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Elemental Analysis Using a Handheld X-Ray Fluorescence Spectrometer

The U.S. Geological Survey is collecting geologic samples from local stream channels, aquifer materials, and rock outcrops for studies of trace elements in the Mojave Desert, southern California. These samples are collected because geologic materials can release a variety of elements to the environment when exposed to water. The samples are to be analyzed with a handheld X-ray fluorescence (XRF) spectrometer to determine the concentrations of up to 27 elements, including chromium (see "Periodic Table of the Elements" on back page).

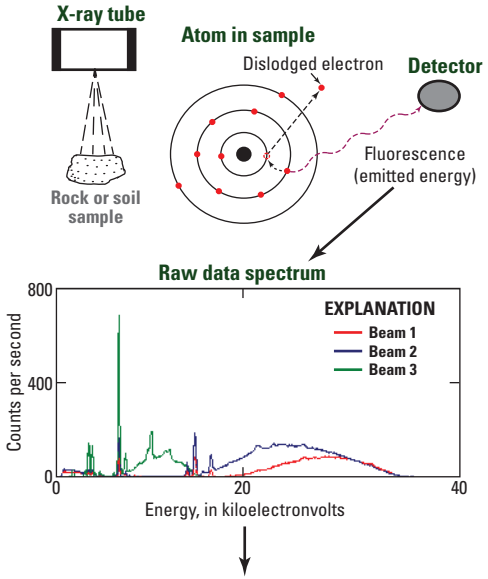
Why are These Data Collected?

The purpose of the XRF data is to determine the presence and concentration of elements in local geologic materials. These data are used for the following purposes:

- As a screening tool to guide further data collection and detailed mineralogic and chemical analyses.
- To evaluate whether the alluvial material composing local aquifers and the trace elements in that material are from a local or more distant source.
- For comparison with the known, average compositions of various soils, alluvium, and rocks to evaluate past and present processes that could act on the alluvium and release trace elements to groundwater.
- For comparison to local and regional water-quality data to determine which of the elements present could be released into groundwater from natural rather than human sources.

How Does it Work?

X-ray fluorescence spectrometry works by irradiating a sample or external standard with an X-ray beam produced by passing an electrical current through an X-ray tube. The X-ray beam dislodges electrons from the inner shells of an element, causing electrons from the outer shells to cascade down to the inner shells to fill in the gaps. The cascading electrons emit energy ('fluoresce') at wavelengths that are unique to each element. A detector measures the energy generated by cascading electrons in the sample, producing a pattern (spectrum) similar to that in figure 1. A computer application matches the spectrum to known spectral patterns to calculate element concentrations in milligrams per kilogram (mg/kg). The instrument uses three different filter and electrical current settings, which are optimized for particular suites of elements.



Example data from a granitic sand

Concentrations in milligrams per kilogram (mg/kg); ±, plus or minus; <, less than; –, data not available

Element	Measured concentration (mg/kg)	Precision (± mg/kg)	Average continental crust (mg/kg)[1]
Arsenic	2.7	0.4	1
Chromium	3.3	1.1	185
Lead	14	0.6	8
Selenium	1.0	0.2	0.05

[1]Hitchon, B., Perkins, E.H., and Gunter, W.D., 1999, Introduction to ground water geochemistry: Alberta, Canada, Geoscience Publishing, Ltd., 310 p.

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Figure 1. Basic X-ray fluorescence principles and example data table.

The handheld instrument (fig. 2) uses a 4-watt X-ray tube and is powered by a 7.2-volt lithium-ion battery. Samples either can be measured in place, after removing debris and large pebbles from the measurement area, or can be ground to a fine powder for analysis. Accuracy is verified through the routine measurement of standards that have known elemental compositions.

Figure 2. Handheld X-ray fluorescence spectrometer and external calibration standards.

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Periodic Table of the Elements

hydrogen 1 **H** 1.0079																	helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122											boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305											aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078	scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.38	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.64	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.798
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62	yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.96	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33		hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]		rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [277]	meitnerium 109 **Mt** [268]	darmstadtium 110 **Ds** [271]	roentgenium 111 **Rg** [272]							

Lanthanides	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.05	lutetium 71 **Lu** 174.97
Actinides	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]	lawrencium 103 **Lr** [262]

hydrogen — Element name
1 — Atomic number
H — Symbol
1.0079 — Atomic weight

Elements detectable with handheld X-ray fluorescence spectrometer