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ASSESSING PUBLIC AND CREW EXPOSURE IN COMMERCIAL FLIGHTS IN BRAZIL

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ABSTRACT

The exposure to cosmic radiation in aircraft travel is significantly higher than at ground level and varies with the route due to the effect of latitude, the altitude of flight, the flight time, and the year according to the solar cycle effects in galactic cosmic ray flux. The computer program CARI-6, developed by the U.S. Federal Aviation Administration, calculates the effective dose of galactic cosmic radiation received by an individual in an aircraft flying the shortest route between two airports of the world. The program takes into account changes in altitude and geographic location during the course of a flight. The aim of this project is to estimate the contribution of cosmic radiation exposure on commercial flights to the Brazilian population. A database, including about 4,000 domestic flights in Brazil, was implemented in Excel spreadsheets based on data flights information for November 2011. Main fields included on the database are the origin and destination of flights, time of departure and arrival, plane type, number of passengers, flight times (take-off, landing and cruse altitude times) and number of flights per year. This information was used to estimate individual and collective doses for crew and passengers. Doses for domestic flights in Brazil range from 1.8 to 8.8 µSv. Considering the occupational limit of 850 h of flight per year for crewmembers and numbers of flights for each route, average occupational dose would be about 0.76 mSv/y. Collective doses, for the total number of flights per year and airplane types were estimated to be 214 and 11 manSv/y for passengers and crewmembers, respectively.

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 most 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 time, at a relatively constant rate. The main sources of natural radiation that contribute to human exposure are the cosmic and the terrestrial radiation [1].

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. However, on its way through the atmosphere until it reaches the earth's surface it loses energy due to interactions with material on the earth's atmosphere. The world average estimated by UNSCEAR 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 [1].

The exposure to cosmic radiation in aircraft travel is significantly higher than that received at sea 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. In relation to the general public, this exposure is not subject to regulation, because it is considered as a voluntary activity, although commercial flights represent a technological increased exposure of people to natural radiation.

The aim of this work was to estimate the contribution of cosmic radiation exposure on commercial flights to the Brazilian population, including the exposure to crewmembers. The work should serve as a baseline for future comparisons of exposures due the growth of civil aviation in the country and to access the contribution of this source to overall public and crew exposure in the country.

2. METHODOLOGY

In a first step standard flights were selected to perform the simulations using CARI-6 code, in order to do an initial sensitivity analysis on main parameters such as flight time, flight altitude, latitude, take-off and landing periods [2]. According to the results of such analysis, a database was implemented in Excel spreadsheets based on flights available for November 2011 [3].

For the present work, only domestic flights were considered. The fields described in the database are the origin and destination of flights; time of departure and arrival; weekly frequency of each flight; airplane type; number of passengers (full capacity for airplane type); airline and flight number; total time of flight; Acronym ICAO (International Civil Aviation Organization) for origin and destination of the flight; and, average cruise altitude and take-off and landing periods. The final database then includes 3872 domestic flights, comprising more than 1,000,000 individual flights per year in Brazil.

Later, the database was complemented with data regarding aircrew. The number of aircrew members was estimated as a function of the type of airplane, based on information available from Boeing [4] complemented by airplane characteristics taken from airplane constructors web sites.

Information on take-off and landing times and on cruise altitude was gathered from consultation with experts and official airlines data (DECEA – Department of Airspace Control – personal information; Air Traffic Coordinator of Jacarepagua Airport in Rio de Janeiro, William Macedo de Lima, personal information).

Doses from individual flights were assessed using the computer program CARI-6, developed by the U.S. Federal Aviation Administration [5]. This program calculates the effective dose of galactic cosmic radiation received by an individual in an aircraft flying the shortest route between two airports of the world. The program takes into account changes in altitude and latitude during the course of a flight, the effects of take-off and landing times, and the effect of solar cycle, as derived from the flight profile entered by the user. The program was used to estimate exposure of crewmembers and the same value was applied to adult members of the public.

3. RESULTS

Average doses assessed for individual domestic flights within Brazil, calculated by CARI-6 software for the year of 2011, ranged from 0.3 up to 8.8 µSv.

With the revenue rate of 73% observed for 2012 for domestic flights in Brazil [7] it was estimated that about 100 million people fly annually in domestic flights in Brazil, with a total collective dose of about 214 manSv per year. A summary of the results based on the state of origin of the flights is presented on Table 1.

More than 40% of all passengers fly from three towns: São Paulo (20.1%), Rio de Janeiro (12.5%) and Brasília (8.9%). The contribution to the total collective dose are 21% for São Paulo, that is the largest town in the country, 12% for Rio de Janeiro, that was the former capital of the country and is a touristic town, and 11% for Brasília, the current capital of the country. Rio de Janeiro and São Paulo towns have two airports each one, with commercial flights and Brasília has only one.

The dose assessment performed for the most usual daily flights in the country, that are those between Rio de Janeiro and São Paulo, present average dose of 1.8 µSv (standard deviation of 0.43 µSv); average doses for Rio de Janeiro and São Paulo flights to Brasília, are 3.37 and 3.24 µSv, respectively.

It can be observed that these flights have very small contribution to the overall exposure of passengers to natural radiation sources. Although not subjected to regulation, as this exposure is seen as voluntary, exposures from individual flights are all below the exemption level of 10µSv.

Frequent flyer however may have doses in excess of this level although below the current lower intervention level of 10 mSv per year in Brazilian Regulation [6]. Also, doses in excess of the dose limits for the public from planned exposures are not expected for frequent flyers making weekly flights at any domestic route within Brazil.

Total collective dose to aircrew members was estimated to be about 11.2 manSv/y. Considering the occupational limit of 850 h of flight per year for crewmembers and numbers of flights for each route, average occupational dose would be about 0.76 mSv/y.

Considering both the maximum number of flights per route per year and the legal limit of 850 flight hours for any crewmember [7,8], about 15% of the flights may lead to individual doses for crewmembers above the annual limit for members of the public, considering that a single group is working on each flight. However, maximum individual dose to a crewmember, considering actual regulations on minimum weekly rest period [8], would be lower than 2mSv/y.

Table 1. Summary of results for public exposure on domestic commercial flights according to the state of origin of the flights.

State	Region	Flights/year	Passengers/year	Collective dose (manSv/a)	Average dose (µSv/flight)
DF	CO	80,080	12,091,456	45.50	3.76
GO	CO	18,356	2,130,856	5.20	2.44
MS	CO	10,764	1,337,492	3.63	2.71
MT	CO	21,060	2,205,632	6.25	2.83
AC	N	3,016	394,368	1.51	3.83
AM	N	17,784	2,437,916	11.75	4.82
AP	N	2,132	341,224	0.38	1.11
PA	N	27,664	3,422,484	10.63	3.11
RO	N	8,684	972,712	3.10	3.19
RR	N	1,456	237,328	0.51	2.14
TO	N	5,096	478,452	1.15	2.41
AL	NE	5,565	872,185	4.21	4.83
BA	NE	53,872	7,809,672	28.09	3.60
CE	NE	23,504	3,673,748	16.21	4.41
MA	NE	11,336	1,728,688	6.15	3.56
PB	NE	6,032	959,192	5.32	5.54
PE	NE	32,448	4,919,356	22.37	4.55
PI	NE	2,758	916,240	3.30	3.60
RN	NE	11,180	1,819,220	8.10	4.45
SE	NE	7,852	1,046,344	3.44	3.29
PR	S	54,860	7,423,000	16.69	2.25
RS	S	43,004	5,812,924	19.03	3.27
SC	S	30,992	4,113,668	8.95	2.18
ES	SE	19,084	2,428,660	5.62	2.32
MG	SE	80,497	9,373,561	23.64	2.52
RJ	SE	114,296	16,877,900	51.23	3.04
SP	SE	236,496	33,209,540	108.52	3.27

CO: Central-west; N: North; NE: Northeast; S: South; SE: Southeast.

4. CONCLUSIONS

Individual doses in domestic commercial flights in Brazil in 2011 would be in the range of 0.3 – 8.8 µSv per flight, depending on the route and the type of airplane. Most usual flights would have average doses of 1.8 µSv, for the Rio de Janeiro – São Paulo route, and about 3.3µSv for the São Paulo – Brasília route.

Doses in excess of the present limit to members of the public can be received by some frequent flyers and crewmembers (less than 15% of the flights). All predicted individual doses, under very conservative approaches, would be however, well below intervention levels.

Collective doses due to domestic commercial flights in Brazil would be about 214 manSv/y and 11 manSv/y for passengers and crew, respectively.

5. REFERENCES

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