French CEA's Site cleanup methodology and related applications

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INTRODUCTION

The establishment of radiological maps for the appraisal and for the monitoring of any work in nuclear environment is a crucial issue to deal with. Radiological evaluations have to be performed, before and after the decontamination process, thanks to an optimized amount of samplings and radiological and chemical analysis. Thanks to the experience feedback, sampling and optimized amount of samples protocols have been established, as well as data analysis and modelling tools.

In order to address these various operations, the very first "**C**ommissariat à l'**E**nergie **A**tomique" (CEA, French Atomic Energy Commission) has implemented over the last 10 years an innovative methodology aiming at characterizing radiological contaminations of its sites. This center was set up in 1946 in the Fort of Châtillon, located in Fontenay-aux-Roses, 7 km south from Paris. After implementation of programs related to evacuation of nuclear materials, a remediation plan of the whole site was elaborated in 1995. Today, the facilities are going through a remediation program that will allow setting up buildings for new research activities.

The goal of this methodology relies on various tools such as expertise vehicles with comprehensive detection performances (VEgAS) and recently developed software platform called Kartotrak. A Geographic Information System tailored to radiological needs constitutes the heart of the platform; it is complemented by several modules aiming at sampling optimization (Stratege), data analysis and geostatistical modeling (Krigéo), real-time monitoring (Kartotrak-RT) and validation of clean up efficiency (Pescar).

The use of all of these tools allows optimizing volumes and cost of the remediation process.

CLEANUP METHODOLOGY

In parallel to the facilities' dismantling, exterior contaminated parcels are also considered for remediation. CEA formalized for the Nuclear Safety Authority, in 2000, its decontamination methodology that was already applied for years on CEA centers. This methodology is partly based on the guide: "Managing places potentially contaminated by radioactive substances" [1].

In this way, CEA initiated the radiological characterization of the whole FAR site many years ago. This approach is based on several steps:

- The historical investigations [2]. Understanding the radiological past of the target area is fundamental to calibrate/orientate the subsequent characterization. This includes gathering information from archives, operational characteristics, materials handled, measurement results, accidents, interviews (workers, residents), maps and aerial views, records about former characterizations or remediations.

- The assumption of a contaminated area. A radiological control with a simple radiation detector shows high level of radioactivity in some areas. The contamination must be confirmed with more measurements.

- The confirmation of the contamination. The dose limits for people may be exceeded, a level of protection necessary for workers undertaking further characterizations is determined.

- The surface characterization. A detailed map of the radiological activity has to be established thanks to surface measures (in situ gamma spectrometry, soil surface samples). The risks to the environment can be identified this way.

- The in-depth characterization. A campaign of drill holes indicates the contamination depth in the ground. The drilling samples should also go through chemical analysis to complete the detailed evaluation. Any potential transfer towards the groundwater has to be considered.

- The rehabilitation objectives. The remediation method of the contaminated area is being set up, actions to carry out in order to excavate and leave a satisfactory residual activity. The waste zoning is established thanks to the previous characterization (2D maps, 3D volumes).

- The remediation process. Together with the removal of the contaminations, a **survey of the operations** is performed is performed to guarantee the safety of the workers.

- The final characterization. Some measures are collected to validate the achievement of the remediation (end-point dose assessment) and to keep informed about the radiological status of the area for any future use.

To satisfy the requirements of the different steps of this remediation methodology, CEA identified the “need” for industrial radiological evaluation, which led to the creation of various tools: vehicles, measuring devices, softwares.

THE EXPERTISE VEHICLES

CEA has developed three vehicles dedicated to expertise and investigating. The second of them, LAMAS II, contributes to perform 2D site cartography established from measurements by in situ gamma spectrometry. LAMAS II vehicle is also includes a radiochemistry laboratory for measurement of α emitters (U, Pu) with low detection limits.

The final prototype, called VEgAS, is equipped with the same measuring devices required for the 2D cartography. One of the main innovations of this vehicle is the installation of DSP10 detectors, newly used in the field of radiological characterization. This vehicle can cover about 1 ha per hour for exhaustive measurement on practicable ground.

The DSPs detect most radionuclides usually found on sites that are contaminated by activities of industry and nuclear research. Their detection limit is described in the following table 1 [3].

TABLE 1: detection performances of the DSP

	TAR ROADS (Pollution of 1 m² area)				GROUNDS (Pollution of 1 m² area and 5 cm thick)			
Radio-nuclides	Detection Limits (kBq.m-2)				Detection Limits (Bq.kg-1)			
	0 km/h	2,6 km/h	5 km/h	10 km/h	0 km/h	2,6 km/h	5 km/h	10 km/h
137-Cs	3	3.7	5	9	57	70	95	168
60-Co	1.6	1.9	2.7	4.8	30	36	50	90

THE SOFTWARE PLATFORM

This platform is based on a GIS, KARTOTRAK, and its various modules (STRATEGE, KRIGEO, K RT, and PESCAR) which can be used at different stages of the characterization process (figure 1).

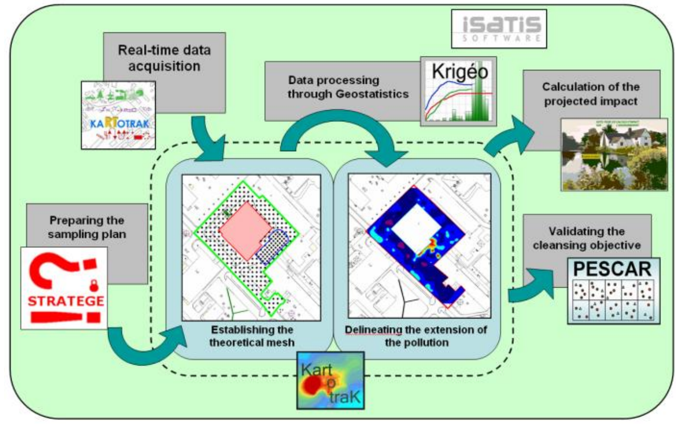

Fig 1: Interaction between the modules of the platform

Kartotrak [4] is a Geographic Information System (GIS) developed by the CEA in 2004. This software is a full visual tool dedicated to the cartography of contaminated places, exterior sites as well as inner facilities. The software contains usual geographical tools (zoom, polygon editing, distance/surface measuring, text editing) which makes it user-friendly to work using vectorial maps as well as raster. Other functionalities have been especially developed to have a very measuring-oriented tool (setting up a systematic mesh in the area to evaluate, or a circular grid [5], collect and store the coordinates of precise spots from the map, display the accurate location of a vehicle, equipped with a GPS, and collect measurements from various devices).

The GIS is also the root for several modules created by the CEA. Based on an experience feedback of over 100 sites, the sampling plan can be established and optimized upstream with STRATEGE [6]which gives advices about the dimension of the mesh, functions of the area of the site to be characterized and the pollution type. Various graphic indicators (probability of reaching a target, impact/relevance of collecting extra measurements…) help the user by providing him information and comparison tools that are necessary to his decision making. At the end of the decontamination process, STRATEGE uses two methods to evaluate the optimal amount of measurements to perform, depending on the confidence interval, in order to determine the activity of residual contamination: the PESCAR method [7] and the Wilks Formula [8].

The module K.RT (Kartotrak Real Time), when equipped in a vehicle, allows to collect many data and to realize quickly a removal of doubt on an area, in order to highlight “areas of interest” which will go through further radiological evaluation. Therefore, this method can reduce the surface to be thoroughly characterized.

Once all measurements are collected, a geostatistical method is applied: the kriging. This is a special interpolation method that demands for the user to analyse the spatial variability of data. As a result, the user can display a map of the estimated contamination of the area. Uncertainty maps and confidence intervals are also provided in order to highlight imprecise areas that might require additional measurements [9] [10].

Risk analysis is performed through the estimation of probabilities of exceeding a given threshold. The results help deciding how many drill holes should be realized for 3D analysis and where to locate them.

An alternative version of Krigéo is based on ISATIS© software [11], it allows considering physical faults between measurements. The 3D analysis and kriging (figure 2) are also performed through this more proficient version.

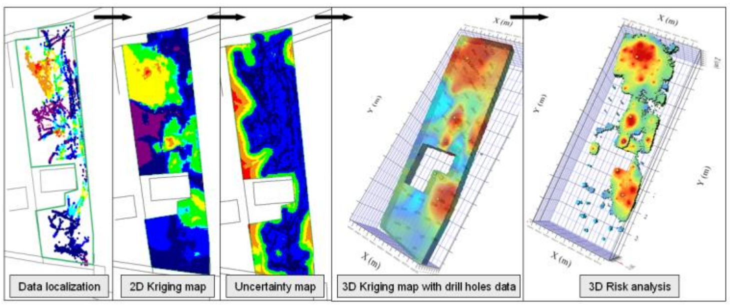

Fig 2: Various geostatistics results displayed in Kartotrak (2D), and Isatis (3D)

CONCLUSION

In order to address the decontamination of the Fontenay-aux-Roses Centre, one of the missions of the CEA has consisted of the development of methodology and setting up measuring devices (VEgAS) and innovative software, improving the process of characterizing the wastes before their removal.

The detection performances of the new detectors allow to measure while driving, in order to quickly highlight contaminated areas in addition to those identified during the analysis of the historical activities. The contaminated areas identified during this removal of doubt will go through further radiological evaluation.

The Kartotrak platform, together with its related modules Stratege, KRT and Krigéo is now suited to manage globally and achieve a cleanup project. It has become an important tool for project managers to make decisions and respect costs and deadlines.

All these developments, as well as the concrete applications on various sites in France, contribute to the acknowledged know-how of the CEA centre of Fontenay-aux-Roses for radiological characterization and remediation of radioactively contaminated soils.

The transfer of the methodology and related software platform to nuclear facilities is under process, aiming at providing a suitable framework to address a tremendously increasing demand about the characterization of contaminated concrete structures and facilities. The first developments have now grown from prototypes to industrial products, ready to be used for many sites and in many cases.

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