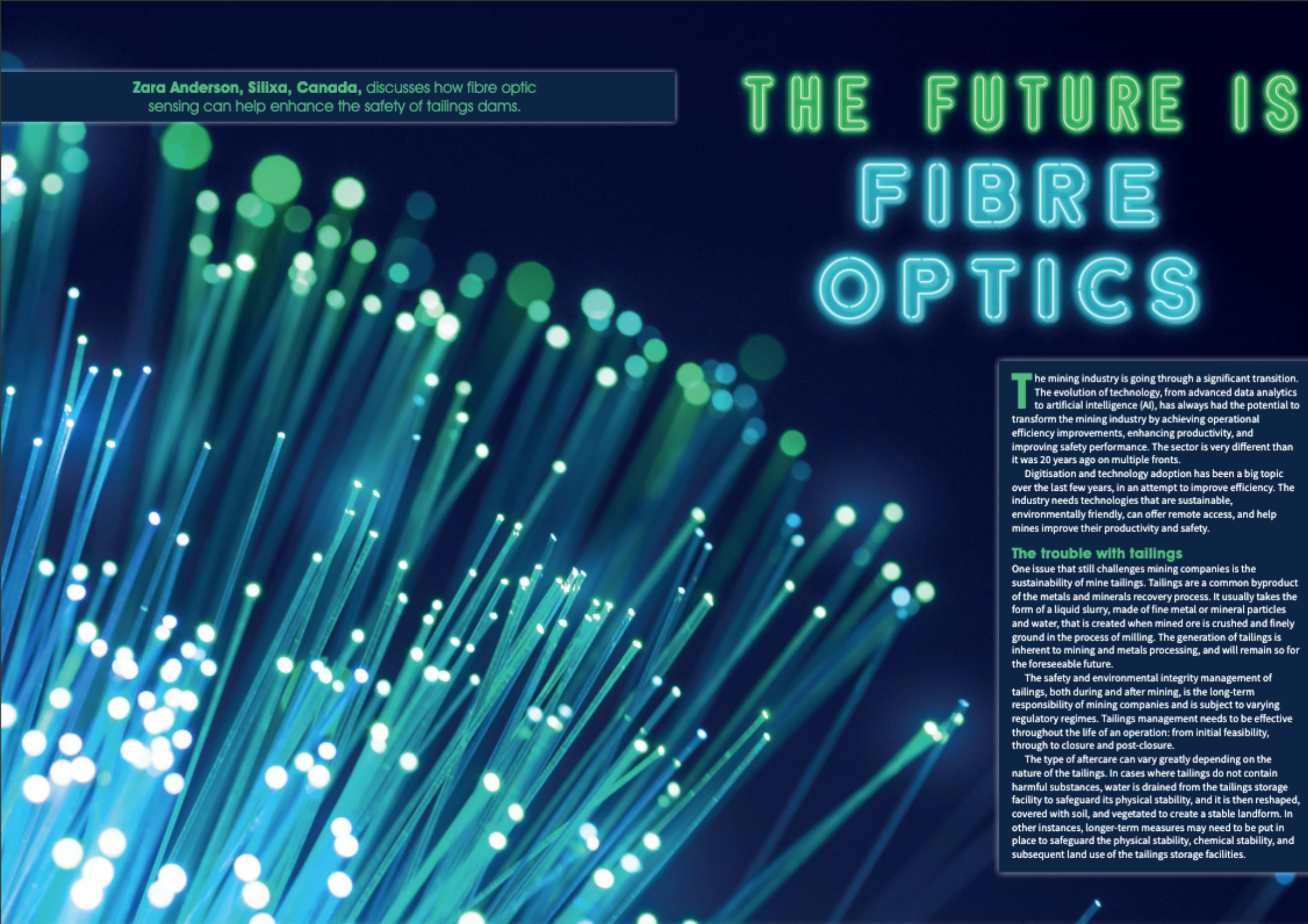
Zara Anderson, Silixa, Canada, discusses how fibre optic sensing can help enhance the safety of tailings dams.

THE FUTURE IS FIBRE OPTICS



The mining industry is going through a significant transition. The evolution of technology, from advanced data analytics to artificial intelligence (AI), has always had the potential to transform the mining industry by achieving operational efficiency improvements, enhancing productivity, and improving safety performance. The sector is very different than it was 20 years ago on multiple fronts.

Digitisation and technology adoption has been a big topic over the last few years, in an attempt to improve efficiency. The industry needs technologies that are sustainable, environmentally friendly, can offer remote access, and help mines improve their productivity and safety.

The trouble with tailings

One issue that still challenges mining companies is the sustainability of mine tailings. Tailings are a common byproduct of the metals and minerals recovery process. It usually takes the form of a liquid slurry, made of fine metal or mineral particles and water, that is created when mined ore is crushed and finely ground in the process of milling. The generation of tailings is inherent to mining and metals processing, and will remain so for the foreseeable future.

The safety and environmental integrity management of tailings, both during and after mining, is the long-term responsibility of mining companies and is subject to varying regulatory regimes. Tailings management needs to be effective throughout the life of an operation: from initial feasibility, through to closure and post-closure.

The type of aftercare can vary greatly depending on the nature of the tailings. In cases where tailings do not contain harmful substances, water is drained from the tailings storage facility to safeguard its physical stability, and it is then reshaped, covered with soil, and vegetated to create a stable landform. In other instances, longer-term measures may need to be put in place to safeguard the physical stability, chemical stability, and subsequent land use of the tailings storage facilities.

Tailings dam failures serve as stark reminders that there is still more to be done if the industry is to reach its ambition of zero harm.

Performance monitoring

According to the International Council on Mining and Minerals (ICMM), performance monitoring of tailings facilities is a key element of responsible tailings management. Monitoring is also a critical input for informing the timely implementation of emergency response plans (ERPs) if indicators are triggered that show upset conditions may occur.

Structural failures of tailings facilities have placed a focus on the adequacy of current monitoring systems and the effectiveness of trigger action response plans (TARPs) and ERPs. The introduction of new technologies has the potential to transform the space at its core. One such technology is fibre optic monitoring.

Utilising fibre optics

Distributed fibre optic sensing (DFOS) is a technology that enables continuous, real-time measurements along the entire length of a fibre optic cable. Unlike traditional sensors that rely on discrete sensors measuring at pre-determined points, distributed sensing does not rely upon manufactured sensors, but instead utilises the optical fibre. The optical fibre is the sensing element without any additional transducers in the optical path.

The interrogator operates by sending a series of pulses down the fibre, and then records the return of the naturally occurring scattered signal against time. In doing this, the distributed sensor measures at all points along the fibre. As the fibre is the sensor, it is also a cost-effective method that can be easily deployed even in the harshest and most unusual environments. Distributed sensing is usually used for acquiring temperature, strain, and acoustic data.

The optical fibre is made of pure glass (silica) as thin as a human hair. It consists of two parts: the inner core and the outer cladding, encapsulated in a protective coating. According to Visiongain analysis, the global distributed fibre optic sensing (DFOS) market was estimated to be valued at US$1033 million in 2020. The market is expected to witness a compound annual growth rate of 10.46% over the next five years to reach US$1867 million by 2026. The analysis also anticipates that the sector will further grow to US$3240 million in 2031.[1]

The DFOS market is expected to see substantial growth fuelled by increasing investment and critical development undertaken by prominent players to include optical sensing monitoring technologies. Growing demand for a highly integrated, cost-effective, and power efficient centralised monitoring system is expected to drive demand throughout the decade.

Integrated fibre optic sensing

Silixa's DamPulse™ solution is an integrated fibre optic sensing-based tailings dam monitoring system that addresses dam integrity, public safety, and environmental protection. It enables operators to identify potential problems in time to facilitate timely maintenance and intervention before failure occurs. The system provides high quality distributed temperature, strain, and acoustic measurements in real time, using a purpose-built optical fibre cable optimally placed for entire structure coverage.

DamPulse provides actionable insight into the state of structural risk for the entire life of dam (including post operation). The optical fibre sensing network can be readily extended enabling an expandable installation to provide a comprehensive lifetime structure monitoring solution. Flexible installations with no power requirement on site also makes this technology beneficial. The cable is simply laid out, covered, and surveyed during construction or expansion. Alternatively, retrofits can be completed using trench and cover or borehole completion methods with no need to manage extra cabling for power or communications.

Temperature, acoustic, and strain data can be collected on the same fibre optic cable. This allows for the implementation of multiple monitoring techniques for identification of increasing seepage flow zones, structural deformation, and material changes through time with large spatial and high measurement resolution. Specific application modules include seepage detection, deformation monitoring, seismic event detection, surface and subsurface imaging, and dam breach detection. It is possible to also detect early signs of liquefaction with a proper system design and analysis. Alarms can be generated from the application modules and output for integration with operator control systems or via a web-based platform.

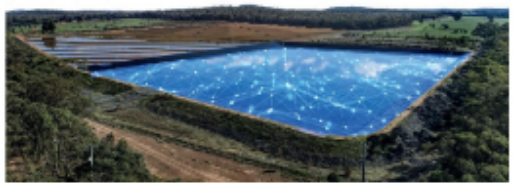


Figure 1. Silixa's DamPulse™, a fibre optic sensing-based dam monitoring solution, delivers ultra-HD quality distributed temperature, strain, and acoustic measurements in real time, offering early alerts of potential problems. This minimises the risk of dam failures.

Utilising temperature and acoustic sensing

Using high-resolution distributed temperature sensing (DTS) measurements, the system uses the natural seasonal temperature variations in the drainage system and reservoir to monitor changes in the seepage flow distribution, and identify, with precision, the location of internal erosion development. The DTS data is processed using the XSeept™ application developed by Hydroresearch, which is deployed today on over 100 embankment dams worldwide.

The application uses high spatial resolution temperature data from Silixa's ULTIMA™ DTS to monitor seepage flow rates along the dam structure. The system will alert the operator of abnormal seepage flow rates which can be an indication of erosion, one of the most common causes of dam failure.

For condition monitoring, the system records acoustic data continuously or on demand to image the sub-surface through advanced seismic techniques. Variations in seismic frequency and velocity highlight any material changes in the dam to aid identification of structural changes.

Seismic surveys can be active (use of external energy sources) or passive (analysis of natural noise or seismic events). Active seismic surveys can be used to image the subsurface, applying techniques such as multi-channel analysis of surface waves (MASW) and other tomographic methods. Applying passive ambient noise interferometry (ANI), where recordings of background noise are used to reconstruct waves travelling between two receivers, can help image a dam with high precision.

Small seismic events, termed microseismicity, caused by movement on faults or by mining blasts, can also be detected using DAS technology. DAS microseismic monitoring can be used to detect seismic movement in dams or induced seismicity in the area surrounding dams where seismic hazard is often an important safety consideration.

Using distributed strain sensing (DSS), local movements can be detected at an early stage using the same optical fibre cable. This provides useful and additional information to the survey points which are normally used to detect movements.

A combination of dynamic and static strain changes offers a better understanding of potential structural changes, and makes early decision-making possible. The system can detect movement changes in the dam and can therefore be used as an early-warning system with continuous monitoring, or as an investigation tool to measure movements regularly.

When it comes to a breach, any change that causes damage to the cable can be detected in real time, irrespective of the interrogator, to activate alarms and trigger ERP. Using purpose-built software, it is also possible to analyse the signal losses along the full length of the cable. Temporal signal loss changes can then be detected before a full cable breach will occur.

Conclusion

By providing early alerts of potential problems, these solutions can help mine operators tackle one of the biggest challenges they face: managing water in tailings dams and maintaining the safety of dams. The system can detect even the smallest changes in the dam structure that could otherwise go unnoticed with conventional technologies, thus helping to reduce the number of 20 or so tailing dams that fail every decade. GMR

References

1. GlobeNewswire, 'Global Distributed Fiber Optic Sensing (DFOS) Market 2021 – 2031: Visiongain Research Inc.', Visiongain, https://www.globenewswire.com/news-release/2021/08/25/2286589/0/en/Global-Distributed-Fiber-Optic-Sensing-DFOS-Market-2021-2031-Visiongain-Research-Inc.html