EARLY MEASUREMENTS IN SCANDINAVIA FOLLOWING THE CHERNOBYL ACCIDENT

J. ROED, K.G. ANDERSSON
Risø National Laboratory,
Roskilde, Denmark

Abstract

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The first cloud from the Chernobyl accident arrived over Scandinavia during the first days following the release. This gave a unique opportunity to study wet and dry deposition of different isotopes on various rural and urban surfaces, to model the wash-off, run-off and weathering processes from the early phase and to investigate the relationship between outdoor and indoor aerosol concentration. The information derived has had great importance for development of computer models to estimate the consequences of such accidental releases. Some of the data collected in the early period is compared to data obtained through recent experiments. A good agreement has been found between these sets of data.

1. INTRODUCTION

When the first cloud from the Chernobyl release reached the town Roskilde in Denmark on the 27th of April 1986, the weather was dry. In contrast, in Gävle in Sweden it rained heavily as the cloud passed. A plume from a later release passed over Denmark while it rained heavily. This presented a unique opportunity to study the behaviour of airborne radionuclides released to the atmosphere, including both dry and wet deposition.

Both forms of deposition are important in nuclear accident consequence assessment. The reason for this is that the external gamma dose due to deposited material can be a major contributor to acute effects [1], and the dose from deposited long lived radionuclides is usually the major long-term hazard [2-4]. In cases where the radioactive material is wet deposited, the effect of run-off can be important [5-9]. Run-off water can carry away a fraction of the deposited radioactive matter through sewers, thus resulting in a less than 100% retention. Later on, some of the initially retained material can be removed by weathering [10-12]. Further, the removal of radioactive matter by processes such as traffic and normal street cleaning must also be considered.

In risk assessment, it is extremely important to deal with contamination in the urban areas as this is where most of the population in the Western world lives. It is, however, not enough to know the total contamination in the urban area. The spatial distribution of the deposited material must also be known.

Deposition on indoor surfaces may also contribute significantly to the external exposure of the population.

2. DRY DEPOSITION

Dry deposition was studied in terms of dry deposition velocities on plastered walls, roof material, street concrete flagstone, asphalt, grass, trees and bushes. The measurements were made in Roskilde during the passage of the cloud. Throughout the deposition phase, the weather conditions were stable, the mean wind speed was $3 m \cdot s^{-1}$ at 8m height and the Pasquill stability was category B–C.

Table I shows the mean values of measured deposition velocities for different radioelements originating from the Chernobyl accident. The results of each single measurement have been given elsewhere[13]. There was no obvious indication that the deposition velocity changed from one area to another, but it clearly differed for the various isotopes examined.

TABLE I. DRY DEPOSITION VELOCITIES OF VARIOUS RADIOELEMENTS (10^{-4} MS^{-1})

Isotope	I*	Cs	Ru	Ba	Ce	Zr
Paved areas	4.6(9)	0.7(7)	3.5(9)	4.6(8)	8.1(9)	9.8(9)
Walls	3.0(4)	0.1(4)	0.4(4)	0.4(4)	0.9(4)	1.3(4)
Windows	2.3(1)	0.5(1)	0.1(1)	0.2(1)		0.1(1)
Grassed clipped	22 (1)	4.3(1)	4.1(1)	5.8(1)	7.7(1)	7.1(1)
Trees	80 (3)	7 (3)	25 (3)	26 (3)	39 (3)	45 (3)
Roofs	33 (3)	2.8(2)	3.4(3)	53 (3)	40 (1)	—

The figure in parenthesis represents the number of measurements made.
* elementary iodine

Particle bound caesium had the smallest value with a mean V_d of about $1 \cdot 10^{-4}$ m s^{-1}, and the highest V_d's of $10 \cdot 10^{-4}$ m s^{-1} were found for particulate cerium and zirconium.

The radionuclides may be divided into two groups, i.e. the volatile group to which I, Cs and Ru belong, and the refractory group which includes Ba, Ce and Zr. Aerosol samplings, mainly using low pressure cascade impactors, in different European countries following the Chernobyl accident [14-17] have shown that these two groups had different particle sizes, that of the first being typically 0.4–1.0 μm compared with 2–4 μm for the second group. The lower deposition velocities which were recorded on grass and roofs for the particles from the first group agreed well with the observation that the larger particles have a higher deposition velocity. For paved areas, walls and trees the deposition velocity did not quite follow this pattern.

3. WET DEPOSITION

Precipitation scavenging or washout of particles and gases from the atmosphere can be significant contributors to ground deposition as was the case in Gävle more than 2000 km from Chernobyl [12]. Run-off is a term used to describe the deposited rainwater which is not retained on the area receiving the rainfall. The following equation is valid for hard surfaces:

$$Q=P-I_a,$$

where Q is the direct run-off in mm, and I_a the initially accumulated rainfall. The amount of run-off from roofs is very sensitive to the construction material [5]. A rainfall (P) of 9.2 mm shortly after the Chernobyl accident gave I_a values of 1.8 mm for cement tile, 4.2 mm for red clay tile, 1.4 mm for eternite (an asbestos type of material) and very nearly 0 mm for silicone treated surfaces. Later it was shown that on road surfaces I_a was 3.8 mm for asphalt and 3.4 mm for concrete.

Table II shows the concentration of different radionuclides in run-off water relative to that in rain water during a rainfall of 9.2 mm. Table III shows the amount of retained wet deposited matter on different types of roofs relative to deposition on a grassed area after a rainfall of 9.2 mm.

TABLE II. CONCENTRATION OF RADIOELEMENTS IN RUN-OFF WATER RELATIVE TO THAT IN RAINWATER FOR A PRECIPITATION OF 9.2 MM

	Isotope			
Surface	**Cs**	**I**	**Ru**	**Ra**
Cement tile	0.49	1.24	0.56	0.40
Red tile	0.55	1.05	0.65	0.58
Eternite	0.14	1.18	0.30	0.37
Silicone treated eternite	0.74	1.00	0.52	0.67

TABLE III. RELATIVE WET DEPOSITION ON DIFFERENT ROOFS

	Slope	**^{137}Cs**	**^{134}Cs**	**^{131}I**	**^{106}Ru**	**^{103}Ru**	**^{140}La**
Grassed area	0E	1	1	1	1	1	1
Cement tile	45E	0.58	0.62	0	0.42	0.27	0.68
Red tile	45E	0.68	0.71	0.43	0.60	0.53	0.69
Corrugated eternite	45E	0.87	0.88	0	0.65	0.64	0.68
Silicon treated eternite	45E	0.12	0.29	0	0.63	0.41	0.33
Corrugated eternite	30E	0.80	0.81	0	0.59	0.55	0.63
Silicon treated eternite	30E	0.18	0.25	0	0.49	0.47	0.22

Of the examined roof materials, only red clay tiles retained a measurable amount of Iodine. Only 20–35% of the caesium and the lanthanum on silicon treated roofs was retained, compared with 60–90% on other types of roof, while the retention of ruthenium was similar for all roof materials.

4. INDOOR DEPOSITION

Some results of a series of indoor deposition measurements following the Chernobyl release are shown in Table IV. The mean indoor deposition velocities were found to be of the same order of magnitude as those recorded outdoors on walls and horizontal pavements. These indoor deposition velocities have been compared with the results of recent experiments, in which porous silica particles of various monodisperse size distributions ranging from 0.5 to 5.5 μm and labelled with neutron activatable tracers were applied [18].

The Chernobyl caesium aerosol was found to have a size distribution which peaked a bit below 1 :m, and atmospheric ^{7}Be is known to be associated with 0.5 to 1 μm particles. The mean indoor deposition velocity of the 0.5 μm silica particles has been found to be $0.61 \cdot 10^{-4}$ m/s in an unfurnished room and $0.82 \cdot 10^{-4}$ m/s in a furnished room, which agrees well with the values given in Table IV for the caesium and beryllium aerosols.

As for the refractory pollutants, such as cerium and zirconium, Chernobyl aerosol particle sizes in the range of 2–5 μm have been reported [14]. As shown in Table IV, the mean

indoor deposition velocity of these was found to range from $3 \cdot 10^{-4}$ to $5 \cdot 10^{-4}$ m/s. In comparison, the mean indoor deposition velocity of 4 μm silica particles has been measured to be $2.42 \cdot 10^{-4}$ m/s in an unfurnished room and $3.11 \cdot 10^{-4}$ m/s in a furnished room.

TABLE IV. INDOOR DEPOSITION VELOCITIES

Isotope	®$_d$, mean deposition velocity (m.s^{-1})
^{137}Cs	6.4 H 10^{-5}
^{134}Cs	6.2 H 10^{-5}
^{131}I (particulate)	1.1 H 10^{-4}
^{7}Be	7.1 H 10^{-5}
^{103}Ru	2.0 H 10^{-4}
^{106}Ru	1.7 H 10^{-4}
^{141}Ce	3.1 H 10^{-4}
^{144}Ce	3.9 H 10^{-4}
^{95}Zr	5.8 H 10^{-4}
^{95}Nb	1.9 H 10^{-4}

5. DISCUSSION AND CONCLUSION

A series of measurements of dry deposition including indoor assessments was performed during the Chernobyl accident. The results provided a good understanding of the spatial distribution of dry and wet deposited material. This has enabled us to model the essential processes concerning dose assessment, which leads to the ultimate goal: the formation of an emergency strategy for areas contaminated after a nuclear accident.

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