World Academy of Science, Engineering and Technology
International Journal of Health and Medical Engineering
Vol:12, No:05, 2018

Solar and Galactic Cosmic Ray Impacts on Ambient Dose Equivalent Considering a Flight Path Statistic Representative to World-Traffic

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Abstract : The earth is constantly bombarded by cosmic rays that can be of either galactic or solar origin. Thus, humans are exposed to high levels of galactic radiation due to altitude aircraft. The typical total ambient dose equivalent for a transatlantic flight is about 50 µSv during quiet solar activity. On the contrary, estimations differ by one order of magnitude for the contribution induced by certain solar particle events. Indeed, during Ground Level Enhancements (GLE) event, the Sun can emit particles of sufficient energy and intensity to raise radiation levels on Earth's surface. Analyses of GLE characteristics occurring since 1942 showed that for the worst of them, the dose level is of the order of 1 mSv and more. The largest of these events was observed on February 1956 for which the ambient dose equivalent rate is in the orders of 10 mSv/hr. The extra dose at aircraft altitudes for a flight during this event might have been about 20 mSv, i.e. comparable with the annual limit for aircrew. The most recent GLE, occurred on September 2017 resulting from an X-class solar flare, and it was measured on the surface of both the Earth and Mars using the Radiation Assessment Detector on the Mars Science Laboratory's Curiosity Rover. Recently, Hubert et al. proposed a GLE model included in a particle transport platform (named ATMORAD) describing the extensive air shower characteristics and allowing to assess the ambient dose equivalent. In this approach, the GCR is based on the Force-Field approximation model. The physical description of the Solar Cosmic Ray (i.e. SCR) considers the primary differential rigidity spectrum and the distribution of primary particles at the top of the atmosphere. ATMORAD allows to determine the spectral fluence rate of secondary particles induced by extensive showers, considering altitude range from ground to 45 km. Ambient dose equivalent can be determined using fluence-to-ambient dose equivalent conversion coefficients. The objective of this paper is to analyze the GCR and SCR impacts on ambient dose equivalent considering a high number statistic of world-flight paths. Flight trajectories are based on the Eurocontrol Demand Data Repository (DDR) and consider realistic flight plan with and without regulations or updated with Radar Data from CFMU (Central Flow Management Unit). The final paper will present exhaustive analyses implying solar impacts on ambient dose equivalent level and will propose detailed analyses considering route and airplane characteristics (departure, arrival, continent, airplane type etc.), and the phasing of the solar event. Preliminary results show an important impact of the flight path, particularly the latitude which drives the cutoff rigidity variations. Moreover, dose values vary drastically during GLE events, on the one hand with the route path (latitude, longitude altitude), on the other hand with the phasing of the solar event. Considering the GLE occurred on 23 February 1956, the average ambient dose equivalent evaluated for a flight Paris - New York is around 1.6 mSv, which is relevant to previous works This point highlights the importance of monitoring these solar events and of developing semi-empirical and particle transport method to obtain a reliable calculation of dose levels.

Keywords : cosmic ray, human dose, solar flare, aviation
Conference Title : ICRHERP 2018 : International Conference on Radiation Health Effects and Radiation Protection
Conference Location : Amsterdam, Netherlands
Conference Dates : May 10-11, 2018