Representative Aerosol Sampling

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*) On a re-examination in February 2009 members of the AKU found out, that a revision of this Loose Leaf is not yet necessary. In September 2009 the new version was editorially revised, but not changed.

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1 Introduction

Representative aerosol sampling is an essential requirement for the detection of radioactivity in the air.

This paper provides information on the selection of the sampling location and on the technical details of the sampling configuration. The selection of filter material and its influence on the result of the measurement will not be discussed.

The particularities of sampling of gaseous iodine and gaseous iodine compounds are also beyond the scope of this paper.

2 Sampling Location

2.1 General Criteria

Radioactive aerosols are transported by wind fields. Therefore, the location for representative sampling of airborne radioactivity should be selected on the basis of the criteria formulated for wind measurement [1]. According to these criteria, the wind is measured 10 m above regular terrain, the distance between sampling location and the next obstacle being at least 10 times as high as the obstacle.

This requirement cannot always be complied with in practice. A practical compromise results from the need to measure, in particular, the activity concentration of breathable dust. From this we can derive a sampling height of 1.5 m to 5.0 m.

In accordance with the above criteria, it is important to keep the distance to the next obstacle (building, bush, tree) as large as possible. Otherwise this may result in a disturbance of the flow pattern and thus in a different distribution of the aerosols compared to undisturbed wind fields [2].

The following meteorological data are essential for an interpretation of the measured values:

- wind direction
- wind speed
- air temperature
- air humidity
- precipitation intensity
- and, possibly, the general weather situation and the correlation of air masses for large-scale monitoring

The frequently used argument concerning resuspension effects when sampling close to the ground is irrelevant fort he assessment of the activity incorporated into the lung through inhalation. However, these effects have to be taken into account when using the results of an aerosol measurement to assess whether these results correspond to immission and dispersion calculations.

2.2 Large-Scale Monitoring

Large-scale monitoring of the radioactivity in the air is dependent upon the distribution of measuring stations in a network. The density of this measuring network is based on the assumptions on the extension of the transported radioactive contaminated air body. The distance to the source and the meteorological parameters play an essential role. Each single measuring station of a network should be representative for a fairly large geographical area with regard to the extrapolation of this area. To assess this requires accurate information on orography and frequency distribution of the wind directions and wind speed (wind rose force) at the sampling location in advance.

Flat terrain is ideal for the sampling location. Complex or hilly terrain and a high building density may have a serious effect on the results of the measurement and may therefore be detrimental to the representativity of the results.

The example (Fig. 1) of a model calculation using the meso-scale flow model FITNAH (**F**low over **I**rregular **T**errain with **N**atural an **A**nthropogenic **H**eat sources) shows how much the wind conditions close to the ground are affected by the topography. The illustration covers an area of approx. 20 km x 20 km; the wind vectors have a distance of 1 km.

Mountain stations are particularly suited for the measurement of large-scale transportations which are not affected by local influences. Using a model calculation, as illustrated in Fig. 1, one can estimate whether the results also apply to a larger area.

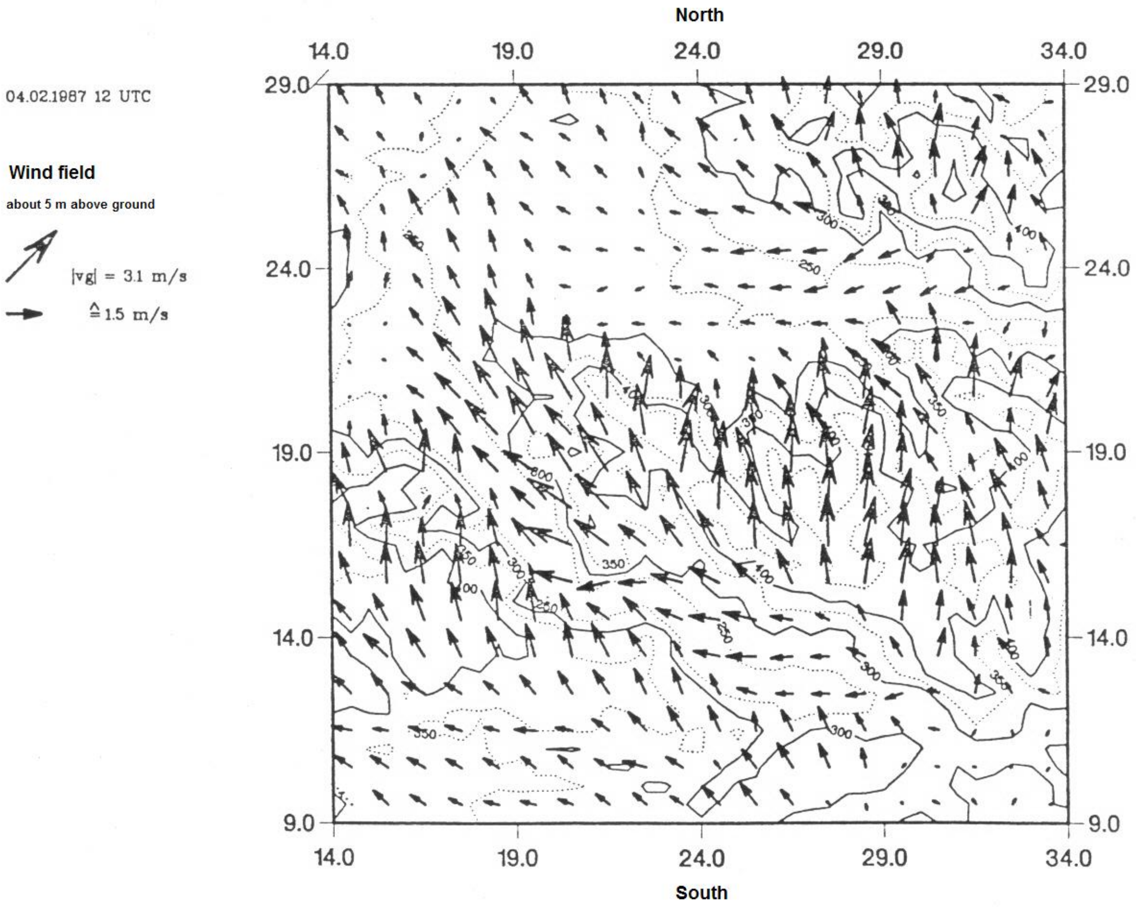

Fig. 1: Wind field close to the ground (about 5 m above ground, wind speed 3.1 m/s)

2.3 Object-Related Monitoring

In this case sampling should be performed, if possible, at the point of the calculated maximum ground-level concentration. This calculation is based on a description of the meteorological situation at the location of the emission source by four-dimensional statistics on the variables wind direction at stack level, wind speed at stack level, diffusion category and precipitation for the calendar year [3].
The continuous registration of the wind direction and the measurement of the precipitation intensity at the sampling location are absolutely essential for the comparison of emission an immission data.

2.4 Mobile Aerosol Sampling

Mobile sampling devices are used for special events and for measuring trips required for an emergency training program at defined measuring locations. With regard to the position of the expected location if the maximum ground-level concentration, the selection of the measuring location should take into account the actual meteorological situation.

Generally, the criteria described under 1.1 also apply to the use of mobile aerosol sampling devices.

The mobile sampling device is to be installed about 1.5 m above ground on a tripod. Depending on the type of sampler, the filter is either mounted horizontally or vertically. With vertical installation, the filter has to face windward. Please keep in mind to observe a sufficient distance to obstacles (buildings, forest edge, measuring trolleys).

Since aerosol sampling also has to be carried out in adverse weather conditions, the sampling device should be protected from rain, for example, by a protective hood.

The operator has to prepare a protocol that includes information on the type of vegetation, distance and direction of the sampling device to the next obstacle, and possible a drawing or a photo (see e.g. Loose Leaf 3.2.7).

Possible measuring and sampling setups are described in the Loose Leaves 3.2.3 and 3.2.4 and will therefore, not be discussed in this paper.

3 Design of the Sampling Location

3.1 Setup of the Sampling Location

Aerosols are collected from the atmosphere by a suitably constructed sampling head and filter devices. The sampling head must be open on all sides to ensure that air flows can reach it from all sides, i.e. shading by walls, roofs, pipes, etc. has to be ruled out.

This requirement is best ensured by a radial-symetrical setup of the sampling head (see 3.2) which should be installed at least 1.5 meters above ground (or above a flat roof, respectively). (If the sampling head is set up on a large flat roof, make sure it is located in the center of the roof to ensure that it is not affected by whirling winds).

If the sampling head can be set up only at the side wall of a building be sure to select that wall (only for object-related aerosol sampling) which runs parallel to the line object - sampling location. Sampling on the side opposite of the object (lee) must be avoided. For large-scale monitoring, installation on a side wall should be avoided.

The sampling head should be provided with a protective hood which should be inclined such that no rain drops or snow will stay on it. For protection against insects, the air inlet may be covered by a non-corrosive stainless steel mesh. To rule out condensation or icing on the sampling head (or on the filter, respectively), the air inlet should be provided with a heater.

To avoid a “short-circuit” between incoming and outgoing air, the sampling head and the air outlet should be properly separated.

3.2 Geometry of Sampling Head and Filter Holder

Based on the requirement for fairly representative sampling and the practical requirement that sampling should not be affected by external conditions (air ventilation, rain, snow, etc.), there are two different alternatives for the geometry of the sampling head and the filter holder [4 to11] (see Fig. 2):

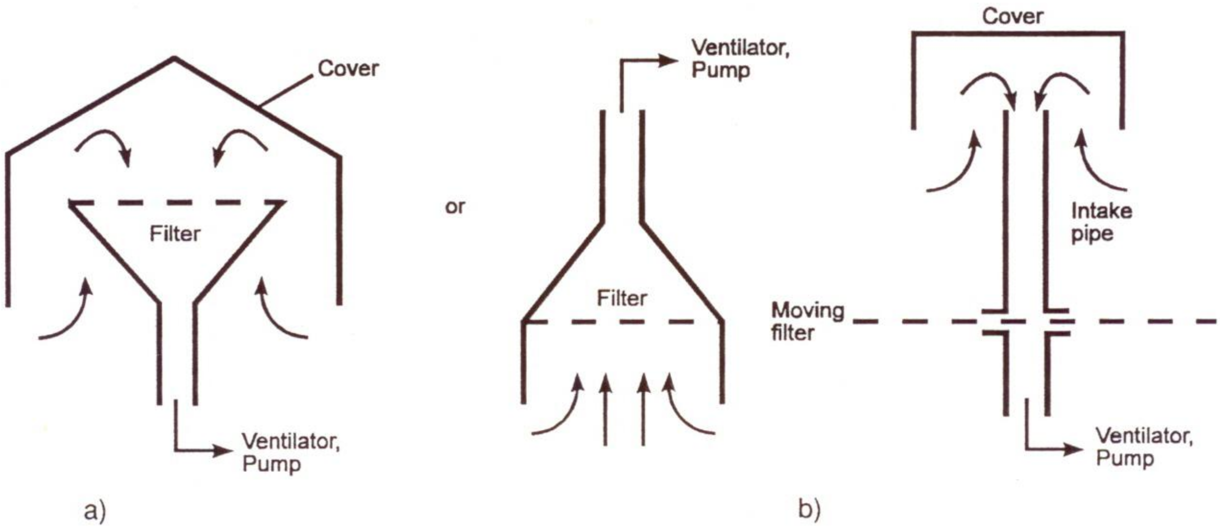

Fig. 2: Geometry of sampling head
(a) sampling head and filter holder integrated or
(b) sampling head and filter holder separated

Both arrangements have practical advantages and shortcomings:

(a) only suitable for fixed filter systems; no wall losses in an air inlet pipe; problems when filter has to be changed on a roof;
(b) also suitable for moving filters (step filter systems); possible wall losses in an air inlet pipe (the pipe must be made of stainless steel, should not include any bends an cross-section changes on the way to the filter and not exceed a length of 3 m, see 3.3).

For both variants it holds:
The shape of the sampling head and the entrance speed of the air into the head and the prevailing wind speed determine the size spectrum of the collected particles, the diameter of the particles that are still covered rising with increasing entrance speed and decreasing wind speed. To be able to collect particles > 1µm AED (aerodynamic equivalent diameter) even at higher wind speeds, a certain minimum aspiration speed has to be maintained at the sampling head. In practice, air flow speeds at the inlet between 1.12 and 3 m/s are quite common.

The absolutely correct sampling of all particle sizes, which would be possible only through isokinetic sampling at variable air flow speed of the sampling air, is not possible in practice. The so-called “total dust”, i. e. the particle collective of about 0.00 to about 150 µm AED can therefore not be collected in a representative manner.

“Breathable dust” (up to particles with 10 µm AED, the so-called “PM 10” standard) can be collected by using size selective inlets which are virtually independent of the wind speed and should be used for dust collection to determine the radioactivity [5, 9-11].

Please refer to the respective literature (especially the VDI regulations) for the mechanical construction of sampling heads and size selective inlets (even a protective cover against rain acts as such). These size selective inlets are commercially available for conventional air samplers (up to approx. 100 m^3/h).

The corrosion-resistant filter holder itself must be constructed such that the filter is sufficiently supported and a bypass of the sampling air is ruled out by suitable seals.

3.3 Air Inlet Pipes

Air inlet pipes should also be made of polished stainless steel V2A or V4A. The drawback of plastic pipes is that they are susceptible to electrostatic charging. Wave-like hoses or hoses stabilized by wires should not be used because they may act as aerosol traps.

With welded pipes one has to make sure that the welded seams are as smooth as possible. This is particularly true for flanged fittings; however, flanged fittings are available on the market, which are nearly without seam, connecting different pipes without gaps.

The ideal air inlet pipe leads from the sampling head directly to the filter without bends and cross-section changes. However, this is hardly possible in practice. Therefore, the number of bends should be kept to a minimum, and the radius of any bend should not be less than three pipe diameters.

The air inlet pipe should be heatable to avoid that the temperature drops below the condensation point and to rule out condensation on the pipe and the filter. The pipe, however, must not be heated up so much that chemical changes or disintegration of the aerosols may occur.

3.4 Volume Measurement

The product of activity concentration (activity per volume) and time is essential for the calculation of the radiation exposure; therefore, the determination of the air volume during the collection time is of special importance. The air flow should always be determined behind the filter. The air flow rate measuring system used for this purpose is often a simple rotameter. It consists of a “float” that is free to move up and down within a vertical tapered tube.

In addition, genuine volume meters, i.e. gas meters, are being used; due to their size, however, these devices are less suitable for automatic operation, e.g. in monitors.

As measuring systems one may also use: rotameters, which, however, still do not allow any electronic integration into the measurement, and small turbines and impeller wheels.

Unfortunately, however, both methods are affected by temperature and pressure. This may falsify the measured value up to 20 % when no temperature and pressure corrections are performed.

Very efficient are measuring methods according to the effective pressure principle. Here, a diaphragm is installed behind the filter; by measuring the difference pressure above the diaphragm, by measuring the absolute air pressure and the air temperature of the flow medium one can exactly determine the flow volume via the general gas equation.

In addition, calorimetric and ultrasound measuring methods are also available on the market.

The use of flow rate measuring systems available on the market are usually designed for a small measuring range only, usually covering 1 to 1 ½ decades. These air flow rate measuring systems, therefore, have to be selected very carefully, since air flow rates between 1 m^3 /h and 500 m^3 /h are encountered in practice in connection with aerosol sampling.

To improve the comparability of measured values it may be advisable for large-scale monitoring to refer the results to the standard volume (0°C and 1013 hPa). This means that the temperature of the air flow as well as the absolute pressure or possibly the difference pressure have to be determined behind the filter for each flow measurement. This is not required for site-specific monitoring. The reference variable should always be stated in reports, i.e. without further explanation “m^3” will stand for the operating cubic meters, “Nm^3” for the cubic meters air at standard conditions.

4 References

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Please note the remarks in loose leaf 1.3 „Erläuterungen zur Loseblattsammlung“.