Assessing public exposure in commercial flights in Brazil

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The exposure to cosmic radiation in aircraft travel is higher than that at ground level and may vary with the route due to the effect of latitude, with the flight altitude, the flight length, and the year due to the cyclic variation observed in earth's flux of cosmic rays. The computer program CARI-6, developed by the U.S. Federal Aviation Administration Civil Aerospace Medical Institute, calculates the effective dose of galactic cosmic radiation received by an individual (based on an anthropomorphic phantom) in an aircraft flying the shortest route between two airports the world. The program takes into account changes in altitude and geographic location during the course of a flight, as derived from the flight profile entered by the user. Although originally developed to quantify the radiation exposure of flight crews, the code performs the dose calculation for a particular flight data provided by the user. Although, for the general public, this exposure is not subject to regulation, because it is a voluntary activity, commercial flights represent a technological increased exposure of people to natural radiation. The aim of this work is to estimate the contribution of cosmic radiation exposure on commercial flights to the Brazilian population. The work shall serve as a baseline for future comparisons of the growth of civil aviation in the country. It shall also open perspectives for discussions on the concept of risk and its public acceptance, relevant to the establishment of radiological protection guidelines. At this first stage, a preliminary study was performed to verify the relevance of the information needed to perform the simulations using CARI-6 code. It was verified that most relevant parameters are the time of flight, the average flight altitude (CV ~ 25%) and latitude (CV ~ 4 %) in domestic flights in Brazil.

Key words: public exposure, cosmic radiation

1. INTRODUCTION

Radiation has always been present in the biosphere, where life has developed. The largest contribution to the various exposures to radiation received by men comes from natural sources. A characteristic of natural radiation is that it has been received by all of the world population, for a long period of time at a relatively constant rate. In general, human exposure to natural sources is an inevitable condition of life on earth. The main sources of natural radiation that contribute to human exposure are cosmic radiation and terrestrial radiation (UNSCEAR, 2000).

Most of the cosmic radiation that reaches the earth is originated outside the solar system and reaches the earth's atmosphere at a fairly constant rate. The cosmic radiation interacts with material on its way through the atmosphere until it reaches the earth's surface. In these interactions, it loses energy. Latitude and altitude affects the cosmic rays flux. According to Shea & Smart (2000), people living 1,600 meters receive twice the exposure to cosmic rays than people who live at sea level. Solar cycles also affect the flux of cosmic rays in the Earth's atmosphere. The galactic cosmic rays observed on Earth are in inverse proportion to the phase of the sunspot cycle (UNSCEAR 2010).

Thus, exposure to cosmic radiation in aircraft travel is significantly higher than the ground level and varies with the route due to the effect of latitude, the altitude of flight, the flight time, and the year due to the effect of the solar cycle in galactic cosmic ray flux. The world average estimated by UNSCEAR (2010) for the effective dose due to cosmic radiation at ground level is 0.38 mSv per year, about 16% of the average worldwide dose from natural sources.

The computer program CARI-6, developed by the U.S. Federal Aviation Administration Civil Aerospace Medical Institute, calculates the effective dose of galactic cosmic radiation received by an individual (based on an anthropomorphic phantom) in an aircraft flying the shortest route between two airports the world. The program takes into account changes in altitude and geographic location during the course of a flight, as derived from the flight profile entered by the user. The flight profile includes the month and year of the flight as the program takes into account the effect of solar cycle on the calculated dose.

Although originally developed to quantify the radiation exposure of flight crews, computer code CARI (CAMI, 2004) is public domain and performs the calculation of the dose for a particular flight, depending on flight time, taking into account variations due to altitude and latitude, but also due to the solar cycle. It is interesting to note that the predicted results show good consistency with measurement data available in the literature (Sohrabi and Esmaili, 2002; Lin et al, 1996)

In relation to the general public, this exposure is not subject to regulation, because it is considered as a voluntary activity, commercial flights represent a technological increased exposure of people to natural radiation. This component of the exposure of the public is, however little studied and few surveys are found in the literature. A survey made in UK observed an increase in exposure to radiation due to commercial flights of about 50%, on average, for the population of England, between the years 1999 and 2002. The total dose in 2002 due to this source accounted for about 10% of the average external exposure in the country (Watson et al, 2005).

The aim of this project is to estimate the contribution of cosmic radiation exposure on commercial flights to the Brazilian population. In this first step, different sources of variability have been assessed in order to verify the effect of simplifying approaches on the calculated dose. The work should serve as a baseline for future comparisons of the growth of civil aviation in the country. The relevance of any study on exposure to natural radioactivity and its technological increases, particularly in this case, in which exposure is considered voluntary, should open perspectives for future discussions on the concept of risk and its public acceptance, which are relevant aspects to consider when defining radiological protection guidelines.

2. METHODOLOGY

Some standard flights were selected to assess the variability of parameters affecting flights in Brazil. At this stage of the work, the collection flights data was done directly at airline sites. The simulations for the doses will be made using the model Cari 6, developed by the U.S. Federal Aviation Administration (FAA, 2011).

A database including all routine commercial flights in Brazil is being implemented in Excel spreadsheets, based on data from November, 2011, for which a publication was made available [1]. In order to simplify the analysis, due to large number of flights, some sources of variability included in the calculations have been investigated. To assess the uncertainty due to the annual variability on cosmic rays flux, a flight from Rio de Janeiro, RJ, to Porto Alegre, RS, was selected. The distance between the two airports is about 2000 km and flight time is about 2 hours. This flight was simulated at different months within 2011 and annually from 1995 to 2011. As flight altitude varies according to the itinerary, this variability was assessed for average altitude flights from 30000 to 38000 feet, based on the information of average flight altitude of 34000 feet. The results presented herein correspond to total flight dose. To assess the latitude differences within Brazil, doses from flights from Rio de Janeiro, RJ to different locations in Brazil were simulated. The airports locations are described on Table 1 and shown in Figure 1. The results of assessing the latitude effect are presented in µSv per hour at a standard flight altitude of 34000 ft.

Figure 1. Airports included in simulations

Table 1. Location of the airports used in this work

City	*IATA code*	*ICAO code*	*latitude*	*longitude*	*elevation (m)*
Rio de Janeiro	GIG	SBGL	22° 48' 36" S	43° 15' 02" W	9
Porto Alegre	POA	SBPA	29° 59' 38" S	51° 10' 16" W	3
São Paulo	GRU	SBGR	23° 26' 08" S	46° 28' 23" W	750
Brasilia	BSB	SBBR	15° 52' 09" S	47° 55' 15" W	1060
Salvador	SSA	SBSV	12° 54' 31" S	38° 19' 21" W	20
Manaus	MAO	SBEG	03° 02' 28" S	60° 03' 02" W	80

3. RESULTS

Figure 1 and 2 present the variability predicted for the Rio de Janeiro – Porto Alegre two hours flight, assuming a 15 minutes period for takeoff, up to a 90 minutes average cruise altitude of 34000 ft, and 15 minutes for landing, totalizing 2 hours for each flight.

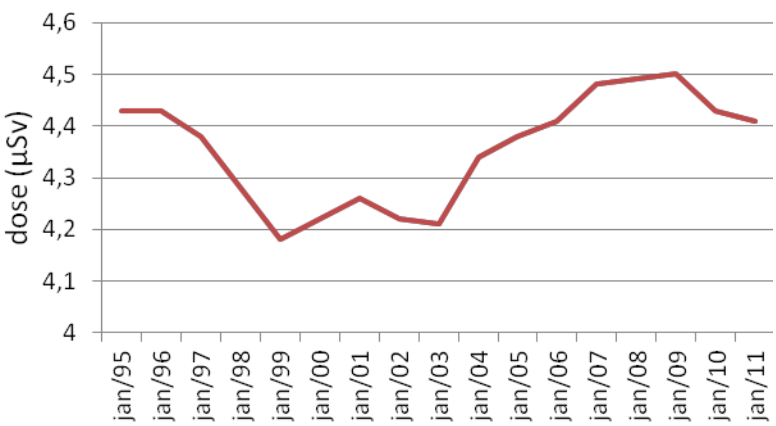

Figure 1. Doses for flights from Rio de Janeiro to Porto Alegre for the same month in different years.

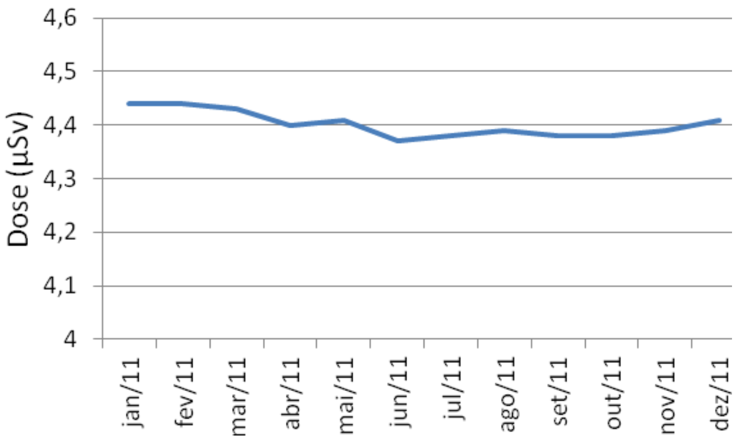

Figure 2. Doses for flights from Rio de Janeiro to Porto Alegre for different months of the same year.

It could be observed that the variability within a single year was much smaller than the variability within a 11 years solar activity cycle. A statistical summary of the results obtained are presented on Table 2. The results for latitude effects are shown on table 3.

Table 2. Summary results for simulations

source of uncertainty	*flights characteristics*	*average dose (µSv)*	*standard deviation (µSv)*	*coeficient of variation (%)*
seasonal aspects*	monthly flights	4,40	0,02	0,56
solar cycle*	annual flights	4,36	0,11	2,49
altitude*	30000-38000 ft	4,41	1,21	27,31
takeoff and landing**	5 to 15 minutes	4,71	0,32	6,79
time at en route altitude***	100 to 140 min	4,71	0,70	14,93

* 15 min take off and landing, 120 min flight

**120 minutes total flight

*** 10 minutes take off and landing

Table 3. Dose rate at en route altitude (34000 ft) for different flights within Brazil

Flight	*dose rate (µSv/h)*
GIG - POA	2,70
GIG - MAO	2,41
GIG - SSA	2,51
GIG - BSB	2,52
GIG - GRU	2,62
POA - MAO	2,46
average	2,54
std.dev.	0,11
CV (%)	4,19

Based on these results, it was decided that the work shall continue using nominal flight time for each route, according to that predicted by airlines. Besides the time of flight, the main source of variability on flight doses is related to the flight altitude. Average altitude to be used for all large airplane (> 80 passengers) flight shall be 34000 ft. For each route, annual averages shall be used, discarding the effect of season on doses. The reference year shall be 2011, for which data for all flights are available. Extrapolation to other years should not be performed due to both the differences in number and routes of flights and also due to the effect of solar cycle on commercial flight altitudes. Although the effect of latitude may contribute with about 5 % for flights within Brazil, individual routes will be kept in the analysis to allow regional assessments in the country.

4. CONCLUSIONS

This work investigated different sources of variability and uncertainty that will be involved in the assessment of public exposure due to commercial air flights in Brazil. Contact with main airlines in Brazil shall be tried to get more information on key parameters such as flight altitude, at least for the most frequent routes. Besides individual and collective doses, the work shall investigate doses to frequent flyers and regional assessments shall be performed and compared to other life quality standards of the people. It is expected that the current profile of exposure of the public to cosmic radiation due to air flights serve as a baseline for future comparisons of the growth of civil aviation in the country. It shall also open perspectives for discussions on the concept of risk and its public acceptance, relevant to the establishment of radiological protection guidelines.

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