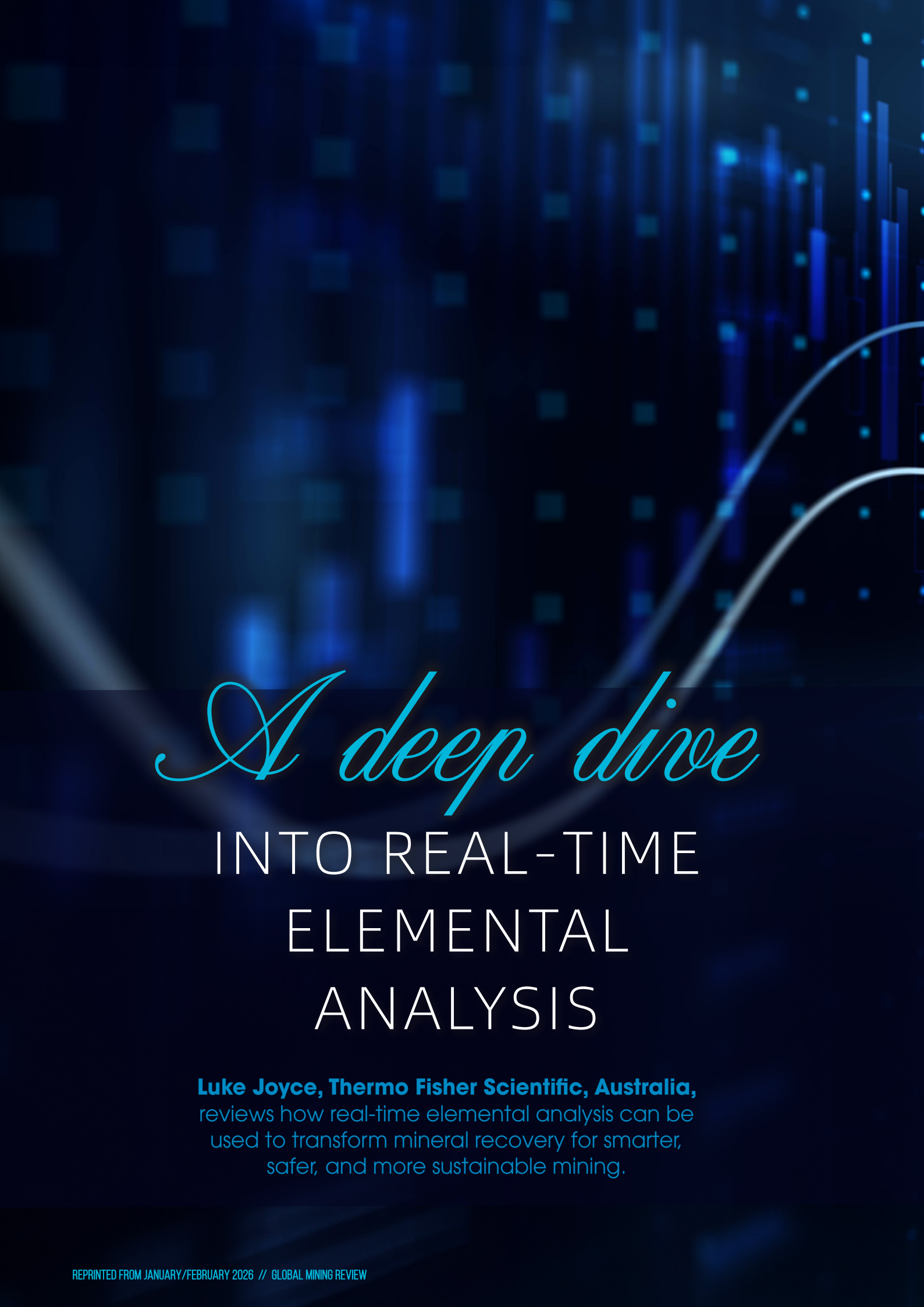

A deep dive INTO REAL-TIME ELEMENTAL ANALYSIS

Luke Joyce, Thermo Fisher Scientific, Australia, reviews how real-time elemental analysis can be used to transform mineral recovery for smarter, safer, and more sustainable mining.

Mining operations are under continual pressure to improve efficiency, maximise recovery, and meet strict environmental and safety standards. As global demand for base and critical minerals grows, mining operators are turning to modern technology to support this operational infrastructure and ensure longevity. In this context, real-time, in-stream elemental analysis is reinforcing its position as a transformative tool. It delivers real-time, accurate assay data from slurry streams, enabling operators to respond rapidly to feed grade changes and process upsets and fluctuations in ore characteristics – enhancing recovery, minimising losses, and advancing sustainability goals.

The evolution of slurry elemental analysis

Historically, mineral processing plants have relied on manual methods for process monitoring and metallurgical balancing, making traditional slurry sampling slow, labour-intensive, and prone to high variability.

Samples collected with hand-samplers or inferior samplers are particularly prone to bias and error, and the time, effort, and manual handling required quickly multiplies in larger plants with numerous streams. Additionally, delays of hours inherent in metallurgical and assay lab-based analysis make it difficult to react quickly to changes in feed grade or process disturbances, limiting the ability to maximise recovery and maintain product quality.

Next-generation online sampling and elemental analysis systems address these challenges by delivering rapid, accurate measurements directly in the process stream. Thermo Fisher Scientific's AnStat-430 and MSA-430 analysers, for example, integrate a multi-element probe, the MEP-400,

to provide minute-by-minute assay readings across single or multiple slurry streams. These systems employ X-ray fluorescence (XRF) technology, a widely adopted technique for elemental analysis, combined with modern innovations that significantly enhance analytical performance. Air-cooled, low-power X-ray tubes replace traditional radioisotope sources, which simplifies regulatory compliance and reduces radiation safety concerns, allowing maintenance activities to be performed safely with lock-out capabilities. Silicon drift detectors and digital signal processors improve count-rate throughput and measurement accuracy, while the probe's design eliminates the need for cryogenic or water cooling, making it more practical for continuous industrial use.

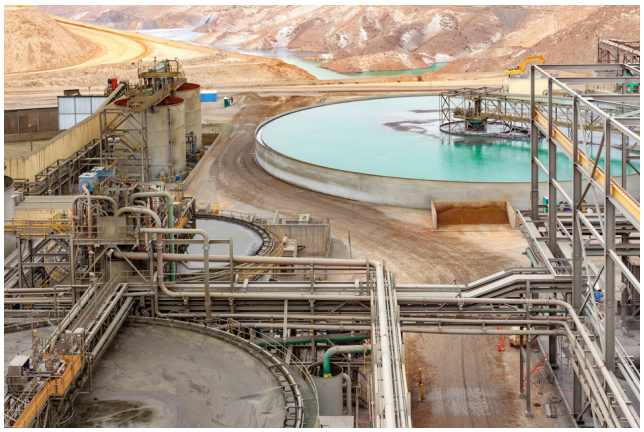

Figure 1. Water treatment facility at a copper mine and processing plant, where online slurry analysers help monitor solids concentration and optimise recovery.

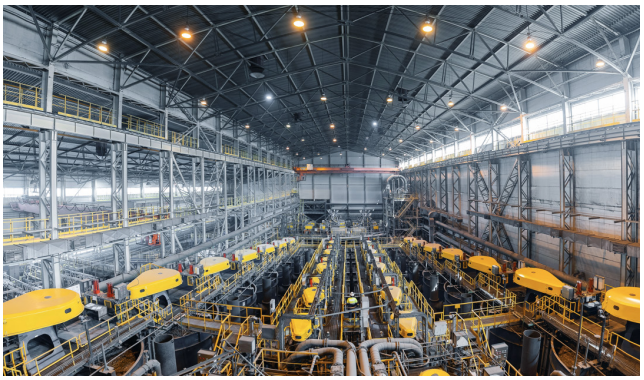

Figure 2. Automated flotation lines in a large-scale processing plant, where online slurry analysers help optimise mineral recovery and process control.

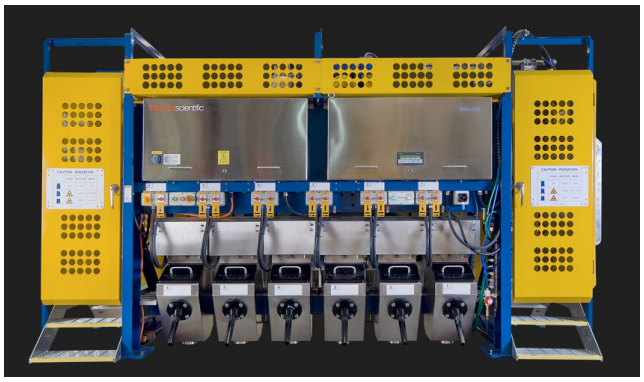

Figure 3. Thermo Scientific™ MSA-430 Multi-Stream Slurry XRF Analyser provides reliable real-time elemental analysis for up to 12 slurry streams.

The result is a tool that delivers real-time insight into mineral streams, enabling operators to optimise recovery, maintain grade, and reduce material losses in ways previously unattainable with traditional sampling and standard laboratory assays. While laboratory verification remains essential for compliance and reporting, online analysers serve as process control tools, complementing lab work and enhancing operational decision-making.

Smarter recovery and process control

Real-time, in-stream elemental analysis plays a central role in modern process optimisation by providing continuous assay data from key slurry streams, including feed, tails, and intermediate flotation stages. Unlike manual sampling, which may require hours or even an entire shift to deliver results, online systems generate near-instant feedback that allows operators to respond to fluctuations in ore grade, mineralogy, or circuit performance. This responsiveness helps maintain stable operating conditions, reduce material losses to tailings, and improve overall metal recovery. It also supports more precise reagent dosing and more consistent concentrate and tailings, particularly in base metal flotation circuits where feed variability can strongly influence recovery.

A critical factor in the effectiveness of real-time analysis is the configuration of the sampling and measurement system. Single-stream stations, such as those used in AnStat configurations, are designed to handle the full flow of one slurry stream, which can be thousands of m^3/h in large operations. These systems deliver minute-by-minute assay data and through their final stage dedicated cross-cut samplers produce highly representative composite samples for metallurgical balancing and calibration for laboratory verification, ensuring strong continuity between online and offline measurements.

Multi-stream systems extend these capabilities by providing online analysis for multiple slurry streams simultaneously. Each stream is delivered to its own dedicated analysis tank, incorporating de-aeration zones, measurement zones, and cross-cut samplers to maintain sample integrity. Because the sampled streams operate continuously and remain separated from collection point to discharge, multi-stream analyser systems can capture a wide range of processing stages without the need for additional pumps or transfer systems – reducing head loss and simplifying plant integration. Smaller plants may rely on a single multi-stream analyser to monitor all major slurry flows, while larger concentrators often combine single-stream and multi-stream systems. In cleaner, rougher, or scavenger circuits, for example,

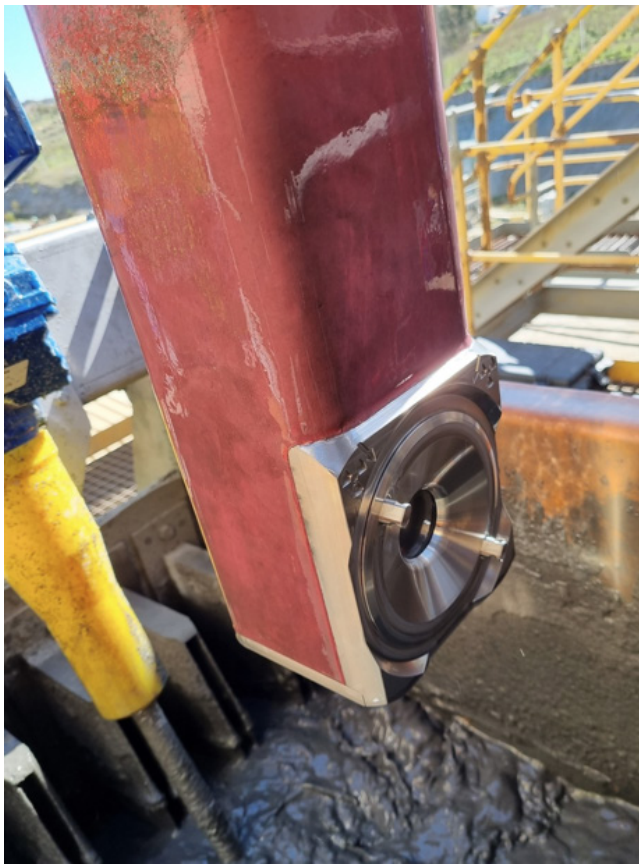

Figure 4. Slurry analysis using the Thermo Scientific MEP-400 Multi-Element Probe.

Figure 5. Thermo Scientific MEP-400 Multi-Element Probe inside a Thermo Scientific MSA-430 Multi-Stream Slurry XRF Analyser.

multi-stream analysis can provide real-time data across several intermediate points, allowing more precise management of circulating loads and reagent addition.

Single and multi-stream systems offer a scalable analytical architecture that enhances process visibility and reduces the dependency on manual sampling. When properly integrated with well-designed sampling systems, in-stream elemental analysis becomes a reliable process-control tool, providing the continuous feedback necessary to maintain efficient mining operations.

Safer operations

Safety has always been a priority in mineral processing, particularly when handling radioactive sources used in traditional slurry analysers. By replacing radioisotopes with low-power, air-cooled X-ray tubes, modern analysers reduce the logistical and licensing burdens of transport, storage, possession, and disposal. Operators can power down the system and perform maintenance safely, without exposing personnel to radiation risks. Facilities can maintain high analytical performance without compromising worker safety.

The latest in-stream probes also contribute to safer operations. Because they employ a fail-safe, retractable shutter, automatic interlocks, and a visual beacon, these cutting-edge probes help to minimise radiation exposure. The probe can be switched off when not in use, further enhancing safety during maintenance or inspection. These features help operators focus on process control rather than administrative compliance, while still delivering high-accuracy, real-time data.

Sustainability and efficiency

Beyond operational and safety benefits, real-time elemental analysis supports more sustainable operations. Mining is an energy-intensive business – comminution alone (the crushing and grinding step) is often one of the largest consumers of a mine's energy, accounting for 25% or more of total site energy, according to a major industry study. In some cases, especially when focusing on electrical consumption, that share can rise to over 50%.

Real-time analysis can help reduce the inefficiencies that lead to material losses in tailings. Studies indicate that a meaningful percentage of metal remains in tailings due to suboptimal recovery, with average recovery ratios around 81%, implying substantial value left behind. By providing faster, more accurate feedback on slurry composition, online systems enable better process control, which not only minimises these losses but also enhances sustainability by reducing waste, conserving extracted resources, and lowering the environmental footprint of mining operations.

Reducing water usage is also top of mind for mines. While global estimates vary, mining water use is a major concern, especially in regions under water stress. Through optimised reagent dosing, stability in process control, and reduced recirculating loads, real-time elemental analysis can support more efficient use of

water in mineral processing by enabling operators to optimise slurry handling and reagent use.

Automating sampling and reducing reliance on labour-intensive lab assays also contributes to holistically more sustainable operations: less manual sampling means less labour, fewer emissions from sample transport, and reduced need for redundant lab infrastructure. Together, these operational gains support more resource-efficient and responsible mining operations.

Real world applications for elemental analysis

Real-time elemental analysis is applicable across a broad spectrum of mining operations. Base metals such as copper, lead, and zinc benefit from accurate, rapid measurements that enable operators to maintain recovery targets and optimise flotation performance. Critical minerals and rare earth elements, increasingly important in high-tech and energy applications, also gain from the rapid feedback provided by online analysers. Advanced probes can measure elements from calcium to uranium, demonstrating flexibility across diverse mineral types and processing streams. Whether in new greenfield installations or modernising of existing plants, in-stream analysis provides the data needed to support efficient, responsive operations.

The ability to retrofit existing systems further enhances their value. Plants can upgrade legacy analysers with new probes, improving accuracy, detection limits, reducing maintenance, simplifying compliance, increasing safety, and extending equipment life without the need for complete system replacement. This flexibility ensures that facilities of all sizes can adopt next-generation analysis techniques while preserving prior investments.

The future of smarter, safer mining

As global demand for metals and critical minerals continues to rise, in-stream elemental analysis is proving indispensable for mining operations seeking smarter, safer, and more sustainable production. By delivering minute-by-minute data across critical slurry streams, these systems empower operators to maximise recovery, minimise losses, and optimise resource use in ways that were previously unattainable.

In addition to operational gains, real-time analysis enhances safety by reducing reliance on manual sampling and radioactive sources, as well as supporting more sustainable practices by conserving energy, water, and other resources. Across diverse minerals and processing configurations, next-generation in-stream analysis is a transformative tool – enabling mining operations to meet growing demand while improving efficiency, safety, and environmental responsibility. GMR