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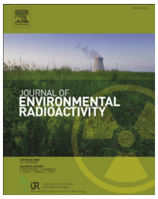

Estimating the terrestrial gamma dose rate by decomposition of the ambient dose equivalent rate

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ABSTRACT

An extensive network of dose rate monitoring stations continuously measures ambient dose rate across Europe, as part of the EURDEP system. Its purpose is early warning in radiological emergencies and documenting its temporal and spatial evolution. In normal conditions, when there is no contribution to the dose rate signal coming from fresh anthropogenic contamination, the data represent the radiation "background", i.e. the combined natural radiation and existing anthropogenic contamination (by global and Chernobyl fallout). These data are being stored, but have so far not been evaluated in depth, or used for any purpose. In the framework of the EU project 'European Atlas of Natural Radiation' the idea has emerged to exploit these data for generating a map of natural terrestrial gamma radiation. This component contributes to the total radiation exposure and knowing its geographical distribution can help establishing local 'radiation budgets'. A further use could be found in terrestrial dose rate as a proxy of the geogenic radon potential, as both quantities are related by partly the same source, namely uranium content of the ground. In this paper, we describe in detail the composition of the ambient dose equivalent rate as measured by the EURDEP monitors with respect to its physical nature and to its sources in the environment. We propose and compare methods to recover the terrestrial component from the gross signal. This requires detailed knowledge of detector response. We consider the probes used in the Austrian, Belgian and German dose rate networks, which are the respective national networks supplying data to EURDEP. It will be shown that although considerable progress has been made in understanding the dose rate signals, there is still space for improvement in terms of modelling and model parameters. An indispensable condition for success of the endeavour to establish a Europe-wide map of terrestrial dose rate background is progress in harmonising the European dose rate monitoring network.

1. Introduction

Across Europe, more than 4500 stations continuously monitor ambient equivalent dose rate. They belong to nation monitoring networks and are operated by national authorities responsible for radiation protection. Together, these networks contribute to the EURDEP system, run by the Joint Research Centre (JRC) of the European Commission.[1] The purpose of the networks and of the EURDEP platform is early warning in radiological emergencies. The data are transferred in almost real time to national and European central servers and are available to the public via an internet page, https://eurdep.jrc.ec.europa.eu/.

The national networks differ in design, as a consequence of different approaches and policies. This complicates joint interpretation of the data. Work aimed to understand the differences and to attempt posterior (or "top down") harmonization by application of harmonization algorithms to the individual results has been an

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[1] more precisely, by the REM group, part of the JRC's Institute for Transuranium Elements, https://rem.jrc.ec.europa.eu/RemWeb/Index.aspx. EURDEP also includes networks of stations for monitoring airborne contamination.

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issue for more than 10 years at the JRC in the framework of the AIRDOS project and related research activities.

No radiological event detectable by the dose rate networks has occurred in Europe since the Chernobyl accident in 1986. The dose rate generated by the Fukushima cloud and subsequent fallout over Europe was about three orders of magnitude below the detection capabilities of the monitors that contribute to EURDEP. Still, data are being collected and stored in routine or background mode. They reflect essentially the natural radiation background. So far, little use has been made of these data. Although made for a different purpose, the data could however be of scientific use. One is the European Atlas of Natural Radiation, which has been under development since 2006 at the JRC, and which will be a collection of maps, including terrestrial gamma dose rate, among others (De Cort et al., 2011; Cinelli et al., 2015). A second possible use is terrestrial gamma dose rate as predictor of the geogenic radon potential (Cinelli et al., 2015; Bossew et al., 2015a,b). In an ambitious first attempt, Szegvary et al. (2007a) generated a terrestrial gamma dose rate map of Europe. Here we refine that analysis. Uses that have been suggested are estimating soil humidity and radon flux from the ground (Szegvary et al. (2007b) and Stöhlker et al. (2012)).

The recorded ambient dose rate has several components, which have to be separated in order to recover the terrestrial gamma component. Among these components are the intrinsic background or self-effect, the contribution of secondary cosmic rays and other minor contributions. The terrestrial background consists of the gamma dose rate produced by U and Th decay series and ^{40}K concentration in the ground, and of an anthropogenic contribution from global and Chernobyl fallout. In addition, rain and snow can cause precipitation of Rn progenies on the ground, which can generate short-lived peaks of relatively high ambient dose rate (called Radon (Rn) peaks).

In this article, we describe the decomposition of ambient dose rate in more detail. In particular, we present three algorithms aimed to separate the Rn peaks from the remaining terrestrial components. So far (autumn 2015), the analyses were performed for German, Austrian and Belgian dose rate monitoring stations. We also discuss properties of that terrestrial background which is, to some extent, temporally variable due to environmental conditions related to meteorology. A relatively complicated problem, also addressed, is estimation of the anthropogenic (fallout) component. We give examples of decomposed dose rate time series. Finally, we discuss uncertainties involved in the procedure.

This paper is devoted to methodological aspects. Detailed statistical evaluation and discussion of the data of all investigated stations, as well as mapping of terrestrial dose rate, will be presented in a future article.

2. Ambient dose equivalent rate

2.1. Definition

The ambient equivalent dose H*(10) is a measurable equivalent of the effective dose, which quantifies the risk to human health associated to radiation exposure. For its exact definition see ICRU-51 or IAEA.[2]

In the following we use the symbol H^* as abbreviation for ambient dose equivalent rate, dH*(10)/dt, for simplicity.

The dose rate probes must be calibrated to yield H^* values for usual environmental radiation fields within some tolerated uncertainty. Calibration and quality assurance of dose rate monitors are rather complicated subjects, not to be discussed here. Given its practical importance, quality assurance of dose rate metrology, in particular with respect to harmonising national European networks, is subject to great efforts. As example we want to mention the long-term experiment for intercomparison of monitors under real ambient conditions INTERCAL (Bleher et al., 2014). In Europe they are mainly coordinated by EURADOS (European Radiation Dosimetry) working group 3, e.g. Wissmann and Sáez-Vergara (2006), Sáez-Vergara et al. (2007), Dombrowski et al. (2009) and Neumaier and Dombrowski (2014).

2.2. Components

Let H*(source; true) be the true ambient dose equivalent rate from a source. Generally the total dose rate H*(true) can be decomposed into the following components:

$$H*(\mathrm{true}) = H*(\mathrm{cosm;true}) + H*(\mathrm{air;true}) + H*(\mathrm{terr;true}),$$

where H*(cosm; true) is the contribution from cosmic rays, H*(air; true) the one of radionuclides in air and H*(terr; true) terrestrial radiation from gamma emitters in the ground and on the ground surface. The terrestrial component, in which we are interested here, can in principle be recovered by subtracting the other components from measured H^*. However, the true dose rate is not known, but only one measured or observed by a detector. The relationship between true and observed dose rate is not trivial, as will be discussed in the following sub-section.

Here we restrict discussion to "background situations", i.e. if no anthropogenically contaminated air is present. Also signals due to activities such as nearby material testing using gamma sources, are excluded in this analysis. Also external contamination of the detector housing seems negligible even in the case of anthropogenic fallout (C. Debayle, personal communication). Pending further information we assume the same for Rn progenies attached to the detector housing.

An overview on physical effects that are visible in the recordings of the German dose rate network is given in http://odlinfo.bfs.de/interpretation.php?lang=EN. Detailed analyses can be found, e.g., in Smetsers and Blaauboer (1994, 1997a,b).

2.2.1. True and observed dose rate

The detector responds to radiation with true dose rate from a source with a count rate N (measured, e.g., in cps), which is a function of the dose rate corresponding to the arriving photon flux and the energy of the radiation. Let N (source) be the detector response,

$$\mathrm{N(source)} = f_{\mathrm{source}}(H^*(\mathrm{source;true})),$$

f_{source} – the source-specific response function. Detectors are designed to guarantee linear response as accurately as possible, i.e.

$$\mathrm{N(source)} = N_0 + R_{\mathrm{source}} H^*(\mathrm{source;true}),$$

R_{source} – the response factor to the source with certain energy or energy mixture. The null-count rate N_0 is source-independent, but depends on intrinsic properties of the detector.

In the calibration procedure, a calibration factor k_{source} is determined such that for a certain type of source, the product

$$H^*(\mathrm{source;observed}) = K_{\mathrm{source}} \mathrm{N(source)}$$

equals H*(source; true). Since the response of the detector depends

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[2] https://www.iaea.org/ns/tutorials/regcontrol/intro/glossaryi.htm, https://www.iaea.org/ns/tutorials/regcontrol/intro/glossaryd.htm#D57.

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