Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

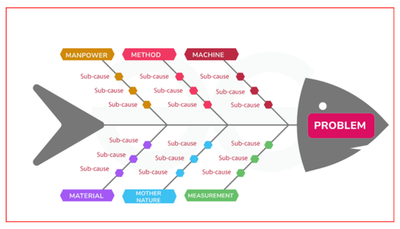
INTEGRATING ROOT CAUSE ANALYSIS (RCA) FOR SUSTAINABLE GEOTHERMAL RESERVOIR MONITORING AND ENERGY PRODUCTION OPTIMIZATION

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INTRODUCTION

- The root cause analysis is a great tool when incorporated in the geochemical monitoring can enhance problem solving and decision making
- The geochemical reservoir monitoring involves chemical analysis to assess how a geothermal reservoir responds to production loads with time
- The chemical monitoring in Olkaria for the production field has identified several issues that are affecting the reliability and efficiency of the power generation
- The major issues identified include carbonate , sulphur and silica scaling, well blockages, well pressure drawdowns and declines which have not yet been fully understood or solved.
- The root cause analysis as a tool in geochemical reservoir monitoring can be a great tool in understanding and mitigating some of these challenges in time.
- The aspect of root cause analysis is finding the main cause of the problem in the geothermal reservoir monitoring—though, has not been embraced as a routine aspect in monitoring and sustainability.

APPLICABLE RCA METHODS

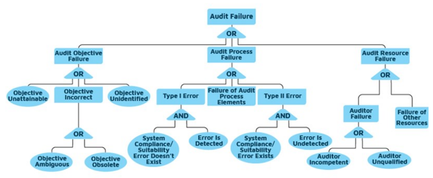


Fishbone Diagram: systematic, visual brainstorming method used to uncover the fundamental causes of a problem rather than focusing on surface-level

COMPONENT	RANKING
Dosing Pump	1
Agitator	2
Pipe & auxiliaries	3
Gate Valve	4
Check Valve	5
Storage Tank	6
Strainers	7
Transfer Pump	8
Motor	9
Dosing Tank	10

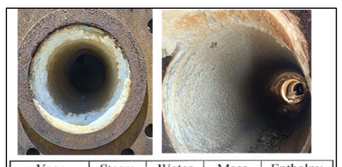
Plunger	Flow the liquid	Not able to flow the liquid	Vibration Reduction in suction Low efficiency	Abrasive Solid particles causing ware
Diaphragm	Flow the liquid	Rapture	Mix oil and liquid	Excessive pressure, overuse
Check Valve	Enhance flow in one direction	Blockage Reverse flow	No flow Wrong flow	Siltation, excessive pressure, Internal wear

FMEA: Is a systematic, proactive risk-analysis method used to identify how a process, product, or system might fail, evaluate the effects of those failures, and prioritize actions to reduce or eliminate risk before failures occur .



Fault Tree Analysis (FTA) is a top-down, deductive risk analysis technique used to identify the combinations of events or failures that can lead to a predefined undesirable outcome, known as the top event.

CASE STUDIES : SCALING AND CORROSION



Year	Steam (t/hr)	Water (t/hr)	Mass (t/hr)	Enthalpy kJ/Kg
2001 July	43.15	0.3	443.45	2742
2001 Sept	37.4	0.8	38.2	2712
2002 mar	7.2	0.2	7.4	2743
2002 July	7.35	0	7.35	2756

OW-34	2001 J	2001 D	2002 J
WHP	5.6	6	5.8
SSP	5.6	3.52	5.6
ENTH	2742	2723	2756
pH@20	7.83	7.99	8.05
X @100 °C	1.030	1.021	1.035
X @180 °C	0.984	0.974	0.990
X @250 °C	0.972	0.958	0.979

Scaling in the brine line, and chemical composition of OW-34 in Olkaria, (Source: Kizito 2006)



Scales from OW-914 well in Olkaria, (Source, Author)



Corrosion in condensate disposal wells in Olkaria field, (Source KenGen, 2017)

- More than 19 wells are steam only with high silica concentrations
- 6 reinjection wells lost to corrosion
- Geothermal power plant scaling, corrosion and elemental sulphur deposition

- Olkaria well OW-34 exhibited an enthalpy of approximately 2672 kJ/kg, which is close to that of dry saturated steam, and experienced unusual chemical characteristics (Kizito, 2006)
- The separated water contained a chloride concentration of about 4000 ppm at atmospheric pressure.
- This elevated solute concentration was attributed to evaporative concentration effects associated with the well's high discharge enthalpy
- The primary cause of this decline was massive silica deposition, which resulted from fluid chemistry that was notably distinct from other wells in the area.
- Given the complexity of geothermal systems and the high costs associated with well development, conducting a Root Cause Analysis (RCA) was essential for this case.
- Currently many wells are experiencing the same problem in the same field, proper RCA and documentation would have saved the situation had it been done

KEY BENEFITS OF RCA IN GEOTHERMAL

1. **Preventing well failures and reducing losses:** Comprehensive reservoir management requires a combination of predictive assessment, optimized engineering design, continuous monitoring, and structured problem analysis and solving.
   - By systematically analysing operational data such as temperature fluctuations, pressure changes, and chemical composition RCA tools (e.g., Fishbone analysis, FMEA, or Fault Tree Analysis) can identify the underlying mechanisms driving deposition rather than only addressing surface symptoms

2. Effective Geothermal Field Management :requires a systematic understanding of reservoir behavior, fluid chemistry, and operational dynamics. Integrating Root Cause Analysis (RCA) into field operations enhances decision-making by moving beyond symptom-based corrections toward identification of the fundamental drivers of performance issues such as scaling, pressure decline, or thermal breakthrough

3. Optimizing Investment Decisions : Strategic investment in geothermal development requires a clear understanding of technical risks, operational challenges, and long-term reservoir behaviour. Integrating Root Cause Analysis (RCA) into planning and operational review processes strengthens investment decisions by ensuring that financial commitments are guided by verified technical insights rather than assumptions or short-term performance indicators.

CONCLUSION

- RCA as a routine practice in both reservoir management and power plant production is a strategic operational necessity.
- Geothermal systems are inherently complex, involving coupled thermodynamic, geochemical, and mechanical processes. Scaling, corrosion, pressure decline, thermal breakthrough, and equipment degradation are intertwined they are typically the result of interconnected system behaviours.
- Without structured analysis and corrective actions leads to recurring failures, avoidable downtime, and escalating operational costs.
- From a technical perspective, RCA provides a systematic framework to identify causal mechanisms across reservoir flow dynamics, fluid chemistry evolution, phase changes, and surface facility operations
- Economically, the value proposition is clear. Studies in reliability engineering consistently demonstrate that structured root cause methodologies reduce repeat failures, lower maintenance costs, and improve asset availability
- Adopting RCA as a routine operational process will therefore:
  a. Increase production reliability and plant availability
  b. Reduce non-productive time and maintenance expenditure
  c. Improve reservoir sustainability and thermal recovery efficiency
  d. Strengthen risk management and investment confidence
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Acknowledgements <AcknowStyle>
Special appreciation to KenGen PLC, for granting me the opportunity for the studies
Kyushu University for the academic support
JICA and GRO-GTP for the financial support

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