DEPOSITION VELOCITY AND WASHOUT COEFFICIENT FOR RADIONUCLIDES BOUND AT AEROSOL PARTICLES

H. Bonka, M. Horn, H.-G. Horn, J. Küppers
Lehrgebiet Strahlenschutz in der Kerntechnik, RWTH Aachen

A part of the radionuclides that are emitted from nuclear facilities and others at normal operation or incidents as well as accidents, respectively, is bound at aerosol particles. The activity distribution of the emitted particle ranges of size is - in dependence of the filtering and operation method of the facility - in the diameter range of $d = 10^{-3} - 30$ µm and varies with time. Therefore, data for the calculation of the dry and wet deposition are required for this diameter range.

The aerosol particles that are emitted into the atmosphere are distributed due to turbulent diffusion. If they reach the vegetation or the ground surface, they are captured on the vegetation element or the ground surface due to inertia effects and Brownian diffusion, see fig. 1. Dry deposition exists, if aerosols remain attached after deposition due to electrostatic, Van der Waals and other forces. In the case of washout, the aerosols are trapped by the falling raindrop due to the same phenomena, mentioned above, see fig. 1, and reach the vegetation and the ground surface with the raindrop. In the ideal case, only aerosol particles which are in the residual moisture after the rain, remain on the above ground plant parts.

Physically the capture of aerosol particles at above ground plant parts and at raindrops can be described in the same way as the capture of aerosol particles on single fibres of fibre filters. The number of particles or the activity, respectively, that is deposited on the vegetation element per unit of time, is

$$\dot{\varphi}(d) = \int_0^h C(z,d) \cdot \bar{u}(z) \cdot f \cdot X_f(z) \cdot E(z,d)\, dz \qquad (1)$$

In this equation $\bar{u}(z)$ is the mean flow velocity in the height z, C(z,d) is the particle- or activity concentration with the particle diameter d, E(z,d) is the deposition rate, and $f \cdot X_f(z)dz$ is the vegetation surface in dz per unit ground surface. It is usual to describe the number of deposited particles with the deposition velocity $v_g(d) = \dot{\varphi}(d)/C(z_1,d)$. Equation (1) can be rewritten as follows, using the particle or activity concentration in the reference height z_1, which can be calculated from the product of the emission rate $\dot{E}(d)$ and the distribution factor $X(z_1)$:

$$\dot{\varphi}(d) = \dot{E}(d) \cdot X(z_1) \cdot v_g(d) = C(z_1,d) \cdot \frac{\dot{\varphi}(d)}{C(z_1,d)} \qquad (2)$$

When calculating the deposition according to this equation, it has to be taken into consideration that the curve of the particle or activity concentration in or above the vegetation must correspond not only to the curve of the activity, where the deposition velocity $v_g(d)$ has been determined experimentally, but also to the reference height z_1. Fig. 2 shows e.g. the onedimensionally calculated concentration curve in or above the vegetation /1/. Sometimes the experimental set-up causes concentration profiles different from those for emissions in great heights. Under such conditions the v_g-values have to be corrected with the concentration ratio C (vegetation)/$C(z_1)$ in order to obtain effective deposition velocities.

In /1/, /2/, /3/ the experimentally determined deposition velocities are compared with those theoretically calculated. A satisfying agreement can be stated, if differentiating between the kind of vegetation, the density of the particle material, the humidity of the atmosphere and the moisture of the surface. For grass, fig. 3 shows e.g. the good agreement between the theoretical curve and the experimental results for the used particle density range of $\rho_p = 1 - 3.6$ g/cm^3 in the experiments. The change of the curves for small particle diameters below approx. 10^{-2} µm is caused by the high concentration decrease in the vegetation.

The deposition on the ground can be described with the transport velocity due to turbulent diffusion $v_{g,tur} = u_*^2/\bar{u}(z_1)$ and the sedimentation velocity $v_s(d)$ /1/.

$$v_{g,B}(d) = \frac{u_*^2}{\bar{u}(z)} \cdot E_B(d, u_*) + v_s(d) \tag{3}$$

$E_B(d,u_*)$ is the deposition rate on the ground. Here, the agreement between measurement and theory is satisfying, too /2/, /3/.

The trapping of aerosol particles on raindrops can be described in the same way as the capture on above ground plant parts, according to equation (1). The number of particles or the activity, respectively, that is transported to the ground with the precipitation intensity I per unit of time is:

$$\dot{\Psi}(d,I) = \int_0^\infty C(z,d) \cdot \Lambda(d,I)\, dz \tag{4}$$

with the washout coefficient $\Lambda(d,I)$ which is defined as follows:

$$\Lambda(d,I) = \int_0^\infty \frac{\pi X^2}{4} \cdot v(X) \cdot N(X,I) \cdot E(d,X)\, d(X) \tag{5}$$

$v(x)$ is the terminal velocity of the raindrops with the diameter X and $N(X,I)$ is the raindrop density distribution.

Fig. 4 shows the calculated curve of the washout coefficient for two rain intensities and various collection efficiencies due to impaction. The agreement with the experimental results is actually not jet satisfying.

/1/ Bonka, H., Horn, M.:
Review on the dry and wet deposition of aerosol particles.
CEC Seminar, Dublin 4(1983)

/2/ Bonka, H. et al.:
Weiterentwicklung der Ausbreitungs- und Ablagerungsrechnungen für radioaktive Emissionen aus kerntechnischen Anlagen und Einrichtungen mit der Abluft.
(in preparation)

/3/ Horn, M.:
Weiterentwicklung der Methoden zur Berechnung der Strahlenexposition um kerntechnische Anlagen.
Dissertation (in preparation)

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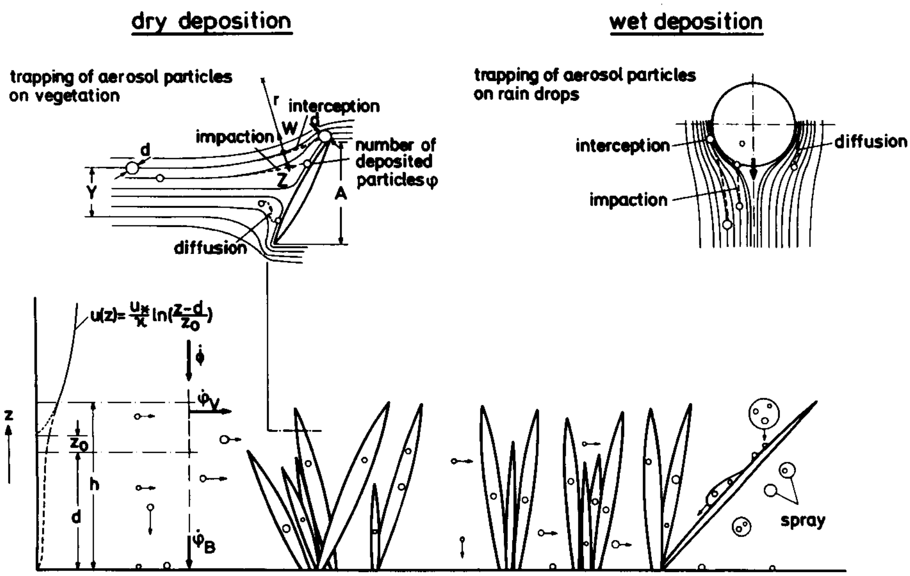

Fig. 1: Dry and wet deposition of aerosol particles on above ground plant parts and on the ground

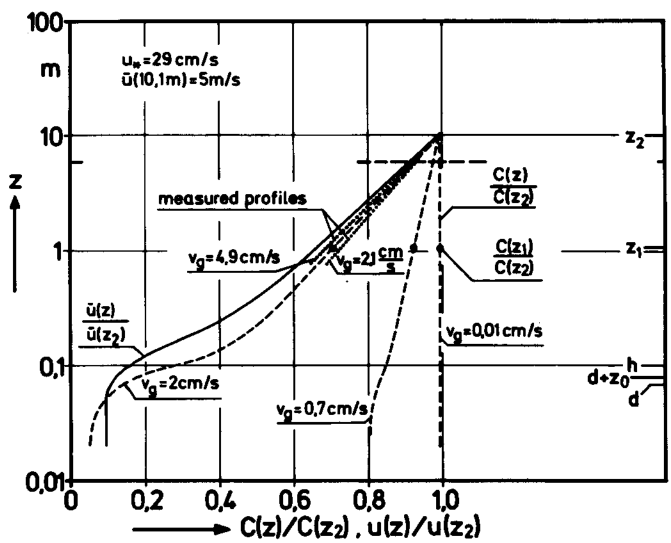

Fig. 2: Wind velocity- and concentration profile at different deposition velocities for grass

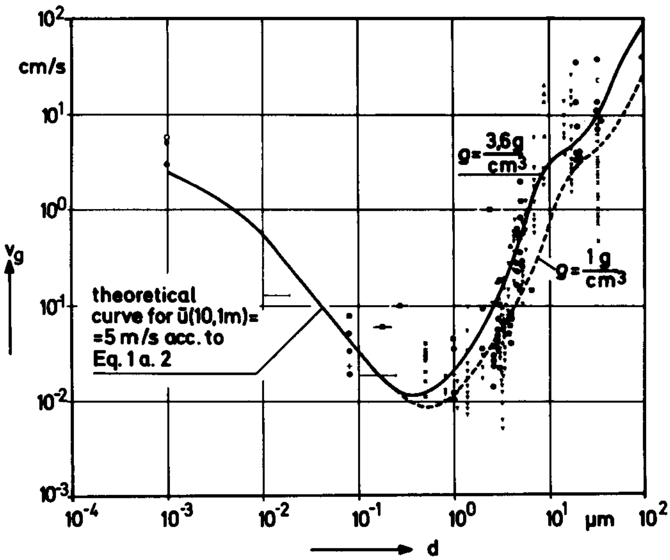

Fig. 3: Comparison of the calculated deposition velocities for aerosol particles on grass with measurements

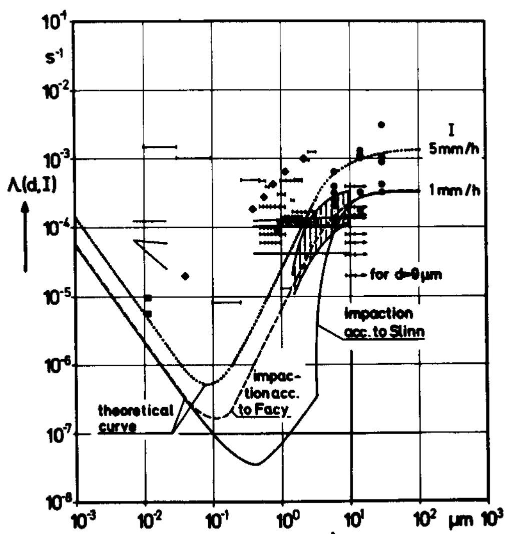

Fig. 4: Comparison of the calculated washout coefficient for aerosol particles with measurements