5.30 DIURNAL VARIATION OF THE MIXING-LAYER HEIGHT AND POLONIUM CONCENTRATION IN THE AIR

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INTRODUCTION

The air pollution strongly depends on thermodynamic state of the atmosphere. The turbulence occurring in the boundary layer of the atmosphere influences the meteorological conditions and especially the convection process and temperature inversion. Among meteorological factors, the height of the mixing layer (h_{mix}) is of great importance. This parameter strongly influences the form and intensity of diffusion in the atmosphere and, as a consequence, the concentration of primary and secondary pollutants in the lower troposphere (*Osrodka, L., K. Skubacz, J. Skowronek, E. Krajny and M. Wojtylak*, 2002). In this connexion, the appropriate evaluation of the mixing layer is necessary to correctly forecast the air quality by means of the dispersion model and as a result of operating activities that can be performed within the pollution monitoring system as well. The description of the atmospheric boundary layer on base of measurements of the natural radioactivity is one of the methods used in evaluation of mixing processes in the atmosphere (*Allegrini, I., A. Febo, A. Pasini and S. Schiarini*, 1994; *Kataoka, T., et al.,* 2003). The concentration of radon in soil and atmospheric air can be an indicator of the atmospheric ventilation. Radon is a gaseous daughter of radium ^{226}Ra that belongs to the uranium series. The radon concentration in air depends on geological structure of the bedding and its movement between the lithosphere and atmosphere. The isotopes of polonium, bismuth and lead called the short-lived radon daughters (^{218}Po, ^{214}Pb, ^{214}Bi i ^{214}Po) are generated as a result of the radioactive decay of radon. The half life of these isotopes influences the ability of its expansion in the atmosphere.

The paper presents a new method of evaluation of the height of the mixing layer. According to this, the concentration of the chosen natural occurring radioactive pollutants in air was observed. Up to the present, the radon concentration in atmospheric air was taken into account (*Porstendörfer, J.*, 1994). The new approach relies on measurement of ^{218}Po polonium concentration. There are some reasons to use this isotope. It is the first radon daughter and reaches the equilibrium in a relatively short time because the half life of radon ^{222}Rn (3.8 days) is considerably longer than the half life of polonium ^{218}Po (3.05 minutes). That is the reason why the concentrations of both isotopes are well correlated. On the other hand, the polonium is a metallic element under normal conditions and can be bound (or not) to the other air-suspended particles. As a free metal atom, claster or aerosol can be then simply separated out on a filter and measured precisely by alpha spectroscopy system. An excellent lower limit of detection of this method can be reached by choosing of appropriate measurement conditions.

METHODOLOGY

The measurement points were located in the two regions in southern Poland: in the town of Katowice (Upper Silesia) and Cracow. The campaign was performed within the period of 2001-2003 from May to October. The concentrations of polonium were measured all the day and night long near to meteorological stations, where the meteorological data was collected. Then, the analysis of temporal variation was performed on the base of the following elements: atmospheric pressure, air temperature, wind velocity, reactive humidity, precipitation, solar

radiation, mixing layer height. A monostatic sodar in Katowice and Doppler sodar in Cracow were used to collect reference data related to the height of the mixing layer.
We measured the polonium ^{218}Po concentration in air instead of radon concentration (Osrodka, L., E. Krajny, M. Wojtylak, K. Skubacz and J. Skowronek, 2003). Measurements of the polonium concentration in air were performed by means of alpha spectroscopy device. Immediately after decaying of radon, about 80-82 % of ^{218}Po occurs as positive ions that are attached to air gas molecules and water particles within 10^{-7} second. This formation is called clasters (free atoms and clasters are called unattached fraction). Then the clasters can generate the bigger particles called "attached fraction". During measurements, the air together with all particles is drawn through a filter with adjusted flow rate. A special semiconductor PIPS CAM detector is placed above this filter and alpha radiation emitted by polonium, that was separated out of air stream and deposited on filter, can be detected by this detector. Our detector was a part of alpha spectroscopy system. Therefore we were able to distinguish alpha particle energy and identify isotopes collected on filters.
The regression method and the Fourier analysis made it possible to find the relationship between the polonium concentration and meteorological conditions. Time variation of the ^{218}Po concentrations was compared with data related to the height of the mixing layer obtained with help of the sodar.

RESULT

The radon concentration in soil gas was measured together with polonium concentration in air as well (Sesana, L., E. Caprioli and G. M. Marcazzan, 2003). The radon probe was located in the depth of around 1m under the surface. The diurnal, short-term variations of meteorological conditions did not affect the radon concentration in this case. However, the cumulative indirect influence of the meteorological parameters like air temperature, wind velocity and rainfalls on the radon concentration in soil gas was observed within long-term periods of anywhere from ten to twenty or tens of days. Furthermore, the assumption of quasi-stable concentration of radon concentration in soil gas was accepted. It is a necessary condition to use this method and evaluate the physical state of the atmosphere.

Mixing layer and polonium concentration

During 3 years anywhere from ten to twenty diurnal measurements of polonium concentration were performed in the lower atmosphere. All measurement companies were done when the height of the mixing layer was well-defined (sunny days). Under such conditions, the following conclusions can be drawn:

- the typical diurnal variations of the polonium concentration in the lower atmosphere were observed with a maximum in the early hours of the morning and a minimum in the late afternoon (Sesana, L., E. Caprioli and G. M. Marcazzan, 2003);
- the statistically significant relationship at significance level of 0.05 occurs between the polonium concentration in the air (C_{Po}) and the equivalent height of the mixing layer (h_e). This relationship is as follow, where α, β – const:

$$h_e = \left(\frac{C_{P_o}}{\alpha} \right)^{\beta} \qquad (1)$$

- the correlation coefficient is better when the height of the mixing layer is averaged over a period longer than 1 hour. This observation can manifest occurring of inertia of the polonium concentration changes in relation to changes of the mixing height.

The following relation was developed to take into account the time delay (h – hour) between polonium concentration and the height of the mixing layer:

$$C_{Po}(t+h) = \alpha \cdot [h_e(t)]^{\beta} \tag{2}$$

After appropriate conversion the following differential equations can be obtained:

$$h'_e(t) = \gamma \frac{C'_{Po}(t+h)}{C_{Po}(t+h)} \cdot h_e(t) \tag{3}$$

or:

$$h_e(t) = h_e(t-\Delta t) \cdot \left(1 - \gamma \frac{C_{Po}(t+h) - C_{Po}(t+h-\Delta t)}{C_{Po}(t+h)}\right)^{-1} \tag{4}$$

These equations describe the diurnal variation of the height of the mixing layer as a function of the polonium concentration in air. So the mixing layer height can be calculated for any time knowing its value and polonium concentration for the specified time (Fig 1).

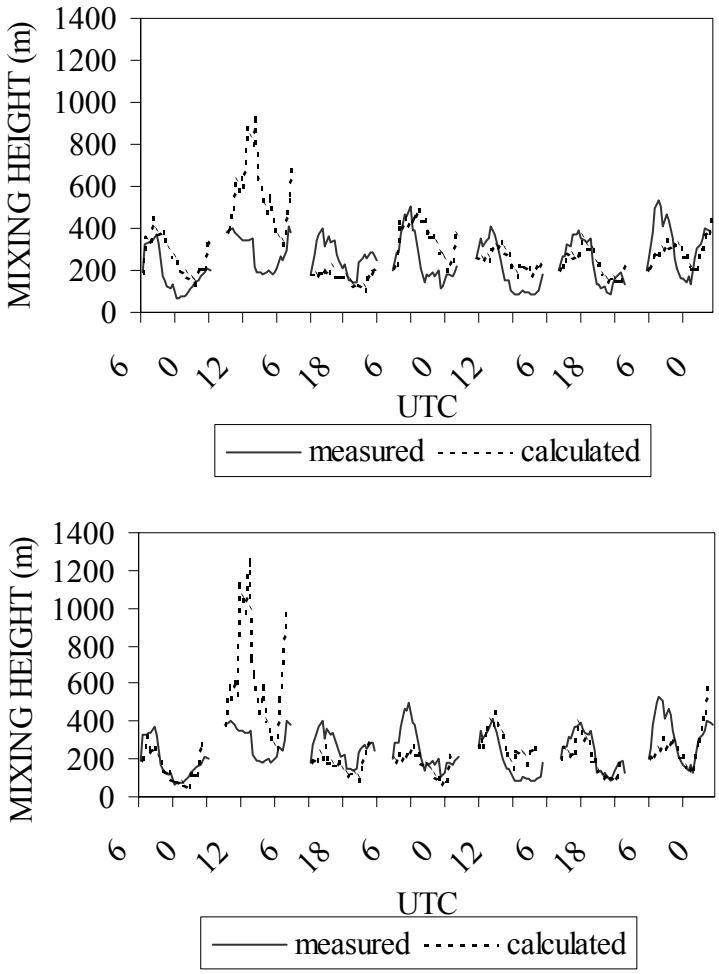

Figure 1. Comparison of the mixing height calculate (eq. 4) and measured by sodar in Katowice for the time delay Δt= 0 h (upper graph) and tΔ= 2 h (lower graph).

CONCLUSION

1. The statistical model of evaluation of the height of the mixing layer on base of polonium concentration in air was developed.
2. The obtained results show that there is a time delay between polonium concentration in air and the height of the mixing layer. The best solution is to introduce into the model a time delay of 2 hours.
3. The developed method gives a good precision for anti-cyclonic, sunny and radiational weather with the well-defined diurnal variations of meteorological parameters (summer time). The results obtained by means of sodar and alpha spectroscopy were good correlated for such cases.
4. The obtained results stimulate to continuation of the investigation to improve and verify the developed model in relation to the other measurement places.
5. The testing of the developed model during the winter time should extend the range of its application in relation to the whole year as well.

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