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A kinematic-based methodology for radiological protection: Runoff analysis to calculate the effective dose for internal exposure caused by ingestion of radioactive isotopes

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We aim to propose a kinematic-based methodology similar with runoff analysis for readily understandable radiological protection. A merit of this methodology is to produce sufficiently accurate effective doses by basic analysis.

The great earthquake attacked the north-east area in Japan on March 11, 2011. The system of electrical facilities to control Fukushima Daiichi nuclear power plant was completely destroyed by the following tsunamis. From the damaged reactor containment vessels, an amount of radioactive isotopes had leaked and been diffused in the vicinity of the plant. Radiological internal exposure caused by ingestion of food containing radioactive isotopes has become an issue of great interest to the public, and has caused excessive anxiety because of a deficiency of fundamental knowledge concerning radioactivity.

Concentrations of radioactivity in the human body and internal exposure have been studied extensively. Previous radiologic studies, for example, studies by International Commission on Radiological Protection(ICRP), employ a large-scale computational simulation including actual mechanism of metabolism in the human body. While computational simulation is a standard method for calculating exposure doses among radiology specialists, these methods, although exact, are too difficult for non-specialists to grasp the whole image owing to the sophistication. In this study, the human body is treated as a vessel. The number of radioactive atoms in the human body can be described by an equation of continuity, which is the only governing equation.

Half-life, the period of time required for the amount of a substance decreases by half, is only parameter to calculate the number of radioactive isotopes in the human body. Half-life depends only on the kinds of nuclides, there are no arbitrary parameters. It is known that the number of radioactive isotopes decrease exponentially by radioactive decay (physical outflow). It is also known that radioactive isotopes decrease exponentially by excretion (biological outflow). The total outflow is the sum of physical outflow and biological outflow. As a result, the number of radioactive atoms in the human body also decreases exponentially. Half-life can be determined by outflow flux from the definition.

Intensity of radioactivity is linear respect to the number of radioactive atoms, both are equivalent analytically. Internal total exposure can be calculated by the time integral of intensity of radioactivity.

The absorbed energy into the human body per radioactive decay and the effective dose are calculated by aid of Fermi's theory of beta decay and special relativity. The effective doses calculated by the present method almost agree with those of a study by ICRP.

The present method shows that standard limit in general foods for radioactive cesium enforced in Japan, 100 Bq/kg, is too excessive. When we eat foods which contain cesium-137 of 100 Bq/kg at 1 kg/d during 50 years, we receive the effective dose less than natural exposure. Similarly, it is shown that we cannot find significant health damage medically and statistically by ingestion of rice which is harvested from a paddy field deposited current (January, 2014) radioactive cesium.