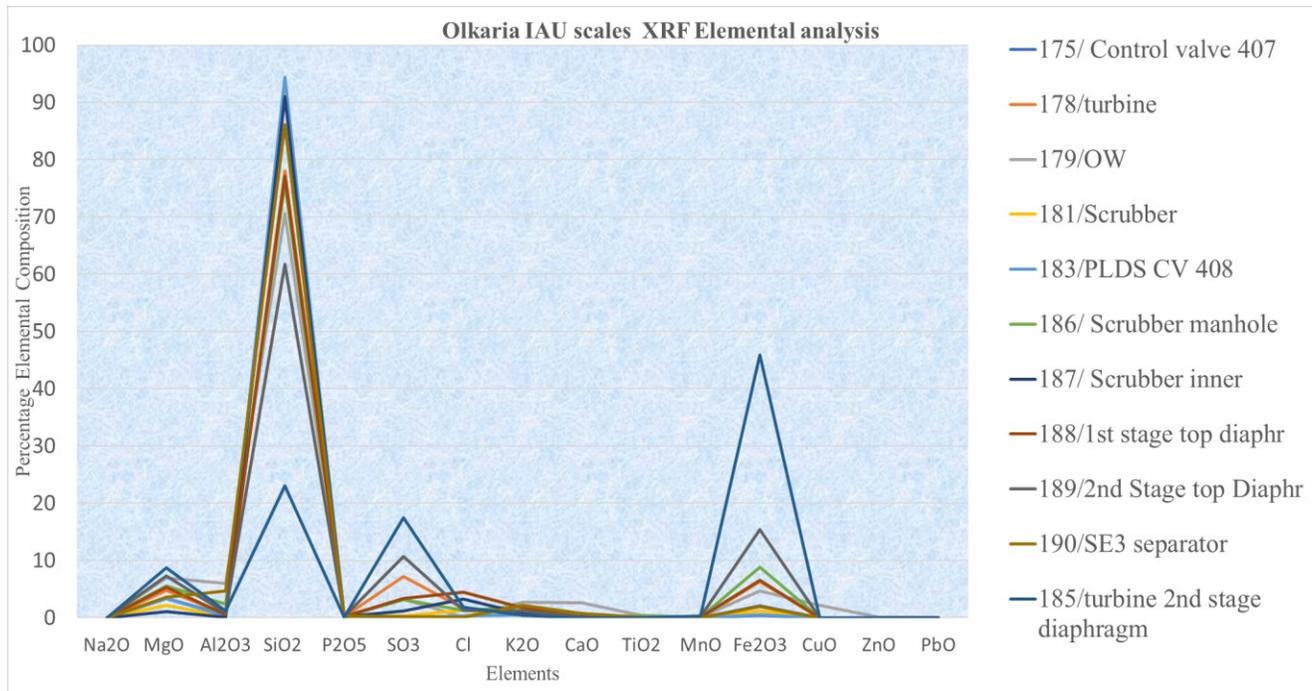


Fig. 7. A graphical representation of OIAU Scales XRF Elemental analysis.

In Fig.7 above, Silica formed the major component in the bulk of the collected samples, with concentrations typically falling between 60% and 95% by weight. The notable exception was the sample from the turbine's 2nd stage diaphragm, which contained significantly lower silica at 23 wt.%. Given the high content of SiO₂, it is probable that these samples contain some polymorphs of silica such as amorphous silica or some other polymorphs. The 2nd stage turbine diaphragm sample had 45 wt.% Fe₂O₃ that was magnetically responsive. This was indicative of primarily an iron oxide from corrosion activities. The iron concentrations in the remaining samples remained below 15 wt.%. The presence of significant SO₃ supports the interpretation that these other deposits primarily comprise various forms of iron and sulfides. The next highest concentration was MgO that ranged between 2-9 wt. %, as well as Al₂O₃, and CaO. This is significant since it could imply the presence of Ca-Mg-Al silicates like smectites within this scaling matrix, (Edwin Wafula et al. Scales Analysis Report. 2025).

4.5. Clogging Ratio Monitoring

The clogging ratio quantifies the efficiency lost due to scaling and other fouling materials on the turbine blades. It reflects how much pressure is needed to maintain the same power output as clogging worsens. The initial ratios of the turbine steam pressure to generator output is measured shortly after commissioning or cleaning. This will represent the optimal performance baseline. A higher clogging ratio indicates increasing resistance to steam flow, a clogging ratio of $\leq 15\%$ or 0.15 is often set as the threshold beyond which cleaning or descaling should be carried out to avoid further damage and loss of efficiency.

Formula:

$$\text{Clogging Ratio} = \frac{(P/G) - (P/G)_o}{(P/G)_o}$$

Where: P , G , $(P/G)_o$, steam pressure, generator out put and baseline ratio respectively.

4.5.1 Olkaria IAU Turbine Blades Clogging ratio trends

Table 2. Olkaria IAU Unit 4 Turbine condition monitoring data.

Olkaria IAU Unit 4 Turbine Blades Clogging ratio trends					
Date	Turbine Inlet pressure(Bars)	Output(MW)	Chest pressure(Bars)	Clogging Ratio	Limit
26/5/2025	4.53	68.49	3.85	0.10	0.15
10/6/2025	4.73	63.96	3.95	0.23	0.15
24/6/2025	4.65	68.34	3.94	0.13	0.15
8/7/2025	4.54	68.01	3.83	0.11	0.15
25/7/2025	4.52	69.85	3.94	0.08	0.15
7/8/2025	4.39	68.52	3.83	0.07	0.15
Baseline pressure =4.4bars @output 73MW					

Table 3. Olkaria IAU Unit 5 Turbine condition monitoring data.

OIAU Unit 5 Turbine Blade Clogging Ratio					
Date	Turbine Inlet pressure(Bars)	Output(MW)	Chest pressure(Bars)	Ratio	Limit
26/5/2025	4.78	52.46	4.16	0.52	0.15
10/6/2025	4.79	70.18	4.13	0.14	0.15
24/6/2025	4.73	67.35	4.06	0.17	0.15
8/7/2025	4.63	65.78	4.06	0.17	0.15
25/7/2025	4.6	65.7	4.06	0.17	0.15
7/8/2025	4.47	65.73	4.04	0.13	0.15

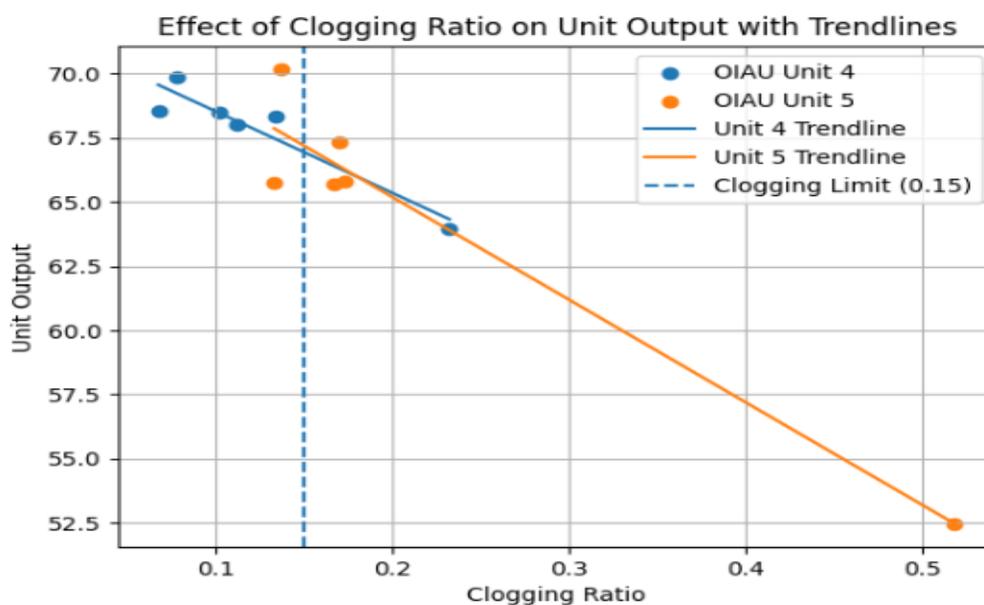


Figure 8. A graphical representation of Turbine clogging ratio effects on the turbine Output

As per tables 3, OIAU Unit 4 has a lower turbine blade clogging ratio and is within the maximum allowable ratio of 0.15 or 15%. This is due to the clean conditions of the turbine after an overhaul carried out on the unit in April 2025. Table 4 presents high turbine blade clogging ratio above the recommended limit for OIAU Unit 5. Fig. 8, explains the decline in output on unit with an increased steam consumption of up to 600t/hr. This is a shift from the design steam flow of 532t/hr to generate 75MW (Sinclair Knight Merz, SKM 2013).

5.0 MITIGATION STRATEGIES AND BEST PRACTICES.

The existing reinjection well infrastructure needs to be optimized by ensuring enough brine is available to sustain the reinjection demands and to balance the well capacity. The separator station upgrades will be necessary to be able to handle the changing conditions of the separation and brine disposal processes. There should also be an enhanced brine management protocols during shutdown.

6.0 CONCLUSIONS

The cost associated with plant downtime, maintenance activities, and the replacement of critical spares and equipment is substantial. However, these costs can be significantly reduced through continuous monitoring and effective control of both the steam and brine phase systems. Given the magnitude of these expenses, the case study demonstrates strong potential for cost savings, as mitigation mechanisms implemented without close supervision tend to be ineffective. This is evidenced by the frequent plant trips occurring at least twice per month primarily due to carryover issues. While the plant plays a vital role in supporting industrialization through energy delivery, it is equally important to critically evaluate and manage the costs incurred in maintaining reliable operations.

7.0 RECOMMENDATIONS

In the short term, mass flow balancing should be achieved by diverting single-phase steam directly to the generating plant while reducing flow to the least affected reinjection wells. At the separator stations and associated scrubbers/demisters, existing level sensors and emergency dump valves should be utilized to detect elevated brine levels and discharge brine before steam enters the turbine inlet. In the medium to long term, reverse-flow protection systems should be installed on hot reinjection wells. These systems, based on differential pressure monitoring, can detect backflow conditions and actuate normally closed valves to prevent brine entrainment into the steam phase. The diverted brine should be routed to retention ponds for temporary storage before being pumped back into the reinjection wells. Additionally, field research and data analysis should be optimized to improve the overall reinjection strategy across the Olkaria geothermal field, thereby enhancing system reliability and operational efficiency.

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