Status and Plans for Implementation 4

The International Atomic Energy Agency (IAEA) is moving to take advantage of environmental monitoring to strengthen its safeguards. The United States and other members have strongly supported this initiative with funding, expertise, and assistance with lab analysis. Implementation will call for careful planning to minimize costs and maximize effectiveness.

FIELD TRIALS

The IAEA has conducted a series of field trials in 11 cooperating member nations to determine how best to conduct environmental monitoring and the results that can be expected. A variety of installations were tested in order to gain experience with reactor operation, enrichment, reprocessing, and other functions that are likely to be employed in a weapon program.

Results from several countries have been released including Sweden, South Africa, Australia, Argentina.[1]

Sweden—tests were conducted in the vicinity of five separate nuclear facilities. Three were nuclear power stations with a total of 10 reactors. The others were a nuclear research facility and a fuel fabrication plant. All were on or near the coast (Baltic Sea or Kattegat, across from Denmark), and samples were taken of coastal water, sediment, and biota up to 30 km away. Analyses proved capable of detecting activation products from reactor operation (e.g., Co-60) up to 20 km from the site. In addition, a small amount of high-burnup plutonium, clearly distinguished from fallout, was found near the research center.

South Africa—an enrichment plant at the Pelindaba site produced the highly enriched uranium used in South Africa's seven nuclear weapons.[2] A second plant on the site produced LEU for South Africa's power reactors. These plants are now closed. Soil, vegetation, and water samples were collected in and near the facility grounds. Swipes were taken in and near the process buildings. The vegetation samples, including those taken well away from the facility,

[1] These results are drawn largely from: Bruno Pellaud and Richard Hooper, "IAEA Safeguards in the 1990s: Building on Experience," *IAEA Bulletin*, vol. 37, No. 1, March 1995.

[2] For further information, see Adolf von Baeckmann, Garry Dillon, and Demetrius Perricos, "Nuclear Verification in South Africa," *IAEA Bulletin*, vol. 37, No. 1, March 1995.

showed traces of enrichment activities. Particle analysis of swipes was consistent with bulk analysis and showed in detail various levels of uranium enrichment, including depleted and natural uranium, and LEU and HEU. The swipes gave comparable results whether taken in the process area, auxiliary rooms, or outside the buildings.

Australia—the Lucas Heights Research Laboratories has conducted a variety of activities. Swipes inside a building housing a small centrifuge enrichment development program that was closed and dismantled 14 years ago still showed evidence of enrichment, including LEU and depleted uranium. One surprising result was the discovery of uranium depleted below declared levels, as low as 0.3 percent. Investigation revealed that this was from initial tests, when the centrifuge was fed with depleted uranium.[3] Starting off with depleted uranium, which has a uranium-235 fraction lower than that of natural uranium, produces tails that are more strongly depleted than are produced from natural uranium. Isotope production included molybdenum-99 (for medical use) from irradiating targets in a reactor. Swipes showed both target material and the irradiated products.

Argentina—the Pilcaniyeu gaseous diffusion enrichment plant produced LEU until 1991. The output was used to improve performance in a heavy water reactor, so the enrichment level was low, only 1.2 percent. This level is harder to distinguish from natural uranium than the 3 percent enriched LEU used for light water reactors. Swipes were taken inside the process and other buildings. Other samples included vegetation and soil around the site, and river water, sediment and biota both up- and downstream of the facility. Analysis showed depleted and natural uranium and LEU consistent with declared activities at the site.

Other countries participating in the field trials included the United States (the K-25 enrichment plant at Oak Ridge, Tennessee), Hungary, Japan, the United Kingdom, Indonesia, Netherlands, and South Korea. A total of 12 trials (two in Japan) were conducted.

Inspectors visited the sites, collected the samples, and sent them to IAEA headquarters. From there they were distributed to various laboratories, including the IAEA's own lab at Seibersdorf, as noted in chapter 3. Labs in the United States, United Kingdom, Russia, Hungary, Finland, Canada, and Australia also participated in the analysis. In the United States, bulk samples were sent to the Oak Ridge National Laboratory, which distributed them among the analytical labs at Oak Ridge, Savannah River Technology Center, Los Alamos and Lawrence Livermore National Laboratories, and Pacific Northwest Laboratory. For example, Livermore analyzed more than 200 samples for the field trials, using ICPMS and TIMS for uranium isotopics, and AMS for iodine-129 from reprocessing or reactor operation. Samples intended for particle analysis were sent to the Air Force Technical Applications Center for distribution to its network of labs, such as at the Vallecitos Nuclear Center and McClellan Air Force Base in California.

The field trials demonstrated the practicality of environmental monitoring under a broad range of conditions. Most declared activities were verified, although in some cases, particularly in the ocean sampling off Japan, the signatures had been so diluted that the results were limited. As would be expected, streams are better sources for samples than oceans. The process can be improved as more experience is gained. Inspectors will be trained to avoid contamination and to pick the best locations for sampling. Distribution and analysis should become more efficient. Data interpretation, in particular, is a skill that takes time to learn. For example, correlations among the isotopes detected in a sample often are more informative of the process under investigation than the quantity of any isotope alone.[4]

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[3] Personal communication with IAEA staff, Apr. 4, 1995.
[4] Briefing by IAEA staff, IAEA, Apr. 3, 1995.

In addition, not all samples will have to be analyzed. Some can be archived until anomalous results suggest a more intensive analysis. Further work will also identify the key signatures that environmental monitoring can expect to identify, allowing improved focus and fewer analytical deadends. Both sampling and analysis will be better in a few years, allowing improved results at lower cost.

If the field trials had only verified activities that were known to have taken place at known sites, then little could be concluded on the feasibility of discovering clandestine activities. However, several anomalies were also discovered that turned out to be due to activities that were unknown to the inspectors. One was the detection of depleted uranium at the Australian site noted above. Another was the detection of plutonium at the Oak Ridge enrichment plant. The source turned out to have been reprocessed uranium with traces of plutonium from the Hanford, Washington facility that had been re-enriched at Oak Ridge many years earlier. Clearly, environmental monitoring can uncover previously unknown activities.

Other anomalies have yet to be fully explained. Cesium found in Hungary could have been from leaky fuel at the reactor, or it could have been from Chernobyl. More was found in downstream sediments than upstream, indicating a reactor source, but the difference could also have been a result of variable fallout or poor sampling.[5] If from the reactor, one would have expected to find cobalt-60 (an activation product of steel) also, as was the case in Sweden, but none was associated with the Hungarian cesium. At another site, a particle of HEU (30 percent enriched) was found that had no relationship to any activities at the site. It may have come from a previous visitor. Contamination, whether from an inspector or introduced in staging areas, is the most probable explanation for most anomalies.

As indicated in chapters 2 and 3, enrichment plants and reprocessing plants are easier to detect than reactors. In particular, reprocessing plants produce a variety of emissions that can be found in several different types of samples. Iodine from Dounreay and Sellafield in the United Kingdom has been detected in samples taken at the Chalk River facility in Canada by using a very sensitive accelerator mass spectrometer. Vegetation samples 30 km from Dounreay showed clear radionuclide evidence of reprocessing.[6] Of course, Dounreay is a very large source; a small, clandestine reprocessing plant probably could not be "seen" from as far away. Enrichment plant signatures are hard to detect using water sampling techniques, even those that concentrate radionuclides from high volumes of water. Lichens and moss are better media for detecting signatures from enrichment plants. Reactors were detected mainly from on-site water samples. A small, clandestine reactor would be quite hard to detect, especially if the background included a significant amount of contamination from fallout from nuclear weapon tests, Chernobyl, or the production and use of radioisotopes for medical or research purposes. R&D facilities were best characterized by swipe sampling inside the buildings; these samples produced unambiguous signatures, especially for isotopes such as uranium-235. Outside such facilities, vegetation and water samples showed evidence of nuclear activities as far as several km away.

The measurement of radionuclides from on-site sampling proved particularly effective. For isotopes of uranium and plutonium, particle analysis gave more precise results than bulk analysis. The combination of on-site samples and particle analysis was so sensitive that samples taken in common areas in enrichment plants showed comparable results to process room samples. However, the field trials also demonstrated that other sampling and analytical techniques work well too; nuclear activities can be detected at

[5] Personal communication with IAEA staff, Apr. 4, 1995.
[6] Ibid.

least several kilometers away from the emission point, and bulk analysis gave the same general results as particle analysis, although not as clearly. However, bulk techniques could analyze a larger portion of the sample, increasing the chances of getting a "hit." The different techniques complement each other and any of them may be most appropriate for particular conditions.

TRAINING

Taking samples for environmental monitoring is somewhat different than conducting conventional safeguards inspections, and inspectors must be adequately trained. Most inspectors are technically competent (they routinely sample process lines and operate sophisticated instruments), and environmental sampling tasks are relatively straightforward. However, the sampling strategy must be carefully planned, and contamination standards are much more stringent than for conventional safeguards. Furthermore, the quality assurance procedures are demanding. For example, inspectors have to record exactly where a sample is taken. The mechanics of the sampling can be taught in a day or two, but proper procedures must be learned over a longer period. In addition, enhanced observational skills (e.g., the ability to notice suspicious or anomalous equipment) must be taught so that inspectors can comply with the new activism in seeking out evidence of proliferation, as suggested by the IAEA Programme 93+2.

Only a few inspectors have had training in environmental sampling techniques. Oak Ridge provided training for most of those involved in the field trials (about 10). An initial training program has been conducted at Seibersdorf, with the first group in June 1995.

TECHNICAL CAPABILITIES AND THE NEW CLEAN ROOM

The IAEA did relatively little of the lab analysis for the field trials and expects to continue to rely on member states for much of the analytical work as environmental monitoring becomes a routine part of safeguards inspections. In fact, it may have to expand its network of laboratories as the work load grows.

The IAEA is building one essential facility for the new safeguards program—a clean lab to receive samples from the field, perform some analyses, and hold other samples until they can be transferred to its network of outside labs. Samples cannot be sent directly to an outside analytical lab because it is necessary to maintain confidentiality for the inspected facility. The samples are kept anonymous, which may involve repackaging and splitting them. As has been noted, it is essential to avoid contaminating these samples, and a clean room—where the air flow is carefully designed and filtered—is necessary to properly handle them. The clean lab will be at Siebersdorf, Austria, where the IAEA already has a large laboratory, but it will be kept separate from the other labs to minimize the risk of cross contamination. It will contain some of the basic instruments such as an electron microscope and a TIMS. The IAEA must be able to independently confirm results (especially positive results) to maintain its credibility with inspected states, but for analyses requiring expensive techniques such as AMS and particle analysis it must continue to rely on member states.

The clean lab is expected to be in operation by the end of 1995. The total cost for the lab itself (not including instruments) will be $3 million, of which $1.5 million is being covered by the United States. The equipment to be housed in the facility will cost approximately another $2 million, which will come from the IAEA's regular budget.[7] Additional funding ($160,000) could be used for a low-level gamma spectroscopy system to screen samples. The clean lab operations will require two professionals and two technicians. U.S. help is technical as well as financial. An American expert has been loaned to the IAEA

[7] Briefing by IAEA staff, Apr. 3, 1995.

for two years to help design and construct the lab, and other expertise also is being transferred.

Many improvements are expected in the future. Instruments and techniques under development in the United States are reviewed in chapter 5. Other work that may be relevant includes environmental restoration of weapons facilities. Studies of soil, radionuclide absorption by vegetation, and groundwater or ocean current movement provide information and models that the IAEA could use.

QUALITY ASSURANCE

The trace levels of materials sought in most samples require very stringent quality control in order to avoid contamination and inaccurate results. For example, inspectors may need new throwaway suits and booties every day. The IAEA is establishing proper procedures for taking and handling samples. Sampling kits have been designed and provided to inspectors with U.S. lab help. Generally two inspectors are needed—one to collect the sample and the other to hold the bag it goes into. The two cannot change roles during the day because of the risk of cross contamination.

Analytical labs also must practice strict quality control, both in the handling of samples and in the analysis. Some of the network labs may have been unaccustomed to the need for such quality control, because contamination occurred several times.

One of the clean lab's important functions will be to ensure adequate quality assurance at all stages.

IMPLEMENTING ENVIRONMENTAL MONITORING

The IAEA has been shifting its fundamental approach to safeguards. In prior years, particularly before the 1991 Persian Gulf War, its objective was primarily to verify that a state was doing what it said it was doing. States were required to declare all their nuclear material and establish a system of controls for it. The IAEA measured the material and verified that none had been misappropriated. Verification that no other activities were taking place was not seen as part of the IAEA's job, even though countries commit under the Non-Proliferation Treaty (NPT) to refrain from developing nuclear weapons in any way. This approach was adequate only if all members could be trusted, in which case such verification arguably would not be needed at all. It was shown to be fundamentally flawed when countries such as Iraq and North Korea proved themselves willing to ignore their commitments.

The new approach embodied in the IAEA Programme 93+2 is much more activist. If fully implemented, as the Board of Governors indicated it would be at the March 1995 meeting, the IAEA will search for undeclared activities. The State's declaration will still be the starting point for verification, but the IAEA will look for signs that contradict it. For example, the IAEA could cooperate with supplier states to determine if any countries are importing equipment inconsistent with peaceful, declared uses of nuclear power. It could also conduct literature searches and demand more information from inspected states.[8] The IAEA might take a country-wide approach—where might an undeclared facility be, considering factors such as national abilities, expertise, and topography, and how does one find it?

The main safeguards focus will still be on nuclear material, but the scope of verification activities will be expanded considerably. Environmental monitoring will be a key part of this approach. Environmental monitoring may serve as a warning flag that other inspections are needed. By itself, it is more likely to indicate subtle inconsistencies, rather than gross discrepancies, if in fact undeclared activities are taking place. It will also raise confidence where they are not taking place. Thus it will be a sorting tool used in combination with other conventional

[8] Personal communication with IAEA staff, Mar. 31, 1995.

safeguards, not a replacement. For example, if a country has reactors but no reprocessing facilities, the IAEA could use environmental monitoring to verify that no reprocessing is taking place. With that assurance, the frequency of inspections to verify that spent fuel has not been diverted (now every three months) could be reduced, since environmental monitoring can give a timely warning.[9]

Such a reduction in inspections entails some risk because a country might send its spent fuel to another country for reprocessing without notifying the IAEA. Alternatively, it could construct a clandestine reprocessing plant and not operate it until ready to quickly construct nuclear weapons. Environmental monitoring would not detect either of these avenues. However, both introduce considerable uncertainty and the potential for delay. Shipping spent fuel could be slow and might itself be detected. The reprocessing country might not apply the same level of secrecy, increasing the potential for detection, or might not even return the plutonium. Unused reprocessing plants, even small ones, are likely to require a significant shakedown period and are likely to release detectable emissions before purifying substantial amounts of plutonium. Therefore, environmental monitoring can support a reduction of inspections if accompanied by political analysis and broader information gathering.

Planning

Further study will be required before environmental monitoring can be fully integrated into the safeguards system. The major uncertainty is over the ability to find undeclared sites. Finding these will be very different than finding undeclared activity at declared sites. Potential proliferants will have greater incentive to build undeclared, covert facilities if they judge that weapon activities co-located with safeguarded facilities will be detected. More field trials are likely to be necessary to develop and test the means to find undeclared sites, especially reprocessing and enrichment plants. By definition, this means long-range monitoring, especially of rivers, which were not intensively examined in the earlier field trials.

The IAEA and several member states, including Canada and several Scandinavian countries, already are discussing field trials specifically designed to detect such activities.[10] Tests in weapon states would be particularly useful, but—given the power of environmental monitoring—they would have to be carefully designed to avoid compromising national security. The United Kingdom might be a possibility.[11]

A detailed plan for implementing environmental monitoring will be needed. An outline was prepared for the June IAEA Board of Governors meeting, but the full plan will not be ready before 1996. The full plan should cover topics such as facilities that will be subjected to environmental monitoring, the level of effort of inspectors at each kind of site, the training and equipment they will need, the labs to which their samples will be sent and the type of analysis to be done, procedures for quality assurance, how current safeguards will be modified, and the cooperation that may be needed with the host state. This plan will need considerable input from IAEA operations personnel and review and acceptance by member nations.

In addition to the general plan, specific plans will be needed for each site. Sampling must be done on the basis of the known operations at the site and expected signatures, possible undeclared activities, and the specific site characteristics such as topography and environmental conditions. The IAEA is documenting signatures from all relevant activities (see chapter 2). A current project at the Pacific Northwest Laboratory is developing a computer program, the EM

[9] Personal communication with IAEA staff, Apr. 4, 1995.
[10] Briefing by IAEA staff, Mar. 31, 1995.
[11] Personal communication with IAEA staff, Apr. 4, 1995.

Assessment Tool, which helps the user to plan inspections based on site and operational characteristics, and on safeguards needs and capabilities. This tool could be quite useful for wide area monitoring.

Initially, the plan will have to focus on sampling at declared sites. It will be very expensive if every safeguarded site has to be exhaustively sampled and analyzed. Nevertheless, the IAEA has to be sensitive to member concerns about being unfairly singled out for closer examination. Perhaps a list of critical facilities can be selected initially, with the number (e.g., 50) large enough to avoid charges of discrimination but small enough to be manageable. Baselines for these facilities could then be established.[12] Baselines will be especially important at research complexes that have a variety of activities that could produce emissions similar to weapons production. (Such places would be logical sites for covert nuclear facilities if remote siting is not possible.) Future samples can then be compared with the baseline to see if any new activities have been introduced.[13]

Data interpretation

Interpreting the information that is developed will be a particularly important function that will also be especially difficult to implement. If a confrontation with an inspected state ensues, it must be based on very strong evidence with virtually no chance of error. The IAEA must spend considerable effort on this area. Confidence is hard to quantify, especially since environmental monitoring is so different philosophically from current safeguards. The United States is providing assistance in this critical area.[14] Russia and the United Kingdom also could provide useful help. However, much of the equivalent work done by member nations is classified and will be difficult to share.

Costs

Adding environmental monitoring to the IAEA's activities should not greatly affect its budget.[15] Over the past nine years, the Safeguards Division budget has been under a zero growth restriction (actually it has been slightly negative when corrected for inflation). Additional costs for inspection and analysis will have to be largely balanced by reductions in other activities, such as material accountancy, and by learning to do more with less. As noted above, the frequency of some inspections may be reduced because of environmental monitoring. The United States paid for most of the field trial laboratory analysis, but the IAEA will have to cover these costs when the activities become routine. U.S. assistance has also included cost-free experts, who are individuals whose services are provided free of charge to the IAEA, but both the United States and the IAEA have limits on how many such experts can be supported. Safeguards in general, and environmental monitoring in particular, cannot be seen as a U.S. operation. Other nations must also be involved both financially and technologically for the IAEA to maintain its credibility. Fortunately, the level and breadth of support from other members has been quite good.

CONCERNS OVER ENVIRONMENTAL MONITORING

The IAEA will have to deal with several concerns on the part of inspected nations. Environmental monitoring is predicated on finding radionuclides released from nuclear facilities to the local environment. Many people are worried about exposure to any radioactive materials. Even though the level of radiation sought by environmental monitoring is far below any that might cause health problems, some people may become concerned that any radioactivity is being

[12] Briefing by IAEA staff, Mar. 31, 1995.

[13] Anthony Fainberg, *Strengthening IAEA Safeguards: Lessons from Iraq*, Center for International Security and Arms Control, Stanford University, April 1993.

[14] Personal communication with IAEA staff, Apr. 4, 1995.

[15] Personal communication with IAEA staff, Mar. 31, 1995.

found. Public opposition could increase just by the knowledge that inspectors are looking for such radioactivity. Release of information on the material found could increase opposition even more, no matter what the levels are. Plutonium is particularly worrisome, as many people are unaware of how ubiquitous it is. Regulatory problems also are possible if radioactive materials are found.

Some states will have to make significant adjustments to accommodate environmental monitoring. Where operators have downplayed the emissions of plutonium and other radionuclides, new approaches to explaining the results will be needed, especially if standards have actually been exceeded. A compensating factor is that environmental monitoring may be quite useful for the state to achieve its own health and safety goals. Overall, most nations should be able to accept environmental monitoring, though they may want to place some conditions on it, such as the release of information.

A second concern is over competitiveness. Emissions can contain information on the process used in an enrichment or fuel fabrication plant. If this information falls in the hands of competitors, it could be damaging. The IAEA employs nationals of many different states, and it is not impossible that one would pass the information to a company back home. This is a more easily managed problem than public opposition. The IAEA already has access to plants with competitive concerns and is able to maintain confidence. Strict confidentiality of the samples, as will be accomplished by repackaging at the Siebersdorf facility, will help.

In addition, the advanced states may worry about compromising their own national security technology secrets. Some of the analytical techniques that are used for environmental monitoring were developed for national security purposes, and these states may not wish them to become more widely known.

CONCLUSIONS

Environmental monitoring will significantly increase the effectiveness of IAEA safeguards, especially for the detection of undeclared activities at declared sites. Implementation should be relatively straightforward, though considerable planning and consultation with all parties to the activity will be necessary. As the IAEA becomes more proficient, and improved technologies are made available, capabilities should expand considerably. U.S. assistance will be essential in this process.