



Common Research Uses for XRF Technology

- **Art & Archaeology**
 - **Artwork**
 - Uhlir, K., et al. Applications of a portable (micro) XRF instrument having low-Z elements determination capability in the field of works of art. *X-Ray Spectrom.*, 2008; **37**: 450-457.
 - Rosi, F., Burnstock, A., Van den Berg, K.J., Miliani, C., Brunetti, B., & Sgamellotti A. A non-invasive XRF study supported by multivariate statistical analysis and reflectance FTIR to assess the composition of modern painting materials. *Spectrochimica Acta Part A* (2008), Article in Press.
 - **Bronze Age Brick**
 - Nodarou, E., Frederick, C., & Hein, A. Another (mud)brick in the wall: scientific analysis of Bronze Age earthen construction materials from East Crete. *Journal of Archaeological Science*, 35 (2008) 2997-3015.
 - **Ceramic Fabric**
 - Padilla, R., Van Espen, P., & Godo Torres, P.P. The suitability of XRF analysis for compositional classification of archaeological ceramic fabric: A comparison with a previous NAA study. *Analytica Chimica Acta*, 558 (2006) 283-289.
 - **Jewelry**
 - Constantinescu, B. et al. Micro-SR-XRF and micro-PIXE studies for archaeological gold identification—The case of Carpathian (Transylvanian) gold and of Dacian bracelets. *Nuclear Instruments and Methods in Physics Research B*, 266 (2008) 2325-2328.
 - **Manuscript Pigment**
 - Van der Snickt, G., De Nolf, W., Vekemans, B., & Janssens, K. μ -XRF/ μ -RS vs. SR μ -XRD for pigment identification in illuminated manuscripts. *Applied Physics A*, (2008) 92: 59-68.
 - **Maps**
 - Castro, K. et al. Noninvasive and nondestructive NMR, Raman and XRF analysis of a Blaeu coloured map from the seventeenth century. *Anal. Bioanal. Chem.*, (2008) 391: 433-441.
 - **Metal Artifacts**
 - Karydas, A.G. Application of a portable XRF spectrometer for the non-invasive analysis of museum metal artefacts. *Annali di Chimica*, **97**, 2007: 419-432.
 - **Monuments**
 - Liritzis, I., Sideris, C., Vafiadou, A., & Mitsis, J. Mineralogical, petrological and radioactivity aspects of some building material from Egyptian Old Kingdom monuments. *Journal of Cultural Heritage*, 9 (2008) 1-13.
 - **Pigmented Wood**
 - Desnica, V. et al. Portable XRF as a valuable device for preliminary in situ pigment investigation of wooden inventory in the Trski Vrh Church in Croatia. *Appl. Phys. A*, 92, 19-23 (2008).
 - **Pottery**
 - Kuhn, R.D. & Sempowski, M.L. A new approach to dating the League of the Iroquois. *American Antiquity*, 66(2), 2001, 301-314.
 - **Stone Tools**
 - Andrefsky, W. Experimental and archaeological verification of an index of retouch for hafted bifaces. *American Antiquity*, 71(4), 2006, 743-757.

- **Botany**
 - **Biodiversity & Bioavailability**
 - Hernandez, A.J. & Pastor, J. Relationship between plant biodiversity and heavy metal bioavailability in grasslands overlying an abandoned mine. *Environ. Geochem. Health*, (2008) 30: 127-133.
 - **Element Replacement**
 - Aslan, A, Budak, G., Tirasoglu, E., & Karabulut, A. Determination of elements in some lichens growing in Giresun and Ordu province (Turkey) using energy dispersive X-ray fluorescence spectrometry. *Journal of Quantitative Spectroscopy & Radiative Transfer*, 97 (2006) 10-19.
 - Dumlupinar, R. et al. Determination of replacement of some inorganic elements in pulvinus of bean (*Phaseolus vulgaris* cv. Gina 2004) at chilling temperature by the WDXRF spectroscopic technique. *Journal of Quantitative Spectroscopy & Radiative Transfer*, 103 (2007) 331-339.
 - **Land Use**
 - Herpin, U. et al. Biogeochemical dynamics following land use change from forest to pasture in a humid tropical area (Rondonia, Brazil): a multi-element approach by means of XRF-spectroscopy. *The Science of the Total Environment* 826 (2002) 97-109.
 - **Root Uptake**
 - Stacey, S.P., McLaughlin, M.J., Cakmak, I., Hettiarachchi, G.M., Scheckel, K.G., & Karkkainen, M. Root uptake of lipophilic zinc-rhamnolipid complexes. *J. Agric. Food Chem.*, 2008, 56, 2212-2217.
 - **Seeds**
 - Young, L., Westcott, N., Christensen, C., Terry, J., Lydiate, D., & Reaney, M. Inferring the geometry of fourth-period metallic elements in *Arabidopsis thaliana* seeds using Synchrotron-based multi-angle X-ray fluorescence mapping. *Annals of Botany*, **100**: 1357-1365, 2007.
- **Building Materials**
 - **Cement**
 - Limbachiya, M.C., Marrocchino, E., & Koulouris, A. Chemical-mineralogical characterization of coarse recycled concrete aggregate. *Waste Management*, 27 (2007) 201-208.
 - Scheidegger, A.M. et al. The use of (micro)-X-ray absorption spectroscopy in cement research. *Waste Management*, 26 (2006) 699-705.
 - **Ceramsite**
 - Xu, G.R., Zou, J.L., & Dai, Y. Utilization of dried sludge for making ceramsite. *Water Science & Technology*, 54(9): 69-79.
 - **Landscaping Mulch**
 - Jacobi, G., Solo-Gabriele, H., Dubey, B., Townsend, T., & Shibata, T. Evaluation of commercial landscaping mulch for possible contamination from CCA. *Waste Management*, 27 (2007) 1765-1773.
 - **Paint**
 - Afshari, S., Nagarkar, V., & Squillante, M.R. Quantitative measurement of lead in paint by XRF analysis without manual substrate correction. *Appl. Radiat. Isot.*, 1997, 48 (**10-12**): 1425-1431.
 - **Treated Wood**
 - Block, C.N., Shibata, T., Solo-Gabriele, H.M., & Townsend, T.G. Use of handheld X-ray fluorescence spectrometry units for identification of arsenic in treated wood. *Environmental Pollution*, 148 (2007) 627-633.
- **Consumer Products**
 - **Conductive Gaskets**

- Prakash, B.N. & Roy, L.D. Assessment of conductive gaskets using X-ray fluorescence technique. *INCEMIC-97*: 1A; 1-2.
 - **Lead Test Kits**
 - Cobb, D., Hatlelid, K., Jain, B., Recht, J., & Saltzman, L.E. CPSC staff report: Evaluation of lead test kits. October 2007.
 - **Packaging**
 - Ida, H. & Kawai, J. Analysis of wrapped or cased object by a hand-held X-ray fluorescence spectrometer. *Forensic Science International*, 151 (2005), 267-272.
 - The Toxics in Packaging Clearinghouse. An assessment of heavy metals in packaging: Screening results using a portable X-ray fluorescence analyzer—Final report. U.S. Environmental Protection Agency under assistance agreement No. X9-83252201 to the Northeast Recycling Council, Inc. 20 June 2007, 1-23.
 - **PBDEs**
 - Allen, J.G., McClean, M.D., Stapleton, H.M., & Webster, T.F. Linking PBDEs in house dust to consumer products using X-ray fluorescence. *Environ. Sci. Technol.* **2008**, 42, 4222-4228.
 - **Plastics**
 - Wickham, M. & Hunt, C. XRF equipment as a RoHS screening tool. *Circuits Assembly*, Feb 2008; 19, 2; ABI/INFORM Trade & Industry, pg. 26
- **Dentistry**
 - **Dental Cement**
 - Ekinci, N., Bayindir, F., Bayindir, Y.Z., & Ekinci, R. The determination of trace elements release from dental cements in artificial saliva by energy dispersive X-ray fluorescence spectrometry. *Analytical Letters*, 40: 2476-2484, 2007.
 - **Dental Identification**
 - Bush, M.A., Miller, R.G., Prutsman-Pfeiffer, J., & Bush, P.J. Identification through X-ray fluorescence analysis of dental restorative resin materials: A comprehensive study of noncremated, cremated, and processed-cremated individuals. *J Forensic Sci.*, (2007) 52:1; 157-165.
 - **Dental Materials**
 - Johnson, T., Van Noort, R., & Stokes, C.W. Surface analysis of porcelain fused to metal systems. *Dental Materials*, (2006) **22**, 330-337.
 - **Elemental Diffusion**
 - Carvalho, M.L., Marques, A. F., Marques, J.P., & Casaca, C. Evaluation of the diffusion of Mn, Fe, Ba and Pb in Middle Ages human teeth by synchrotron microprobe X-ray fluorescence. *Spectrochimica Acta Part B*, 62 (2007) 702-706.
 - **Restorative Dentistry Composites**
 - Preoteasa, E.A. et al. Analysis of composites for restorative dentistry by PIXE, XRF and ERDA. *Nuclear Instruments and Methods in Physics Research B*, 189 (2002) 426-430.
 - **Tartar**
 - Abraham, J.A., Grenon, M.S., Sanchez, H.J., Valentinuzzi, M.C., & Perez, C.A. μ X-ray fluorescence analysis of traces and calcium phosphate phases on tooth-tartar interfaces using synchrotron radiation. *Spectrochimica Acta Part B*, 62 (2007) 689-694.
- **Drugs & Medicine**
 - **Ayurvedic Drugs**
 - Mahawatte, P., Dissanayaka, K.R., & Hewamanna, R. Elemental concentrations of some Ayurvedic drugs using energy dispersive XRF. *Journal of Radioanalytical and Nuclear Chemistry*, Vol. 270, No. 3 (2006) 657-660.
 - **Bacterial Genetics**
 - Makarova, K.S. et al. *Deinococcus geothermalis*: The pool of extreme radiation resistance genes shrinks. *PLoS ONE*, 2(9): e955.
 - **Biomedical Alloys**

- Oliveira, N.T.C., Aleixo, G., Caram, R., & Guastaldi, A.C. Development of Ti-Mo alloy for biomedical applications: Microstructure and electrochemical characterization. *Materials Science and Engineering A*, 452-453 (2007) 727-731.
 - **Bone Tissue Composition & Disease Detection**
 - Lima, I. et al. Bone diagnosis by X-ray techniques. *European Journal of Radiology* (2008), Article in Press.
 - Voglis, P., Attaelmanan, A., Engstrom, P., Larsson, S., & Rindby, A. Elemental mapping of bone tissues by the use of capillary focused XRF. *X-Ray Spectrometry*, (1993) 22: 229-233.
 - **Breast Tissue Composition & Disease Detection**
 - Farquharson, M.J. & Geraki, K. The use of combined trace element XRF and EDXRD data as a histopathology tool using a multivariate analysis approach in characterizing breast tissue. *X-Ray Spectrom.* 2004; **33**: 240-245.
 - **Cell Labeling & Immunofluorescence**
 - McRae, R., Lai, B., Vogt, S., & Fahrni, C.J. Correlative microXRF and optical immunofluorescence microscopy of adherent cells labeled with ultrasmall gold particles. *Journal of Structural Biology*, 155 (2006) 22-29.
 - **Liver Tissue Composition & Disease Detection**
 - Gurusamy, K.S., Farquharson, M.J., Craig, C., & Davidson, B.R. An evaluation study of trace element content in colorectal liver metastases and surrounding normal livers by X-ray fluorescence. *Biometals*, (2008) 21: 373-378.
 - **Risk Assessment**
 - Gerhardsson, L. et al. In vivo XRF as a means to evaluate the risks of kidney effects in lead and cadmium exposed smelter workers. *Appl. Radiat. Isot.*, (1998) 49:5/6, 711-712.
 - **Toxicology**
 - Gamarra, L.F. et al. Kinetics of elimination and distribution in blood and liver of biocompatible ferrofluids based on Fe₃O₄ nanoparticles: An EPR and XRF study. *Materials Science and Engineering C*, 28 (2008) 519-525.
 - Gherase, M.R. & Fleming, D.E.B. Fundamental parameter approach to XRF spectroscopy measurements of arsenic in polyester resin skin phantoms. *X-Ray Spectrom.* 2008; **37**: 482-489.
 - Herman, D.S., Geraldin, M., Scott, C.C., & Venkatesh, T. Health hazards by lead exposure: Evaluation using ASV and XRF. *Toxicology and Industrial Health*, 2006; **22**: 249-254.
- **Food**
 - **Food & Drug Administration (FDA) Use**
 - Palmer, P., Webber, S., Ferguson, K., & Jacobs, R. On the suitability of portable X-ray fluorescence analyzers for rapid screening of toxic elements. *FDA/ORL/DFS Laboratory Information Bulletin*, LIB #4376, 1-15.
 - **Milk**
 - Perring, L. & Andrey, D. ED-XRF as a tool for rapid minerals control in milk-based products. *J. Agric. Food Chem.* (2003) 51: 4207-4212.
 - **Rice**
 - Meharg, A.A. et al. Speciation and localization of arsenic in white and brown rice grains. *Environ. Sci. Technol.* **2008**, 42, 1051-1057.
 - **Spices**
 - Al-Bataina, B.A., Maslat, A.O., & Al-Kofahi, M.M. Element analysis and biological studies on ten oriental spices using XRF and Ames test. *J. Trace Elem. Med. Biol.* Vol. 17 (2) 85-90 (2003).
 - **Tea**
 - Nas, S., Gokalp, H.Y., & Sahin, Y. K and Ca content of fresh green tea, black tea, and tea residue determined by X-ray fluorescence analysis. *Z Lebensm Unters Forsch* (1993) 196: 32-37.
 - **Water**

- Barreiros, M.A., Carvalho, M.L., Costa, M.M., Marques, M.I., & Ramos, M.T. Application of total reflection XRF to elemental studies of drinking water. *X-Ray Spectrom.* (1997) 26: 165-168.
- **Forensics**
 - **Automobile Paint (Original Finish)**
 - Suzuki, E.M. & McDermot, M.X. Infrared spectra of U.S. automobile original finishes. VII. Extended range FT-IR and XRF analyses of inorganic pigments in situ—Nickel titanate and chrome titanate. *J Forensic Sci*, 51 (3) 2006, 532-547.
 - **Ink Determination**
 - Zieba-Palus, J. & Kunicki, M. Application of the micro-FTIR spectroscopy, Raman spectroscopy and XRF method examination of inks. *Forensic Science International*, 158 (2006) 164-172.
 - **General**
 - Trombka, J.I. et al. Crime scene investigations using portable, non-destructive space exploration technology. *Forensic Science International*, 129 (2002) 1-9.
 - Zieba-Palus, J., Borusiewicz, R., & Kunicki, M. PRAXIS—combined μ -Raman and μ -XRF spectrometers in the examination of forensic samples. *Forensic Science International*, 175 (2008) 1-10.
 - **Gunshot Residue**
 - Berendes, A., Neimke, D., Schumacher, R., & Barth, M. A versatile technique for the investigation of gunshot residue patterns of fabrics and other surfaces: m-XRF. *J Forensic Sci*, September 2006, Vol. 51, No. 5.
 - **Multilayer Paint Coats**
 - Zieba-Palus, J. & Borusiewicz, R. Examination of multilayer paint coats by the use of infrared, Raman and XRF spectroscopy for forensic purposes. *Journal of Molecular Structure*, 792-793 (2006) 286-292.
- **Fuel**
 - **Biodiesel/Diesel**
 - Barker, L.R., Kelly, W.R., & Guthrie, W.F. Determination of sulfur in biodiesel and petroleum diesel by X-ray fluorescence (XRF) using the gravimetric standard addition method—II. *Energy & Fuels*, 2008, 22, 2488-2490.
 - Nioroj, K., Intarapong, P., Luengnaruemitchai, A., & Jai-In, S. A comparative study of KOH/Al₂O₃ and KOH/NaY catalysts for biodiesel production via transesterification from palm oil. *Renewable Energy*, (2008), Article in Press.
 - **Nuclear Fuel**
 - Mogensen, M., Pearce, J.H., & Walker, C.T. Behaviour of fission gas in the rim region of high burn-up UO₂ fuel pellets with particular reference to results from an XRF investigation. *Journal of Nuclear Materials*, 264 (1999) 99-112.
- **Geology**
 - **Gemstones**
 - Pappalardo, L., Karydas, A.G., Kotzamani, N., Pappalardo, G., Romano, F.P., & Zarkadas, C. Complementary use of PIXE-alpha and XRF portable systems for the non-destructive and in situ characterization of gemstones in museums. *Nuclear Instruments and Methods in Physics Research B*, 239 (2005) 114-121.
 - **Rock Composition**
 - Dal Piaz, G.V. & Ernst, W.G. Areal geology and petrology of eclogites and associated metabasites of the Piemonte Ophiolite Nappe, Breuil-St. Jacques area, Italian Western Alps. *Tectonophysics*, 51 (1978) 99-126.
 - Flowers, R.M., Bowring, S.A., Mahan, K.H., Williams, M.L., & Williams, I.S. Stabilization and reactivation of cratonic lithosphere from the lower crustal record in the western Canadian shield. *Contrib. Mineral Petrol.*, (2008) 156: 529-549.
- **Manufacturing**

- **Alloy Production & Development**
 - Cernohorsky, T., Pouzar, M., & Jakubec, K. ED-XRF analysis of precious metallic alloys with the use of combined FP method. *Talanta*, 69 (2006) 538-541.
 - Harata, M., Yasuda, K., Yakushiji, H., & Okabe, T.H. Electrochemical production of Al-Sc alloy in CaCl₂-Sc₂O₃ molten salt. *Journal of Alloys and Compounds*, (2008), Article in Press.
- **Machine Maintenance**
 - Panalytical. Ed. Laboratorytalk Editorial Team. XRF spectrometry to manage machine maintenance. *Laboratorytalk*, <http://www.laboratorytalk.com/news/pna/pna119.html>, Accessed 7 October 2008.
- **Plating Effluent**
 - Chang, S.H. et al. Screening long-time plating effluent qualities by sorbent sorption with XRF analysis. *Journal of Hazardous Materials B*, 138 (2006) 67-72.
- **Raw Materials**
 - Falcone, R., Hreglich, S., Vallotto, M., & Verita, M. X-ray fluorescence analysis of raw materials for the glass and ceramic industries. *Glass Technol.*, 2002, 43(1), 39-48.
- **Paleontology**
 - **Fossils**
 - Olivares, M., Etxebarria, N., Arana, G., Castro, K., Murelaga, X., & Berreteaga, A. Multielement μ -ED-XRF analysis of vertebrate fossil bones. *X-Ray Spectrom.* 2008; **37**: 293-297.
 - Reiche, I. & Chalmin, E. Synchrotron radiation and cultural heritage: combined XANES/XRF study at Mn K-edge of blue, grey or black coloured palaeontological and archaeological bone material. *Journal of Analytical Atomic Spectrometry*, 2008, **23**, 799-806.
 - **Paleoclimate**
 - Daryin, A.V., Kalugin, I.A., Maksimova, N.V., Smolyaninova, L.G., & Zolotarev, K.V. Use of a scanning XRF analysis on SR beams from VEPP-3 storage ring for research of core bottom sediments from Teletskoe Lake with the purpose of high resolution quantitative reconstruction of last millennium paleoclimate. *Nuclear Instruments and Methods in Physics Research A*, 543 (2005) 255-258.
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- **Pollution**
 - **Air**
 - Harper, M., Pacolay, B., Hintz, P. Bartley, D.L., Slaven, J.E., & Andrew, M.E. Portable XRF analysis of occupational air filter samples from different workplaces using different samplers: final results, summary and conclusions. *J. Environ. Monit.*, 2007, **9**, 1263-1270.
 - **Industrial Waste**
 - Lin, K. & Chen, B. Dose-mortality assessment upon reuse and recycling of industrial sludge. *Journal of Hazardous Materials*, 148 (2007) 326-333.
 - Ohbuchi, A., Sakamoto, J., Kitano, M., & Nakamura, T. X-ray fluorescence analysis of sludge ash from sewage disposal plant. *X-Ray Spectrom.* 2008; **37**:544-550.
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 - **Radiation**

- Al-Saleh, F.S. & Al-Harshan, G.A. Measurement of radiation level in petroleum products and wastes in Riyadh City Refinery. *Journal of Environmental Radioactivity*, 99 (2008) 1026-1031.
 - **Soil**
 - Carr, R., Zhang, C., Moles, N., & Harder, M. Identification and mapping of heavy metal pollution in soils of a sports ground in Galway City, Ireland, using a portable XRF analyser and GIS. *Environ Geochem Health* (2008) 30:45-52.
 - Markey, A.M., Clark, C.S., Succop, P.A., & Roda, S. Determination of the feasibility of using a portable X-ray fluorescence (XRF) analyzer in the field for measurement of lead content of sieved soil. *Journal of Environmental Health*, 2008, 70(7): 24-29.
- **Space Exploration**
 - **Martian Rock & Soil Analysis**
 - Blake, D.F. et al. Definitive mineralogical analysis of Martian rocks and soil using the Chemin XRD/XRF instrument. 34th Lunar and Planetary Science Conference League City, TX, USA, 17 Mar 2003, <http://hdl.handle.net/2014/6351>.
 - **Robotic Exploration Missions**
 - Huntress, W.T., Moroz, V.I., & Shevarev, I.L. Lunar and planetary robotic exploration missions in the 20th Century. *Space Science Reviews*, **107**: 541-649, 2003.
- **Testing Validity**
 - **Detection Limits**
 - Cesareo, R. et al. The use of a European coinage alloy to compare the detection limits of mobile XRF systems—A feasibility study. *X-Ray Spectrom.* 2007; **36**: 167-172.
 - Rousseau, R.M. Detection limit and estimate of uncertainty of analytical XRF results. *The Rigaku Journal*. 18:2 (2001) 33-47.
 - **Reliability**
 - Mans, C., Janssen, A., Hanning, S., Simons, C., & Albar, D. Further developed handheld XRF instruments deliver reliable screening analysis. *Elektronik Praxis* (2007) <http://www.elektronikpraxis.vogel.de/themen/elektronikmanagement/strategieunternehmenfuehrung/articles/90630/>.
 - **Reduction of Hazardous Substances (RoHS) Verification**
 - Baliga, J. RoHS verification using XRF. *Semiconductor International*, Dec 2005; 28, 13; ABI/INFORM Global, pg. 32.
 - **Standards**
 - Mans, C., Hanning, S., Simons, C., Wegner, A., Janssen, A., & Kreyenschmidt, M. Development of suitable plastic standards for X-ray fluorescence analysis. *Spectrochimica Acta Part B* 62 (2007) 116-122.
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- **Transportation**
 - **Helicopters**
 - Becker, A. Application of an X-ray fluorescence instrument to helicopter wear debris analysis. *Australian Government Department of Defence: Defence Science and Technology Organisation—Air Vehicles Division*. DSTO-TR-2116. 2008.
 - **Roadways**
 - Lough, G.C., Schauer, J.J., Park, J.S., Shafer, M.M., Deminter, J.T., & Weinstein, J.P. Emissions of metals associated with motor vehicle roadways. *Environ. Sci. Technol.* **2005**, 39, 826-836.