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A Discussion of Procedures and Equipment for the Comprehensive Test Ban Treaty On-Site Inspection Environmental Sampling and Analysis

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Summary

This paper is intended to serve as a scientific basis to start discussions of the available environmental sampling techniques and equipment that have been used in the past that could be considered for use within the context of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) on-site inspections (OSI). This work contains information on the techniques, equipment, costs, and some operational procedures associated with environmental sampling that have actually been used in the past by the United States for the detection of nuclear explosions. This paper also includes a discussion of issues, recommendations, and questions needing further study within the context of the sampling and analysis of aquatic materials, atmospheric gases, atmospheric particulates, vegetation, sediments and soils, fauna, and drill-back materials.

Contents

1.0 Sampling and Analysis

The efficacy of sampling and analysis within a Comprehensive Nuclear-Test-Ban Treaty (CTBT) on-site inspection (OSI) depends on the procedures and equipment available to sample the mobile and fixed signature radionuclide elements or compounds and on the ability to distinguish the nuclear explosion signatures from background signals and attribute them to a nuclear source. The CTBT text explicitly states:

> *69. The following inspection activities may be conducted and techniques used, in accordance with the provisions on managed access, on collection, handling and analysis of samples, and on overflights:*
>
> *(d) Environmental sampling and analysis of solids, liquids and gases from above, at and below the surface to detect anomalies…*

Nuclear explosion signatures released to the environment must be separated and distinguished from primordial and man-made backgrounds in soils, sediments, air, and surface and underground water. Certain portions of the nuclear fuel cycle, such as reactors and reprocessing facilities, as well as medical and industrial radioisotope production that may be upwind or upriver, will contribute radionuclides that serve as a background source against which a CTBT OSI must reliably analyze for a nuclear explosion; past nuclear tests also provide a source of background radionuclides through their worldwide fallout or at the actual test locations. The delay time between the nuclear explosion and the date of the OSI will determine which radionuclides would be analyzed based upon their half-lives. Various sampling and analysis technologies have been considered here for application to an OSI. Sampling procedures and equipment discussed are aimed at aquatic, airborne particulate, gas, vegetation, sediment and/or soil, and fauna media. Specific procedures must be selected based upon the application scenario; for example, sampling in the northern latitudes under freezing conditions, sampling at the equator under tropical rainforest conditions, sampling in the mid-latitudes under desert conditions, and sampling in the marine environment require different equipment and procedures. Costs associated with the sample collection and analysis procedures and equipment can be estimated once all factors listed above are considered. Cost is driven primarily by the sampling frequency and density which in turn drive the amount of equipment required, laboratory analysis requirements, and also impact maintenance, infrastructure, and personnel costs. Equipment maintenance and resupply costs at the Comprehensive Nuclear-Test-Ban Treaty Organization's Equipment Storage and Maintenance Facility must be included. Costs are also incurred for all equipment calibration, meteorology, and hydrology evaluations, as well as for quality assurance and analysis standards.

For an OSI, samples should be collected upwind or upriver from the possible nuclear explosion site as well as within the confines of the inspection area which according to the Treaty could cover up to 1000 km^2. Sampling frequency will depend on whether the OSI is sampling puffs or plumes and whether or not the signature signal is diluted by background or is elevated due to releases from the nuclear explosion. The areas to be sampled, and the procedures and equipment to be considered, are determined by the distance from the possible nuclear explosion location at which the radioactive effluent might be detected. Sparse sampling to drive down costs not only lowers the probability of detection but provides no sampling capabilities for areas farther from the point source; thus, transport of the radionuclides to a distant point does not get covered. Environmental sampling and analysis should be based upon a statistical evaluation of the number of samples and sites to be pursued.

2.0 Common Issues for Further Study

Onsite environmental sampling within the context of the CTBT would be preceded by a radiation detection over-flight or an extensive and costly ground survey. The aerial ground survey could identify specific locations wherein a possible test might be located. If the survey used gamma-ray identification systems, then the detection of short-lived radionuclides on the ground/vegetation surfaces would indicate no further sampling would be required. However, if the over-flight and ground surveys only established the fact that radioactivity was present, environmental sampling could be used to detect the radionuclides produced by the event and differentiate them from non-test background sources. Concepts of Operations (ConOps) need to be written for each of the technology applications that precede environmental sampling. The advantages and disadvantages of each technique and the cost of its application need to be questioned before implementation. If a technique is too costly from either a hardware, software or manpower consideration, then alternate methods of identifying the area to be environmentally sampled must be found.

The constraints defined by the CTBT treaty and the costs of environmental sampling and analysis, may limit the extent of environmental sampling. The costs, time, and knowledgeable personnel limit the applicability of a complete sampling of the environment; thus, an adaptable sampling and analysis plan must be formulated to cover the variations that will occur for the environmental sampling of various regions including climates, seasons, and many more factors which need to be discussed. ConOps need to be written for each type of sample arising from aquatic regimes, atmospheric gases, subsurface gases, atmospheric particles, vegetation, sediments and soils, fauna, and sampling through a drill-back process. A statistical evaluation should be pursued to cover the sampling and analysis as well as the accuracy and precision of that analysis; these needs include sampling variations as well as background complications, the area to be sampled, and the number of samples. A local solution is needed to address the movement of any sample type due to the transmission of diseases to man, to animals, and to vegetation. A training plan and schedule are required that addresses all equipment operation and ConOps. Since there are many issues across the environmental sampling and analysis topic, it is suggested that activities and topical areas be identified and the issues for each type of sampling mode be analyzed and solved. The topical areas would be for the areas of surveys, aquatics, atmospheric gases, atmospheric particulates, vegetation, sediments and soils, fauna, and drill-back sampling. Specific procedures and equipment can be identified once the final radionuclide list for an OSI is chosen.

2.1 Aquatic Recommendations/Issues for Further Study

In general, the technologies to sample and analyze aquatic species are available; however, research and development into the modification of technologies to meet cost-effective needs of an onsite inspection are required. The sampling of water should include the collection of aquatic particulates, ionic species, and colloids. Technology needs to be capable of sampling in fresh, marine, and brackish waters. The collections need to ensure that a large volume of water is sampled; this should entail technologies to collect the aforementioned species from up to 40,000 liters to ensure a good detection probability. The sampling must be capable of handling waters containing a high sediment load. It is unlikely that drilling would be used to obtain a deep-well aquatic sample due to cost, complexity, and the manpower required; thus, it is expected that aquatic sampling will be limited to surface waters.

2.2 Atmospheric Gas Recommendations/Issues for Further Study

In general, the technologies to sample and analyze atmospheric gases are available; however, research and development into the modification of technologies to meet cost-effective needs of an onsite inspection are required. This is particularly true for the onsite collection and measurement of ^{37}Ar. There are differences in the analysis and collection requirements for atmospheric gases versus those for soil gases. Soil gases must have some method to ensure that their field collection is only from the subsurface and contains no atmospheric gas components. Thus, it is expected that a tracer gas must be used above the soil gas collection point to ensure a surface contamination free environment. The analysis can occur at the sampling site but would be more easily achieved by taking the collected field sample to a central laboratory analysis point that would be a part of the OSI regime. Xenon gas analysis systems such as the SAUNA could be used.

2.3 Atmospheric Particle Recommendations/Issues for Further Study

In general, the technologies to sample and analyze atmospheric particulates are available; however, research and development into the modification of technologies to meet cost-effective needs of an onsite field inspection are required. The collection and analysis can be accomplished at the sampling site or the analysis can be at a separate central facility for the OSI. The larger the volume of air to be sampled, the more expensive and labor-intensive the collection; large-to-small sampling volume equipment is available for commercial purchase. A radionuclide aerosol sampler/analyzer (RASA)-type instrument similar to that used within the IMS could be used as currently configured or with the collection and analysis systems separated.

2.4 Vegetation Recommendations/Issues for Further Study

A study needs to be completed that discusses the different types of vegetation that might be encountered; this needs to cover the various regions, climates, and seasons of the world. This study provides the types of materials to be collected such as lichens and mosses that concentrate the radionuclides of interest. Consideration must be given to the sampling of vegetation whose roots are shallow as well as those whose roots penetrate to soil depths of 10 meters such as sage brush. Water can move through the root system to the surface plant, and thus an aquatic collection can be made by this method without drilling a water sampling hole. Analysis typically requires ashing equipment to reduce the volume of the sample to a reasonable size for analysis by a gamma-ray spectrometer. It is quite unlikely that an OSI will use vegetation collections because the types of vegetation vary greatly, there are regional and local restrictions on the movement of vegetation from various points within a region due to disease transfer modes, and the fact that the costs associated with sample collection and analysis can be quite high.

2.5 Sediments/Soils Recommendations/Issues for Further Study

In general, the technologies to sample and analyze sediments and soils are available. They just need to be modified to be transportable and simple to operate. However, sampling of a 1000 km^2 area would require a rather large complement of personnel, which would probably exceed the CTBT-allowed OSI staff. Sampling is accomplished as a function of depth such that the background in the area is defined by the soil that is at depth whereas the surface soil particles represent the recent fallout. The sampling of fine particulates from surface soil can be accomplished by blowing the fine ground dusts into the air followed by their collection with a small portable air particulate sampling system; this can be accomplished with a

100-cubic feet per minute portable system. The sampling of sediments via core sampling is much more complicated, requiring boats as well as personnel. Thus, it is very unlikely that sediments would be collected from aquatic areas.

2.6 Fauna Recommendations/Issues for Further Study

Fauna collection is unlikely to occur due to the need to either kill or capture the fauna. This type of sampling requires a fairly large complement of personnel and the capability to ash the sample prior to analysis. In addition, local laws and regional cultures often preclude the sampling of specific species. However, samples such as insects may be sampled along with items such as regurgitated raptor pellets. It is quite unlikely that an OSI will use fauna collections because the types of fauna vary greatly, there are regional and local restrictions on the movement of fauna from various points within a region due to disease transfer modes, and the fact that the costs associated with sample collection and analysis are quite high.

2.7 Drill-Back Recommendations/Issues for Further Study

A separate paper should be written that includes issues such as the probability of obtaining a sample based upon the CTBT knowledge and constraints and the history of drill-back success or failure. How is the drilling site located? Does the cavity need to be reached when drilling? What are the costs of drilling and can they be accommodated within the CTBT budgets? How does the drilling equipment reach the site? How is the radioactive gas and mud separated and handled during drilling? Decontamination of the equipment is needed or new equipment needs to be purchased for each OSI.

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