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FORCED DECONTAMINATION OF FISSION PRODUCTS DEPOSITED ON URBAN AREAS

A LITERATURE STUDY

Lisbeth Warming

Abstract. Long-lived fission products may be deposited in the environment following a serious reactor accident. Areas of special concern are cities where the collective dose might be high because of the population concentration.

An extensive literature list is presented here. Only a few of the references deal with the problem as a whole. Some references deal with non-radioactive materials but give us useful information about the behaviour of particles on outdoor surfaces.

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1. INTRODUCTION

The interest in decontamination of outdoor areas occurs in two time periods. The first, 1957-67, appears in connection with atmospheric nuclear explosions carried out in the fifties, some of which led to widespread contamination. These were mainly dealt with by military organisations, and many of the reports were classified although some of them were released later. The second period began in the late seventies in connection with public concern about nuclear power plant safety. The focus in this study is on the later period.

The publications from the early period concentrate on contamination by particles larger than 100 um, whereas particles smaller than 10 um might be dominant in an accidental power plant release.

Further, there have been occasional accidents at laboratories and industrial facilities leading to extensive decontamination efforts. In the thirties industry used radium extensively, leading to some cases of severe in- and outdoor contamination which have recently been discovered and the clean-up programs reported.

Three literature studies of related subects have been reported, namely those of Widemo,1980, Faust,1980, and Fore,1982.

The efficiency of a dose reduction effort is usually described by the decontamination factor, DF, defined as the ratio of the contamination level before to that after the effort. The DF is often measured as the ratio of the exposure rate before to that after the decontamination.

2. DECONTAMINATION PRINCIPLES

Forced reduction of doses from radionuclides deposited on outdoor surfaces can be obtained by treating the contamination in three essentially different ways: decontamination, surface removal and fixation. A fourth way is to let nature act as decontaminator, but weathering is outside the scope of this survey.

Countermeasures at a large and complicated area such as a town will always be a combine of the first three principles. Some of the methods mentioned here will sometimes be decontamination and sometimes surface removal depending on how hard or repeatedly it is applied.

Cesium-137 is one of the most important radionuclides to be taken into account. At a contamination of a concrete surface it is noticed that the specific concentration of Co-60 falls to zero within one mm from the surface, but the concentration of Cs-137 drops only 50% 5 mm into the material. One reason for this is that cesium is more easily dissolved and also might ionexchange with sodium and potassium in concrete, (Rose 1982).

The particle size of the contaminant as well as that of the road particles play an important role in determining how well a road surface may be decontaminated. Sartor, 1974, and Revitt, 1980, give a discussion of ordinary road pollution, particle size and efficiency of road cleaning. Corn, 1961, discusses the adhesion of particles of various sizes to solid surfaces.

2.1. Decontamination

The most elegant approach to decontamination is to remove the contaminant without spoiling the surface. This is particularly important if we have to deal with widespread outdoor contamination, as could occur in an urban area after a severe reactor accident. In this case we would like to return the town to normal conditions as soon as possible.

The efficiency of this type of decontamination might not be very high, but it can usually be done reasonably fast at low cost. It will remove at least small contaminated particles so that resuspension and inhalation doses will be avoided.

The decontamination methods avaiable are washing, firehosing, light sand-blasting, vacuum cleaning, brushing.

As early as 1957 Pinson reported a series of decontamination experiments. His preliminary results show efficiencies of 98 - 45% (DFs of 50-2), highest for sandblasting.

2.2. Surface removal

Removal of the contaminated surface itself is less elegant but very thorough. It is also costly in terms of procedure and loss involved and usually a rather slow decontamination method. For an urban contamination with many houses and large areas involved it can be a difficult principle to put into practice. The high efficiency is of course due to the fact that you can eliminate all contamination, but only if it can be effected without spreading the contaminated materials.

It is an expensive way to decontaminate because vast amounts of waste have to be transported carefully (sometimes over long distances) so as not to spread the contamination. It requires a lot of room for the deposition of the waste. Further you have to add the cost of reestablishing the surface, and materials for this are not always readily avaiable.

Methods in this category are scraping, spalling, roof renewing, planing and demolishing.

A workshop was held in 1980 on Concrete Decontamination. In the proceedings (Currie, editor) descriptions are given of a large variety of machinery that can be appropriately used for removing a concrete surface.

2.3. Fixation

Another way of dealing with a contamination is to apply a substance to the surface to prevent its spreading and if the layer is thick enough it will also provide some shielding. The efficiency of the dosereduction using this principle will increase with the amount of covering substance and thereby with cost.

Methods here are painting, ploughing, overturning paving stones and covering roads with a new layer of asphalt.

Fixation will not be treated in this paper, but it should be mentioned that Jensen, 1979, has calculated shielding factors for asphalt covering of roads.

3. METHODS

Several examples are given in the literature of decommissioning of houses or sites with the requirement of unrestricted use. The effort always combines many methods from sand-blasting and washing to total removal of buildings. White (1980) describes the clean-up of a town house previously used for radium dial painting work. NLO (1982) reports on the decommissioning of a formerly U-Th sampling plant site together with some nearby properties. Parrott (Cristy,1981) describes the clean-up at ORNL following a release of plutonium.

Methods reported in the literature are disscussed below.

3.1. Washing with detergent

Ureda (1976) describes the cleaning of the concrete inside of a hot cell, which had previously been used for investigations of fuel burnup samples and was contaminated by mixed fission products. First a foamer was applied to loosen the contaminant and afterwards the loosened material was removed by vacuum-cleaning and finally all surfaces were wiped with "Big K" solvent. The DFs obtained varied from 1.1 to about 50.

3.2. Firehosing

Wiltshire (1965 and 1966) has made a set of experiments with firehosing. The contaminant was La-140 on sand and the particle size was large, 44-88 m, 88-177 mm or 300-600 m. Asphalt road surfaces and roofs of different materials were contaminated and firehosed soon after. The dose rate reductions obtained varied from 10 to 1000, biggest for the largest particles on the smoothest surface. More than two firehosings of an area did not increase the decontamination significantly.

Warming (1982 and 1984) has done similar experiments with asphalt and concrete roads contaminated with either Rb-86 (and Cs134), Ru-103 or Ba-La-140. The contaminant was sprayed onto the road surface dissolved in water. This means the particle size was that of ordinary loose particles on the road, but further chemical reactions with the surface material might take place. Two days after deposition a single firehosing gave an exposure rate reduction of about 2 (see fig.3.2). For Rb-86 (and Cs-134) almost no reduction could be noticed after 40-50 days, whereas for Ru-103 the reduction was 1.2 independent of time. Scrubbing, use of detergent or potassium fertilizer did not improve the decontamination factor.

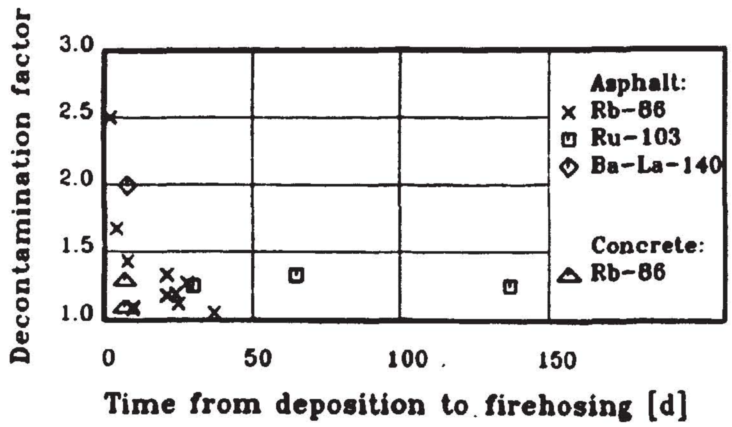

Figure 3.2. Results of decontamination attempts by a single firehosing of various road surfaces with different contaminants. It should be noted that the decontamination is best if the firehosing is done within 14 days of the contamination.

Miller (1960) firehosed a concrete slab roof and a composition shingle roof, both contaminated with fall-out from weapons tests. In a second effort the concrete slab roof was scrubbed with detergent before the fire hosing. Roed (1981) washed 30 roof samples with fall-out cesium in the laboratory. Only a few of his samples could be decontaminated with DFs of more than 2. Miller obtained DFs of 2.5 - 3. Halter (Cristy,1981) states that the speed of using a water cannon is slow: 3 - 6 min/ft^2.

3.3. Washing with high-pressure water

In Currie (1980) two papers reported decontamination of plutonium-contaminated concrete surfaces using high-pressure washing. At Oak Ridge Parrott has decontaminated a concrete cell. The water had detergent added to it, and a cell within the cell was constructed in order to prevent spreading of the contamination. In places where the contamination levels were highest a DF of about 1000 was obtained. At Mound a 60 000 sq ft concrete floor was decontaminated (Combs). The process used needed simultaneously five oprators. In total the cost was 300 mandays and 55 000 $ (1972-value). The first cleaning reduced the average contamination from 2 10 cpm to 5 10 cpm corresponding to a DF of 40.

A third paper (Currie, 1980) by Hilaris describes a set up with a water jet, that could be used for outdoor surfaces like roads.

Halter (Cristy,1981) finds that high pressure water cleaning is the fastest method available, 10 - 15 sec/ft .

3.4. Vacuum sweeping

This can be an efficient procedure if the contaminant is dry deposited and has not been wetted by rain and dew. If you have a contaminant that has reacted chemically with the surface, vacuum sweeping means removal of loose particles which have acted as shielding (Roed,1981 and Warming,1982).

3.5. Sand-blasting

White, 1980, describes sand-blasting of some indoor painted I-beams and how it was necessary to take measures like enclosures and effective air-cleaning. The contaminant was radium and the beams had been painted several times on top of the contamination. The sand-blasting was done at a speed of 2.5 m /h with two persons involved, namely an operator and a health physics assistant. The reduction in surface contamination obtained was from about 10-3 Ci/cm to about 10-6 Ci/cm , which is a DF of 1000.

Roed (1981) reports sandblasting efforts of roof materials. A total of 30 samples of 0.1 m was taken from different roofs and the Cs137 (from fallout) contamination was measured before and after sand-blasting in the laboratory. Most DFs obtained were between 1 and 3 with three exceptions at 5 to 6.

3.6. Flame cutting

By flame cutting you remove a thin layer (a few mm) of the surface. If this is contaminated it is essential to collect dust and aerosols created in the process. Eberling et al, 1984, have made a set of investigations on indoor concrete surfaces contaminated with a mixture of Co-60 and Cs-137.

A single flame cutting gave a decontamination factor of 1.5 to 2.5, but four successive cuttings could reduce the contaminations to background level (see Table 3.5)

Numbers of cuttings	Surface concentration Ci/cm2
Initial	2.1 10-
1	1.5 10-
2	7.5 10-
3	4.5 10-
4	background

TABLE 3.6. Surface contamination after several flame cuttings

The cost of a decontamination of this type is stated to be 376.-DM/m .. The time consumption is 150 min/m for one skilled worker plus one health physics assistant, and the cost of these two persons is 350 DM/m or 93% of the total.

3.7. Spalling

Halter (Cristy,1981) describes concrete spalling including the problems of the waste created. The speed at which it can be done is rather high 30 - 60 sec/ft . No decontamination efficiency is given.

3.8. Mechanical sweeping and planing

Barbier (in Currie,1980 and Cristy,1981) lists the cost of operating with different available machinery. Wire brushing with one operator cost only 0.004 $/m and one machine can cover 9 km /y. Health physics monitoring will add about 50% to the cost. A road planer runs at a cost of 0.2 - 0.6 $/m depending on the depth to which it loosens the surface, (0.6 to 2.5 cm). Each machine is reconed to be able to do about 1.5 km per year, the cost of monitoring is insignificant in this context. Removal of the debris is not taken into account. Barbier recommends rebuilding the cabs of the machines with shielding in order to protect the operator.

3.9. Snow clearance

In winter snow clearance can be a common activity in an urban area and any contamination deposited on top of snow is easily removed. One experiment with rubidium sprayed onto a snow- and ice-covered road has been reported by Warming (1982), 66% of the activity was removed in two weeks by ordinary snow clearance.

4. ANALYSIS AND RECOMMENDATIONS

In 1962 Cook wrote a set of recommendations on decontamination practice, the main principles of which are still valid, but no results of possible efforts are given.

Starbird (1969) has developed a code for calculating the reduction of indoor doses due to possible decontamination out-of-door.

The decontamination of a Po-210 laboratory (Gilbert,1976) led to a set of recommendations for building construction in order to ease the cleaning after use of radioactive materials.

In Ayres,1970, IAEA, 1974 and NRC(WASH-1400), 1975, several series of decontamination methods are recommended depending on surfaces and weather conditions. The results are rather optimistic with respect to obtainable decontamination factors, becau the data given are based on the decontamination of large particles (>100 m). WASH-1400 recommends a DF of 2 or 20, depending on means, to be used in consequence modelling. According to later experiments an overall DF of less than 10 is probably more realistic (Gjørup,1982).

Also Simon,1975/1980, deals with rather large particles, > 25 m. For hard urban surfaces most decontamination factors given are below 10.

At Battelle, Pacific Northwest Laboratories a computer program, DECON, has been developed. It is designed to assist personnel engaged in the planning of decontamination activities. Tawil (1984) describes how DECON was used in the NUWAX-83 exercise. DECON is meant to be used for the cleaning-up of a contamination following a reactor accident or nuclear detonation. It takes into account: time, cost, radiological standard, rate at which efforts can be applied, manpower, equipment and efficiency, when it recommends a decontamination procedure. One conclusion given is that if the cost of a clean-up exceeds the property's value, it is recommended that it should be condemned.

Federal Emergency Management Agency, FEMA, 1980, has issued recommendations for architects and engineers on how to take decontamination into account in the design and planning of new structures.

5. CONCLUSIONS

In the literature you can find a number of forced decontamination efforts. The decontamination factors obtained vary wildly. It is about 1 - 5 for sand-blasting and firehosing and approaching infinity with the total removal of the contaminated object.

A few papers state the cost of the effort. In general it is found that a gentle action that keeps the surface relatively unharmed gives a DF below 10, it is rather fast and the cost is mainly that of manpower. If a road planer or similar machinery is used, part of the surface is removed and might need repair. It gives DFs up to 1000, it is slow, 1 - 100 m^2/h, and the cost is mainly that of the machinery (1 - 10 $\$/m^2$), but to this should be added the cost of removing and storing the debris.

6. REFERENCES

AYRES J.A. (Editor). Decontamination of Nuclear Reactors and Equipment. The Ronald press Company. New York. 1970.

CORN M. The Adhesion of Solid Particles to Solid Surfaces -I. A Review. J.Air Poll.Contr.Ass. Vol.11 p523 1961

COOK A. Principles and Recommended Practice for Decontamination of Radioactive Areas and Equipment. AHSB (S) R32 1962

CRISTY G.A. and JERIGAN H.C. (EDITORS) Environmental Decontamination. Proceedings of Workshop. CONF-791234 1981

CURRIE A.J. (Editor). Proceedings of the Concrete Decontamination Workshop. CONF-800542,PNL-SA-8855. 1980

EBERLING W.,BOEDEKER B. and ROSE K. Dekontamination von Betonoberflaechen durch Flammstrahlen.(In German). EUR 8969 1984

FAUST R.A.,FORE C.S. and KNOX N.P. Nuclear Facility and Decommissioning and Site Remedial Actions. ORNL-EIS-154 V1 1980

FEMA: FEDERAL EMERGENCY MANAGEMENT AGENCY Decontamination Considerations for Architects and Engineers. TR1 1980

FORE C.S., FAUST R.A. and BREWSTER R.H. Cleanup and Treatment of Radioactively Contaminated Land including Areas near Nuclear Facilities. A Selected Bibliography. ORNL/EIS-199 (NVO/AEIC-243), DE83 003330 1982

GILBERT K.V.,WRIGHT E.M. and MADDING R.D. Report on the Decontamination and Decommisioning. MLM-2239 1976

GJØRUP H.L., N.O.JENSEN, L.KRISTENSEN. O.J.NIELSEN, E.L.PETERSEN, T.PETERSEN, J.ROED, S.THYKIER-NIELSEN, F.H.VINTHER, L.WARMING and A.AARKROG. Radioactive Contamination of Danish Territory after Core-melt Accidents at the Barsebäck Power Plant. RISØ-R-362 1982.

IAEA. VALLARIO E.J. Ed. EvaluAtion of Radiation Emergencies and Accidents. Selected Criteria and Data. Technical Reports Series No. 152. 1974.

JENSEN P.H. Dæmpningsfaktorer for gammastråling fra deponeret radioaktivitet opnået ved pløjning af jord og asfaltpålægning af veje. Private communication (internal report in Danish).

MILLER C.F. The Radiological Assessment and Recovery of Contaminated Areas. CEX-57.1 1960

NLO Inc.Cincinnati,OHIO. Phase 1 Remidial Action of Properties Associated with the Former Middelsex Sampling Plant Site. NLCO-006EV-Rev 1, DE82 017059, 1982

NRC. RASMUSSEN N. Ed. Reactor Safety Study. An Assessment of Accident Risk in U.S. Commercial Nuclear Power Plants. WASH-1400 (NUREG-75/014) 1975

PINSON E.A.,MERIAN R.F.,BOECKER B.B. and DICK J.L. Monitoring and Decontamination Techniques for Plutonium Fallout on Large Area Surfaces. ITR-1512 (DEL) UC-41 1957

REVITT D.M. and ELLIS J.B. Rain Water Leachates of Heavy Metals in Road Surface Sediments. Water Research. Vol 14, p 1403 1980

ROED J. Undersøgelse af overfladedeponering med henblik paa beregning af deponeringen af luftbåret materiale frigjort ved kernenedsmeltning i kraftreaktorer (in Danish). Risø-M-2274 1981.

ROSE K. Ermittlunq von Kontaminationen zweks Planung des Abbaus von Kernkraftwerken (in German). Diplomarbeit Fachshule Lübeck. WS 1981/82.

SARTOR J.D.,BOYD G.B. and AGARDY F.J. Water pollution aspects of street surface contaminants. Journal WPCF Vol 46 P458 1974.

SIMON A.D. Entaktivierung Dekontamination. (1975 in Russian, 1980 translated into German). Militaerverlag der Deutschen Demokratischen Republik 1980.

STARBIRD A.W. Decontamination of Finite Rectangular Areas. AD 695 668, 1969

TAWIL J.J. and STRENGE D.L. Decontamination Analysis of a Radiologically Contaminated Site. PNL-SA-11548 E 1.99, DE84 008321 1984

UREDA B.F. Building 003 Decontamination and Disposition. AI-ERDA-13158 1976

WARMING L. Weathering and Decontamination of Radioactivity Deposited on Asphalt Surfaces. RISOE-M-2273 1982

WARMING L. Weathering and Decontamination of Radioactivity Deposited on Concrete Surfaces. RISOE-M-2473 1984

WHITE J.M. The Decontamination of Radium from a Commercial Building Located in a Large Canadian City. Am.Ind.Hyg.Ass.J. 41 p49-60 1980

WIDEMO U. and GYLLANDER C. Dekontaminering av mark och bygnader. En litteraturstudie (in Swedish). STUDSVIK-K2-80-338. 1985

WILTSHIRE L.L. and OWEN W.L. Removal of Simulated Fallout from Asphalt Street by Fire- hosing Techniques. AD 641 480 1965

WILSHIRE L.L. and OWEN W.L. Three tests of Firehosing Technique and Equipment for the Removal of Fallout Simulant from Asphalt Street and Roofing Materials. USNRDL-TR-1048 1966

6.1. Titles found, text not available

CLARK D.E. Jr, and COBBIN W.C. Removal of simulated Fallout from Pavements by Conventional Street Flushers. USNRDL-TR-797 1964

DICK J.L. Monitoring and Decontamination Technique for Plutonium Fallout on Large-area Surfaces. WT-512 1961

HEISKELL R.H., KEHRER W.S., and VELLA N.J. Design Criteria for Roof Washdown. USNRDL-TR-789 1964

MALONEY J.C, and MEREDITH J.L. Simple Decontamination of residental Areas McCoy III. USNRDL-TR-33 1962

MALONEY J.C, and MEREDITH J.L. Decontamination of Land Targets, Vehicles and Equipment. NDL-TR-66 1966

OWEN W.L., SARTOR J.D., and VAN HORN W.H. Performance Characteristics of Wet Decontamination Procedures. USNRDL-TR-335 1960

OWEN W.L., SARTOR J.D, Radiological Recovery of Land Target Components - Complex I and II USNRDL-TR-570 1962

OWEN W.L., COBBIN W.C., and SHELBERG W.E. Radiological Reclamation Performance Summery USNRDL-TR-88-71 1967

RYAN J.T. et al. Radiological Recovery Concepts, Requirements and Structures, Vol I. General Considerations final report. AD-450606 1964

SARTOR J.D., CURTIS H.B., LEE H., and OWEN W.L. Cost and Effectiveness of Decontamination Procedures for Land Targets. Research and Development Technical Report. USNRDL-TR-196 1957

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