Studies on the behavior of particles in relation to humans and the deposition of suspended radioactive substances in the atmosphere

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1. Introduction

Radioactive material released into the atmosphere from a nuclear facility or radiological terrorism contains a variety of radionuclides, which can be carried by the wind from the ground and then fall back to the surface, settling on the ground, buildings, and people. Because people do not feel symptoms of radiation exposure, in some cases they may not realize they are contaminated and continue with their daily activities, spreading beyond the contaminated area. This kind of dispersion has led to the need to study the various deposition processes in the atmosphere. This study reviewed a number of internationally published papers to gather data on various deposition processes. It is a good source for understanding the deposition and removal of radioactive particles on various "surfaces" such as human hair, skin, and clothing.

2. Methods and Results

In environmental engineering, particle deposition is typically defined by the deposition rate, which when multiplied by the concentration in air (Cair) gives the mass flux (F) to the surface per unit area (in kg/m2/s).

randomly in time, with an average event rate of 10 8 events/s.

$$F = v_d c_{air} \quad \text{--------} \quad (1)$$

Particle deposition on various surfaces, including gravitational settling, inertial collision, inertial blocking, turbo capture, and electrophoresis, which are relevant to the deposition of radioactive particles on human hair, clothing, and skin. Experiments included low-flow environments in test chambers, the use of wind tunnels to mimic outdoor conditions, and underpass experiments. Experiments used both moving and stationary subjects, and in some cases, mannequins were used instead of humans. While the measurements varied widely across the experiments, they generally emphasized that particle deposition rates are faster on skin than on hair or clothing.

A summary of the data for deposition rates on skin, clothing, and hair for different particle diameters and experimental conditions is shown below.

Table1. Summary of data on deposition velocities on skin, clothing, and hair for different particle diameters and experimental conditions. .

Surface	Reference	Comments	Particle diameter	Deposition velocity × 10^{-4} [m/s]
Skin (office)	Fogh et al (1999)	Subjects sitting in a test chamber	0.5 um 4.5 um 8 um	99-161 712-1288 1079-1921
Skin (simulated outdoor)	Fogh et al (1999)	2 m/s fan air 4 m/s fan air	1 um 1 um	55-81 84-136
Skin (office)	Andersson et al (2004)	High moisture Normal moisture	2.5 um 2.5 um	49-86 11-38
Hair	Fogh et al (1999)	Subjects sitting in a test chamber, excluding data from full haircut*	0.5 um 2.5 um 8 um	20-26 14 34
Hair	Andersson et al (2004)	Subjects sitting in a test chamber	0.5 um 2.5 um	12-26 8-18
Clothing	Fogh et al (1999)	Jumper and shirt in a test chamber, vertical orientation	0.5 um 4.5 um	12-22 19-35
Clothing	Fogh et al (1999)	Ten common clothing materials in a test chamber, vertical orientation	0.5 um 2.5 um 8 um	0.23-1.17 7.3-17.6 27-145
Clothing	Ljegren et al (2016)	Vertical cotton coupons for a release in a subway, stationary person	2.75 um (MMAD)	17-31
		Vertical cotton coupons for a release in a subway, walking person	2.75 um (MMAD)	50

The table lists some experimental studies that have investigated particle deposition on humans. They found that 1) particle deposition is generally greater on skin than on hair and clothing, 2) particle deposition is greater on people with more moisture on their skin, 3) the deposition flux on people increases with wind strength, and 4) the proportion of particles deposited on hair, skin, and clothing, respectively, depends on hair length, assuming that all hair surfaces are available for deposition. The largest uncertainty in particulate matter deposition on the human body was found to be clothing type, as the actual surface area and surface roughness varies depending on the weave arrangement and tightness of the garment. This could cause deposition rates to vary by a factor of 2 to 20. The removal of particles from contaminated individuals was due to the spread of contamination by wind, human movement, and contact with other surfaces. Experiments showed that most particles resuspended within two to six hours, depending on the intensity of physical activity. The greatest uncertainty in particle removal from the skin was dependent on skin moisture, the transfer rate of a single contact, and the number of objects/people a person comes in contact with per hour.

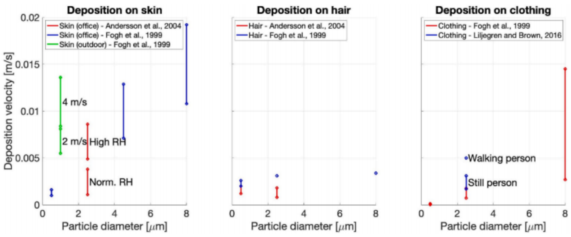

Fig. 1 Particle deposition velocity on different surfaces as function of the particle diameter..

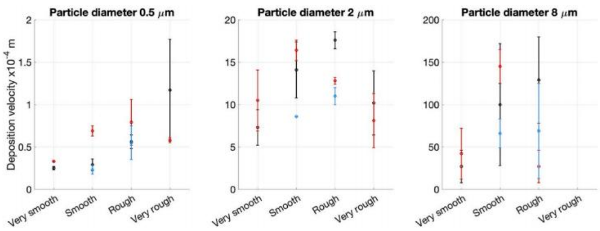

Fig. 2 Deposition velocity as function of clothing roughness and particle size.

3. Conclusions

No data were found on the removal and reuse of particles from hair. Although this study did not directly use radionuclides, the data on the adhesion of radioactive and non-radioactive particles showed that the uncertainty due to the radioactivity of the particles was lower than the uncertainty due to the radioactivity. This could help improve our understanding of the deposition and removal of radioactive particles. This can help minimize exposure to radioactive particles and develop responses to radioactive contamination. It can also help develop predictive models for radioactive contamination that take into account factors that affect the deposition and removal of radioactive particles.

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