Monitoring of airborne artificial radioactivity with total beta counting

Jussi Paatero, Blagorodka Veleva* and Juha Hatakka

Finnish Meteorological Institute
P.O. Box 503, FI-00101 Helsinki, Finland
*National Institute of Meteorology and Hydrology
Tsarigradsko Chaussee 66, Sofia 1784, Bulgaria

Abstract

Both in Finland and in Bulgaria the national weather services started networks for airborne radioactivity monitoring in the late 1950s because of the intense testing of nuclear weapons. Soon the institutes in both countries adopted monitoring methods for airborne total beta activity because these methods are relatively simple and cost-efficient. A comparison of results from Finland and Bulgaria indicate that the temporal behaviour of airborne total beta activity is very similar in these countries. However, a few cases of different behaviour can be observed, e.g. in December 1966 owing to a leaking underground nuclear test in Semipalatinsk, former USSR.

Keywords: Airborne radionuclides, nuclear tests, nuclear accidents, beta counting

1 Introduction

Many countries initiated surveillance programmes for environmental radioactivity due to the intense atmospheric testing of nuclear weapons in the late 1950s. Both in Finland and in Bulgaria the national weather services (Finnish Meteorological Institute [FMI] in Finland, and National Institute of Meteorology and Hydrology [NIMH] in Bulgaria) developed monitoring programmes for airborne radioactivity. There were several reasons why these weather services took part in the national radioactivity monitoring programmes. The main reason was the in-depth understanding of the various atmospheric processes having an influence on the transport, concentration and deposition of airborne radionuclides. Meteorological stations were often operating with a 24/7 working scheme, which was important due to the limited number of automated instruments available. Also the means of communication were usually well developed compared to the general level of communication technology. Soon both institutes adopted monitoring methods for airborne total beta activity because these methods are relatively simple and cost-efficient. An overview of the results and certain special cases are presented in the following.

2 Experimental methods

The FMI began measurements of total beta activity in the air in the early 1960's. Daily and weekly aerosol samples have been collected onto glass fiber or paper filters at several stations. At first all the filters were measured in the FMI's laboratory with GM counters, but since 1982 two successive automatic alpha/beta analyzers have been used [1]. The detector arrangement used in the analyzers consists of five large-area (600 cm^2) gas-flow proportional counters. The flow gas is a mixture of argon (90 %) and methane (10 %). Background samples (unexposed filters) and reference samples are measured daily. The total beta activities of the samples are measured five days after the end of sampling, when the short-lived ^{222}Rn progeny have decayed into ^{210}Pb and the ^{220}Rn progeny have decayed into stable lead. The measured total beta activity consists mainly of ^{210}Pb/^{210}Bi and possible artificial beta emitters.

In Sofia, the NIMH started the measurements of atmospheric radioactivity in 1958. The aerosol total beta activity was measured initially three days and, since 1965, five days after the end of sampling. During the years the monitoring station network expanded and since 1969 a network of 5 daily aerosol stations has been operated. The aerosol samples are collected on paper filters. The air volume is measured with a flow meter. The samples are changed every day at 6:00 UTC (8:00 Local Standard Time). The radiation detectors have changed from GM counters to proportional counters and, in the beginning of the 1980s, to plastic scintillator detectors [2].

3 Results and discussion

3.1 Monthly mean concentration of total beta activity

The comparison between the total beta activity concentration values between Sofia, Bulgaria (42°41´N, 23°20´E) and Nurmijärvi, Finland (60°30´N, 24°39´E) shows that the concentrations measured in Sofia are usually higher than at Nurmijärvi excluding a few cases, e.g. during December 1966 (Fig. 3.1). This situation was due to a leaking underground nuclear test in Semipalatinsk discussed below. The last Chinese atmospheric nuclear test took place in Lop Nor in October 1980 and its stratospheric debris returned to the troposphere in spring 1981. Between summer of 1981 and spring of 1986 the amount of artificial radionuclides in the air was low. The Chernobyl accident in April 1986 changed the situation. In Finland April 1986 and in Bulgaria May 1986 showed the record-high monthly average total beta activity concentration. Most of the Chernobyl-originated activity remained in the troposphere where it was relatively quickly removed by decay and deposition. From 1987 onwards the contribution of artificial beta emitters to the total beta activity has been insignificant compared to ^{210}Pb, excluding the two incidents discussed below,. The variations of total beta activity (≈^{210}Pb) concentration are related to large-scale weather phenomena that govern the movement of maritime and continental airmasses [3, 4].

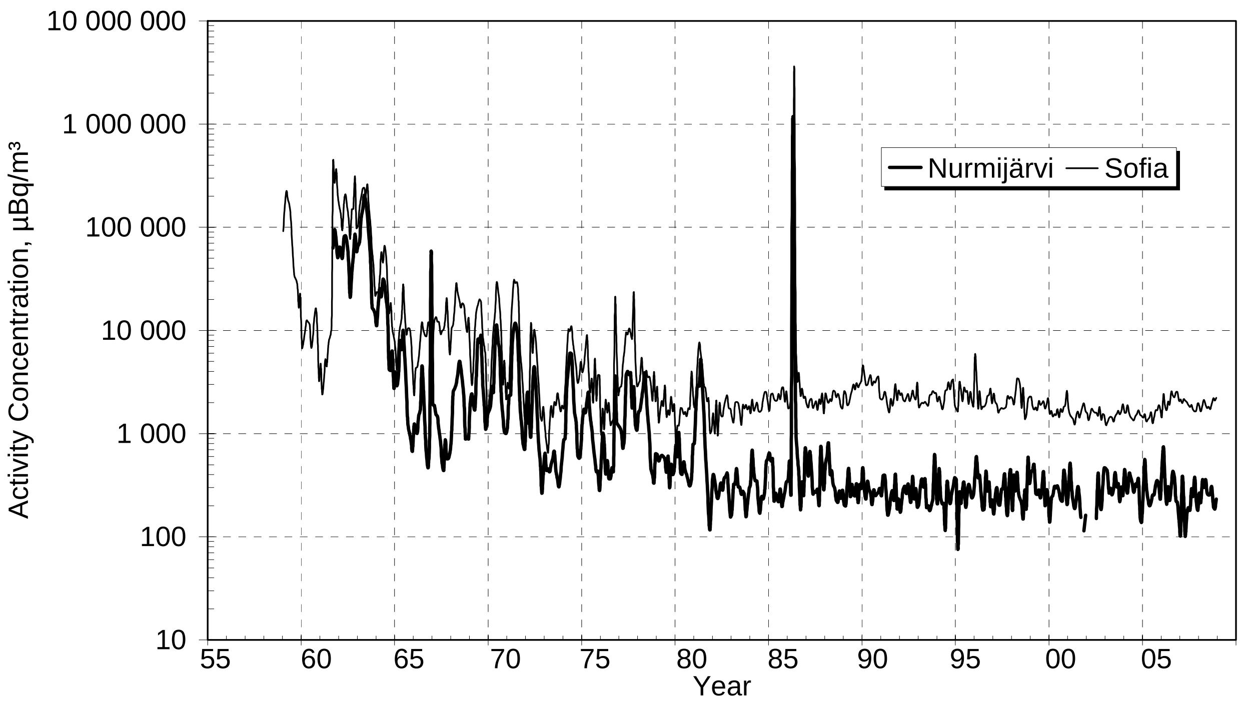

Figure 3.1: Airborne total beta activity (µBq/m³) in Nurmijärvi and Sofia, monthly mean values.

3.2 Leaking underground nuclear test in Semipalatinsk 1966

Just before the Christmas of 1966 the level of airborne radioactivity started to increase significantly, three orders of magnitude (Fig. 3.2). An autoradiograph of an air filter showed a uniform blackening of the film, in other words, there were no hot particles present. In addition a more detailed analysis including gamma spectrometry showed an unusual fission product mixture. The meteorological situation combined with constant absolute vorticity trajectory calculations indicated that the source of the plume was in Central Asia. Based on the seismographic observations it was suggested that the radioactivity originated from an underground nuclear test at the Semipalatinsk test site 18 December 1966 04:58 UTC. The passage of the fission products through the soil into the atmosphere caused a high fractionation of the nuclides. Strontium-89 and caesium-137 were enriched in the nuclide mixture compared to their fission yields. These nuclides have noble gas precursors which facilitated their escape into the atmosphere. Owing to a stable inversion layer around the 850 hPa pressure level the vertical dilution of the plume was prevented thus preserving the high concentration of the fission products [5].

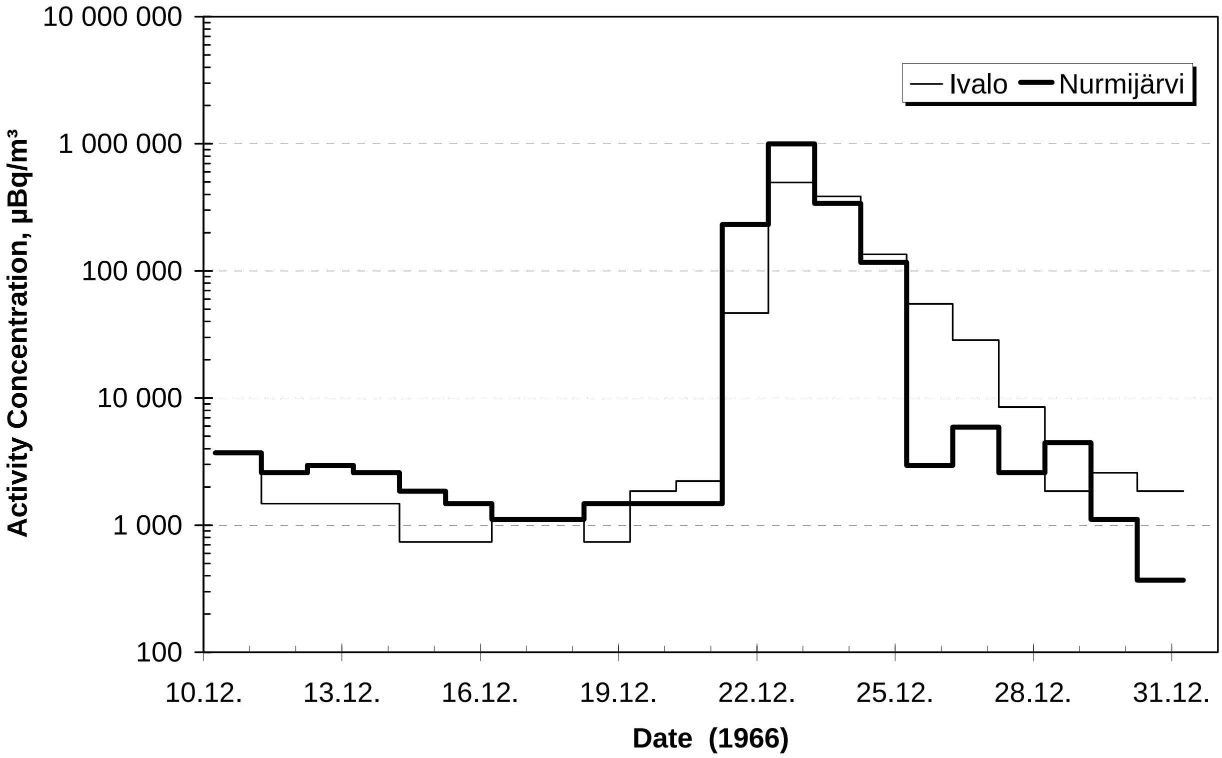

Figure 3.2: Airborne total beta activity (µBq/m³) in Ivalo (68°36´N, 27°25´E) and Nurmijärvi (60°30´N, 24°39´E) in December 1966.

3.3 Leaking underground nuclear test in Novaya Zemlya 1987

Soviet Union performed an underground nuclear test at the Novaya Zemlya test site 2 August 1987 02:00 UTC. The leaking radioactivity was observed in Norway, Sweden and Finland a few days later (Fig. 3.3) [6, 7]. Bjurman et al. [7] estimated that 200 TBq of iodine-131, 0.2 per cent of the total amount produced in the explosion, was released into the atmosphere. The total beta activity concentration in the air masses reaching northern Finland was so low that with weekly aerosol samples the exceptional activity was barely observed [6].

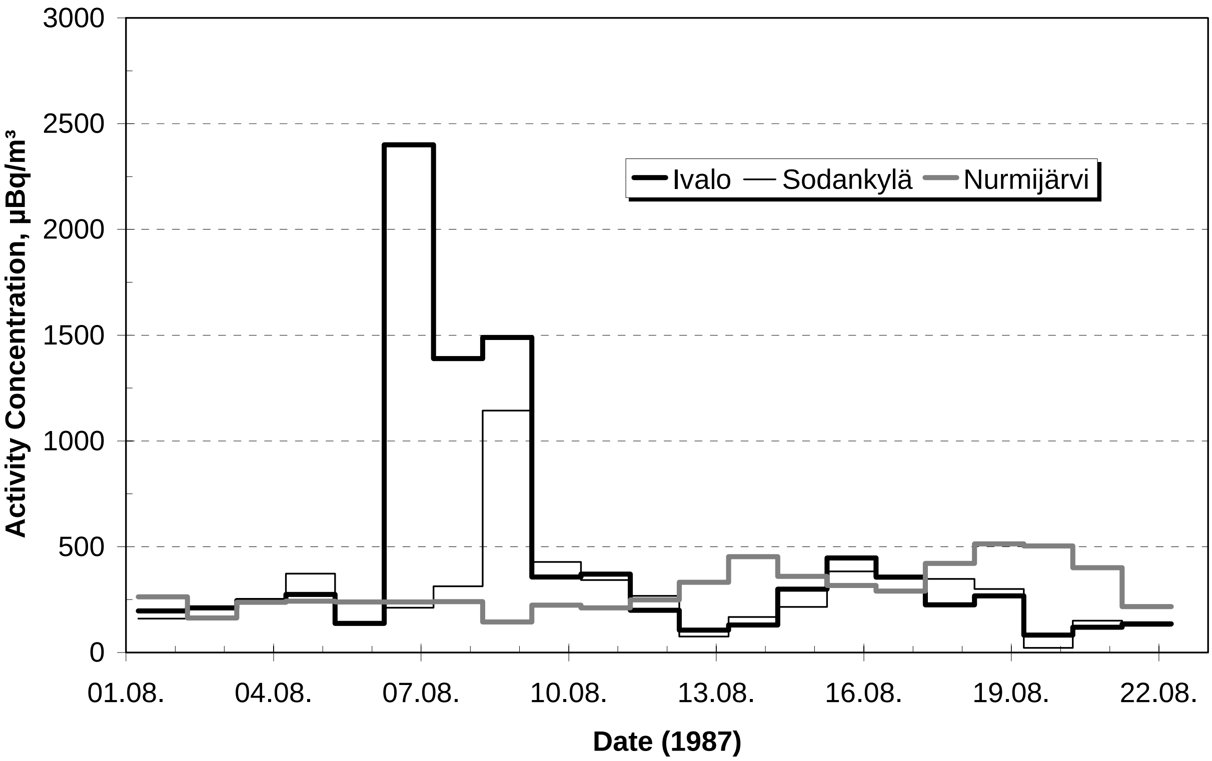

Figure 3.3: Airborne total beta activity (µBq/m³) in Ivalo (68°36´N, 27°25´E), Sodankylä (67°22´N, 26°39´E) and Nurmijärvi (60°30´N, 24°39´E) in August 1987. [5]

3.4 Incident at Sosnovyi Bor nuclear power plant in 1992

The Sosnovyi Bor nuclear power plant (four RBMK reactors) is situated in Russia 50 kilometres west of St. Petersburg. In the third reactor a fuel channel valve was broken on March 24, 1992, 1.37 EET (UTC+2). This incident led to a release of fission products into the atmosphere [8]. Air mass trajectory calculations showed that the plume from Sosnovyi Bor moved first to north-west and then turned to south on the south coast of Finland. The aerosol sample of March 24-25 (06-06 UTC), 1992 in Helsinki was put into contact with an X-ray film for 24 hours. One large and about 10 smaller hot particles were found from the autoradiogram. In Central Helsinki the amount of fission products in the air from the Sosnovyi Bor incident was only 1/5000 compared to the plume from the Chernobyl accident (Fig. 3.4).

4 Conclusions

Often monitoring of airborne total beta activity is considered less important than gathering nuclide-specific data. Nonetheless, the total beta activity monitoring has been shown to be a reliable and a sensitive surveillance and screening method. The method is also cost-efficient as it can be utilised with relatively simple instruments and laboratory staff without academic degrees. These reasons have directed also the European Union to adapt the method for its routine radiation monitoring system.

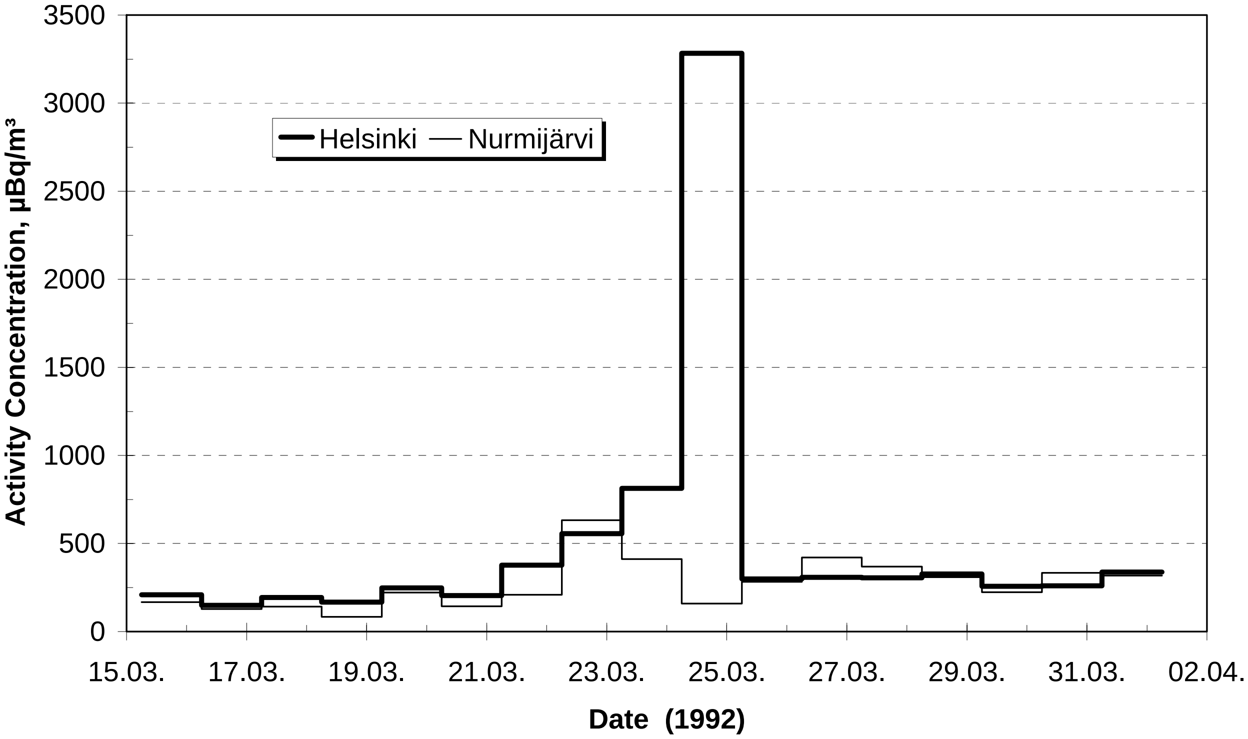

Figure 3.4: Airborne total beta activity (µBq/m³) in Helsinki (60°10´N, 24°57´E) and Nurmijärvi (60°30´N, 24°39´E) in March 1992. [7]

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