BIO-MECHANICAL REMOVING OF CONTAMINATED SOILS: A FIELD EXPERIMENT

A. Jouve, H. Maubert and E. Schulte
Institut de Protection et de Sûreté Nucléaire
Département de Protection de l'Environnement et des Installations (IPSN/CEA)
13108 St Paul lez Durance France

ABSTRACT

If, in spite of safety precautions, a major nuclear accident would occur, countermeasures should be taken to attenuate the impact of radioactive deposits. The European RESSAC program (Rehabilitation of Soils and Surfaces after an Accident) aims at studying actions for normal life return in contaminated zones. One of them, called the Decontaminating Vegetal Network (D.V.N) associates the biological action of turfing plants, producing a dense root-network capable to trap the top contaminated soil particles, and the mechanical efficiency of a turf harvester which can remove only 1 cm of soil. This performance, not associated with other techniques of soil removal such as scrapers or bulldozers, leads to minimize the waste production. The D.V.N is a vegetal cover spread over the contaminated soil, using the hydro-seeding technique. The growing plants are forming a pleasant lawn which may have a positive impact on the public opinion compared to techniques using bitumen mixtures to cover the soil. Field experiments involving labelling solutions of stable molybdenum salts simulating the contamination of the soil have shown that this technique can be applied as well on homogeneous cultivated soil surfaces as on roughly ploughed soils.

INTRODUCTION

Eventual nuclear accidents cannot be expected to end as fortunately for the environment as the accident of Three Miles Island. Although the RESSAC program was initiated before Chernobyl accident, this accident confirmed the need of studying the consequences of an accident for the environment as well as the countermeasures to be applied to minimize the transfer of radionuclides in the food chain. An universal countermeasure capable of removing the radioactive contamination from the environment do not exist to our knowledge. But different countermeasures adapted to single particular condition may finely lead to decontaminate most of the environment. Cultivated fields frequently represent a large part of soil occupation around nuclear sites, e.g. up to 40% of the whole area around the Chernobyl reactors, so that decontamination of fields may be of economical priority, especially in small countries compared to Russia or Ukraine, like France. The return of rural populations after the application of emergency plans may depend on the possibility to re-use fields for normal agricultural production. The Decontaminating Vegetal Network (D.V.N) studied within the RESSAC program allows to scrape a soil layer of 1 cm, involving grass seeding to produce turfing plants with a root mat layer, thus facilitating the top soil removal. The quantity of contaminated soil removed (15 kg m-2) can reasonably be stored within field edges, in piles allowing self-absorption of the irradiation flux. Such disposal, properly managed, may render wastes available for a possible subsequent management or treatment. This advantage is not associated with methods of deep-ploughing or deep placement (1) in which the top contaminated soil layer is transferred below the arable layer rendering irreversible a possible subsequent management. The technique of deep placement is not in agreement with the actual philosophy of nuclear waste management, considering that actions leading to an irreversible situation must be avoided. The D.V.N technique allows to decontaminate cultivated fields without irreversible adversely affecting consequences for ecosystems.

PRINCIPLE AND METHOD OF THE D.V.N.

In case of a radioactive contamination of the soil by fallout, the upper layer of the soil minerals trap most of the radionuclides (Fig. 1) (2). The excess of negative charge on minerals allows them to bind radionuclides with cationic electric charge. Caesium, which is the most abundant radionuclide after a nuclear accident, have the added property to have an hydrated ionic radius of 1,67 10^{-10}m compatible with the penetration into edge inter-layer of some clays (1,2 10^{-9}m). Moreover, in the case of a nuclear accident, the released mass of caesium is very small compared to its radioactivity level so that, reciprocally, clay sites of fixation are in excess, favoring caesium immobilization by clays.

Plutonium has also been recorded to remain in the first top centimeters of soils (Fig.2) (3). Assuming that the migration rate in the soil profile is a slow process, the D.V.N can remain on the contaminated soil for quite long time (about 1 year) without adversely affecting rehabilitation success. On the contrary , the additional time allows further grass growth and can be used to organize harvesting the D.V.N with a turf harvester.

More generally, nuclear or non nuclear accidents involving atmospheric dispersion of xenobiotics result in the contamination of the soil surface. Therefore, the D.V.N technique could be applied as well for non nuclear as for nuclear pollutions.

The D.V.N Technique

The plant uptake of radionuclides obviously cannot be expected to absorb efficiently the contamination of the soil (4) even if the plant roots are concentrated in the soil layer where the contamination is available. But plants can produce a natural mat capable to trap the top contaminated soil particles, preventing the resuspension of contaminated dust, and facilitating its subsequent removal.

In order to use the natural advantage of the soil to immobilize radionuclides, the tillage of the soil must be avoided to prevent dilution in the soil profile.

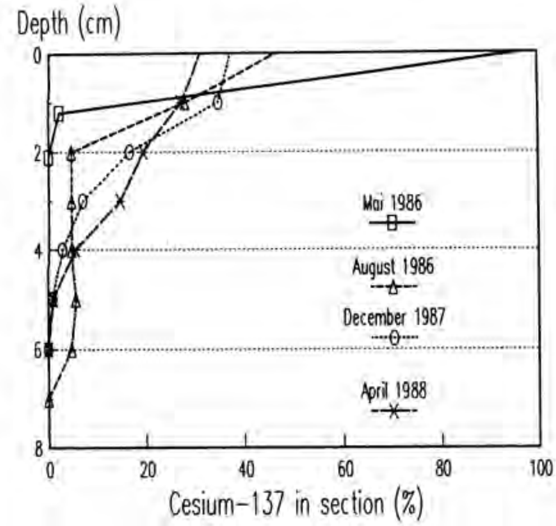

Fig. 1. Cesium-137 from Chernobyl fallout in Cadarache loamy clay soil (after Legrand).

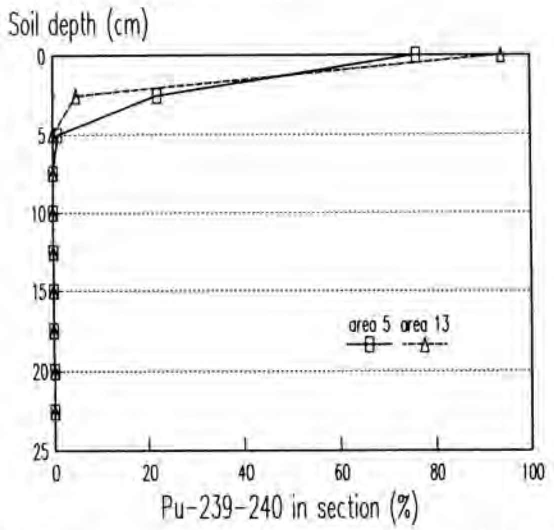

Fig. 2. Examples of normal plutonium distribution in Nevada Test Site soils. (After Essington and Fowler.)

The problem of soil decontamination have been expected to be solved by the technique of turf transplantation. This technique is used to fasten the installation of lawn by transplanting turf mats harvested with a turf harvester, from a producer field to a garden or a sport court.

The adaptation of this technique leads to sow grass without tillage of the soil by spreading a growing medium including grass seeds and a fertilizer. This growing medium will subsequently cover the soil and prevent the resuspension of contaminated soil particles. Plant roots will fast leave the growing medium to invade the natural soil and form a dense root-network imbedding contaminated soil particles and allowing the turf harvester to remove the first top cm of the contaminated soil, together with the initial growing medium. The added advantage of the growing medium which prevents the resuspension of contaminated dust, is to ensure a good grass growth even in unfavorable conditions (poor soil, birds feeding on seeds).

In order to solve the problem of resuspension, the D.V.N must be sown very fast after the accident. This can be carried out by the technique of hydro-seeding used to sow grass on slopes of road edges for retaining the soil. This technique allows to spray the mixture of seeds and the growing medium mixed in water. Generally, the hydro-seeding machine has a tank volume of 2 or 3 m3 and a pump which sprays the mixture via a fire-hose nozzle. Price and quantity of the hydro-seeding mixture components are given in Table I.

TABLE I

The hydro-Seeding Mixture

Component	Dose rate g m-2	Price $ km-2
Pure meadow (1) (Poa pratensis)	10	84200
Meadow 60% Rye grass 40% (2) (Lolium perenne)	30	*
Mixture of (1) + (2) + (3) + (4) (3) Festuca pratensis, (4) Trifolium repens.	40	*
Polysaccharides	25	16140
Organic matter	230	4380 (urban waste compost)
Fertilizer (N-P-K, 10-20-20)	10	2631

* The price of seeds is similar for each of the three different possibilities of grass species.

It is currently possible to carry out the hydro-seeding technique using an helicopter. Turbulences produced by the propeller are without adversely affecting action on the seeding homogeneity. On the contrary helicopters generally have a better performance in the application of pesticides or fertilizers than machines driven on the soil surface. Nevertheless especially in dry conditions, turbulences may produce contaminated dust resuspension so that checking the opportunity of sowing by helicopter may be necessary according to climatic conditions. The rapid application achieved using hydro-seeding by helicopter (0.3 $km^2 day^{-1}$) may favor the choice of this system compared with the use of trucks.

After the development D.V.N plants, turf mats can be harvested with a turf harvester, a very old technique used in England some centuries ago to transplant grass from permanent pastures to gardens around castles. Nowadays, the machine has a motor driven moving blade which gives alternative strokes (frequency of about 20 Hz) on the vertical profile of the soil, 1 cm below the soil surface. These alternative strokes associated with the machine travelling allow to release a turf layer which can be rolled like a carpet. The optimum cutting width of 45 cm allows to avoid the heterogeneity of the turf mat thickness. Therefore, the harvested surface cannot exceed 15000 m day^{-1}, a performance not compatible with the decontamination of large areas.

Experiments carried out in an experimental field, have shown that after 5 months of growth the turf has a sufficient root mat to be removed with a turf harvester (4). Different soil surface micro-topographies were tried to simulate different states in which cultivated fields may be found during the seasons of the year when an accident may happen such, as roughly ploughed fields. The soils were sprayed with a solution of ammonium molybdate, which was intended to simulate radionuclide contamination of the soil. Although the molybdenum did not behave like caesium, which is the main long living radionuclide released during an accident, the different soil surface micro-topographies were decontaminated with the same efficiency as the control representing a very homogeneous surface. In-homogeneous soil surfaces such as the roughly ploughed soil tested in our field may be improved by rolling the turf after shooting of the grass to rearrange the soil structure under humid conditions. The main limitations of the turf harvester are that it is unsuitable for stony soils.

Trials carried out during this field experiment showed that the turf harvester can also cut a soil layer without plant growing. This trial has been made on a humid soil with a quite continuous structure, two conditions which may be considered as favorable, but not representative of all possible soil properties. Nevertheless, this indicates that the turf harvester may also be used for the decontamination of fields where grass cannot grow. Aggregating agents such as organic polymers used for soil conditioning may be used to replace the D.V.N. or improve the soil structure.

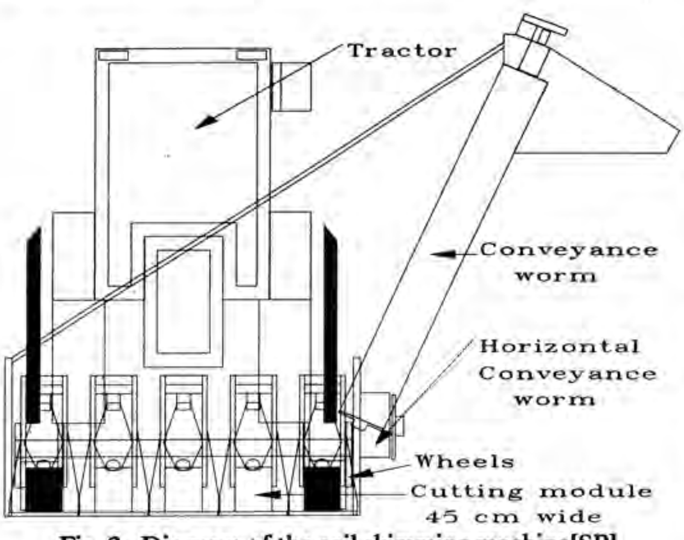

Fig. 3 . Diagram of the soil skimming machine[SP].

Investigations are currently made to improve the existing machine. The prototype will have 5 modules of 45 cm blades, associated to a conveyance worm to transfer wastes into a trailer. This machine can be driven by a tractor normally used in agriculture. (Fig. 3)[SP]

Main constraints of the machine would be the following :

- Adapted to a tractor of a 100 kw power.
- Able to scrape 0.05 km^2day-1.
- Able to scrape only 1cm of depth.
- To be decontaminated using a high pressure water jet.
- Without manual handling of turf mats.
- With a sufficient confinement of dust.
- Adapted to soil irregularities.
- With a conveyor to transfer turf mats in a trailer.
- Able to work on a humid soil.

The planned machine is coupled up in front of a tractor, constituted of a rigid underframe which leans on the soil with 4 wide band wheels, forming a carriage. This carriage has 2 subsets, a waste transfer set rear, a scraping set forward.

The Waste Transfer Set

Turf mats cut by the blades are slipping on a slope up to a horizontal conveyance worm, connected with an inclined conveyance worm which is dumping the wastes into a trailer. Conveyance worms are propelled by hydraulic engines.

The Cutting Set

It is composed of 5 modules set out in quincunx on 2 axes perpendicular to the machine travelling. Modules are independents one from the other, in order to be adapted to the ground profile. Each module works such as a planar with a bed plate in 2 parts, separated by a blade. In this case the front part of the bed plate is replaced by a roller. The blade-roller set is linked to the underframe with elastic elements. The alternative movement of the blades is given by an eccentric shaft driven by an hydraulic engine. A general hydraulic pump is driven by the tractor engine. Characteristics of the machine are given in Table II.

TABLE II

Characteristics of the Machine

Length	2050mm
Width	4250mm
Max height	3750mm
High below the outlet	2750mm
Necessary power	40 kW
Capacity	0.05 km^2day-1
Weight	1500 kg
Cutting width of a blade	45 cm
Cutting width of the machine	2005mm
Vertical stroke of a blade	±5 cm
Inclination of a blade	±5°
Cutting depth	1 cm
Strokes frequency of a blade	20 Hz
Overlaps of the blades	5 cm

CONCLUSION

Unfortunately the field experiment did not allow to give data on the efficiency of the D.V.N technique, because the tracer used to simulate the behavior of aesium was not appropriate. Nevertheless, it has been shown that when the D.V.N is applied on soil surfaces with in-homogeneous micro-topography such as roughly ploughed soil, its efficiency to remove the contamination is comparable to that of an homogeneous soil surface. The field experiment also proved that the turf harvester can cut a bare soil with a continuous structure. This indicates that the application of an organic polymer such as soil conditioners, may be used on soils where plants may have difficulties to grow.

In order to apply the D.V.N technique on fields of several km, the turf harvester performances must be improved with respect to requirements of radioprotection and economical benefit. The RESSAC program is planning to study a new machine, adapted from the turf harvester with 5 modules of 45 cm capable of integrating the surface variation. A demonstration of this technique will be held in the Chernobyl zone in summer 1992 in the framework of a contract with the Commission of the European Communities on mechanical countermeasures techniques.

ACKNOWLEDGEMENTS

This study is partially financed by the Commission of the European Communities DG XII.

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