Mobile Platform for Radiological Characterization of Sites under or after Decommissioning – 15139

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ABSTRACT

Nowadays, nuclear industry is facing a crucial need in establishing radiological characterization for the assessment and the monitoring of any remediation work. Regarding its experience in this domain, the French Commission for Atomic Energy and Alternative Energies (CEA) of Fontenay-aux-Roses, established an important feedback and developed a sound methodology for radiological characterization. A clean-up project is managed from the initial surface characterization to the final one, once volumes of contaminated soil have been removed.

Samples are collected via recognized methods and data is gathered by real-time acquisition with different conveyance such as all-in-vehicles, cart, walking, helicopter or drone. Accurate radiological analyses are performed on site thanks to the mobile laboratories cluster, called SMαRT. It enables to realize long-time gamma spectroscopy, chemical preparation for alpha spectroscopy or beta liquid scintillation counting. Data is processed with geostatistics via the software Kartotrak, 2D or 3D mapping are created with the associated uncertainty and probability map. Drilling profiles with geological data (layers composition, particles size, etc.) are studied in order to understand the behavior of the contamination in depth. Source term, contaminated volumes and sanitary impact are calculated in order to determine the optimum excavation depth. Finally, data is stored in an online site that insures the traceability of the whole process. This just-in-time production model allows a fast response and control of costs and avoids the disadvantages of radioactive material transport.

This whole innovative process, developed inside the mobile platform, requires all these tools that have been used in France and continuously evolving for more than 10 years thanks to a learning organization.

INTRODUCTION

The CEA started its nuclear program in 1946 in the “fort de Châtillon”, in Fontenay-aux-Roses, 7km south of Paris. After two generations of nuclear facilities, a remediation plan of the whole site was elaborated in 1995. Facilities are going through a remediation program that will allow setting up buildings for new research activities. In parallel to the facilities dismantling, exterior contaminated parcels are also considered for remediation.

During the decommissioning of a nuclear site, the operator must identify and classify the various wastes while optimizing the costs. At all stages of the decommissioning, radiological measurements are performed to determine the initial situation, to monitor the demolition and clean-up, and to verify the final situation. Radiological evaluations have to be performed as well, before and after the decommissioning and dismantling process, thanks to an optimized amount of measurements and/or radiological and chemical analyses.

Thanks to the experience feedback, sampling and optimized amount of measurements protocols have been established, as well as data analysis and modelling tools. To address these various operations, the CEA has developed a sound methodology, applied by the mobile unit, and composed of several tools to estimate the radioactive contamination in soils. These developments involve the measurements with the LAMAS [1], and VEgAS [2] vehicles, as well as modelling with the Kartotrak software [3] that converts radiological data into interpolation maps and analyses with the mobile laboratories SMαRT [4].

This equipment has been designed so that it can be transported into large contaminated areas for characterizing, monitoring and analyzing, with a full autonomy. This mobile platform is perfectly adapted to wide areas as NORM (Naturally-Occurring Radioactive Materials) sites.

The methodology has been applied on hundreds of exterior sites and CEA centers and is being developed abroad thanks to IAEA collaborations. CEA formalized for the Nuclear Safety Authority, in 2000, its decontamination methodology based on several steps and which is continuously evolving (Cf. Figure **1**):

-Historical investigations: understanding the radiological past of the target area is fundamental to calibrate/orientate the subsequent characterization. A functional analysis allows identifying the plant processes and the potential associated impacted areas.

-Surface mapping: a detailed map of the radiological global counting is established thanks to surface measurements and generally associated with in situ gamma spectrometry and soil samples. The process is the same whatever the method of measures (from a single backpack to a drone or a vehicle).

- In-depth characterization: a campaign of drill holes evaluates the contamination depth in the ground. Any potential transfer towards the groundwater is considered.

- Rehabilitation objectives: realistic scenarios of rehabilitation are defined. Source term, ratios, volumes of contaminated soils and radiological impact assessment are calculated and according to the costs/benefits analysis, the excavation depth is defined.

- Remediation process: together with the removal of the contaminations, a survey of the operations is performed to guarantee the safety of the workers.

- Final characterization: some additional measurements are collected to validate the remediation objective (end-point dose assessment) and to establish the radiological status of the area for any future use.

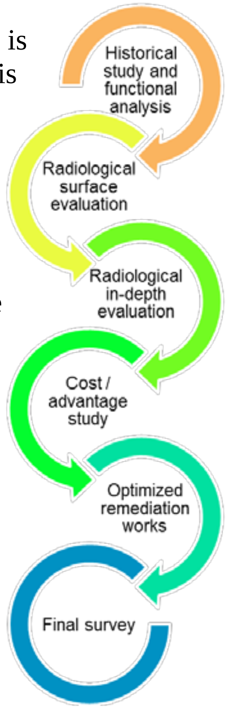

Figure 1: Main methodology steps

HISTORICAL INVESTIGATIONS

Studying the site or facility documentary records is an unavoidable step prior to the radiological characterisation of a site with suspected pollution. Historical investigations ensure major savings in time and money for the rest of the characterisation project.

The Studied Area

The very first step is to define thoroughly the studied zone. Areas can extend from several square meters to thousands of hectares. It is necessary to separate the area into distinct zones where the soil matrix is different. Indeed, radiological background noise may vary with the soils nature and radiological mapping is best performed on similar matrices. The CEA Clean-up section (SAS) has developed a camera which detects and identifies the surface driven over during the real-time characterization.

Historical Study

The historical study is based on a thorough analysis of archives, plans, reports and aerial views realized every year by the “French geographical institute” (IGN). The aim is to gather as much information as possible about the history of the site. These archives highlight information about areas which have to be specifically considered. For instance, it’s possible to point out dismantled facilities where pollution may have occurred.

Functional Analysis

Testimonials from former workers, reports and specific radiological evaluations are collected and gathered in order to highlight any area of interest. It describes places where pollutions remain, cleaned places, the state of nuclear facilities.

RADIOLOGICAL SURFACE MAPPING

The main innovations in surface mapping concern the time control. Real-time mapping is performed. The developed devices have a fast response and a full autonomy. A large amount of data can be collected quickly. Thus, time is saved during the acquisition phase and most often, there is no need to come back for more measures.

The CEA has developed several tools adapted to different types of areas. Two vehicles are dedicated to large areas expertise and investigations. Lighter methods are applied to perform real-time mapping where vehicles cannot access. Walking, using a cart, a helicopter, or even a drone are efficient ways to do so.

Real-time Measurement Devices

The first vehicle, called LAMAS (Cf. Figure 2), is a laboratory vehicle which is mainly used for monitoring during clean-up operations [3]. Atmospheric measures of artificial α and β aerosols, Rn-22 and irradiation measures as well as meteorological measures are realized. Radiochemical measures are also realized. The working environment is consequently measured in real-time to control the safety of workers. Distant monitoring is also possible via an on-board secured LAN and a remote control software that use VPN encryption.

Figure 2: Presentation of the LAMAS

Conceived in 2008, the second vehicle, called VEgAS [2], is exclusively designed for site characterization. The vehicle is a four-wheel drive with a speed control system in order to keep a constant speed during the data acquisition. The air coming into the driver’s cabin is filtrated and a beacon can be installed to warn the workers if a high level of aerosol is detected.

Figure 3: Devices equipping the VEgAS

One of the main innovations of this vehicle is the two DSP10 detectors of 25-liter volume (plastic scintillators), newly used in the field of radiological characterization. The use of both devices, located underneath the vehicle, enables to cover a 2-meter wide area.

A sodium iodide detector (NaI) (2.4-liter crystal) and a high-efficiency Germanium gamma detector (HPGe) are also included, at the back of the vehicle (Cf. Figure 3).

This whole equipment is able to identify a surface pollution of Cs-137 or Co-60 from 30 to 100 Bq/kg and to perform cartography of 0.5 ha/hour. The vehicle is equipped with a GPS which provides the coordinates of every collected data with great accuracy, less than a meter in most favorable cases, thanks to a real-time differential correction.

Data is collected in real-time, with a 1-second frequency and are gathered in the front of the vehicle.

Finally, the cart, named CEsAR (Cf. Figure 4), is composed of a trolley which can hold several measuring devices as NaI detector (2’’, 3’’ or 8’’) or GeHP detector. In addition, lead shield can be added to limit the solid angle of the detector. Data (measure result and precise localization) is collected in real-time, with a 1-second frequency. A laptop can be fixed on the trolley in order to visualize data. Real-time acquisition helps to have better precision as it is possible to make more measures on specific areas.

Drones with measuring devices and GPS embedded are being tested with the same methodology.

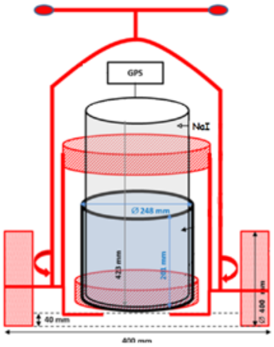

Figure 4: The CEsAR trolley

Softwares

Four software are used during the radiological characterization to have a real-time display.

Terrasync, is used with the GPS to give a submetric position and a quality index. The position of each data point is really important since the geostatistic processing is based on it.

Kartotrak [5] is a GIS (Geographical Information System) developed by the company GEOVARIANCES in collaboration with the CEA. This tool is dedicated to the radiological and chemical mapping of polluted sites, soils and facilities. Different kinds of data can be used depending on the measurement devices. The module processes spectrum and compiles all inputs. First, it collects and stores the coordinates of precise spots from the map. Then, it displays on the map the accurate location of the vehicle and collects measurements from various devices. The module K.R.T. (Kartotrak Real Time) allows to collect numerous data and to realize quickly a removal of doubt on an area, in order to highlight “areas of interest” for further radiological evaluation.

Pascalys and Interwinner, are used together to model the activity thanks to transfer functions. Massic activities are calculated with a self-absorption correction for each matrix.

Sampling Plan

Sampling plays a crucial role in the characterization. The sampling plan dimension must be optimized for the use of geostatistics in data processing. For an initial mapping, a regular approach is generally favored to obtain a homogeneous coverage of the zone. When the sampling step is too large, larger security margin should be taken and optimization is not precise. There are more risks of leaving pollution in soil or excavating non-contaminated area, and therefore sending non-radioactive wastes in the waste storage.

While preparing a taking campaign, the sampling plan is established upstream with Kartotrak [5]. Various graphic indicators (probability of reaching a target, impact of collecting extra measures, etc.) help the user by providing him information and comparison tools that are necessary to make a decision (Cf. Figure 5).

The sampling plan is performed as soon as data is available. A sampling optimization is performed in term of amount but also in term of information quality.

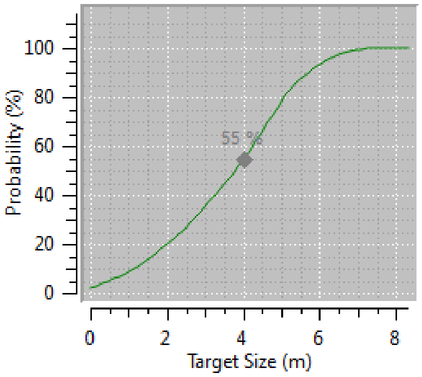

Figure 5: relevance of the mesh size: probability of reaching a 4 meter wide target for a 6-meter mesh

Sampling Methods

As already explained, samples have to be drawn on the same matrix. Several samples are collected. To be sure of the representativeness of the final sample, they are homogenized and reduced with alternate shoveling (Cf. Figure **6**) and quartering (Cf. Figure **7**) methods. These methods have been chosen and improved thanks to feedback of hundreds of campaigns.

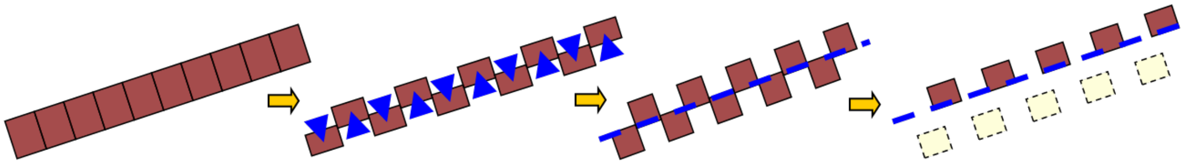

Figure 6 : Alternate shoveling method

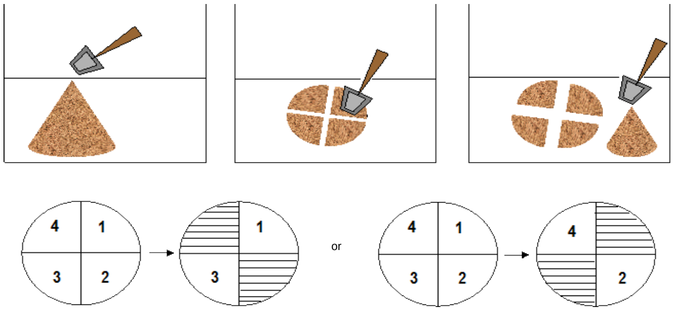

Figure 7: Quartering method

In addition to a numeric storage, several characteristics are written in a notebook. Thus, it contains, for each sample, information on soil matrix, localization, humidity or any other noteworthy information. The measuring devices characteristics are also recorded. This notebook will follow the samples during the analysis phase. Traceability is a really important point during the process. It is crucial not to have any information loss. For large taking campaigns, samples are checked in advance in the database and identified with a bar code label. Data storage and traceability play a substantial role in time and money saving.

ANALYSES IN THE MOBILE LABORATORIES

Radiochemical analysis is crucial for the radiological evaluation process to optimize the clean-up operations. Gamma-emitting radionuclides can usually be measured in-situ as little or no sample preparation is required. Alpha and beta-emitting radionuclides are a different matter. Analytical chemistry laboratory facilities are required. Even though these types of analyses are common in activities such as exploitation, monitoring, and cleaning up of nuclear plants, some polluted sites do not have suitable infrastructures for the reception and treatment of radioactive samples. Mobile facilities can overcome this lack: a shelter can be placed in the vicinity of nuclear facilities under decommissioning, or of contaminated sites. Radiological analysis can then be performed without the disadvantages of radioactive material transport. This set-up allows a fast response and a control of costs.

The current operations for the characterization of radiological soils of CEA nuclear facilities, lead to a large increase of radiochemical analyses. To manage this high throughput of samples in a timely manner, the CEA has developed mobile laboratories for the clean-up of its soils, called SMαRT (Shelter for Monitoring and nucleAR chemistry, Cf Figure **8**). This laboratory is dedicated to the preparation and the radiochemical analysis (α, β, γ) of potentially contaminated samples. SMaRT can also be used in a post-accident situation. The success of this system leads the CEA to sign collaboration with Eichrom® laboratories with the aim of bringing skilled staff on many sites from CEA under decommissioning or partner’s ones.

Figure 8: SMαRT placed in the vicinity of the studied area

Description

The laboratory is installed in a container called « shelter», transportable via road and airline. It can be moved using a lifting crane via slings through integrated rings or using a fork lift via incorporated holes. Furniture and equipment is fastened to stabilize them during transport. The lab is split in different areas:

-In the first zone, samples are received in a dedicated cupboard equipped with retention trays. A locker is also available for staff personal belongings.

-The second zone contains a wet laboratory bench and two ducted fume hoods, for the chemical preparation of the samples. Each one extracts the hazardous vapors from the work area with a flow rate of 850m^3/h through an active carbon chemical filter, and a high efficiency filter before being rejected in the environment. In the first hood, solid samples are heated, dissolved in concentrated nitric acid, and diluted for specific radionuclides extractions. The main extraction techniques used are liquid/liquid extraction for plutonium and strontium, and resin exchange chromatography for other actinides. The laboratory equipment (pumps, centrifuge, and balances) is fixed on the workbench.

An air-handling unit conditions the air and creates a -10Pa depression in the lab. Three split-type air conditioner units assure a stable temperature in the shelter. After the chemical preparation, the samples are transferred into containers adapted to the geometric requirements of the measurement and finally moved to the third zone, which contains the α, β, and γ spectrometers, described in the next section.

Waste created during the sample preparation is stored in specific containers in the last zone, the technical room. The sink, the dishwasher, and the security shower are connected to a double tank, to control the quality of waste water before discharge. This room also contains the electric supply system, the fire alarm system and the low oxygen detection system. The general design of the shelter is given in Figure 9.

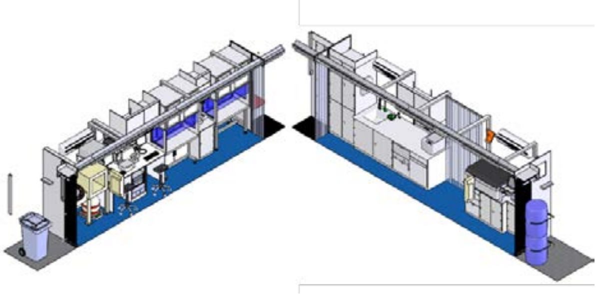

Figure 9: General design of the shelter

Nuclear Instrumentation Devices

Once samples have been collected, they are redirected to the SMαRT where a more accurate analysis (long time gamma spectroscopy, chemical preparation for alpha spectroscopy or beta liquid scintillation counting) can be performed.

Gamma spectrometer: the detector used for gamma spectrometry analysis is a coaxial type HPGe detector (Canberra® GC2518). Its characteristics (a relative efficiency of 25 % and an energy resolution of 1.8keV at 1.33MeV and 0.850keV at 122keV) are suitable for the measurement of low and medium activities of current gamma tracers. The detector head is set inside a shielded measurement cell covered with low-level lead (50Bq/kg). It is connected with an automatic sample loader that allows a continuous measurement and with the analyzer software Interwinner 7 provided by Itech Instruments®. This heavy equipment (2500kg) is firmly fixed to the shelter, by the creation of fastening arms, for holding the equipment during transports.

The process of radiochemical separation and electrodeposition used in the SMαRT allows the realization of sub-samples optimized for measurement by alpha spectrometry. Two complementary methods have been selected for the measurement of alpha emitters: the alpha spectrometer with semi-conductor detectors and the liquid scintillation counter PERALS®.

Alpha semi-conductors: The alpha-emitting radionuclides are mainly encountered in the nuclear industry, at the front end (uranium, plutonium) and at the back end of the fuel cycle (Pu-238, Pu-239, Pu-240 and Pu-242, Am-241 and Am-243, Np-237 and Cm-242 and Cm-244). An eight semi-conductors ensemble provided by AMETEK® can, with an adapted counting time and a specific chemical preparation, identify, quantify and discriminate the expected alpha-emitters radionuclides (resolution (full width at half maximum) around 20keV), and can reach very low detection limits. This technique involves a long chemical preparation step which may be unsuitable in some cases such as post-accident situations. Liquid scintillation is more suitable in post-accident situations as it does not require a long chemical preparation.

Alpha liquid scintillation PERALS®: The PERALS® (Photon-Electron rejecting Alpha Liquid Scintillation) allows a faster measurement of some alpha-emitting radionuclides, such as plutonium or uranium. The principle of the sample preparation is based on a liquid-liquid extraction in which the isotope of interest is isolated with a scintillating and complexing agent which is the matrix condition appropriated to the measurement. The principle of detection of alpha particles is based on the liquid scintillation technique, associated with a α/β pulse discriminator (PSD), which allows the rejection of 99 % of β pulses. The two detectors 8100AB, provided by (ORDELA®) are inserted in an electronic NIM rack. The detector characteristics (efficiency 99.7 %, background < 0.001cpm, resolution of 200keV at 4.78MeV), allows quick analysis (24 h) of solutions containing uranium or plutonium.

Beta liquid scintillation: The SMαRT is equipped with a liquid scintillation counter connected to a sample loader, which allows the continuous counting of beta emitters such as H-3, C-14, Sr-90 and Pu-241. The B2910TR model provided by Perkin Elmer® has a loading capacity of 408 samples.

Missions

SMαRT-1 is the latest tool developed at CEA to extend and complement the measuring and monitoring capabilities provided by the mobile laboratories LAMAS and VEGAS. SMαRT combines timely and cost effective analyses with high sample throughput. It produces accurate data precious for 2D and 3D contamination mapping. SMαRT can perform 16 plutonium and strontium analyses, more than 200 gamma spectrometry and hundreds of alpha/beta counting a week.

GEOSTATISTICAL DATA PROCESSING

The objective of geostatistics is to study any qualitative phenomenon which develops structurally in space and/or in time. Geostatistical processing is based on several exploration and data processing steps (exploratory data analysis, analysis of data spatial structure, data interpolation by kriging, risk analysis). In the context of initial mapping, it is useful to work with the most direct raw information possible (counting, dose rate…) without necessarily seeking to use coefficients to obtain mass or surface activities. The objective is to represent the variations. Absolute values will be obtained from the results of sample measurements by a multivariable geostatistical processing.

It is important to work with consolidated data (same measurement protocol, same conditions…) which have been double-checked. The data processing enables mapping for activities, uncertainties, and threshold overrun.

On the basis of these different mappings, particularly those related to risk analysis, it is possible to quickly identify uncertain zones, under-sampled zones or those with a high variability. This means the gathering of additional measurements or samples can be oriented towards these zones, almost in real time, to optimize the data collection.

2D Mapping

Data is collected and processed through geostatistics with the software Kartotrak that provides 2D or 3D mappings which help the project manager in taking decisions.

Once all measures are collected, basic statistics are provided: data basemap, histogram analysis, on-the-fly data transforms (logarithmic and gaussian transform). Classical experimental variograms can then be computed in order to highlight the spatial structure of the data, if there is one. This variogram usually shows if a relevant sampling plan has been performed. Otherwise, the project manager should add measures to the dataset and then improve as much as possible the knowledge about the studied phenomenon. If needed, the variogram cloud can be calculated in order to analyze the dataset, and mask temporarily some outliers that affect the variogram and generate a nugget effect.

Next, the variogram is fitted interactively using common basic structures (spherical, exponential, and cubic).

The user can afterwards perform kriging by defining the size of the kriging mesh of the specific area as well as the number of neighboring samples. Variance maps and confidence intervals are also provided in order to highlight imprecise areas that require additional measurements, as illustrated on Figure **10**[6].

This module allows estimating the spatial variability of measured activity levels and then predicting the probable values at non-sampled locations using ordinary kriging.

This step can be realized on site, during characterization, or remotely with no radiological hazard, as every data is stored on line. This step prevents to realize too much samples or more than necessary. Thus, it enables to save money in comparison with an exhaustive characterization.

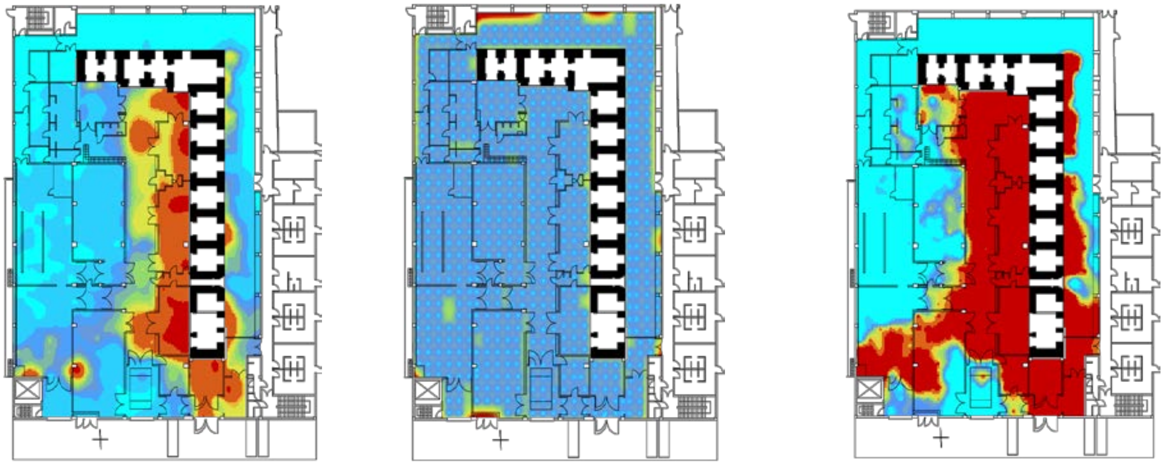
Kriging map Variance map Probability map

Figure 10: Various maps visualized in Kartotrak

Risk Analysis

Risk analysis is performed through the estimation of probabilities of exceeding a given threshold. Numerous thresholds can be chosen so that the user can decide with best information available the next actions to perform on site. In particular, the results help deciding how many drill holes should be realized for 3D analysis and where to place them especially.

IN DEPTH RADIOLOGICAL CHARACTERIZATION

In-depth radiological characterization means carrying out a certain number of measurements over the block to be assessed. The objective is to take into account phenomena of contamination migration and diffusion in the ground, and to determine the extent of the pollution.

3D Sampling Plan

This step is performed during the geostatistical data processing. Usually, some drill holes are located at hot spots in order to know the exact depth of contamination. Some are also set in contamination-free areas to make sure that no activity has been avoided. Mostly, drill holes are located in "intermediary" areas, where it helps to define the extent of areas with high-probability of measuring a high activity.

Drillings and Measurements

Different drilling techniques are used. Auger holes or sonic drillings are usually realized. No fluids are used with the sonic drillings (rotation and high frequency vibration are used to core), which is a real advantage when the main objective is to prevent the pollution leaching or migration.

The detection technique must take into account parameters such as the depth, the nature of the land, or the need for containment in the case of a serious pollution. Regulations regarding the sampling of certain radionuclides or chemical contaminants are also to be respected, in particular for volatile compounds, when the sampling method is decided on.

Geologic Analysis

The drilling samples should go through chemical analysis to complete the detailed evaluation. As soon as cores are extracted, direct measurements are performed. First, X and γ scanning are realized with a small lag in order to highlight hot spots. A chemical scanning is realized with a PID probe so that volatile elements can be detected.

A geologic study is performed on the core: geologic layers are defined and natural ground depth and groundwater table is stated. Besides, particle size analysis is executed.

Logging can be realized in the drilling holes to detect an irradiant source in depth around the hole. This measurement is often realized with a NaI device with a 10-second acquisition and a 20 cm lag. The orbital position of this source is known thanks to a lead shield. Graphs present the logging profiles with the measure results functions of depth (Cf. Figure **11**). High value in surface can correspond to a surrounding soils influence or an overlying surface (bituminous coating for instance).

Samples are realized according to a sampling step and sent to the laboratory for analysis. With the mobile laboratory Smαrt, there is no downtime: the analyses are realized just after the sampling and results can be obtained the day after. This reactivity is essential because results can impact the position of the next drilling. Each data is written in a single excel file. Once data is recorded, different studies start.

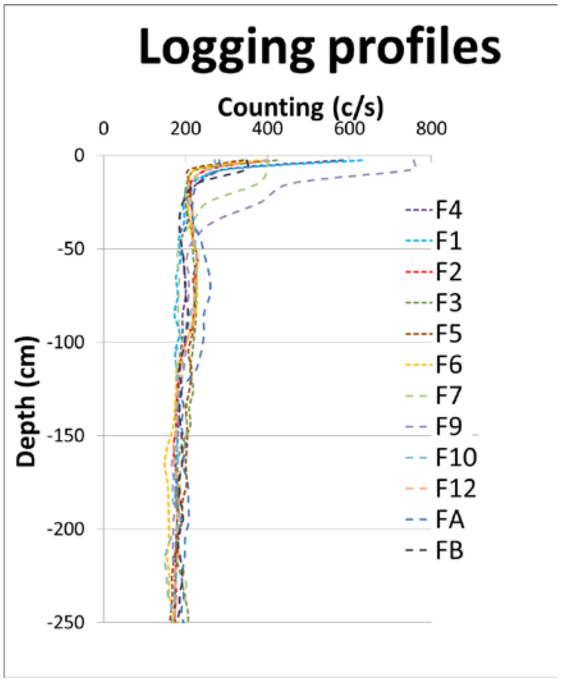

Figure 11: Logging profiles

Natural Ground Level (NGL) Modelling

The natural ground level is modelling on all the area (Cf. Figure **12**). This level corresponds to the original soil which has never been reworked by man. Natural ground properties are different from the backfill and contamination evolves in a different way (due mainly to colloids). When pollution is stopped by natural ground, its model is really important because it enables to better estimate the extent of pollution.

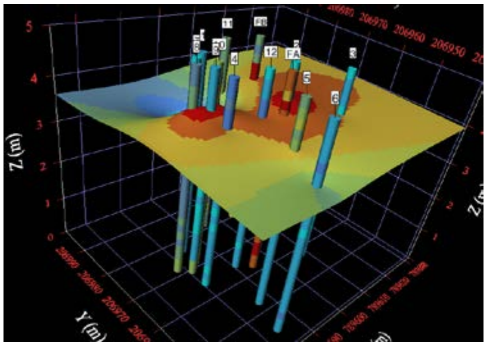

Figure 12: Natural ground level modelling

Migration Profiles

From all radiological and radiochemical data, migration profiles are plotted, functions of depth (Cf. Figure **13**). Migration rate depends of radionuclide, type of pollution and soils but sometimes similarities can be noticed on drillings in the same areas. In France, there is no threshold in radiological assessment but some sites have level for each radionuclide. For a drilling, it is possible to determine a depth from which the activity does not exceed the chosen threshold for each radionuclide. From this depth, a volume estimation of contaminated soils can be calculated. The volume is different depending on the number of radionuclides taken into account.

These drilling profiles with geologic data allow to understand the behavior of the contamination in depth, and then to be able to perform the excavation the most properly.

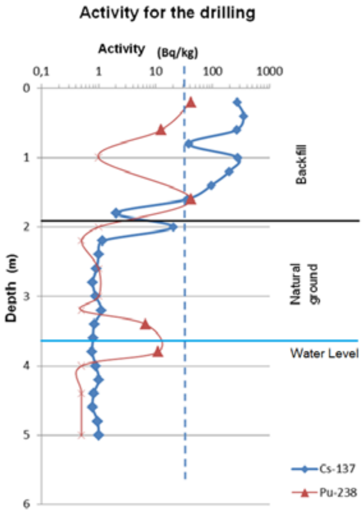

Figure 13: Migration profile of Cs-137 and Pu-238

COST-BENEFITS STUDY

A study of the costs, benefits and impact of the clean-up operations is carried out. This study aims at determining for each zone, the optimum excavation depth according to a remediation scenario and considering technical and financial constraints. Lots of questions come into consideration at this point in a remediation project, so this study is essential and relevant answers can be provided.

<u>3D Mapping and Volumes of Contaminated Soils</u>

A 3D geostatistical study is performed as soon as there are enough drillings and sample results. As for 2D mapping, it uses geostatistics to analyze data and estimate activity as well as risk level. Activity maps are produced with the associated risk. The volume of soils whose activity is above a define level (specific to a remediation scenario) is calculated. The uncertainty is determined as well. This method allows a global estimation but does not provide information about the localization of the contaminated soils. It is possible that clean soils may have to be removed to reach the contaminated ones. Furthermore, as the first method of volumes estimation, it depends on the number of radionuclides taken into account.

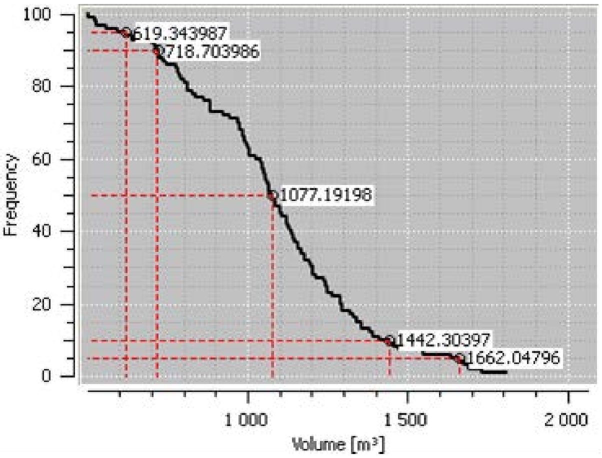

Figure 14: Volumes exceeding the define level and risk associated

Source Term Calculation

Finally, the source term is calculated by averaging the activity by soil slices (Cf. Eq.1 and Figure **15**). The slice thickness is an optimization volume – works precision trade-off.

$$Ts\ [Bq] = Activity\ [Bq/kg] * slice\ width\ [m] * area\ [m^2] * soil\ density\ [kg/m^3] \qquad (Eq.1)$$

Simulations have shown the importance of detection limits in the source term calculation. When the results of the analyses are below the detection limit, the activity value taken into account is the detection limit divided by 2. For the average, it is possible to take this value into account or to ignore it (Cf. Figure **16**).

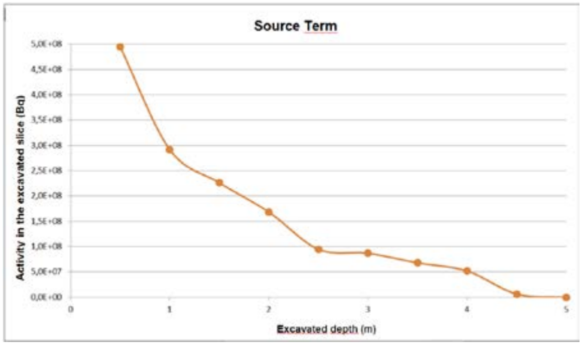

Figure 15: Source Term plot

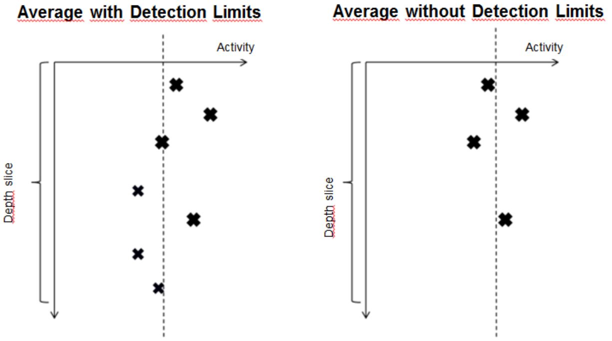

Figure 16: Detection Limit influence

Typical Spectrum

Depending on the quantity and quality of analyses, the typical spectrum (ratios) is calculated. It matches with the proportion of a radionuclide in the total activity, depending on the type of emission. The α/β ratio deduced from the typical spectrum can be represented over depth (Cf. Figure **17**). Its variation can detect pollution or the limit of natural ground.

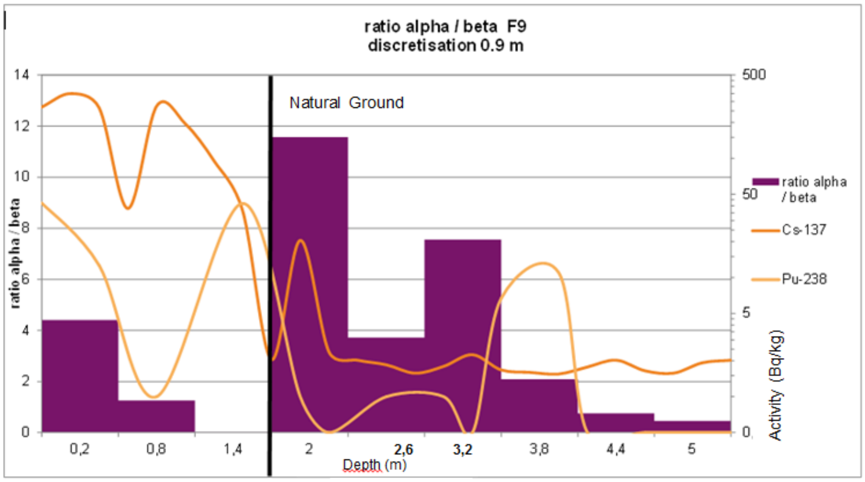

Figure 17: α/β ratio functions of depth

Radiological Exposition Evaluation

In France, there is no waste release threshold; consequently the remediation process aims at removing the maximum of the artificial activity considering technical and economic constraints. This is the ALARA approach (as low as reasonably achievable).

For each remediation project, different scenarios are generally proposed to define the future use of the site [7]. It is obvious that the radiological impact objective will be different if the site becomes a waste storage or a primary school. The scenario takes also into account technical constraints such as buildings stability or accessibility problems. In addition, financial means could influence the final choice when the budget allocated to the project is restrictive. In the end, the radiological evaluation file outlines the most relevant scenarios and the project manager decides which one to apply.

The basic remediation scenarios are the ones described in the IRSN guide [8]. New scenarios can be created to best meet the uses foreseen for the site.

The resulting graphic (Cf. Figure **18**) presents the average activity and the dosimetric impact after remediation in function of the excavation depth according to the chosen scenario. This type of graph shows the excavation depth to which there is no further significant decrease of impact. The cost line gives an indication about the technical constraints which sharply increase the cost, as shoring or underpinning to avoid damaging a building stability.

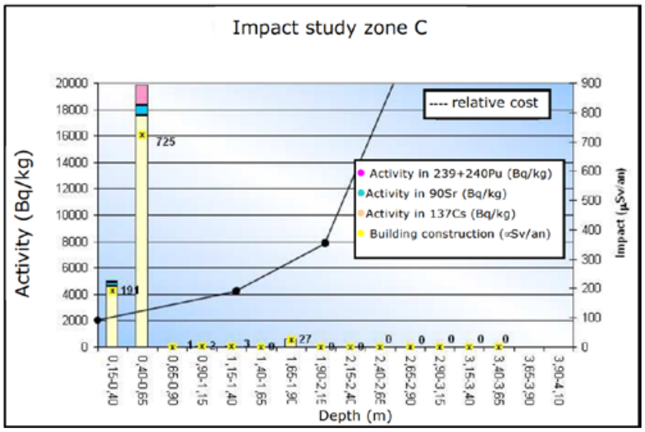

Figure 18: Radiological impact study results

Considering all this information including the result of the geostatistics study, the optimized excavation depth is chosen.

FINAL SURVEY

Several methodologies enable verification that the remediation objective has been reached, and a determination of the average residual activity in order to assess the radiological impact after remediation of the site. They are usually based on statistical data processing (verification of homogeneity, estimation of an average activity, comparison with a regulatory threshold …) and therefore on a random sampling strategy.

Kartotrak software uses two methods to evaluate the optimal amount of measures to perform, depending on the confidence interval, in order to determine the activity of residual contamination: the PESCAR method (Benoit, 2004) and the Wilks Formula (Wilks, 1942).

CONCLUSION

After 10 years of feedback, the Mobile Unit is an original approach developed by the CEA for soil characterization. The gathering of all these independent and essential tools in the unit helps to develop a sound methodology with hundreds of characterized sites. Investigations take a critical place and each project should be carefully optimized. Accuracy, traceability as well as time and money saving are the main goals from to initial to the final survey. The vehicles, mobile laboratories and online data storage site have been created to achieve these objectives. Furthermore, the use of geostatistics allows an efficient data processing while quantifying the risk. Finally, different innovative studies, applying recognized methods, complete the learning process.

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