



HHXRF, TXRF, MICRO-XRF

Protecting our planet

XRF Analysis Solutions for
Environmental Stewardship

Innovation with Integrity

Ensure your environmental responsibility

Bruker's X-ray fluorescence (XRF) analyzers includes various handheld, portable and benchtop spectrometers. They provide elemental analysis solutions to monitor the presence of heavy metals and other dangerous elemental pollutants in soil, water, air, the buildings we live, work, learn, and play in, and in everyday products. Our XRF spectrometers are used around the world to help protect our planet and its people.

XRF analysis of dangerous elements

Earth's natural resources, including the air we breathe, the water we drink, and the soil we grow our food in, are susceptible to pollutants. Multiple measures are in place to help mitigate pollution and Bruker has a variety of technical solutions to monitor their efficacy.

Protection from exposure to dangerous levels of heavy metals and other toxic elements in the places and objects we interact with every day is a priority. Screening for their presence is critical.

XRF is a non-destructive metal and elemental analysis method with minimal to no sample preparation requirements which provides identification and compositional data for environmental samples such as water, soil, plants, air filters, dust wipes, and consumer products.

Several Bruker XRF instruments can be used to measure the presence and composition of heavy metals and other dangerous elements:

- Portable XRF spectrometers (S1 TITAN, TRACER 5, CTX) quickly screen samples of environmental interest for elemental contaminants in-situ or wherever needed.
- Micro-XRF spectrometers (M4 TORNADO, M1 MISTRAL, ELIO) provide elemental density distribution information to help pinpoint the location of restricted elements such as lead in electronic components and other consumer products.

- TXRF spectrometers (S2 PICOFOX, S4 T-STAR®) easily determine ultra-low elemental levels (sub-ppb) of dangerous metals in liquid, air filter, plant, food, live tissue, and soil samples.

Handheld, mobile, and portable benchtop XRF analyzers (HHXRF and PXRF)

S1 TITAN, TRACER 5 and CTX are the most agile XRF analyzers to simultaneously measure elements from fluorine (F) to uranium (U) at concentrations as low as parts-per-million (ppm) to high percentage levels. These analyzers can be used on samples of any form (liquid, solid, powder, film) and the analysis can be performed in any location – in the lab,



in the field, or even aboard a ship. Factory ready calibrations for heavy metals, sulfur in fuels, and other hazardous materials are available. EasyCal PC software is also available for customers to develop their own calibrations.

Portable and laboratory benchtop micro-XRF analyzers (micro-XRF)

M4 TORNADO, M1 MISTRAL, and ELIO are micro-XRF spectrometers providing composition and element distribution information. The high-performance laboratory spectrometer M4 TORNADO provides a small spot size (down to $< 20 \mu\text{m}$) and allows multilayer analysis (12 selectable layers and 2D area scans). The industrialized compact benchtop M1 MISTRAL provides a small spot (down to $100 \mu\text{m}$) and some multi-layer analysis (2 nm – $60 \mu\text{m}$ thickness range). The non-contact, portable ELIO has a spatial resolution of 1 mm with some multi-layer analysis.



Figure 1
Handheld, mobile, and portable benchtop XRF analyzers (HHXRF and PXRF)
Left top: S1 TITAN
Left bottom: TRACER 5
Right: CTX

Portable and laboratory benchtop total reflection X-ray fluorescence analyzers (TXRF)

S2 PICOFOX and S4 T-STAR[®] are mobile and laboratory TXRF spectrometers for ultra-trace (sub-ppb) to high percentage elemental analysis and achieve ICP-like detection limits. These instruments only require very small sample amounts in the ng or μg range and have low operating costs. Moreover, these “green” analyzers do not require the use of time-consuming sample digestion with hazardous chemicals or laboratories with hoods and exhausts.



Figure 2
Portable and laboratory benchtop micro-XRF analyzers (micro-XRF)
Left: ELIO
Right top: M4 TORNADO
Right bottom: M1 MISTRAL



Figure 3
Portable and laboratory benchtop analyzers (TXRF)
Left: S2 PICOFOX
Right: S4 T-STAR[®]

Environmental Safety Regulations

Water and air

Clean and safe water and air are critical for life. Local governments and global organizations issue guidelines for the standardization and regulation of water and air quality. Heavy metals and other dangerous elemental contaminants, which are significant pollutant threats must be monitored.

TXRF spectrometers provide multi-element trace analysis of water, including halogenides. It provides a mobile solution to quantify air particle composition in the field for real-time analysis. It has the sensitivity of ICP-OES and AAS for heavy metal analysis without needing external calibrations, extensive sample preparation, or high maintenance costs, even at ultra-trace (sub-ppb) levels.

Portable XRF analyzers provide the ability to screen for heavy metals in suspect bodies of water which is of particular importance in areas where old piping with lead (Pb) is used to distribute water for human consumption.

Soil and sediment

Soil free from heavy metals or elevated levels of other dangerous elements is as important for growing safe food as it is for ensuring a secure area where children play, and all

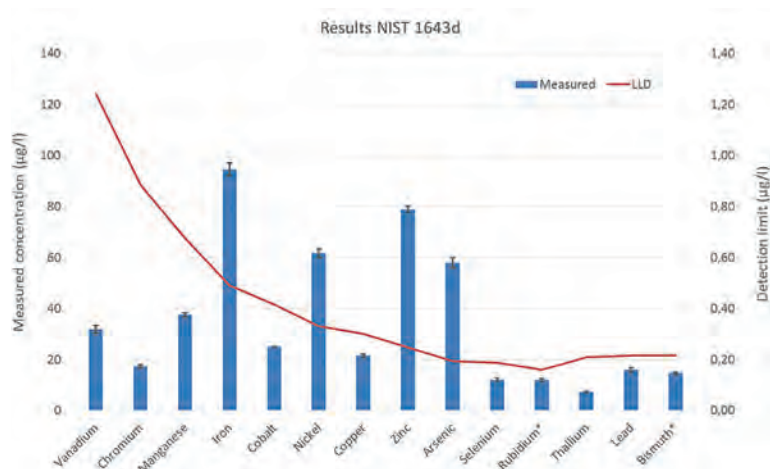
partake in outdoor sports. Environmental protection organizations provide guidance and methods to analyze soil and sediment with XRF to make sure regulated levels of metal pollutants are not exceeded.

XRF analysis with handheld and portable spectrometers is used to screen soil in commercial and urban areas as well as at construction and industrial sites. It also helps track elemental contaminants distributed by extreme weather debris migration.

TXRF analysis is particularly advantageous for the direct measurement of a wide range of elements in sewage, with no pretreatment.

Figure 4

Analysis of the NIST 1643d water standard with the S4 T-STAR® TXRF spectrometer and calculated lower limits of detection.



El	PPM	+/- [%2]
Cr	25K	1494
Fe	9219	662
As	3573	75
Cu	1947	105

Figure 5

Portable XRF analyzers quickly screen soil for heavy metals like As and Pb as well as for dangerously high levels of other metals like Cr, Fe, and Cu.

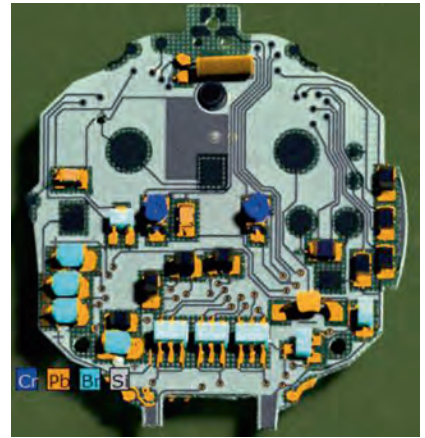
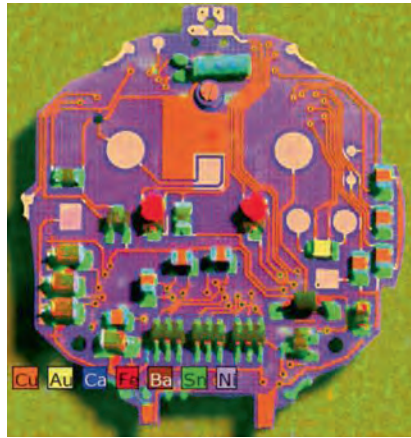
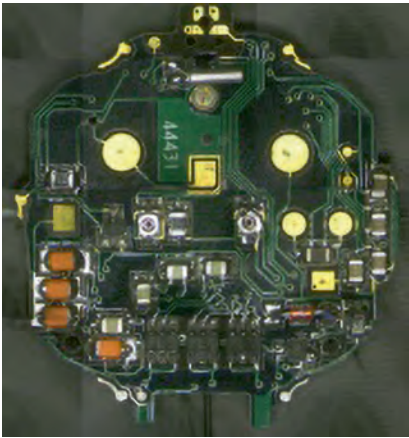


Figure 6

Micro-XRF can be used to create maps for RoHS compliance such as the examination of a digital watch PCB. The optical image is stitched with the acquired spectroscopic data to provide a clear picture of not only the elemental distribution of the sample but also a designation of the presence of RoHS elements.

RoHS/WEEE/ELV

Governments enact directives for restrictions on hazardous substances (RoHS), waste from electrical and electronic equipment (WEEE) and end of life vehicles (ELV) as safety measures to prevent exposure to dangerous levels of materials like Pb, As, Br, Cr, and Cd. Screening for these is essential for reuse/recycle programs.

Consumer products

Fast and non-destructive screening of consumer products for heavy metals is essential. Toys, trinkets, clothing, and decorative objects are not the only products to be tested. Personal care products including nutraceuticals and cosmeceuticals also need to be safe for use.

Handheld and portable XRF as well as TXRF is particularly convenient for safety and quality screening of large volumes of materials and for on-site testing. These analysis techniques can be used at shipping or loading docks, in stockrooms, at store counters, and even at remote border security inspection stations.



Figure 7

Handheld and portable XRF analyzers can be pre-programmed with specified pass/fail limits for concentration ranges of dangerous heavy metals, such as Pb, As, and Hg which have been used in whitening cosmetics throughout history.

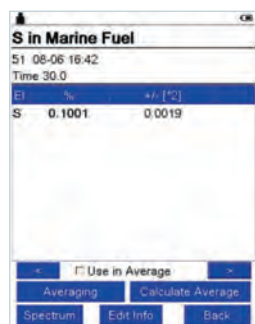
Comply with Industrial Regulations

Runoff pollution control

It is critical to prevent metals dispersed from power generation, construction, mining, and manufacturing or even from overuse of fertilizers to stream or seep into our soil and water. Although initial levels may be within set limits, they can concentrate over time to toxic levels when released to the environment. Primary sites, perimeters, and runoff streams need to be monitored to help any reclamation or regulatory clearance efforts.

The efficacy of waste treatment systems also needs to be ensured. Bruker provides vital tools to enable analysis of metals which are airborne and collected on filters, concentrated in soil, or waterborne to help protect the environment.

The ultra-low detection level capability of TXRF analyzers enables analysis of elements which are harmless at low levels, but very dangerous at slightly higher levels.



Element	Reference sample		Wastewater	
	1 ppm Se	0.015 ppm Se	before Se treatment	after Se treatment
S	425	74.3	569	412
K	2.05	4.42	16.6	12.3
Ca	515	39.5	1404	1027
Se	0.93	0.011	0.346	< 0.011
Br	0.015	0.041	204	98.9
Sr	0.787	0.624	5.54	3.28

Worker and vicinity safety

Preventative environmental protection programs recommended by governments and industrial organizations are essential to protect workers and surrounding areas from pollutant contamination. Construction, repair, and general industry sites need to be inspected before, during, and after use to meet safety regulations.

Handheld XRF analyzers are used to monitor surface Hg contamination from process streams, vessels, and storage tanks during decommissioning to help protect the health and safety of workers.

Portable XRF analyzers are particularly useful in meeting many recommended monitoring actions. They are used to screen soil at industrial sites, during mining reclamation, at lead-based-paint blasting removal sites, and to confirm remediation efforts at hazardous materials sites. Portable XRF spectrometers can also be used to prove the use of low-sulfur fuel in engines for large transport vehicles such as cargo ships and aircraft.

Figure 9

The CTX portable XRF analyzer allows the input of threshold concentration values of sulfur, heavy metals or other elements to enable quickly identifiable compliance results. powered plant.

Figure 8

Results before and after wastewater treatment measured with the portable S2 PICOFOX TXRF spectrometer (concentrations given in mg/L) to monitor selenium wastewater treatment system efficacy at a coal powered plant.

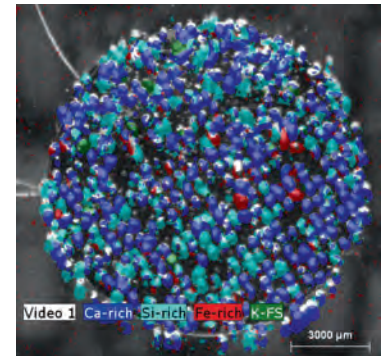
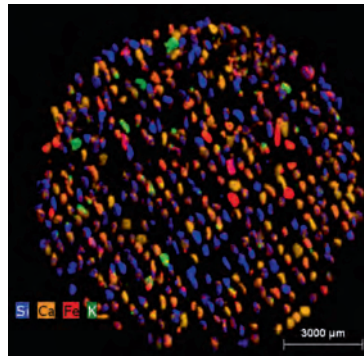
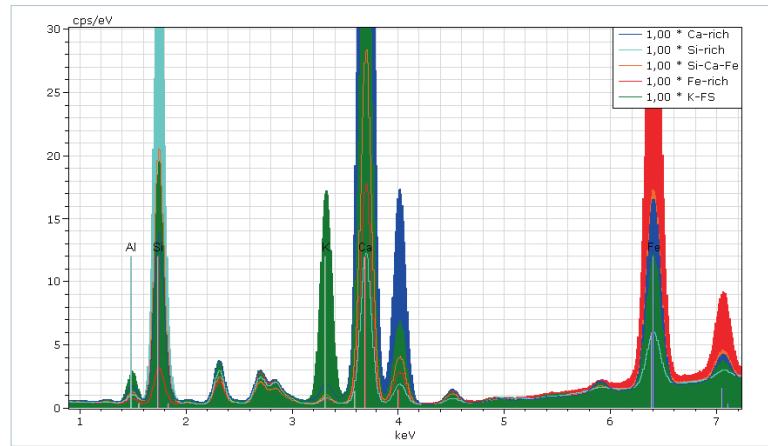
Advanced Applications

Environmental forensics

Tracking down the origins of deliberate or accidental waste discharge is a key role of forensic water analysis and can require a rapid response to the analysis of water samples taken from streams or groundwater bores.

Forensic soil analysis aids criminal investigations in multiple ways. Different characteristics of soils may help investigators understand a crime scene, whether a burial has occurred, or even retain traces of human remains. One aspect of forensic soil analysis involves fingerprinting the constituents of soils to derive a soil provenance, linking it to a specific geographic location.

Micro-XRF enables elemental analysis of mineral grains and other particulate matter. Elements measured in each grain allow easy identification of the minerals present and their relative abundances. Where collected due to transfer – on a shoe or on clothing – these data can be used for direct comparison to samples taken at crime scenes or to databases of regional soils.



Research and education

XRF analysis is a research tool applicable to multiple areas of environmental science. It provides information on elemental identification, composition, and distribution for multiple sample types. It is critical technology for research institutes.

XRF spectrometers help develop knowledge, methods, and skills as well as bring the periodic table to life in the classroom. They enable teachers to connect students with the relevance of science, technology, engineering, and math in the world around them.

Portable XRF analyzers are particularly beneficial to provide students with experiential, value-driven science with instant feedback which engages them in the classroom, on environmental field trips with real-world samples, and even back in the lab.



Figure 10

The M4 TORNADO micro-XRF spectrometer enables finger-prints of the source location (provenance) of soil, sand, or other environmental detritus through compositional analysis of residues on boots or tires.

Figure 11

Bruker's high-value handheld and portable XRF, micro-XRF and TXRF spectrometer solutions enable scientists to make breakthrough discoveries and develop new applications that improve the quality of human life.

Further Information

Handheld/mobile/portable X-ray fluorescence (HHXRF and PXRF) spectrometers have the capability to non-destructively qualify or quantify nearly any element from fluorine to uranium, depending on specific instrument configurations.

- S1 TITAN
- TRACER 5
- CTX

www.bruker.com/hhxf



Micro-X-ray fluorescence (micro-XRF) spectrometers are the instruments of choice for the elemental analysis of non-homogeneous or irregularly shaped samples as well as small objects or even inclusions.

- M4 TORNADO
- M1 Mistral
- ELIO

www.bruker.com/micro-xrf



Total reflection X-ray fluorescence (TXRF) spectrometers are well-established for the ultra-trace element analysis on a variety of samples and very small sample amounts in the μg , ng or pg range. The transportable instruments can be used in field and laboratory.

- S2 PICOFOX
- S4 T-STAR®

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