Chapter 9

Atmospheric Radioactivity and Its Variations

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9.1 INTRODUCTION

9.1.1 Historical

Within a few years of Becquerel’s discovery in 1896 of the radioactivity of uranium, it was recognised that the atmosphere itself is naturally radioactive. In 1900, Wilson\(^1\) investigated the electrical conductivity of air and showed that it could be explained by low level ionisation of the air, and two years later Elster and Geitel\(^2\) showed that a negatively charged wire exposed in the atmosphere became radioactive. The same authors\(^3\) showed that soils and rocks are sources of radon and thoron, radioactive gases which will produce radioactive decay products in the atmosphere (see also Section 9.2.1).

Initially, the hazards from radioactive material were not appreciated, but their importance was accepted by the time of the discovery of fission in 1939. Consequently the nuclear weapons and power industries that developed in the 1950s and onward recognised the need to monitor and control emissions to the atmosphere.

Systematic and extensive measurement programmes of atmospheric radioactivity began in about 1952, to monitor the effects of nuclear weapon testing. The results provided information on the long-range transport of artificial and natural radionuclides in the atmosphere and contributed to the understanding of exchange processes between the stratosphere and the troposphere, and between the hemispheres. Junge’s book, *Air Chemistry and Radioactivity*,\(^4\) of 1963 presents early advances
in this subject. Measurements were also made of the dispersion of atmospheric radioactivity resulting from routine releases from nuclear manufacturing facilities.

Very few accidents at nuclear facilities have resulted in measurable dispersion of radioactivity beyond the immediate neighbourhood of the plant. These include a reactor fire at Windscale (UK) in 1957 and a release from a reprocessing plant near Kyshtym in the Urals (USSR) in the same year. The much publicised reactor accident at Three Mile Island (USA) released only minor amounts of radioactivity, and that at Chernobyl (USSR) in 1986 dwarfed the earlier events. The effects of Chernobyl will require several further years’ study for a full assessment.

This chapter is an attempt to summarise the understanding of the sources, atmospheric behaviour and the consequences of natural and artificial radioactivity.

9.1.2 The nature of airborne radionuclides

Fifty years after the start of the work that led to the use of nuclear weapons, and 30 years after the first nuclear power stations began operation, natural radioactivity still dominates that created by man. Numerous radionuclides, both natural and man-made, may be detected in the atmosphere. Tritium (\(^{3}\)H), carbon-14 (\(^{14}\)C) and others have both natural and industrial sources. The chemical and physical properties of nuclides to be found in the atmosphere vary widely. Some follow the geochemistry of a stable counterpart. Thus \(^{3}\)H and \(^{14}\)C follow the cycles of hydrogen and carbon, although their atmospheric behaviour is influenced by their initial chemical forms.

Radon, and several man-made radionuclides, are noble gases, while thorium and uranium are among the most refractory of metals. The decay products of radon associate with submicrometric particles in the atmosphere, but involatile radionuclides from Chernobyl were dispersed in particles up to \(10^9\) times more massive. Many are transported as inert particles through the atmosphere while others undergo chemical and physical transformations that profoundly influence their fate.

These differences have important consequences for the atmospheric distribution of radioactivity. The long-lived \(^{85}\)Kr (the half-life \(t_1 = 10.8\) years) remains in the atmosphere until it decays. Carbon-14 present chiefly as \(^{14}\)CO\(_2\) also has a long enough residence time in the air for widespread mixing. As tritiated water, \(^{3}\)H has a residence time of only a few days and initial dispersion is limited to a scale of order 1000 km. The small particles that transport radon decay products behave similarly, but large