

Urban Decontamination Experience at Pripyat Ukraine – 13526

Sergiy Paskevych*, Dmitry Voropay**, and Eric Schmieman***

*Institute for Safety Problems of Nuclear Power Plants, National Academy of Sciences of Ukraine (36 a Kirova str. Chernobyl, Kiev region, 07200 Ukraine) email: serpua@gmail.com
telephone: +380-50-747-23-43 Fax +380-45-935-14-34

**Federal State Unitary Enterprise «Russian State Center of Inventory and Registration and Real Estate – Federal Bureau of Technical Inventory» (37-2 Bernadsky Prospekt, Moscow Russia 119415) email architecxp2@rambler.ru, telephone +78-45-355-64-28, Fax +78-45-355-64-28

***Battelle Memorial Institute (PO Box 999 MSIN K6-90, Richland, WA 99352 USA) email Eric.Schmieman@PNNL.gov, USA mobile +1-509-942-9580, UA mobile +380-50-358-49-67, USA Fax +1-509-375-6969, UA Fax +380-45-792-88-32

ABSTRACT

This paper describes the efficiency of radioactive decontamination activities of the urban landscape in the town of Pripyat, Ukraine. Different methods of treatment for various urban infrastructure and different radioactive contaminants are assessed. Long term changes in the radiation condition of decontaminated urban landscapes are evaluated.

INTRODUCTION

Over the last 30 years, humanity has experienced a number of large-scale radiation accidents, which have resulted in the contamination of large areas. The consequences of these accidents have global environmental and human impacts.

The explosion of the Unit 4 reactor at Chernobyl nuclear power plant in 1986 led to widespread radioactive contamination of the surrounding areas. Pripyat, a city located three kilometers from the destroyed reactor became unsuitable for human life. 49,360 people were evacuated within 36 hours after the accident, and about an additional 70,000 people were evacuated from surrounding areas in the subsequent few weeks. A 30-kilometer exclusion zone around Chernobyl, in which residence is not permitted, remains in effect today and for the foreseeable future.

The accident at Fukushima-1 nuclear power plant in 2011 also resulted in the evacuation of a population (110 000 people) and resulted in an exclusion zone with a 20-kilometer radius around the nuclear power plant. After the accident at the Fukushima nuclear power plant Japan has experienced some of the same problems that were observed in the Chernobyl exclusion zone in the first years following the accident, specifically the problem of remediation of, and return to local authority, settlements and radioactively contaminated areas. Recently the Japanese government has set targets for reduction of radioactive contamination in the exclusion zone and

other affected areas.

Chernobyl experience may be of value to Japanese planners in two respects: to know what worked at Chernobyl and might be worth implementing at Fukushima; and to know what did not work at Chernobyl and can be avoided at Fukushima. Urban landscape decontamination requires special methods that have not been widely practiced or researched. The success of the clean-up and exposure of clean-up workers is a function of the effectiveness of methods and tools used for decontamination. We are convinced that the Chernobyl experience can help to solve problems in the Fukushima exclusion zone, especially to avoid the use of inefficient methods of decontamination and to avoid unnecessary exposure of workers.

This paper presents the results of the effectiveness of decontamination of urbanity of the landscape of the city of Pripjat. During 1986 - 1989 a significant work effort was made to clean up the urban landscape. Initially, authorities believed that the use of traditional and innovative methods of decontamination would enable the urban environment to be sufficiently clean to allow the safe return of the population living in the city of Pripjat. It was planned to use both mechanical and chemical methods of removal of radioactive substances from contaminated surfaces - roads, sidewalks, lawn soil, walls and roofs of buildings and structures. Also, to eliminate radiation contamination in Pripjat there were developed new, at that time, methods of chemical and biological decontamination of the soil surface, and the method of fixing soil to prevent the transfer of radioactive dust.

The main objective of this paper is to provide to provide some historical data on the practical effectiveness of decontamination urban landscape of the city of Pripjat.

DESCRIPTION (methods)

Field studies

To compare the effectiveness of decontamination methods, research and prototype testing were conducted at multiple sites in the city of Pripjat. Information presented here is based on data from archives of some of the works carried out in the city in 1987-1988.

On selected areas of the urban landscape, field studies included assessment of the environmental status of both contaminated and decontaminated areas, their levels of contamination, and the distribution of radionuclides in the soil horizon.

Sampling methods

Sampling was performed with standard radio-ecological techniques available at that time. At

each site, soil samples were collected at 5-fold repetition, layer by layer using a special drill.

Laboratory studies

Samples were air dried and homogenized. From the dried, homogenized sample an aliquot was taken for measurement.

Spectrometric and radiochemical methods research

The measurement of gamma-emitting radionuclides in the samples was performed by semiconductor spectrometry using germanium detectors and a multichannel spectrum analyzer (ORTES).

Determination of strontium-90 was performed by the method of liquid-liquid extraction using phosphorus organic acid (2-ethyl-2-hexyl phosphoric acid) as the extractant, followed by analysis of the spectrum using a beta-spectrometer (Quantulus).

DISCUSSION

The Chernobyl accident led to the entry into the environment 50 million curies (MCi), of radioactive fission products, representing about 3.5% of activity of the reactor core immediately prior to the explosion. About a third of the activity ejected from the destroyed reactor dropped on the industrial site of the Chernobyl nuclear power plant, about a third fell in the Chernobyl exclusion zone, and the remaining third spread primarily across Ukraine, Belarus, and Russia.

Pripyat is located 3 km from the Chernobyl nuclear power plant, which led to intense radioactive contamination and high external exposure levels. In the first months after the accident, levels of background radiation in some parts of the city reached 1 R/h. Average background levels ranged from 200 to 500 mR/hr. After the decay of short-lived radionuclides, the situation had improved sufficiently in the city that it was decided to decontaminate the city infrastructure. The main problem at the start was to find the cheapest and most effective ways for cleaning large areas of buildings, equipment, roads, parks and lawns.

An important component of the work in a radioactively contaminated city is not only decontaminating an area, but further rehabilitation of the treated areas for specific reuse. For example, decontamination of soil cover in the city might only require shallow treatment to enable planting of ground cover to prevent wind blown transport of radioactive aerosols, but soils in agricultural areas might require quite deeper treatment to prevent bioaccumulation by crops.

Urban landscapes in Pripyat were decontaminated by mechanical, chemical and biological methods.

Mechanical method of decontamination

Mechanical decontamination is to physically remove the top layer of soil and dispose of it safely in a permitted radioactive waste disposal site. The effectiveness of this method depends on the technical tools that are used to remove the contaminated soil.

To clean the lawn of Pripjat we used autoscraper (CD¹ - 26), grader (CD - 10), motor grader with loader tipper (CD - 10), Bulldozer (CD-6) and a shovel (CD-6). This equipment, which was standard commercially equipment available at the time was used to remove soil to a depth of 5 - 10 cm. Field studies had determined that most of the activity was concentrated in the upper 0 - 3 cm soil layer [1].

Using normal civilian equipment two major drawbacks: no system of personnel protection against ionizing radiation, and we could not accurately control blade height in response to microrelief features. This led to removal and disposal of large amounts of waste, some of which was not actually contaminated. In addition there was a problem with the transfer of contaminated soils across decontaminated or uncontaminated areas, which resulted in the contamination of clean areas.



¹ Coefficient of decontamination is defined as $CD = A_0 / A_d$ where A_0 = activity prior to decontamination and A_d = activity after deactivation.



Mechanical decontamination led to the formation of huge amounts of waste. Mechanically decontaminating one hectare generated from 1000 to 1500 tons of radioactive waste. Such amounts needed to be buried, which led to the formation, in areas adjacent to Pripjat and Chernobyl, about 800 “graves”, excavated trenches in which were buried radioactive waste.

Cleaning the site with shovels provided only temporary effectiveness. Figure 1 shows the long-term dynamics of the radiation background on soil decontaminated by a shovel to a depth of about 5 cm compared to control sites which were not decontaminated [2].

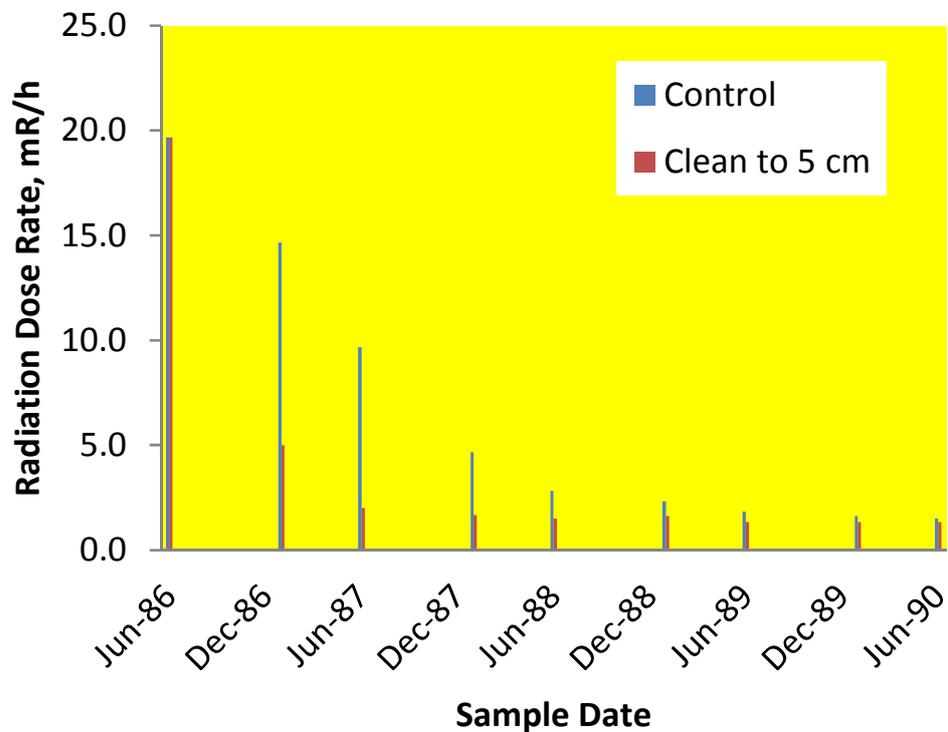


Figure 1 - Long-term data on changes in the levels of gamma-background in the decontamination lawns of Pripyat.

Figure 1 shows that although there is initially a large difference in external dose rates between decontaminated areas and control (not decontaminated) areas, the difference is not significant after 3-4 years.

Another mechanical method of decontamination utilized was applying a layer of soil or sand to shield radiation. Decontamination factor of this method depends on the thickness of the protective layer. Measured results were in the following ranges: with a thickness of 10 cm soil layer, CD=3. At 20 cm, CD=9, 30 cm, CD=24, at 40 cm CD= 63. This method was used for cleaning the areas that border the town of Pripyat, specifically the territory of the abandoned village Semihody. After cleaning up the village background radiation changed from 3.5 - 1.5 mR / h to 0.5 - 0.3 mR/h [3].

It should be noted that in September 1986 a unique method of decontamination was used in Pripyat. Decontamination using a big industrial vacuum cleaner mounted on a truck. This dust-cleaning technique was initially developed to clear airfields. Vacuum airfield equipment can be used to clean dry hard surfaces such as concrete and asphalt. Machines were used to remove dust and small objects (up to 200 grams) from roads and roadsides of Pripyat. After the accident four units were sent to Pripyat. These machines decontaminated the territory near the administrative building of Chernobyl (adjacent to ChNPP Units 1 & 2). Scientists of the Research and Development Institute of mounting technologies were deployed to study the vacuum which was used in the city of Pripyat. This method proved highly effective decontamination. It was observed that background radiation in areas treated by vacuum systems was reduced up to 35 times.



Photo vacuum system in Pripyat town (photo of by Elena Kozlova)

Chemical decontamination method

Chemical methods were used for decontamination of buildings and roads of the city. In general, the decontamination solution treated roof and exterior walls of buildings. Scientists were trying to figure out the technical feasibility and the practical effectiveness of cleaning buildings from contamination. Sulfanol was used for decontamination. Sodium sulphate had been developed for military use indecontamination of military equipment and weapons contaminated with chemical agents such as such as soman and mustard gas. Sulfanol is highly soluble in water, allowing automated preparation of large amounts of decontamination solution using special military vehicles.

In Pripyat it was found that application of 0.5% solution of SF-2U can reduce surface contamination of about ten times (in some cases, the efficiency was higher). Surface dose rates prior to decontamination of buildings of the 4th district of Pripyat town was in the range 0.3 - 0.9 mR/h. After decontamination it was in the range 0.05 - 0.2 mR/hr. Surface contamination decreased from 50,000 beta-counts/cm² min to 300 - 600 beta-counts/cm² min.





Photos - chemical decontamination of houses in the city of Pripjat with fire trucks and special vehicles of the military chemical service.

Particularly alarming to scientists and the military were contamination levels measured on the roofs of buildings, 100 000 beta- particle/cm² minute. Surface contamination this high caused external dose rates up to 150 mR/hr. Roofs of buildings, being the top element of the urban landscape, are affected by gusty winds which cause the contaminated dust to become airborne. The airborne dust is not only an inhalation hazard while airborne, but in the urban environment the dust tends to settle in specific localized areas that can become even more highly contaminated. Additionally, rainfall washed radioactive contamination from the roofs to street level. This transport in the urban environment also tends to lead to highly contaminated specific areas. Over time, these urban infrastructure effects emerged as significant accumulators of radioactive substances.

Realizing the danger, roofs of buildings were decontaminated by chemical. After decontamination, the background radiation on a roof was typically reduced by 20 times, to 3 - 7 mR/hr, and the uncontrolled redistribution of contaminants was also greatly reduced

Chemical decontamination was also used on concrete and asphalt roads of the city, but the

effectiveness of their treatment was different. In some places, it was possible to reduce the background dose rate by forty times [5], in other places efficacy was significantly lower.

The effectiveness of biological decontamination method

Following radioactive contamination of large areas of the urban landscape, one of the major sources of airborne contamination is the suspension of dust adjacent to roadways. This source was so intense in Pripyat that periodic dust suppression by spraying water needed to be frequently performed immediately following the accident. It was recognized that a more comprehensive approach to dust fixation or decontamination of roadsides was needed. A variety of biological methods were tested and evaluated during the summer of 1987. –First, a layer of soil was removed, and then dust was fixed with special chemical compounds. This method was developed by experts of the North Branch of the Academy of Agricultural Sciences, the Ukrainian Agricultural Academy, Moscow State University, and MV University, Kola Branch of the USSR.

Because roadsides in the Pripyat-Chernobyl area were without organic soil cover, attempts to grow grass cover failed. Grass sown exhibited poor germination rate and required labor intensive maintenance. Consequently, roadside areas were covered with 5-cm layer of peat and fertilized. Then the treated ground was sown with ryegrass, timothy, alfalfa and other perennial grasses. Finishing work on the formation of a growing medium included treatment with a dust-fixing mixture of waste from sugar production and then a layer of an aqueous solution of latex SKS-65 GP [4]. After the grasses grew, the radiation level was reduced ten times less and, more importantly, significant reductions in the activity of the aerosol concentrations in air in the city were observed, creating more favorable conditions for work in the aftermath of a radiological accident.



a)



b)

Photos showing the process of applying synthetic chemicals to deactivate the surface soil (a), the surface after the application of synthetic substances (b). (photo by Lidia Loginova)

CONCLUSIONS

1. Decontamination of the urban system requires the simultaneous application of multiple methods including mechanical, chemical, and biological.
2. If a large area has been contaminated, decontamination of local areas of a temporary nature. Over time, there is a repeated contamination of these sites due to wind transport from neighboring areas.
3. Involvement of earth-moving equipment and removal of top soil by industrial method achieves 20-fold reduction in the level of contamination by radioactive substances, but it leads to large amounts of waste (up to 1500 tons per hectare), and leads to the re-contamination of treated areas due to scatter when loading, transport pollutants on the wheels of vehicles, etc..

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