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REMOTE MONITORING FIELD TRIAL

Application to automated air sampling

Report on Task FIN-E935 of the Finnish Support Programme to IAEA Safeguards

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ABSTRACT

An automated air sampling station has recently been developed by Radiation and Nuclear Safety Authority (STUK). The station is furnished with equipment that allows comprehensive remote monitoring of the station and the data. Under the Finnish Support Programme to IAEA Safeguards, STUK and Sandia National Laboratories (SNL) established a field trial to demonstrate the use of remote monitoring technologies. STUK provided means for real-time radiation monitoring and sample authentication whereas SNL delivered means for authenticated surveillance of the equipment and its location. The field trial showed that remote monitoring can be carried out using simple means although advanced facilities are needed for comprehensive surveillance. Authenticated measurement data could be reliably transferred from the monitoring site to the headquarters without the presence of authorized personnel in the monitoring site. The operation of the station and the remote monitoring system was reliable.

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1 INTRODUCTION

The purpose of the present field trial is to demonstrate the use of environmental air sampling with remote data transmission for possible future use of the International Atomic Energy Agency (IAEA). The objectives are to support the IAEA goal of placing specific facilities under remote monitoring safeguards, to maintain or improve the current level of safeguards reliability, to reduce inspection costs to the IAEA, to reduce radiation exposure to inspectors and to reduce intrusiveness to the facilities.

The trial is a joint effort between the Radiation and Nuclear Safety Authority (STUK) and the U.S. Department of Energy, which is represented by Sandia National Laboratories (SNL). STUK developed an automated high-volume aerosol sampling station for environmental radiation monitoring (Toivonen et al. 1997). The station is located on the roof of STUK headquarters, and was selected to be the remote monitoring site because of its infrastructure and accessibility. SNL developed means for comprehensive remote surveillance of the station. Sensors have been strategically placed on the air sampling station and throughout the room to provide knowledge about access to the room, motion within the room and access to the equipment cabinet. The sensors send authenticated state-of-health data and alarms to a collection unit, which then forwards this information, with radiation data files produced by the station, to authorized users at remote sites.

Plans for installations of remote monitoring equipment were discussed between 1995 and autumn 1997. The main installations for the automated air sampling station were performed in 1997 and finished in winter 1998. The first version of remote monitoring data transmission was available in autumn 1997. SNL's remote monitoring equipment was sent to STUK in January 1998 and the installation team visited STUK 10–18 February 1998. A test period of six months finished at the end of august 1998.

During the field trial authorized users were able to remotely monitor the station itself, the radiation data, the weather data and the data produced by different sensors. This was demonstrated in Vienna, March 1998, when a connection between the IAEA and the STUK www server was established. The data was accessed through internet and direct modem connection. Normal operation of the station as well as artificial incidents were demonstrated.

2 AUTOMATED AIR SAMPLING STATION

STUK continuously monitors airborne radioactive substances. The surveillance is performed using manually operated air samplers (Fig. 1) located in different parts of Finland. Samples are collected into glassfibre filters which are mailed to STUK. The filters are manually prepared suitable for quantitative gamma-ray analysis. STUK reports average concentrations periodically (Leppänen and Niskala 1996). Average concentration of different nuclides (Bq m^{-3}) is calculated from the activities of the filter (Bq), measured by a gamma-ray spectrometer, and the volume of filtered air (m^3). Average concentrations are needed for estimating the radiation hazards that airborne radioactive substances may cause in an accident.

The manual samplers are often operated in a way which does not easily allow monitoring of their status during the sampling. The status can

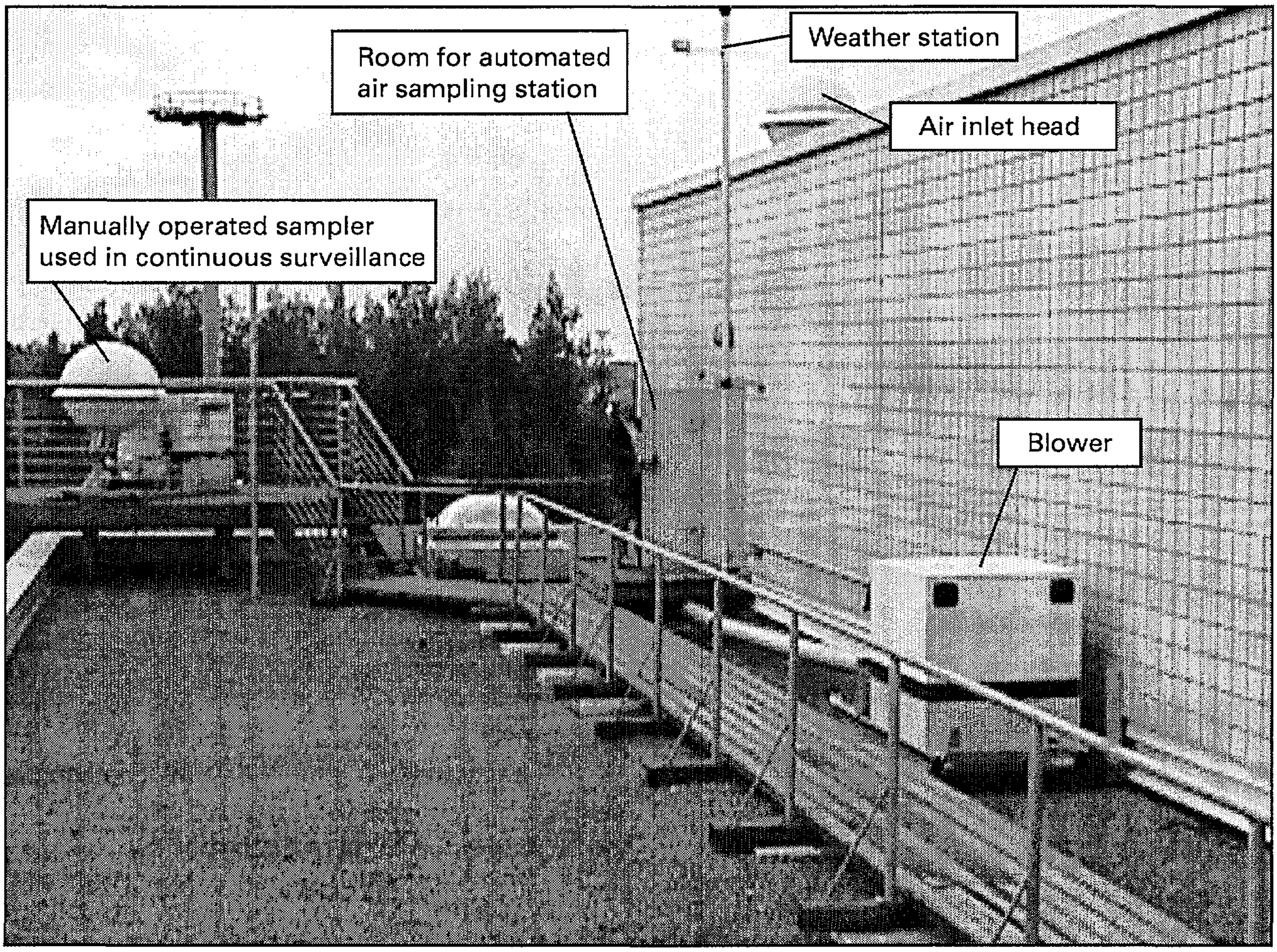

Figure 1. *The sampler used in continuous surveillance of airborne radioactive materials (left). The new fully automated sampling station is located inside the building. The air inlet head and blower of the automated station are outside. The detectors of the weather station are located on the top of the pole. The automatic sampling station is in routine operational use; it replaces the present manual sampler.*

be verified only on-site, not in the remote site (e.g. in the headquarters of STUK). The measurement data is available only after tedious sampling, sample transportation, sample manipulation and laboratory procedures.

A new fully automated air sampling station has been developed in which air monitoring surveillance is combined with remote monitoring equipment (Toivonen et al. 1998). The station filtrates radioactive substances from the air, monitors radionuclides collected on the filter in real-time, changes the filter and prepares it for on-site high-resolution gamma-ray analysis. All of these procedures are performed automatically. Furthermore, the station collects, stores, analyses and presents radiation data, weather data and process data which are integrated via the local network (Fig. 2).

The detection sensitivity of Cinderella is superior compared with any other automated sampling

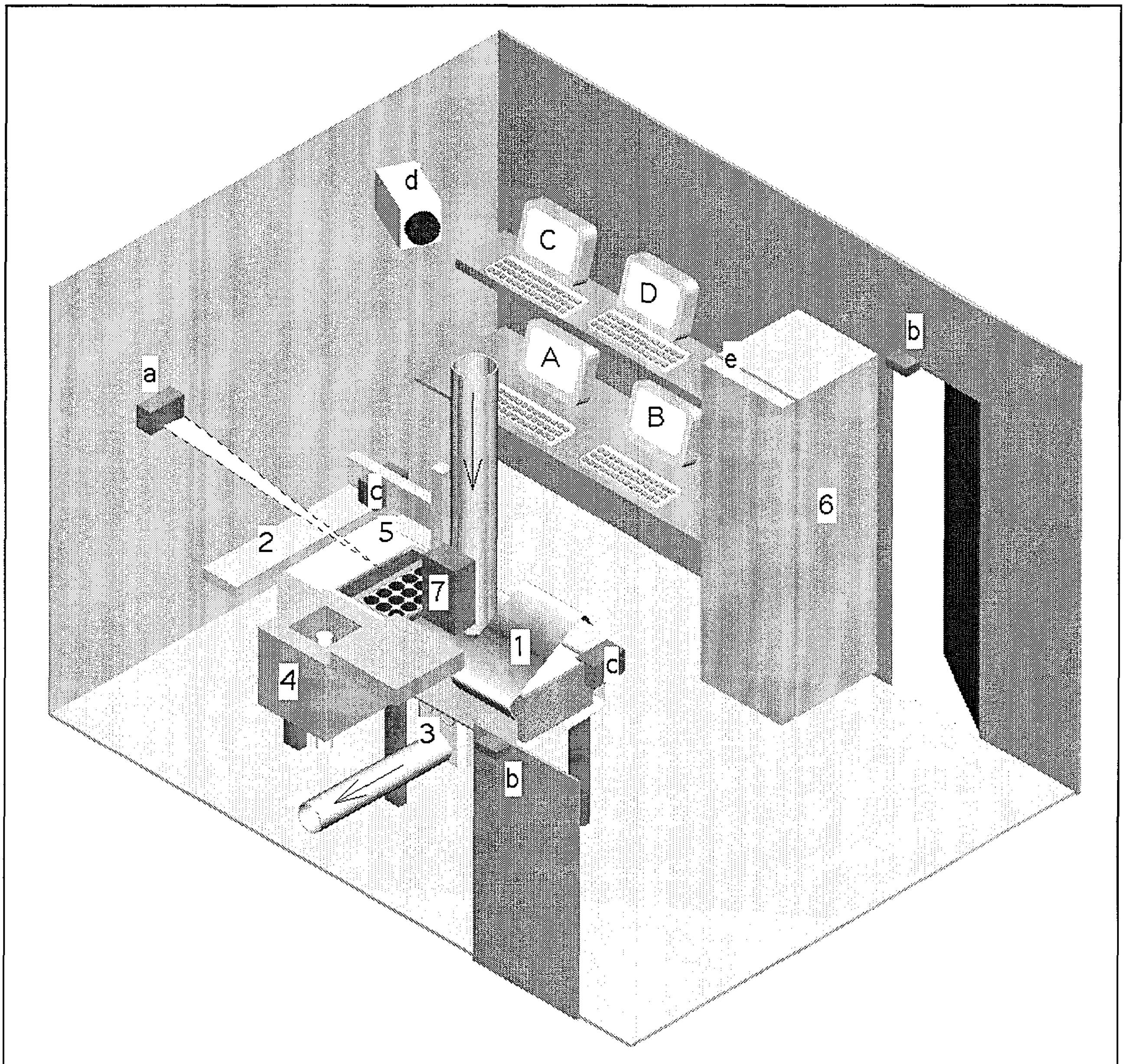

Figure 2. *Automated air sampling station. The equipment consists of 1) air sampling unit, 2) sample preparation unit, 3) real-time monitoring and alarm unit, 4) counting unit, 5) sample storage, 6) cabinet for remote monitoring equipment and 7) aerosol authentication apparatus. The remote monitoring system has a motion sensor (a), door sensors (b), air sampler door sensors (c), a video camera (d) and cabinet door sensors (e). Computers are for real-time monitoring (A), process monitoring and HPGe data acquisition and presentation (B), weather data measurements (C) and intranet/internet connections (D).*

and measuring equipment. The quality of the data is as good as can be achieved in the best manual systems with laboratory measurement.

2.1 Air sampling and filter preparation

Sampling is fully automated. Once a week the operators of the station mount fresh filters into cassettes which are then loaded in the clean filter storage (Fig. 3). In the mean time the station is working in automatic mode. Before sampling the cassettes are automatically moved into the filtration unit. In the cassette the filter is supported by a metallic grid and a specially designed base. The base consists of 15 circular holes, each with a diameter of 77 mm, arranged in a 3 × 5 matrix through which the air flows. Thus, the total area for particle deposition is 700 cm^2. The air flow rate through the filter can be selected between 300 to 800 m^3h^{-1}.

After sampling, the filter cassettes are automatically moved to the cassette storage. Filter treatment is performed by a sample manipulator (Fig. 4). The automatic process consists of filter identification, filter cutting into 15 pieces and their transfer into a plastic beaker, and beaker transfer between the sample storage and the gamma-ray spectrometer. Radiation background, produced by naturally occurring short-lived daughters of radon is reduced by decay between the end of sampling and start of counting. The decay is

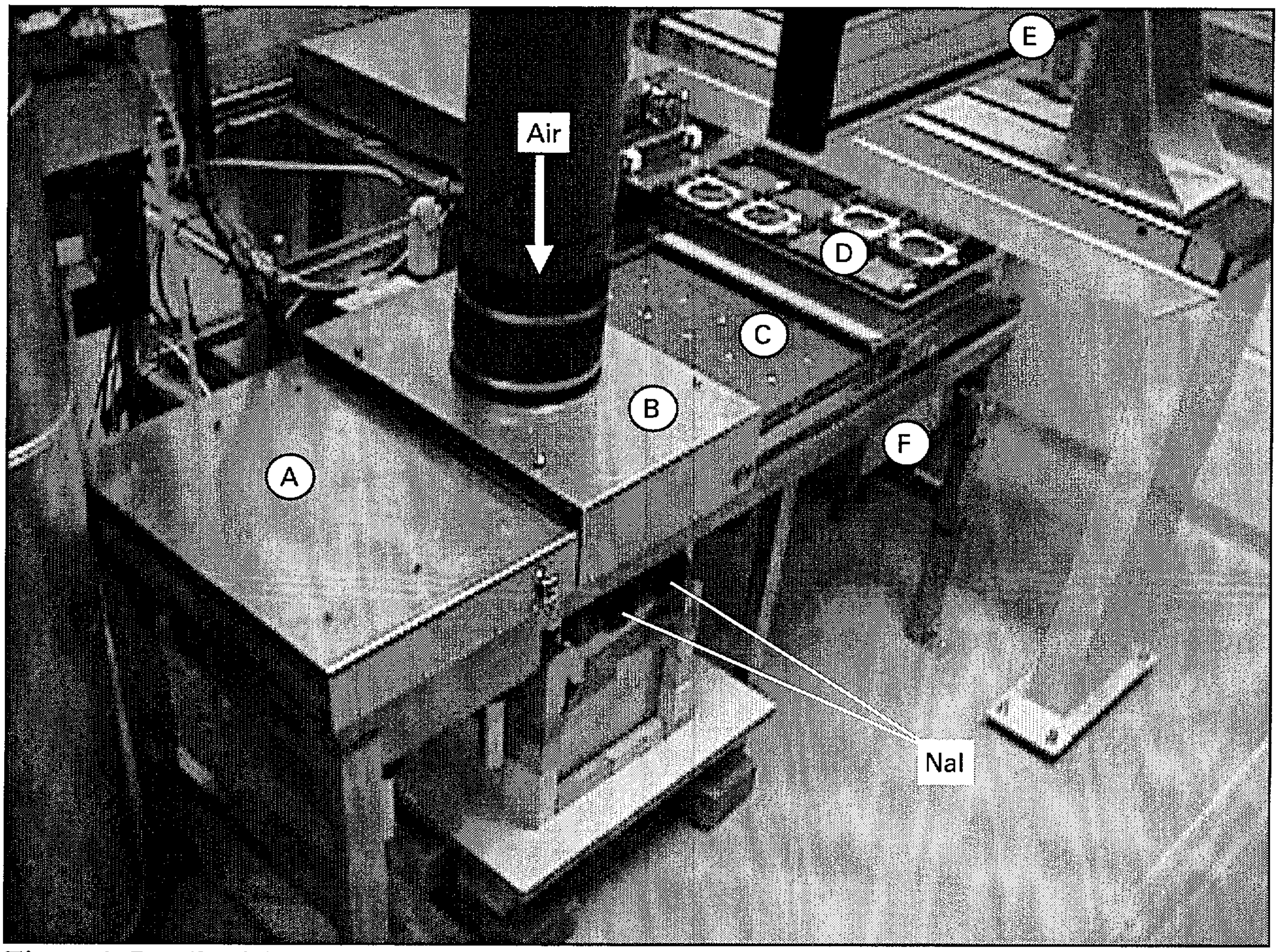

Figure 3. *Details of the air sampler. Clean filter storage (A) contains up to 7 cassettes which are automatically moved to the filtration unit (B) for sampling. 2 NaI scintillation detectors, located below the filter, are for real-time activity monitoring and alarm. After sampling the filter is moved to the sample manipulation table (C) in which the filter is cut in 15 pieces by a robot. The pieces are put in an empty beaker located in the sample storage (D). Sample manipulator (E) performs filter cutting and transfers the pieces into the beakers. After cutting, empty cassettes are moved to the cassette storage (F).*

needed to reduce the background which would hamper the detection of man-made radionuclides. The automatic duty cycle of the station is 1 d sampling, 1 d decay and 1 d measurement.

2.2 Monitoring of radioactive materials on the filter

Real-time monitoring of the filter is intended for alarm purposes but it also reveals the mode of operation of the equipment. Filter changes, shutdown of the station and abnormal radiation situations are easily traced.

Real-time activity monitoring of the filter is performed with 2 NaI scintillation detectors located below the filter (see Fig. 3). The energy range is 0–3 MeV in 256 channels and the resolution is about 40 keV at 662 keV. The peak of ^{40}K at 1460.8 keV is used for stabilizing the energy calibration against drift caused by temperature changes. The background shield is constructed of lead bricks and reduces the background radiation coming from directions other than the filter.

Special software, known as ACM, has been designed to collect the data and to visualize the spectra. The real-time software reads spectra in 1 min intervals from the multichannel analysers, calculates time-dependent cumulative spectra (sum of the counts) and saves the spectra to the hard disk. Sum spectra for the periods of 10 min, 2 h and 1 d are calculated for both detectors. The software is able to display the raw data in several

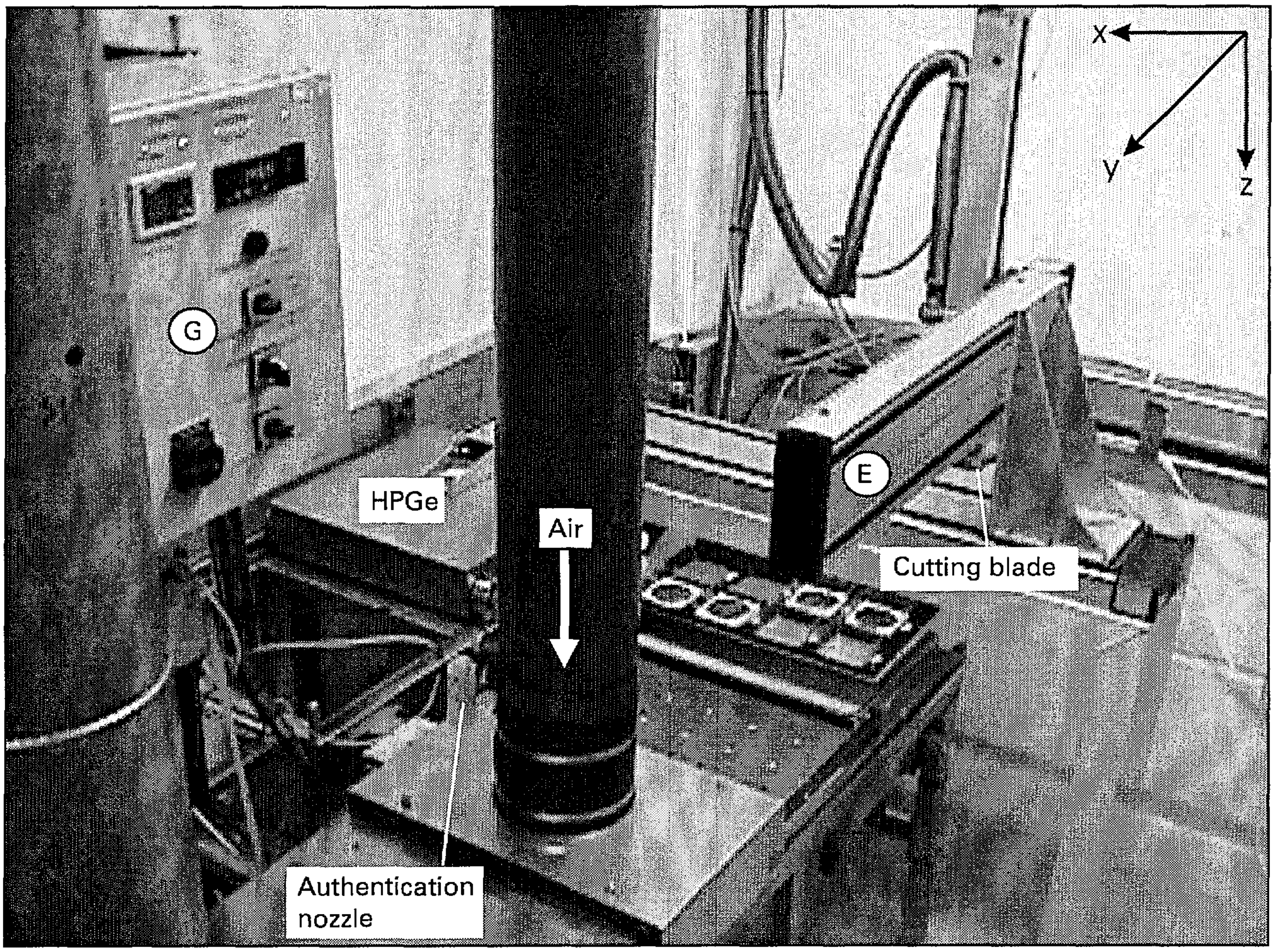

Figure 4. *Sample manipulator (E). The cutting blade (see also Fig. 7) of the arm (E) moves in the x–y–z direction. The control panel (G) for manual operation of the sampler and the HPGe detector are located behind the sampling unit. The nozzle of the aerosol authentication apparatus is on the broadside of the air inlet tube.*

different views such as spectrum channel contents, total count time series, region-of interest count time series and color-coded spectrum time series (Fig. 5). The images are saved on the disk for intranet/internet access. The spectra are analysed in real time. An alarm signal is generated should the total count rate exceed threshold limit or an unusual shape of the spectra occurs.

2.3 Gamma-ray analysis of the filter

Nuclide composition of radioactive materials on the filter is analysed using a high-resolution gamma-ray spectrometer after 1 d decay (Fig. 6). The relative efficiency of the electrically cooled HPGe detector is 100 %. The detector is placed in a copper- and tin-lined lead shield. The diameter of the detector is 89.8 mm and the height is 54.4 mm. Thus, the counting geometry is near optimum since the diameter of the active part of the samples is 77 mm and height of the stack of the filter pieces is about 8 mm.

Energy, efficiency and peak shape calibrations are checked before starting a new sample analysis. A 10 min quality control measurement takes place when the background cover shield is open (Fig. 7). A calibration source, attached on the surface of the cover, is then moved above the detector. The source does not disturb the actual sample measurement.

For various nuclides, minimum detectable concentrations (MDC) are typically 1–10 µBq m^{-3} (Toivonen et al. 1998). These limits are far better than the CTBT requirement of 10–30 µBq m^{-3} for ^{140}Ba. MDC is a function of ^{212}Pb concentration:

$$MDC = \sqrt{a + bC_{Pb}},$$

where C_{Pb} is the ^{212}Pb concentration, a = 16.57 and b = 0.4649 for ^{140}Ba (Fig. 8). The shape of the curve

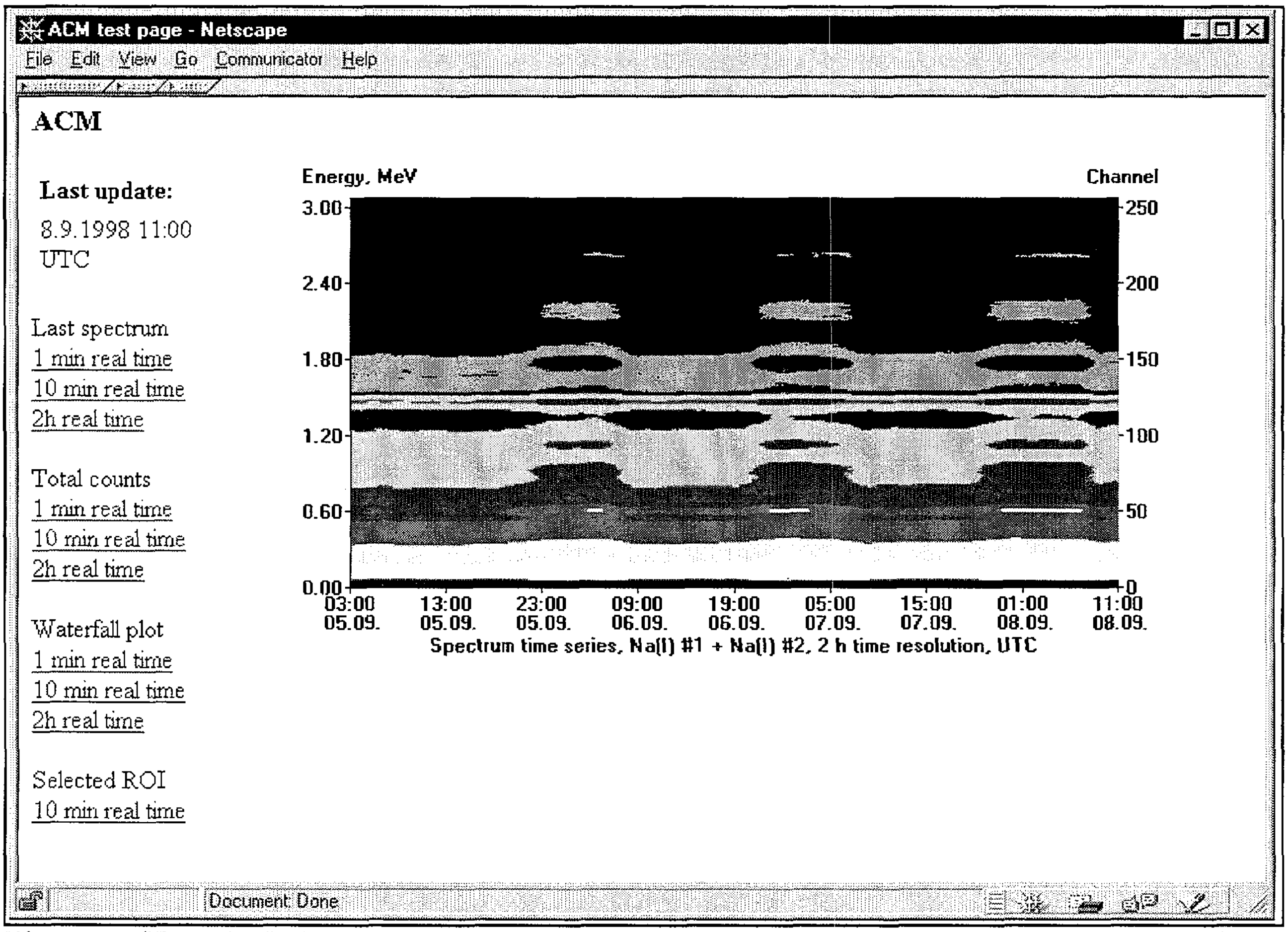

Figure 5. *"Waterfall" picture generated from NaI spectra. Each vertical line represents an individual spectrum, color-coded according to the amount of pulses in the channels. Time is in the horizontal axis. The present data was collected between 5 September 1998 03:00 to 8 September 1998 11:00, UTC. Elevated radon background during the early morning hours of 6, 7 and 8 September is clearly visible.*

is a square root because only the constant background and the thoron progenies have an influence on the baseline of the spectrum.

2.4 Sample authentication

A simple authentication system (Ylätalo et al. 1997) has been implemented in the sampling station. An aerosol tag added to the filter during sampling reveals possible tampering efforts. The tag could be an invisible chemical dispersed onto the filter at the end of the sampling sequence or it could be another signature that can be detected only by using special equipment. In the present field trial, particles of known size, shape and composition are injected into the inlet tube of the sampler. The particles are deposited on the filter from which they can be detected using different methods (Fig. 9). Tampering will be revealed in subsequent laboratory analyses if the observations do not match known characteristics of the particles.

2.5 Weather data

The automated sampling station is equipped with a weather station which measures wind speed and direction, air temperature and rain (see Fig. 1). The temperature of room air, circulated through the PVC tubes around the NaI detectors, is also measured. Indoor temperature measurements are useful state-of-health indicators.

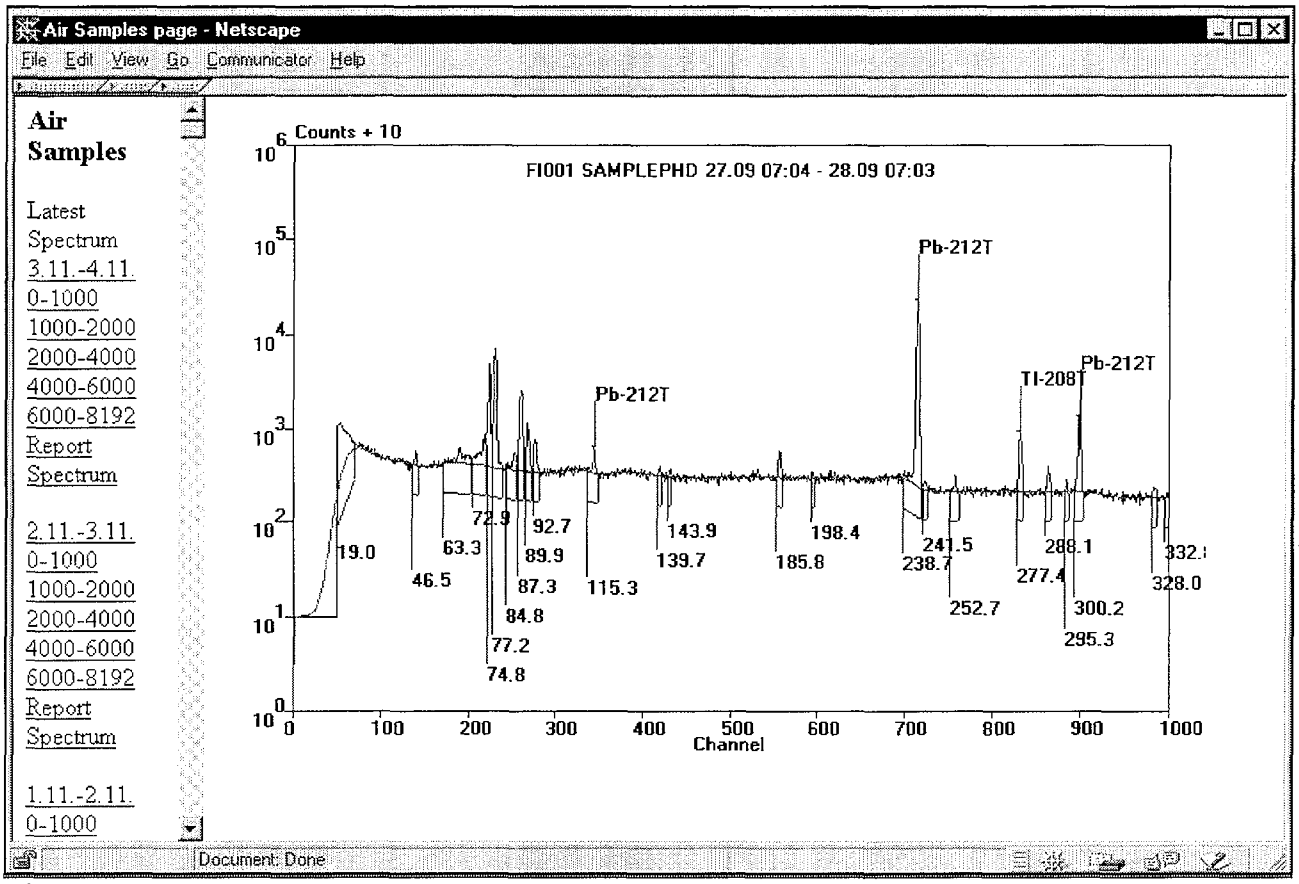

Figure 6. *Part of a typical gamma-ray spectrum (channels 1–1000) from a sample collected between 27–28 September 1998. The nuclide identification is based on suggestions performed by the Gamma-98 computer code (Leppänen 1998). Before identification the peaks of the background are subtracted. Most of the unidentified peaks refer to background nuclides. So far, the automated analysis is verified manually to prevent false identification.*

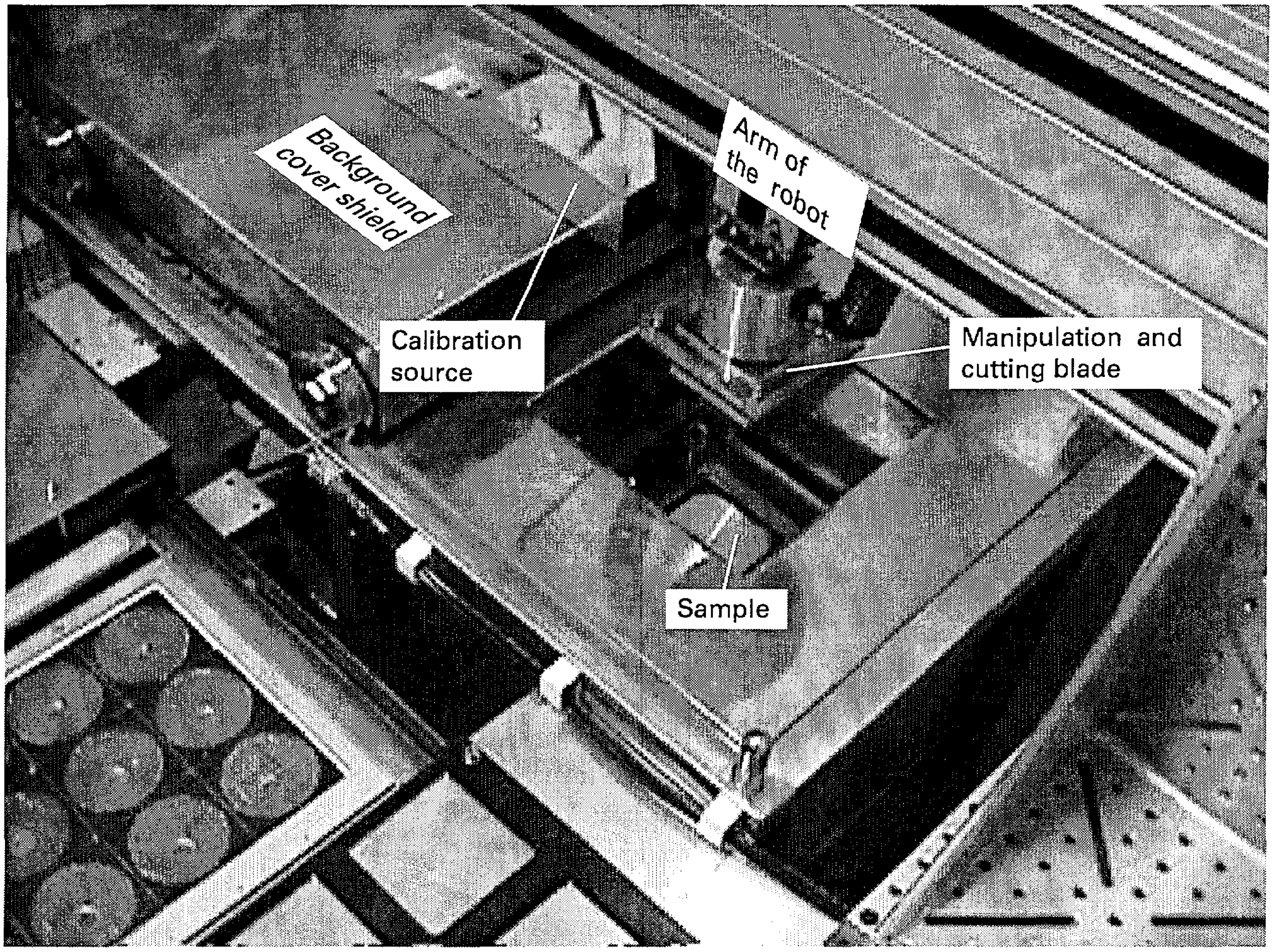

Figure 7. Sample transfer. The background cover shield of the HPGe detector is open and the cutting / manipulation blade is taking a sample out of the detector. The calibration source is located on the surface of the cover.

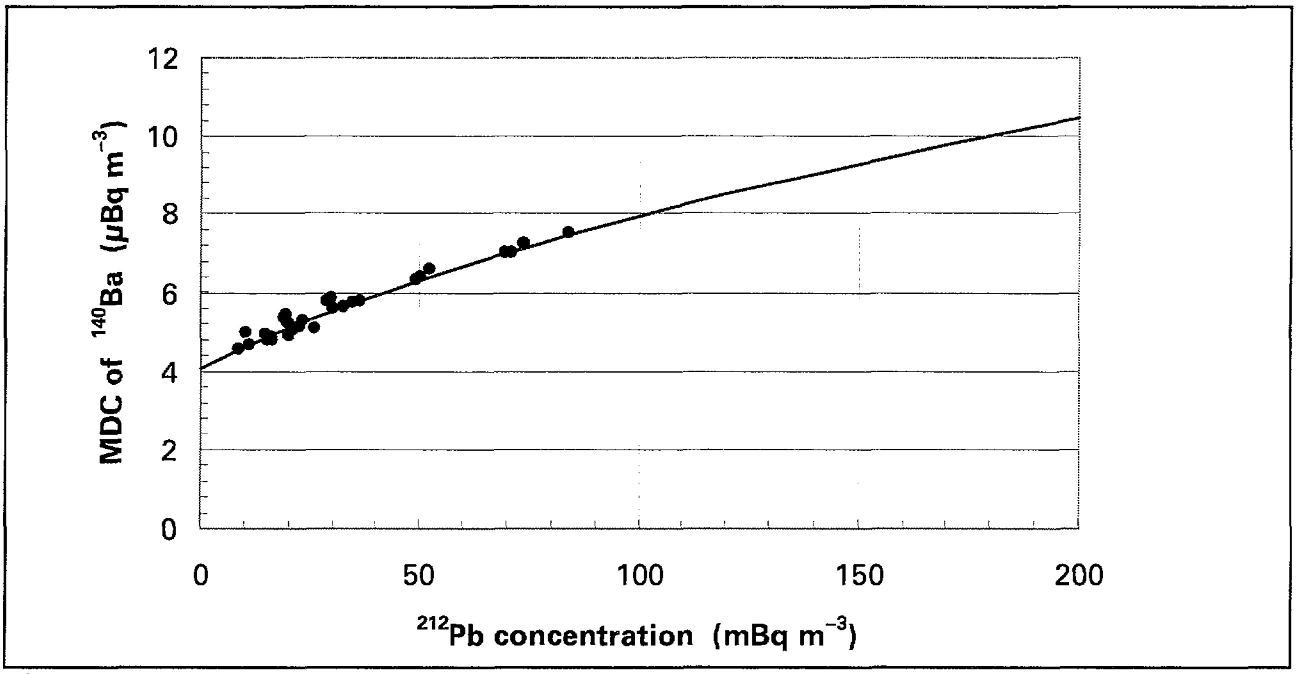

Figure 8. Mininimum detectable concentration (MDC) of ^{140}Ba as a function of ^{212}Pb concentration. Radon progenies are decayed off and the energy of ^{7}Be, 477 keV, is below the major peak of ^{140}Ba, 537 keV. The MDC calculation was performed for the baseline width of 2.5 FWHM.

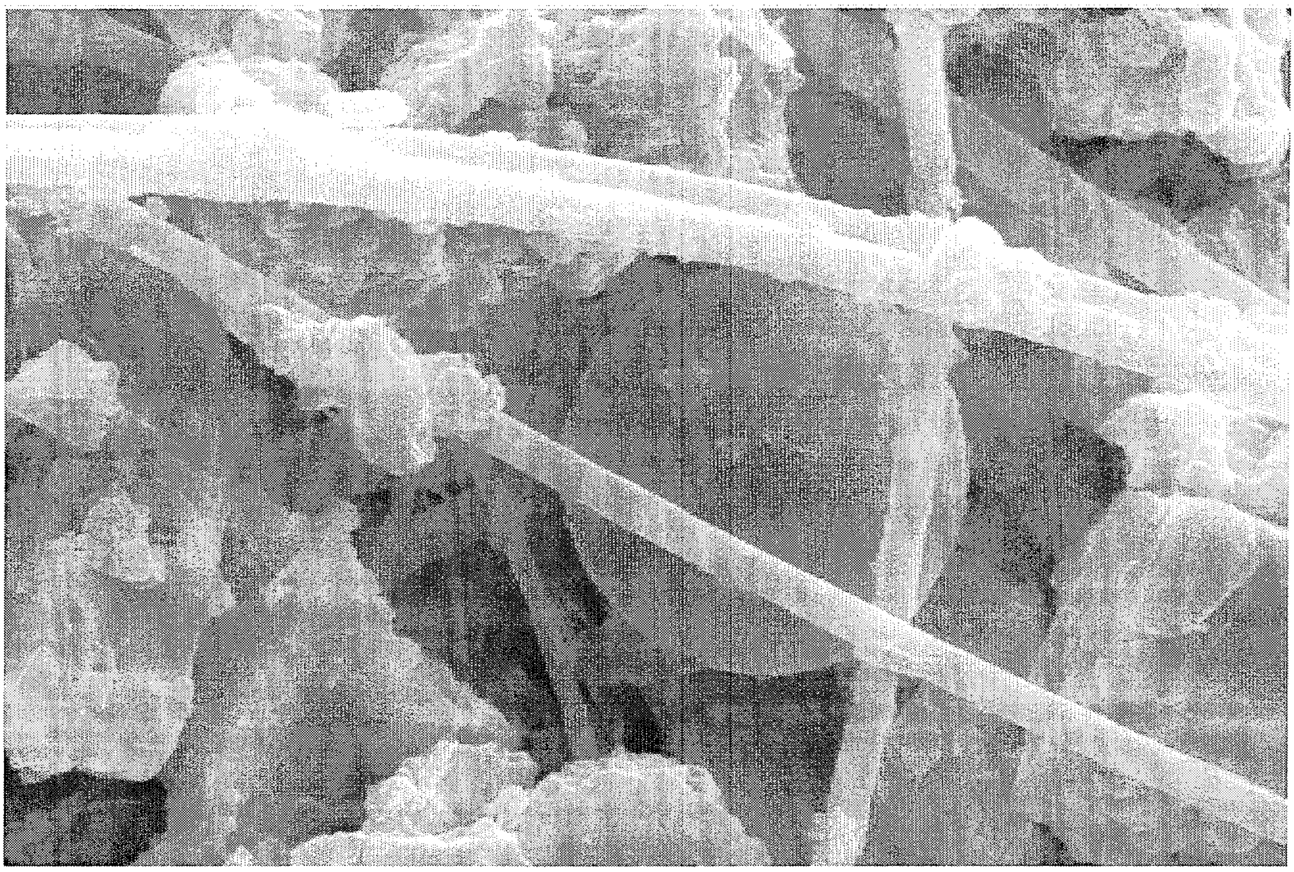

Figure 9. *SEM-picture of a spherical tag particle on a glassfibre filter loaded by outdoor dust particles of irregular shape. Here, the diameter of the tag particle is approximately 3 µm.*

3 REMOTE MONITORING OF THE AIR SAMPLING STATION

The remote monitoring concept consists of surveillance of the measurement data and state-of-health data as well as monitoring the station itself.

3.1 Monitoring of measurement data and state-of-health data

Monitoring the state-of-health and the environment of the air sampling station ensures that the station is operating as designed and it is functioning in an environment that allows proper air sampling.

The station is equipped with indicators that look after the sampling process and functioning of the equipment. Indicators implemented into the station are

- Air pressure in the sampling pipe
- Total volume of sampled air
- Current air flow rate
- ON/OFF-indication based on pressure information

The data for circumstances of air inside and outside of the laboratory consists of

- Temperature inside the laboratory
- Temperature of air nearby NaI detectors
- Temperature of outside air
- Wind speed
- Wind direction
- Rain (ON/OFF)

Low-resolution gamma-ray spectrometry reveals the mode of station operation. The on-line radiation surveillance system contains

- NaI spectra measured with intervals of 1,10 and 120 min
- Gross gamma with the same intervals
- Ratio of Low/High energy region

The presence and internal consistency of natural radioactive materials in the samples indicate that air sampling has been performed, the sample is fresh and the volume of filtrated air is of the right order of magnitude. Remotely monitored HPGe data consists of

- Spectra in a specified format
- Results of the spectrum analysis
- Picture of the spectra
- Quality assurance measurement data

The computer system of the automated station consists of a computer for process data and HPGe measurements. Separate computers are used for NaI measurements, weather data and www services (Fig. 10). The site collection unit in the SNL cabinet also has a computer. STUK's computers are on a separate network, which is connected to the STUK local area network and Internet via a firewall computer. The computers share data with each other by sharing disk resources of the network. Secure ID cards authenticate the Internet connections. The site collection unit performs data communication via modems.

Results of the spectrum acquisition and process data are available for authorized users through a www server. Status of the operation of the station and links to environmental and process conditions, real-time activity monitoring and gamma-ray analysis are visible in the home page (Fig. 11). Figs. 5 and 6 as well as Fig. 11 are taken directly from the screen of the computer and are typical examples of the www pages.

Weather data, real-time activity monitoring data, HPGe data and process data are periodically updated to the database of the www server. The size of one HPGe spectrum is 102 kB and two spectra per day takes about 6 MB per month. The 5 pictures of one spectrum (channels 0–1000, 1000–2000, ..., 6000–8192, see Fig. 6) on the www server are 5 to 15 kB each (gif format) and need

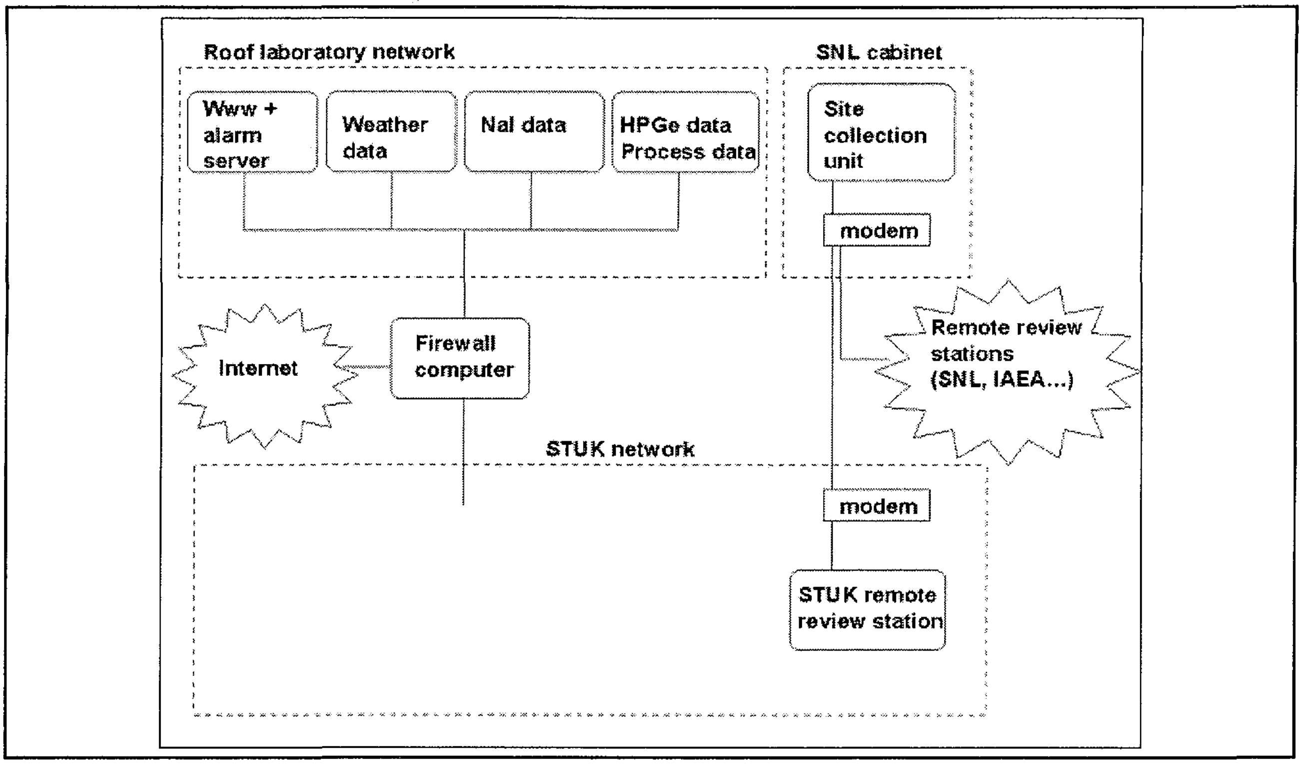

Figure 10. *Computer system of the automated air sampling station. The roof laboratory network and STUK's network as well as SNL's cabinet are separated.*

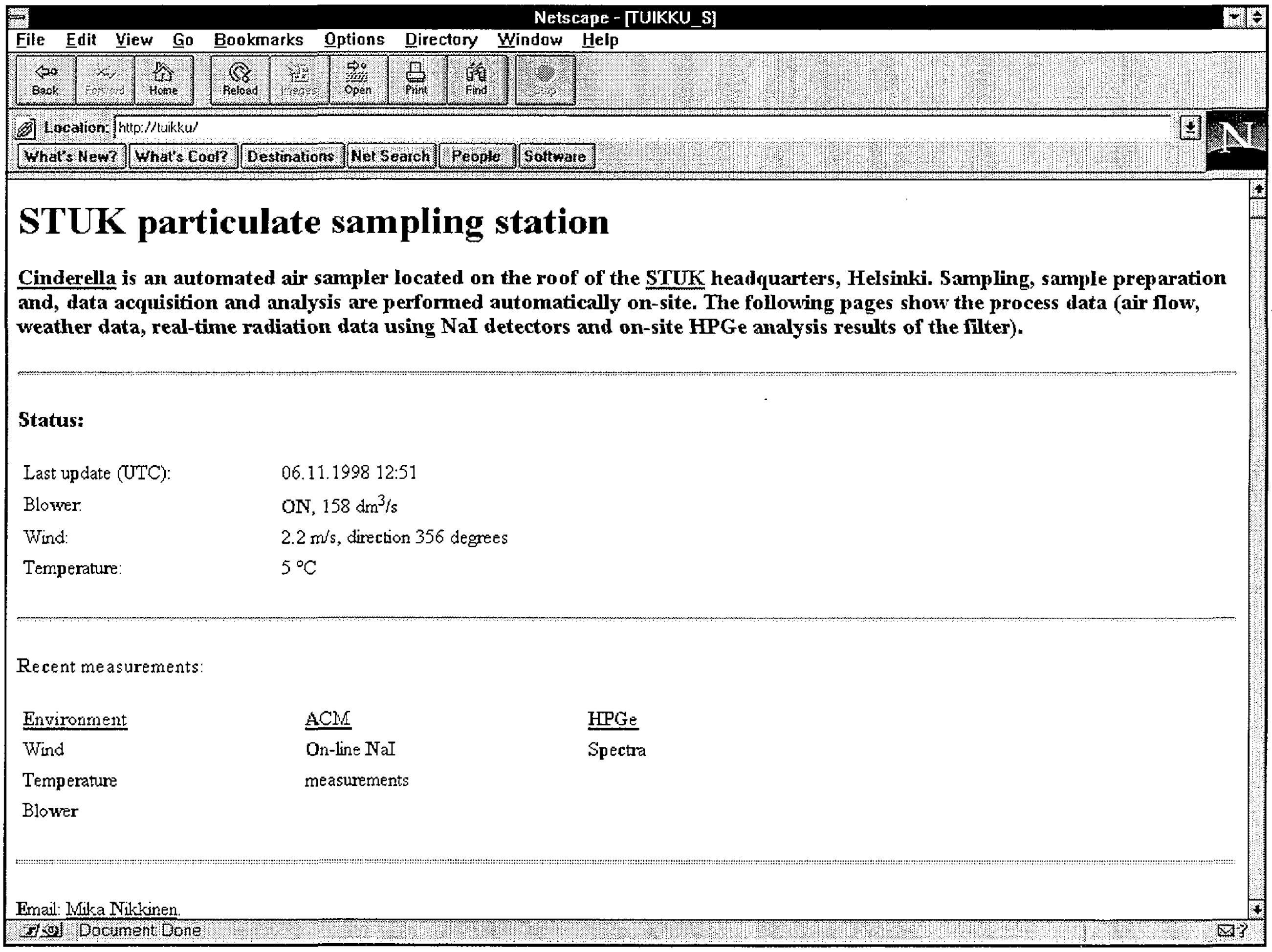

Figure 11. *Home page of the report system for the automated air sampling station.*

about 1.4 MB per month. The NaI spectra are produced at a rate of about 100 MB per month. Thus, periodic compression of the spectra and subsequent data archiving is needed. The process data and the weather data take about 1 MB per month. The total space needed for HTML pages is about 10 MB per month without NaI spectra.

3.2 Monitoring of the station and its location

SNL's equipment continuously monitors the air sampling station and the room where it is located. This provides another means of assurance that the air sampling is performed as intended and the air samples are authentic. The monitoring concept is to have knowledge of access to the room, motion within the room, and access to the air sampling station and the equipment cabinet. This is accomplished through the use of balanced magnetic switches over the two doorways, a motion detector within the room, a break beam, tamper-indicating switches on the clean filter storage section and the used cassette storage section of the air sampler, and a video camera (see Fig. 2). The break beam is installed near the air sampling station to detect movement of the sample manipulator, which performs the filter cutting and transfer of filter samples to a beaker. The tamper-indicating switches on the air sampler and the break beam trigger video images when an alarm is detected. All of the sensors communicate with the site collection unit via a sensor network (Fig. 12). The unit forwards the monitoring data and radiation files to authorized users at remote sites.

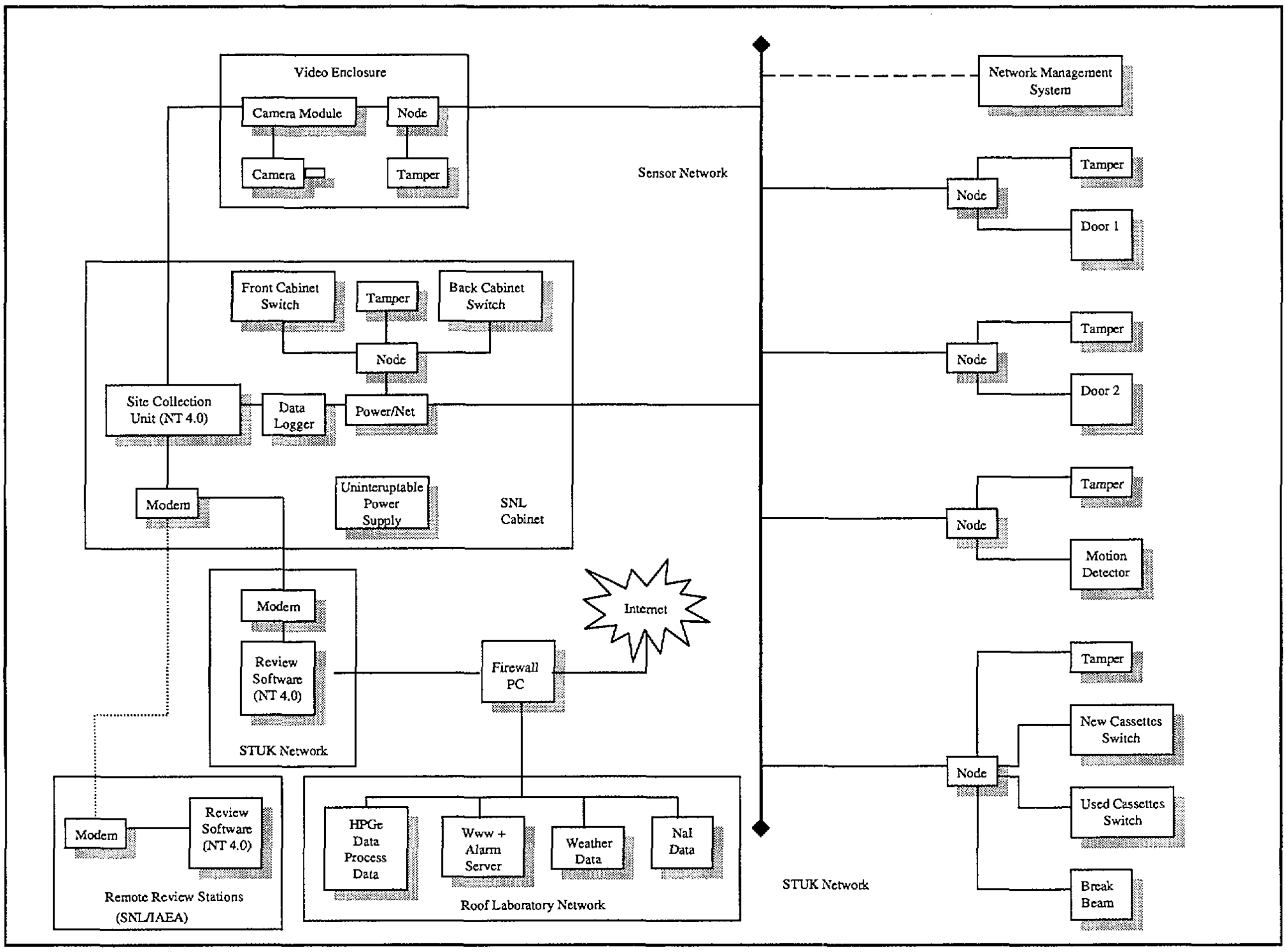

Figure 12. *Diagram of the remote monitoring system.*

SNL's remote monitoring system architecture consists of (Fig. 12):

- Site collection unit
  which is located in the air sampling room and collects, logs and stores sensor data received from the sensor network. Video images are also stored on the unit. They are transmitted from the video system to the site collection unit over a separate connection. Additionally, the unit receives data files from the STUK PCs. These files are forwarded to the remote review stations upon request. The site collection unit connects to the STUK remote review station and off-site review stations via a modem.

- Remote review station
  which resides at the STUK facility and provides STUK personnel with the capability to review sensor data and video images through Sandia provided software, as well as review the radiation analysis data through STUK provided software. This review station is a Windows NT based PC provided by STUK. Additional remote review stations receive data via dial-up telephone modems and reside outside of the STUK facility, i.e. Sandia National Laboratories.

- Sensor network
  which provides a medium for sensor data collection and sensor-to-sensor communication using a proven commercially accepted technology standard for industry sensor, and control and status applications. The network provides the cable plant to enable authenticated communications between the sensor nodes and the network server. Each sensor, the network server, and the video system are connected through an authenticated node. Sensors include a motion detector, a break beam, balanced magnetic switches, and tamper-indicating switches. The video system receives event trigger information from sensors on this network. The programmable network server, or data logger, is the repository for sensor event data. Sensor data is passed from the programmable network server to the site collection unit and subsequently to the stations for remote review.

- Video System
  whose key component is the digital camera module (DCM-14). The DCM-14 is an image capturing system housed in a self-contained module that can interface to both European and United States standard cameras. The images are digitized, and then compressed, authenticated, and sent to the site collection unit. The digital camera module can store approximately 500–600 images in a 10 Mbyte card. A video enclosure houses the video node, the digital camera module and the camera.

The video camera is located in the room with the air sampling station, equipment cabinet (housing the site collection unit, the cabinet node, the programmable network server and the power supply) and the door in its field of view (Fig. 13). Trigger signals are received from the sensors via the network and image data is sent to the site collection unit via a separate cable. Video trigger information is captured at the site collection unit for correlation with sensor event data.

***Figure 13.** A typical picture taken by the video camera during the installation of SNL's equipment, i.e. 20 February 1998.*

4 EXPERIENCES DURING THE FIELD TRIAL

4.1 Experiences with STUK's remote monitoring equipment

In general, the basic software and hardware components operated very well during the field trial. However, there are still some software and hardware related issues that need to be improved in the near future.

- Some of the original temperature probes were too sensitive for the electromagnetic field. The problem was overcome by replacing the probes.
- Remote data loading of the HPGe spectra is difficult using FTP services (STUK firewall).
- Analyzer of the HPGe spectra went gradually out of order. Counting was stopped randomly and many spectra were lost until the fault was located in the power unit of the analyzer. After repair the analyzer worked as designed.
- Resolution of the HPGe spectrometer was found to be very good. The energy calibration drifted 5 to 6 channels during a half-year operation. Because the analyzing software performs an internal energy calibration, this caused no problem until another analyzing software was tested without internal energy calibration. An adjustment of the energy calibration was then made and a monthly check-and-adjust routine was introduced.
- The power supply of the electrically cooled HPGe detector is secured with an aggregate of STUK headquarters. However, during the first electricity outage the aggregate was not started. Fortunately it happened during a working day and rapid operation of personnel prevented warming of the detector. The cords were moved from the aggregate outlets to those that were not affected by the break. In the near future an additional instrument will be implemented to prevent restart of the cooling after long-lasting outages.
- The spectrum analysis software works well, though it needs minor practical improvements in reporting and displaying the results. Combined with the web pages it provides a valuable tool for an expert, who can from any place rapidly see if abnormal observations are made or a further interactive analysis of a spectrum is needed. The spectrum can then be downloaded rapidly from the web page and analyzed on the expert's computer. The analysis software also produces an alarm message to pagers and GSM-phones when an abnormal nuclide is identified, which further improves the usefulness of the daily sampling in operational air surveillance.

4.2 Experiences with aerosol authentication system

Because of limited space around the sampler, the aerosol authentication apparatus was placed about 1 m apart from the air inlet tube (only the aerosol nozzle is visible in Figs. 3 and 4, not the main apparatus). Therefore particle losses to the inner surfaces of the hosing were studied. The losses were found to be negligible. Using a mixing unit that performs stirring of the tag suspension twice a day eliminates particle settling in the tag reservoir. Periodic stirring is needed more often provided that particles > 5 µm in diameter are used.

Aerosol authentication as well as the mixing unit was turned off several times for testing and maintenance. A few days pause caused considerable deposition into the tubes. Pressurized air was used for resuspending the particles. The piping from pressurized air delivery to the tag atomizer was temporarily connected to the output pipe of the liquid, yielding a reverse flow to the reservoir and, consequently, re-mixing of the tag suspension. Thus, an additional mixing system would be necessary for long-lasting breaks. This could be carried out using a separate valve that is controlled by a timer.

4.3 Experiences with SNL's remote monitoring equipment

4.3.1 Image and event management

The software products by SNL are simple and easy to use. Because STUK was doing some installations to the sampling system, a lot of images were stored in a working day (up to 100–200 images). In the normal operation (automated sampling and sample preparation) some 5–7 pictures are generated daily. Additional images are taken when reloading and removing filter cassettes.

- When there are over 200 images stored in the database, the queries to the database are rather slow. Also, downloading of the large volume of images is time consuming.
- The "real time monitoring" program located in the computer of the site collection unit is difficult to use when the update option is on. The data is updated once per 30 seconds and the update will take some 15 seconds. The only practical choice is to turn the update option off during the review.
- Browsing the images is easy; however, the naming convention is difficult to follow. There is no information seen with the picture browser, or which event has caused the picture to be taken. This would be a very practical addition, especially when trying to locate possible error conditions.
- The quality of the images is rather low. It is difficult to identify people seen in the pictures (see Fig. 13). However, the images were not necessarily designed for recognition, only for providing assurance of possible tampering.
- All the images are not necessarily synchronized with the events. An opening event of the bin of the new cassettes may be taken a few seconds prior to the opening (the camera takes pictures without events; pictures are saved on the basis of triggering signal of the sensors). Thus, in the picture there is often only a person walking towards the sampler. This might be somewhat confusing when analyzing the results.
- State-of-health reports from certain sensors are not consistent in time. For instance, a sensor will report state of health several times within a few minutes, and then not again for twenty minutes. The reports are continuous, however.

The pictures are downloaded to the review workstation once per every two weeks. The downloading software works quite smoothly. Opening the Data & Image Review program takes an exceptionally long time (1 min in 133 MHz Pentium). Additionally, transfers to the remote review workstation located at SNL take too long.

- If the date and time are not in US format, the review is not working at all. This is due to the problem when comparing the dates. This can be overcome by setting a separate user account for the user of the site collection unit, where the date and time format are set to US.
- The resolution of the viewer is fixed to 800x600. When selecting 1024x768 display resolution the display might be cut to half (Windows "feature" ?).
- Installation of the Data & Image Review program into a Windows NT workstation is straightforward. However, the default directory is c:\mims, which prohibits installation of the database into a network.
- Analysis tools, such as calculating time since last system failure and state-of-health intervals, would be useful additions to the remote review station.

Otherwise, the software products seem to work as expected. The computer in the cabinet has been booted a few times but this is not an unexpected behavior of the typical data acquisition computer running Windows NT.

4.3.2 Remote monitoring hardware (camera and network)

The camera does not use the daylight saving flag. The program that polls the images from the camera does not synchronize the time of the camera and the time of the site collection unit. The syncronization is working only if the time difference is less than 4 minutes. Otherwise the only possibility for syncronization is to put a serial cable to the camera (the camera container has to be opened) and use special software. However, this option was not used.

There were some problems just after setting up the system in the laboratory. The camera took images once every five minutes. This was caused by the magnetic field of the sampler pump electrical control unit (high power inverter). The problem was cured using more shielding and setting up the grounding of the system more securely.

The basic introductory course was quite comprehensive but the introduction to managing the network could have more emphasis. A more extensive course might be of good practice. The database operations and user training were very well set up.

4.4 Demonstration of the remote monitoring system

In March 1998, SNL and STUK demonstrated the remote monitoring system to the IAEA in Vienna. Normal operations as well as abnormal situations were demonstrated. During the day of performance no extra activities, such as unnecessary motion, were allowed in the roof laboratory. However, it was agreed that at a non-scheduled time an intruder would enter the room and tamper with the air sampler and radiation detectors. The intruder mounted a low-active ^{60}Co source near the NaI detectors for a short period (STUK personnel in Vienna did not know this).

A connection was established between the IAEA and the STUK www server. An overview of the environmental monitoring system and www pages was given. Process data, meteorological data and spectrum data were reviewed via www pages. During the presentation it turned out that the NaI detectors discovered abnormal radiation levels. The time of the exposure was visible in the NaI spectra and ^{60}Co was identified.

Additional information was detected by SNL's remote monitoring system. The door to the air sampler room was opened, motion was detected and an image was taken as the result of someone opening the clean filter storage of the air sampler. The image taken at the time the radiation level went up proved that indeed someone tried to influence the air sampler. Thus, the remote monitoring system succeeded to reveal tampering efforts. Authenticated data was reliably transferred to the remote site without the presence of personnel in the monitoring site.

5 DISCUSSION

The field trial was a unique safeguards application. Integration of remote monitoring equipment with the STUK radiation monitoring system was a challenging task. Efficient data transfer is a fundamental requirement of remote monitoring.

The field trial showed that part of the remote monitoring could be carried out using simple means. However, advanced facilities are needed for comprehensive surveillance. The field trial demonstration proved that authenticated measurement data could be reliably transferred from the monitoring site to the headquarters without the presence of authorized personnel in the monitoring site.

In general, the remote monitoring equipment functioned very well although minor reversals occurred during the trial. Useful experience was obtained. The major problems were related to the amount of data to be transmitted via slow modem links and the slow response of the review software. However, a comprehensive vulnerability assessment of the whole system was not possible within the frames of the present IAEA safeguards support programme.

The field trial utilized data transfer through telephone lines. The volume of data, however, is so large that this concept is not adequate in all operational systems. In the future, other alternatives should be considered. Internet would provide a cheap transfer channel for those sites where infrastructure exists. Data encryption and authentication are of course required. Dedicated satellite links are the best solution but the costs may be large. The data transfer concept of the CTBTO, based on VSAT (Very Small Aperture Terminal), is excellent and would be valuable for the safeguards application as well.

The present air monitoring system cannot be directly applied to other surveillance programmes. The equipment and the monitoring concept as a whole must be tailored separately in each case. However, the experience is very important when applying remote monitoring at other sites using different monitoring equipment. The field trial showed that it is possible to construct a fully automated air sampling station that can be operated unattended, including full protection and monitoring of the sample and the data.

REFERENCES

Leppänen A, Niskala P. Air-radioactivity surveillance programme in Finnish Centre for Radiation and Nuclear Safety. Internal Report, 1996.

Leppänen 1998. GAMMA-98 computer code (personal communications).

Toivonen H, Leppänen A, Ylätalo S, Lehtinen J, Hokkinen J, Tarvainen M, Crawford T, Glidewell D, Smartt H, Torres J. Finnish remote environmental monitoring field demonstration. Symposium on international safeguards, Vienna, Austria, 13–17 October 1997. IAEA-SM-351/48.

Toivonen H, Honkamaa T, Ilander T, Leppänen A, Nikkinen M, Pöllänen R, Ylätalo S. Automated high-volume aerosol sampling station for environmental radiation monitoring. STUK-A153, 1998.

Ylätalo S, Toivonen H, Lehtinen J. Authentication of particulate air samples by aerosol. Informal Workshop on Authentication and Communications, Paris, 9–12 July, 1997.

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