

Behind the scenes: Scientific analysis of samples from nuclear inspections in Iraq

Scientists at the IAEA's Seibersdorf Laboratories have co-ordinated analytical efforts to document important findings

Over the past year, IAEA inspectors investigating the nuclear capabilities of Iraq under authority of the United Nations Security Council frequently have captured international headlines. Behind the scenes, work has been far less visible but no less important in documenting the results of the on-site nuclear inspections carried out by the IAEA's UN Action Team.

At the Agency's research laboratories in Seibersdorf, Austria, scientists and technicians have focused their efforts on the measurement and analysis of hundreds of samples collected during inspections. They include smear samples taken from various sites in Iraq to detect potential undeclared nuclear activities; samples of uranium and plutonium compounds; samples of construction materials such as graphite, steel, and beryllium; and samples of soil, vegetation, water, rocks, and ores. (See table on next page.) The results helped inspectors to map the Iraqi nuclear programme, both with respect to declared and undeclared activities.

In studying the samples, scientists have applied a range of sophisticated and sensitive analytical techniques to obtain information on the chemical and isotopic composition of elements and compounds. (See box, pages 28-29.) These techniques are among those commonly applied at the Seibersdorf Laboratories, which were set up 30 years ago to provide scientific support to IAEA programmes.

This article reports on this co-ordinated scientific effort, including significant results. In

particular, it describes the analysis of samples that were unique to the Iraqi inspections, primarily environmental samples and materials of construction, and that required the application or development of new analytical methods and protocols.

by D.L. Donohue
and R. Zeisler

Sample handling protocol

The analytical schemes applied to the non-nuclear material samples were especially developed to suit the needs of the inspectors for

An alpha-particle spectrometry analysis at Seibersdorf.



Mr Donohue is Head of the Isotopic Analysis Unit, Safeguards Analytical Laboratory, and Mr Zeisler is Head of the Chemistry Unit, Physics-Chemistry-Instrumentation Laboratory, at the Seibersdorf Laboratories. The authors wish to acknowledge the valuable contributions of their colleagues to this work.

rapid and selective measurements, without demanding the optimum performance in terms of precision. Usually, a preliminary measurement was performed to screen the samples for the presence of important components such as uranium, plutonium, or radionuclides.

This was accomplished with high-resolution gamma spectrometry and energy-dispersive X-ray fluorescence spectrometry (XRF). The first method has a high sensitivity (nanogram to microgram levels) for radionuclides having a relatively short half-life, as in many fission products and certain isotopes of plutonium. XRF was used to screen for the presence of uranium, with a detection limit of about 1 microgram per square centimeter. It should be remembered that uranium is a naturally occurring element, present in soil at a concentration of about 1 microgram per gram. This fact caused certain analytical problems associated with the "blank" levels, primarily in the environmental samples.

Following the initial screening measurements, those samples which showed elevated levels of uranium or plutonium were scheduled for non-destructive assay, followed by chemical dissolution and analysis. Most samples were

treated and dissolved in the Chemistry Unit of Seibersdorf's Physics-Chemistry-Instrumentation (PCI) Laboratory to minimize the danger of contamination. Before dissolution, selected samples were submitted to the Atom Institute of the Austrian Universities in Vienna for measurement of fluorine and chlorine by neutron activation analysis.

The major methods applied to the determination of uranium content were laser-excited optical fluorescence and isotope dilution mass spectrometry. The use of these two independent methods, along with other complementary methods, was especially valuable in the analysis of uranium ores from Al Qaim, as discussed later.

The chemical treatment of samples containing uranium or plutonium depended on the matrix; filter paper smears were digested in nitric acid; soils, ores, and rocks were dissolved in nitric/hydrofluoric acid; and graphite or metal pieces with suspected surface contamination were leached with nitric or hydrochloric acid. Certain analytical techniques, such as isotope dilution mass spectrometry, required further chemical processing steps. Thus, the analysis of one sample could involve measurements with several analytical techniques and a significant number of chemists and analysts. All told in 1991, nearly 900 samples were treated at Seibersdorf from eight on-site inspections in Iraq. (See table.)

Samples from Iraq processed at Seibersdorf Laboratories in 1991

Inspection	Non-Nuclear Materials	Nuclear Materials
1st	48	31
2nd	35	0
3rd	139	51
4th	41	0
5th	49	61
6th	7	0
7th	139	141
8th	6	105
Total	464	389

Measurements requested

Sample category	Sample types	Analysis requested
Non-nuclear materials (Environmental)	Smears Vegetation Soil Debris Rocks, Ores Water	Presence of U, Pu or radionuclides Amount of U, Pu Presence of F, Cl U, Pu isotopics Presence of high explosives
(Materials of construction)	Graphite Steels Beryllium Unknown metals	Purity, type or identity
Nuclear materials	Uranium metal Uranium compounds Plutonium compounds Polonium U, Pu waste & scrap	Amount of U, Pu U, Pu isotopics Amount of polonium Compounds of U, Pu Trace elements in U compounds

Selected results of analyses

The results of analyses provided the IAEA's UN Action Team with important information. When combined with the observations of the inspectors in Iraq, they were used to arrive at a more complete understanding of the nuclear activities under investigation.

Evidence of electromagnetic separation of uranium isotopes. The revelation that Iraq had been utilizing the electromagnetic isotope separation process (EMIS) for enriching uranium-235 came as a surprise to many people in the scientific community. It was not until the third inspection, in July 1991, that the Iraqi authorities admitted to the existence of this programme and described in detail the nature of their activities.

The Iraqi declaration contained information about the large facilities at Tarmiya and Ash Sharqat, the number of isotope separators (calutrons) which had been operated at Tuwaittha and Tarmiya, and the amount of uranium-235 which had been successfully separated. The third inspection team was shown parts of the isotope separators which had been dismantled,

destroyed, and buried in an attempt to conceal this programme. A few parts from the ion sources and collectors of the calutrons were brought back to Seibersdorf for analysis. In addition, samples were taken from the declared product batches, covering a range of uranium-235 enrichment from depleted uranium (less than 0.1 wt%) up to around 6 wt%.

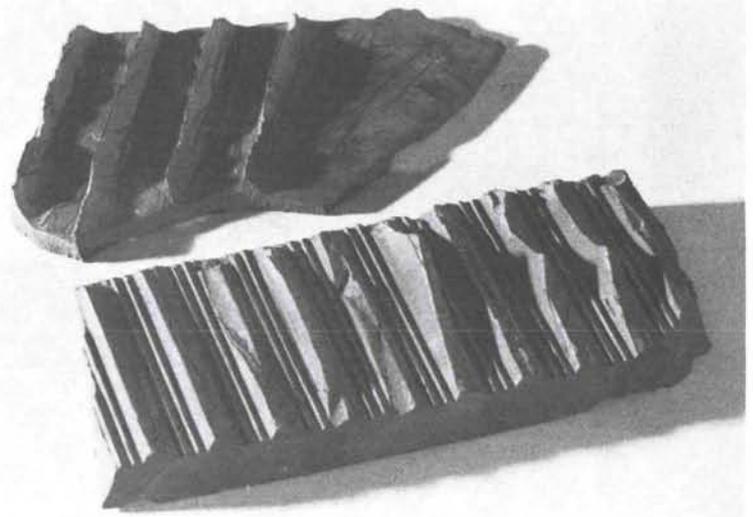
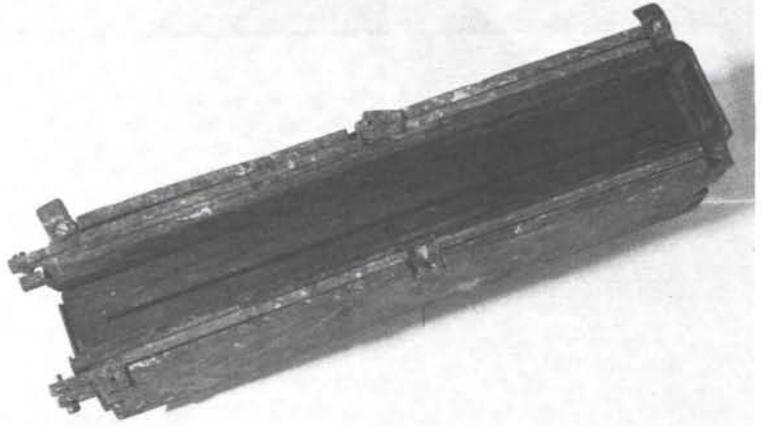
The ion source and collector pieces were from the large (1200 mm) calutrons which were declared to have been in operation at Tarmiya. These graphite pieces were scraped with a razor blade to remove about one gram of powder from the surface which was then leached in nitric acid to dissolve the uranium. This was followed by isotopic measurements using a mass spectrometer at Seibersdorf's Safeguards Analytical Laboratory (SAL).

Results showed that the ion sources sampled for analysis contained only natural uranium. (*See table below.*) The data from the sampled collector pieces show enrichments not exceeding about 6%.

The Iraqi declaration included five batches of uranium nitrate product solution from the EMIS work at Tarmiya. These were stated to contain several hundred grams of enriched uranium with a uranium-235 content of between 3 and 6 wt%, as well as other recovered material with depleted or near-natural uranium-235 abundance. The product solutions had been removed from five tanks at Tarmiya and buried in plastic bottles. Each bottle was sampled by the IAEA inspectors and the samples were analyzed at SAL by thermal ionization mass spectrometry for the isotopic composition, and by isotope dilution mass spectrometry for the uranium content.

Results showed that the isotopic information matches closely with the declarations. The concentration data were combined with the measured volumes of solution in the bottles to arrive at a statement of the total amount of material present. (*See table on page 30.*)

Evidence of plutonium production. Iraq had declared in July 1991 a programme for the reprocessing of spent fuel to recover plutonium. Approximately 2.26 grams of plutonium were obtained by dissolving one spent fuel assembly from the 10% enriched fuel for the Soviet IRT-5000 research reactor. It was also learned that the Iraqis had irradiated natural uranium fuel pins in the IRT-5000 reactor. This resulted in a further 2.7 grams of plutonium being produced. IAEA inspectors sampled all of these plutonium-bearing materials and sent them to SAL for immediate analysis. The most rapid analytical method was chosen to be high-resolution gamma spectrometry, which would give a measurement of the abundance of plutonium isotopes (except



for plutonium-242) and americium-241. From these data, it was possible to infer the most recent date of chemical processing of the samples, which gave an approximate timetable for the irradiation and reprocessing activities that were undertaken. The estimated separation dates were between October 1988 and December 1990. (*See table on page 30.*)

Analyzed samples included parts from Iraq's calutron programme for uranium enrichment: an ion source (top) and pieces of a graphite collector.

Results of isotopic measurements for calutron pieces

Sample	²³⁵ U Abundance (wt %)	Remarks
Ion Source 1	0.71	Natural Uranium
Ion Source 2	0.71	Natural Uranium
Collector 1-1	0.76	Slightly Enriched
Collector 1-2	5.82	Enriched
Collector 1-3	4.76	Enriched
Collector 1-4	0.39	Slightly Depleted
Collector 1-5	6.84	Enriched
Collector 2-1	0.06	Highly Depleted
Collector 2-2	5.94	Enriched
Collector 2-3	4.22	Enriched
Collector 2-4	0.79	Slightly Enriched

Techniques applied at SAL on Iraq samples

Analytical method	Measurement – Safeguards
High-resolution gamma-ray spectrometry	Pu isotopic abundances Amount of ²⁴¹ Am, ²³⁷ Np (Presence of radionuclides)
Alpha-particle spectrometry	²³⁸ Pu abundance (Presence of ²¹⁰ Po)
X-ray fluorescence spectrometry	Major, minor, trace elemental analysis
K-edge densitometry Hybrid XRF K-edge	Amount of U, Pu, Th, Np in solutions
McDonald/Savage potentiometric titration	Amount of Pu in pure nuclear materials
NBL modified Davies/Gray potentiometric titration	Amount of U in pure nuclear materials
Optical emission spectrometry	Trace elements in U compounds
Thermal ionization mass spectrometry	U, Pu isotopic abundances
Isotope dilution mass spectrometry	Amount of U, Pu in small samples

Analytical techniques, capabilities, and support

Two specific branches of the IAEA's Seibersdorf Laboratories have been involved with the analysis of samples from the Iraq inspections: the Safeguards Analytical Laboratory (SAL) and the Physics, Chemistry and Instrumentation Laboratory (PCI). Most of the work was done in SAL's Chemical Analysis and Isotopic Analysis Unit and PCI's Chemistry Unit.

Additional support was provided by the Research Centre (ARC) in Seibersdorf, the Atom Institute of the Austrian Universities in Vienna, and by one commercial and several governmental analytical laboratories in other countries. ARC supplied rapid alpha-particle measurements for screening of non-nuclear material samples for the presence of uranium.

Samples of steel were sent to a commercial metallurgical laboratory to determine the type, and, therefore, their usefulness for building gas centrifuge components. Government laboratories in several countries accepted samples on which they performed highly sensitive and precise measurements; one such technique which proved very useful was the isotopic analysis of microscopic particles containing nearly pure compounds of uranium.

Safeguards Analytical Laboratory (SAL). Analytical capabilities at SAL have been developed over the years for two basic purposes:

- *The analysis of routine safeguards inspection samples containing significant amounts of uranium or plutonium.* This capability for off-site destructive

analysis offers the highest levels of precision and accuracy in order to detect small cumulative losses of safeguarded material (bias defect detection).

- *The application of techniques of chemical analysis for use in on-site measurements, either by the State safeguards system or by IAEA inspectors.* In this role, SAL acts as a training ground for inspectors and is in a position to advise the IAEA inspectorate about analytical methods in use at safeguarded facilities.

For the Iraq assignment, the techniques selected for the first type of analysis, that of routine safeguards samples, were chosen for their high precision and accuracy, their selectivity for uranium or plutonium, and in some cases their sensitivity (because of the problems associated with shipping large samples). (See table.)

Certain techniques, such as high-resolution gamma spectrometry and X-ray fluorescence spectrometry, are capable of measuring a large number of isotopes or elements. For this reason, these methods were extensively used in screening the non-nuclear material samples, whereas the more traditional safeguards analytical techniques were used for the nuclear material samples.

Physics, Chemistry and Instrumentation Laboratory (PCI). PCI performs a broad range of measurements in support of IAEA programmes. Activities range from the measurement of radionuclides in the environment (such as was done for the International Chernobyl Project) to the provision of quality control standards under the Analytical Quality Control Services (AQCS) programme.

For screening and analysis of inspection samples from Iraq, a variety of measurement techniques was available in PCI that are broadly divided between non-destructive and destructive analysis methods. (See table.) Non-destructive methods include:

Neutron activation analysis (NAA). This was the primary method used to determine fluorine and chlorine in the special inspection samples. NAA involves the irradiation of samples in a nuclear reactor to produce radioactive isotopes of the elements present, followed by immediate counting of the gamma-ray spectrum. From the intensities of characteristic gamma emission lines, it is possible to calculate the concentration of the original elements present. NAA can be quite rapid, allows for a large number of samples to be measured by automatic equipment, and is essentially non-destructive.

Gamma spectrometry. This was used extensively to assay the samples for radioactivity and the presence of uranium above the background level of about one microgram per gram of sample. Also measured were fission product elements resulting from the reprocessing of spent reactor fuel. Once again, the advantage of this method is its ability to give a quick analysis, without elaborate sample preparation. Another advantage is the broad coverage it offers for detection of radionuclides without any prior knowledge of the sample composition.

X-ray fluorescence analysis. Whether excited by a radioisotopic source such as cadmium-109 or an X-ray tube, this method is a rapid screening technique with a detection limit for uranium of about

1 microgram per square centimeter. Most other elements of interest will also be measured by this method (except for the lightest ones), thus making it ideal for determining the composition of metals, powders, or solutions. Quantitative information can be obtained if appropriate standards are available.

Among the destructive analytical techniques at PCI are:

Laser fluorimetry. This method offers the highest sensitivity and accuracy for uranium determination. It relies on the optical fluorescence of uranium compounds following illumination by ultraviolet laser light. The sample preparation for such measurements involves ashing the specimen in air at 500°C to remove all organic components, followed by dissolution in hot nitric acid. In some cases, it is necessary to chemically separate the uranium from interfering elements by a solvent extraction procedure. The final measurement by laser fluorimetry is performed in a phosphate medium to achieve a high luminescence yield.

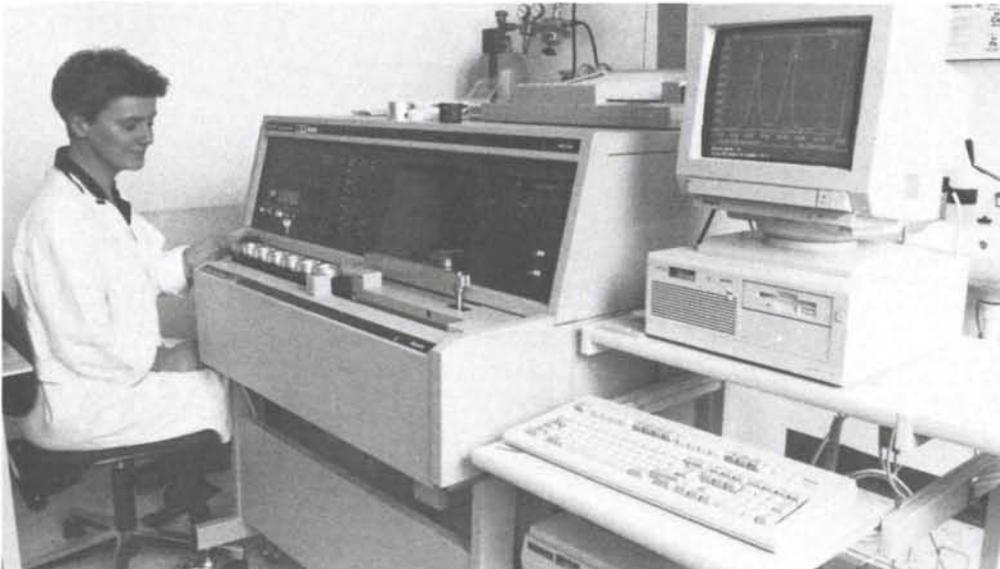
Inductively coupled plasma-atomic emission spectrometry (ICP-AES). This technique was used to obtain information about the concentration of uranium and many other elements in dissolved samples. It relies on the atomization and excitation of the sample atoms in a high-temperature argon plasma. The excited atoms emit light at wavelengths which are characteristic for each element. The intensity of the emission at a given wavelength is a measure of the concentration of the element in the original sample. This method was especially useful for measuring the trace elements in water samples from the pool of Iraq's IRT-5000 research reactor and the spent fuel storage ponds. The presence in such samples of elements from the fuel cladding would be indicative of corrosion or damage to the fuel, with serious consequences. The ICP-AES results, in conjunction with the pH and conductivity measurements, gave a consistent picture of the integrity of the fuel rods in these locations.

Alpha-particle spectrometry. Certain measurements of plutonium in Iraqi samples were performed using this technique. Its sensitivity and selectivity for

Techniques applied in PCI on Iraq samples

Non-Destructive Analysis	
Analytical Method	Measurement
Neutron activation analysis (NAA)	Amount of F, Cl, U, and elemental composition
Gamma-ray spectrometry	Amount of U and radionuclides (fission prod.)
X-ray fluorescence spectrometry	Amount of U and elemental composition
Conductivity and pH	Ionic concentration of solutions
Destructive Analysis	
Laser-excited optical fluorimetry	Amount of U
Inductively-coupled plasma atomic emission spectrometry	Amount of U and trace elements
Alpha-particle spectrometry	Amount of U and Pu

plutonium is quite high, with a detection limit of less than one nanogram. Quantification of the amount of plutonium present is accomplished by the addition of a plutonium-236 tracer in a known quantity. The alpha-particle energy spectrum is then accumulated using a silicon semiconductor detector, and the lines of plutonium isotopes 238, 239, and 240 and the tracer are measured. Interference by the presence of uranium on this measurement is minimal because of its longer half-life and the lower alpha-particle energies emitted.



X-ray fluorescence spectrometer, one of the analytical techniques applied to samples from nuclear inspections in Iraq.

FEATURES

Selected results of analysis of samples from Iraq

Measurements of uranium nitrate solutions

Sample	Declared ²³⁵ U (wt %)	Measured ²³⁵ U (wt %)	Measured U Concentration (mg/g)
Tank 1-1	<0.1	0.088	0.781
Tank 1-2	<0.1	0.094	0.787
Tank 2-1	0.1 - 0.5	0.176	0.583
Tank 2-2	0.1 - 0.5	0.176	0.581
Tank 3-1	0.5 - 1.0	0.614	0.294
Tank 3-2	0.5 - 1.0	0.614	0.295
Tank 4-1	1 - 5	3.23	0.702
Tank 4-2	1 - 5	3.26	0.130
Tank 5-1	5 - 10	5.80	1.221
Tank 5-2	5 - 10	5.81	0.647
Tank 5-3	5 - 10	5.81	0.992
Tank 5-4	5 - 10	5.80	0.517
Tank 5-5	5 - 10	5.81	0.800

Plutonium isotopic analysis by high resolution gamma spectroscopy

Sample	²³⁹ Pu abundance (wt%)	Pu Content (grams)	Estimated separation date
Spent fuel - 1	87.38	0.565	89/02
Spent fuel - 2	87.38	0.902	89/01
Spent fuel - 3	87.38	0.100	89/02
Spent fuel - 4	87.36	0.097	88/10
Natural - 1	94.54	0.047	90/07
Natural - 2	94.57	0.036	90/07
Natural - 3	95.89	0.050	n/a
Natural - 4	98.32	1.087	90/08
Natural - 5	99.10	0.498	90/03
Natural - 6	97.95	0.842	90/12

Uranium determination in phosphate ores

Sample	U content by laser fluorimetry (ppm)	U content by IDMS (ppm)	U content by gamma-ray spectrometry (ppm)
Ore - 1	63.8	56.7	61.5
Ore - 2	73.0	72.8	69.0
Ore - 3	84.5	—	87.7
Ore - 4	160.0	—	175.0

Analysis of steel by X-ray fluorescence

Sample	Element concentration - wt%						
	Fe	Cr	Ni	Mn	Mo	Co	Cu
1	47.4	18.8	25.7	1.1	4.7	0.2	1.1
2	67.5	15.2	12.2	1.4	2.2	0.2	0.3
3	67.0	16.0	11.8	1.5	2.1	0.3	0.3
4	64.6	16.6	13.4	1.5	2.7	0.2	0.2
5	64.8	16.2	13.3	1.5	2.8	0.1	0.3
6	64.8	16.2	13.3	1.5	2.8	0.1	0.3

Uranium recovery from phosphate ores. A large fraction of the uranium starting materials for the EMIS programme came from domestic uranium mines at Al Qaim. The amount of uranium obtained can be estimated from the weight of ore processed and the concentration of uranium in the ores. This information would represent an upper limit on the amount of indigenously produced uranium starting materials which were available for the EMIS or other processes in Iraq.

Several ore samples were brought back to Seibersdorf by the inspection team; the uranium content was determined by gamma-ray spectrometry and, after dissolution, by laser-excited optical fluorescence at PCI and by isotope dilution mass spectrometry at SAL. Considering the low concentration of uranium in the samples, the agreement between the various techniques is quite good. (See table on page 30.)

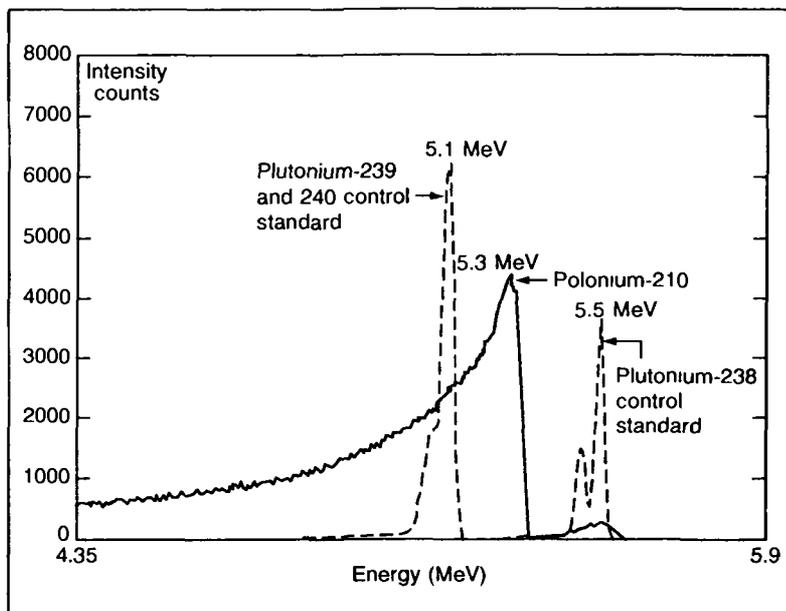
Identification of materials of construction.

During inspections, teams took a group of samples to investigate the nature of certain industrial processes in use in Iraq and to determine their possible connection to a clandestine nuclear activity. An example of this type of analysis concerned several pieces of steel which were suspected of being used for making gas centrifuge equipment for uranium enrichment. Special types of steel (maraging steel) are needed for making the rotors of gas centrifuges which must withstand very high stresses. These steels can be identified by their elemental composition, as well as by their metallurgical properties. The samples received were in the form of small irregular pieces each weighing approximately five grams. These were measured by wavelength-dispersive XRF at SAL.

Results suggest that three types of steel were found, none of which were of the special type used for centrifuge rotors. (See table on page 30.)

This kind of screening analysis can provide rapid results to the inspectors to guide their efforts in the field more effectively. A method such as XRF is needed for such measurements because the coverage of elements is broad and samples can be measured directly without chemical processing.

Another sample which was investigated in this way was a cylinder of heavy gray metal approximately 15 centimeters long and 2.5 centimeters in diameter which was suspected of being used in development work relevant to nuclear weapons. Results showed it contained 50% tungsten; 20–25% cobalt; 1–2% copper; and 1–2% niobium. These elements, however, only add up to about 80%, implying that there were other components which could not be measured. XRF is not capable of measuring the



Alpha particle energy spectrum of smear sample

lightest elements (below sodium, in this case). The most likely other component is carbon. In that case, the cylinder would be a sintered rod of tungsten-carbide, with cobalt metal used as a binder. The density of the sample (13.5 g/cm^3) is also consistent with this interpretation. Such materials are commonly used for making machine tools.

Detection of polonium-210. Documents returned by the sixth inspection team revealed that the Iraqis had been working on radioisotope neutron generators for the initiation of a chain reaction in a nuclear explosive device. These neutron generators are made with the alpha-particle emitting isotope polonium-210 and beryllium. Therefore, evidence of polonium-210 in samples from Iraq would shed light on the existence of this programme and would possibly indicate where the work had been carried out.

One smear sample from a glove-box which had been removed from the Tuwaitha Nuclear Research Centre and buried in the desert showed unusually high alpha-particle activity, according to readings of contamination meters in the field. Smear samples were taken and returned to Seibersdorf, where an alpha-particle energy spectrum was taken. Results clearly showed a peak in the smear sample at 5.3 MeV, in agreement with the expected energy for alpha particles from polonium-210. (See graph.) This interpretation also was confirmed in tests by a government laboratory.

Measurement of water samples from fuel storage pits. IAEA's UN Action Team has the task of removing all high-enriched nuclear fuel from Iraq, both fresh and irradiated. The fuel is at present in several locations: the reactor pool

**Measurements of
water samples
from fuel storage
pits**

Sample	pH	Mg (ppm)	Al (ppm)
1	8.0	47	0.03
2	7.9	57	<0.01
3	7.9	62	0.03
4	8.0	72	0.03
5	7.1	24	<0.01
6	7.7	52	0.04

and spent fuel storage pool of the IRT-5000 reactor, and in 14 pits in a storage location outside of Tuwaitha. Before arranging the transport of this fuel, it is of critical importance to know whether the fuel has corroded to the point of releasing fission products into the surrounding water. Samples of approximately 100 millilitres were taken from the IRT-5000 location, as well as from most of the pits, and brought back to Seibersdorf for analysis. The samples were assayed for radioactivity with gamma spectrometry at SAL and PCI, followed by pH measurements and spectroscopic analysis (inductively coupled plasma-atomic emission spectrometry) to determine the trace element content and to look for evidence of corrosion of the cladding (aluminum and magnesium). (See table.)

In these cases, there was no evidence of corrosion of the fuel elements, as might have occurred if the pH had been higher than about 10. In the event of corrosion, the concentration levels of magnesium and aluminum would be expected to rise by several orders of magnitude. If the uranium core of the fuel was affected, there would be detectable amounts of fission products in the water.

Lessons learned

Over the past year, a range of analytical techniques at the IAEA's Seibersdorf Laboratories have proved to be valuable assets for the evaluation of results from inspections in Iraq, and for the planning of follow-up activities. The value of such analytical results can also be measured by what they do not find, namely convincing evidence of yet undeclared nuclear programmes. In this respect, there is reliance on the sensitivity and selectivity of the analytical methods for uranium, plutonium, and other important components of the samples. These analytical capabilities — whether employed at Seibersdorf, commercial laboratories, or at government institutes — give a measure of assurance for the detection of a significant undeclared nuclear programme.

There have been several lessons learned from this analytical effort. Among them:

- The importance of prior consultation with analysts to plan the sampling effort. Here, the emphasis is on the choice of sampling and analysis methods which will give the best chance to arrive at a valid conclusion, free from interferences, blank effects, or erroneous results.
- The importance of using sampling methods that have been well thought out (validated). This must take into account what is known beforehand about the requirements and potential problems associated with the techniques that will be applied.
- The necessity of selecting analytical methods that give rapid and reliable results.
- The importance of applying inference methods to the results that take into account the sources of random and systematic error inherent in the data. In many cases, this analytical uncertainty can make the difference between a correct conclusion and a faulty one.

One important overall conclusion that emerged was clear: the IAEA was fortunate to have a wide range of analytical techniques at its disposal, supported by an efficient scientific infrastructure and well-qualified technical staff. Without this in-house analytical capability, the analysis of these samples would have been much more difficult to co-ordinate and would have led to delays or erroneous conclusions. Delays would have resulted from the necessity of establishing or activating a network of analytical laboratories using well-validated methods which were willing to take on a large sample load at short notice.

Additionally, the advantage of having these measurements carried out by a UN-related agency at an international laboratory by an international team of scientists and technicians should not be underestimated. This is important to establish the independence and impartiality of results, thus enhancing the credibility of conclusions.

In the future, it may well be necessary to build on the experience gained thus far and to strengthen the analytical capabilities available to the IAEA for responding to changing needs.