

# IN-FLIGHT EXPOSURE TO COSMIC RADIATION ALONG SOME COMMERCIAL AIRLINE ROUTES TO AND FROM NIGERIA

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## ABSTRACT

The study of "external" radiation called cosmic radiation that strikes the earth from anywhere beyond the atmosphere is of great importance in radiation protection. All human beings are exposed to an uncontrollable amount of cosmic radiation on the ground level. Those who travel in space, airline crews and frequent flyers are exposed to additional level of cosmic radiation during their trip but unfortunately many of them are not aware of this. This work calculates the exposure of aircrews and frequent flyers to cosmic radiation during travel along some air routes to and from Nigeria. The effective dose was computed using a dedicated software CARL 6M, developed by US FAA. The study focuses on the significance of the in-flight exposure, assessment and estimation of in-flight exposure using the dedicated software and some ways of controlling the exposures so that airline crews and frequent flyers are not exposed to fatal levels of radiation. It was observed that the cosmic radiation doses received by passengers and crew members on board on flights from Lagos Nigeria to countries in America were more than what they received en-route countries in Asia.

**Keywords:** Cosmic Radiation, Radiation Protection, Exposure, Effective Dose.

## INTRODUCTION

Cosmic rays are very high energetic charged particles that constantly bombard the earth from outer space at speeds approaching that of light. Some of these particles originate from the Sun, but most come from sources outside the solar system and are known as galactic cosmic rays (GCRs). Cosmic-ray particles that arrive at the top of the Earth's atmosphere are termed primaries; their collisions with atmospheric nuclei give rise to showers of secondary particles that penetrate the earth's atmosphere and sometimes even the earth's surface. The radiation hazard outside the Earth's magnetic field is

mainly due to protons and energetic, highly charged nuclei (HZE particles). Protons are produced as part of solar particle events (SPE) and are also the most abundant of galactic cosmic rays (GCR). Thus these galactic cosmic rays (GCRs) consist of high energy protons (85%), helium (14%) and other high energy nuclei HZE ions (Schimmerling, 2011). The remainders are electrons and nuclei of heavier atoms. Unlike x-rays or gamma rays, which are highly energetic forms of light, cosmic rays are actually particles of normal matter i.e. rather than being an actual ray, cosmic ray is just a singular particle – an atom that was stripped of its electrons when

accelerated to enormous speeds. Recent discoveries have shown that cosmic rays originate from supernova-the death explosion of massive stars (NASA, 2012). Exposure to this form of radiation isn't much of an issue on the surface of the earth because the earth's atmosphere serves as a protective layer. But when traveling at high altitudes, there is less of that protective layer above humans and one gets exposed to higher levels of this radiation.

In 1990, the International Commission on Radiological Protection (ICRP) recommended that aircrew members be classified as occupationally exposed. They also recommended a reduction in the occupational exposure (i.e. from 50 to 20 mSv.y<sup>-1</sup> averaged over 5 years, with not more than 50mSv in a single year) as well as a reduction in the general population exposure (i.e. from 5 to 1 mSv.y<sup>-1</sup>) (ICRP, 1991). Around the world, there is some disagreement over which limit is "the right one" or "the safe one", but the principle of "ALARA" (As Low As Reasonably Achievable) is well accepted. In keeping with currently accepted practices and standards all unnecessary radiation exposures shall be considered undesirable. All radiation exposure shall be limited to As Low As Reasonably Achievable - (ALARA).

Quantifying the levels of atmospheric ionizing radiation is of particular interest to the aviation industry since it is the primary source of human exposure to high-linear energy transfer (LET) radiation. High-LET radiation is effective at directly breaking DNA strands in biological tissue, or producing chemically active radicals in tissue that alter the cell function, both of which can lead to cancer or other adverse health effects (Wilson et al., 2003; Wilson et al.,

2005). Studies of exposure of these flight attendants have suggested adverse reproductive health outcomes (Aspholm et al., 1999; Lauria et al., 2006; Waters et al., 2000). ICRP classifies crews of commercial aircraft as radiation workers (Bartlett, 1997). The US National Council on Radiation Protection and Measurements (NCRP) reported that among radiation workers monitored with recordable dose, the largest average effective dose in 2006 (3.07 mSv) was found in flight crew. In contrast, the average for the workers with the second largest effective dose, commercial nuclear power workers, was 1.87 mSv (NCRP, 2009). However, aircrews are the only occupational group exposed to unquantifiable and undocumented levels of radiation.

There is an important national need to understand and to predict the real-time radiation levels for the commercial aviation industry and the flying public. These will have broad societal, public health, and economic benefits.

## MATERIALS AND METHOD

An important part of this work was the collection of information, particularly the statistics on aircraft movements, flight plan data and airport location data. These data were collected from Nigerian Airspace Management Agency (NAMA) at Murtala Muhammed International Airport, Ikeja, Lagos, Nigeria. Twenty international flights travelling to different parts of the World from Murtala Muhammed International Airport (MMIA) were selected. The selected flights cover flights travelling to Europe, America, Asia, and Africa. These twenty selected flights took place both in June, 2012 and December, 2011. This enables comparison between the levels of cosmic radiation exposures received by passengers and crew

members in rainy season(June, 2012) and those received in harmattan season (December, 2011).

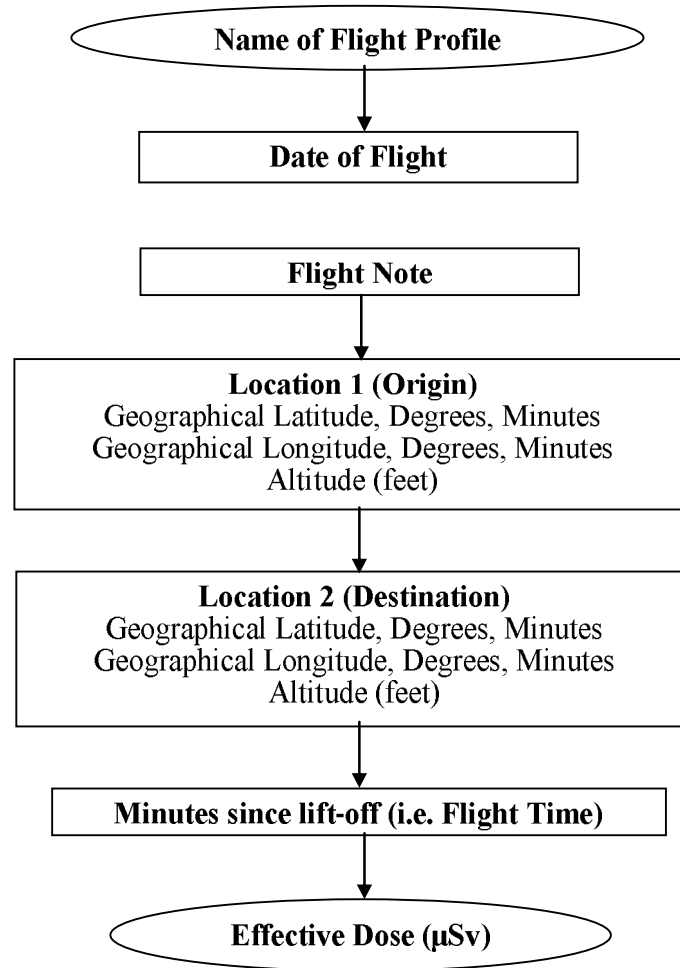
### ***CARI 6M***

The CARI 6M (Civil Aero medical Research Institute) was developed by the United States Federal Aviation Authority(FAA) (O'Brien, 1978). CARI 6M is a more sophisticated version of CARI 6M available since December, 2001 which allows the user to store and process multiple flight profiles and to calculate dose rates at user specified locations in the atmosphere. It estimates the effective dose (in  $\mu\text{Sv}$ ) received by an individual on an aircraft flying in a user-specified route. The estimates are specific to a given month of travel because the program takes into account the impact of solar activity on the level of cosmic radiation. With CARI 6M, the user enters a route consisting of waypoints (geographic coordinates and altitudes) and the program assumes the shortest route between each successive pair of waypoints. CARI 6M calcu-

lates the radiation dose received during any change in altitude.CARI 6M is available for download (free) from the FAA website. Records are taken and calculations are done according to the chart given in Figure 1 developed by Salah El Din et al(2010).

### ***Airport Coordinates and Elevation***

Table 1 gives the list of airport locations with their respective coordinates and elevation. International Civil Aviation Organization (ICAO) is an international body that promotes understanding and security through cooperative aviation regulation. Every airport in the world is being monitored, controlled and regulated by ICAO and each of these airports has a standard ICAO code used by ICAO to identify them. Apart from the ICAO code, we have the geographical latitude (degree and minutes) of the airport under review and following this is the geographical longitude (degree and minutes) of the airport under review. Then the altitude in feet, which is the height above sea level, of the individual airport is stated.



**Figure 1: Schematic Diagram for calculating Flight Radiation Dose using CARI 6M (Adapted from Sallah El Din et al (2010))**

**Table 1: Origin and destination Airports' coordinates and elevations (FAAN, 2012)**

<b>Origin</b>					
S/N	Airport Location	ICAO Code	Latitude	Longitude	Altitude (feet)
1	Ikeja Lagos Nigeria	DNMM	North 6o 34.50I	East 3o 19.30I	135
<b>Destination</b>					
S/N	Airport Location	ICAO Code	Latitude	Longitude	Altitude (feet)
1	Heathrow London UK	EGLL	North 51o 28.30I	West 0o 27.20I	80
2	Paris France	LFPG	North 49o 0.00I	East 2o 32.00I	387
3	Libreville Gabon	FOOL	North 0o 27.50I	East 9o 24.90I	39
4	Johannesburg SA	FAJS	South 26o 8.30I	East 28o 14.80I	5558
5	New York USA	KJFK	North 40o 38.38I	West 73o 46.73I	13
6	Luanda Angola	FNLU	South 8o 51.70I	East 13o 13.90I	243
7	Brussels Belgium	EBBR	North 50o 54.10I	East 4o 29.90I	184
8	Dubai UAE	OMDB	North 25o 15.10I	East 55o 21.90I	34
9	Doha Qatar	OTBD	North 25o 15.50I	East 51o 33.90I	35
10	Beirut Lebanon	OLBA	North 33o 48.70I	East 35o 29.40I	87
11	Kigali Rwanda	HRYP	South 1o 58.10I	East 30o 8.30I	4891
12	Atlanta GA USA	KATL	North 33o 38.42I	West 84o 25.62I	1026
13	Houston TX USA	KIAH	North 29o 58.83I	West 95o 20.38I	98
14	Istanbul Turkey	LTBA	North 40o 58.50I	East 28o 48.90I	157
15	Frankfurt Germany	EDDF	North 50o 1.90I	East 8o 34.20I	364
16	Amsterdam Holland	EHAM	North 52o 18.50I	East 4o 45.80I	0
17	CiudadDelEste Paraguay	SGES	South 25o 27.20I	West 54o 51.60I	846
18	Entebbe Uganda	HEUN	North 0o 2.50I	East 32o 26.30I	3782
19	Campinas Brazil	SBKP	North 28o 25.72I	West 81o 18.97I	96
20	Riyadh Saudi Arabia	OERK	South 23o 0.30I	West 47o 8.30I	2170

## RESULTS AND DISCUSSION

Tables 2 to 5 show the Aircraft Name, Aircraft Type, Date, ATD (Actual Time of Departure), Flight Route, Flight Time, and the effective dose calculated. Based on the airport coordinates with elevation above and the given data below, the effective dose was calculated using a computer program code CARI 6M using the chart in Fig. 1. CARI 6M calculates the effective dose (in  $\mu\text{Sv}$ ) using the date of the flight; origin airport coordinate and elevation; destination airport coordinate and elevation; and the time since lift-up (i.e. flight time). When all these information are processed, the result for each flight profile is displayed on the screen and these results are separated for each continent i.e. for America, Asia, Europe or Africa.

The results obtained give estimates of the effective dose received by twenty commercial airlines that travelled along international routes to countries in America, Asia, Europe and Africa, from Murtala Muhammed International Airport, Ikeja, Lagos Nigeria

in June, 2012 (Rainy) and December, 2011 (Harmattan).

With distinct clarification, it is observed from Figure 2 that the cosmic radiation dose received by passengers and crew members on board on flights from MMIA, Ikeja Lagos Nigeria to countries in America were more than those received by passengers and crew members travelling to countries in Asia. The only reason for this is the East-West Effect.

An established fact is that cosmic radiation is more at the poles than at the equator and considering the bars for Africa in Figure 2, there are five countries which include: South Africa (Latitude  $26^{\circ} 8.30'$  South), Angola ( $8^{\circ} 51.70'$  South), Rwanda ( $1^{\circ} 58.10'$  South), Gabon ( $0^{\circ} 27.50'$  North) and Uganda ( $0^{\circ} 2.50'$  North). Gabon and Uganda lie on the equator while South Africa lies at the poles, the charts illustrated in Figure 2 distinctively show that the cosmic radiation for South Africa ( $0.283\mu\text{Sv}$ ;  $0.285\mu\text{Sv}$ ) is higher than that for Gabon ( $0.049\mu\text{Sv}$ ;  $0.049\mu\text{Sv}$ ) and Uganda ( $0.165$ ;  $0.166$ ).

**Table 2: Computed effective dose received by passengers and crew members on flights to America from MMIA in June 2012**

S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu\text{Sv}$ )
1	ARA107	A345	01/06/12	15:19	Lagos Nigeria – New York USA	660	0.383
2	DAL55	A332	01/06/12	21:42	Lagos Nigeria – Atlanta GA USA	731	0.450
3	UAL143	B777	01/06/12	22:17	Lagos Nigeria – Houston TX USA	811	0.474
4	GTI8616	B744	06/06/12	19:48	Lagos Nigeria – Ciudad Del Este Paraguay	568	0.311
5	GTI5443	B744	08/06/12	02:26	Lagos Nigeria – Campinas Brazil	506	0.297

**Table 3: Computed effective dose received by passengers and crew members on flights to Asia from MMIA in June 2012**

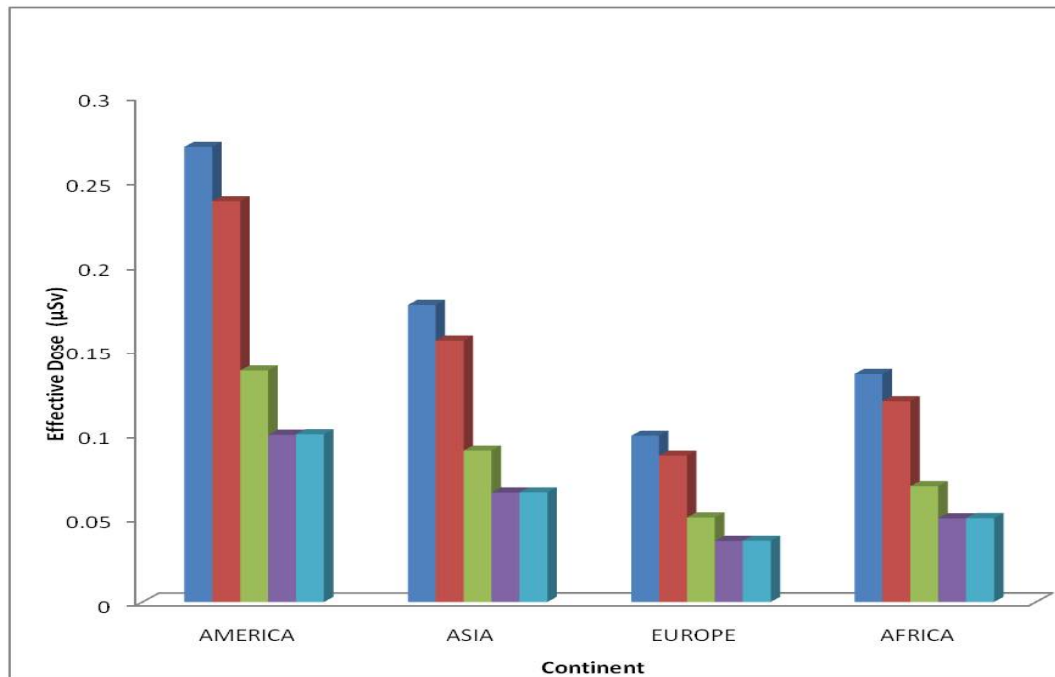
S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu$ Sv)
1	UAE784	B773	01/06/12	14:24	Lagos Nigeria – Dubai UAE	470	0.227
2	QTR593	A333	01/06/12	14:20	Lagos Nigeria – Doha Qatar	442	0.214
3	THY626	B739	02/06/12	22:09	Lagos Nigeria – Istanbul Turkey	371	0.198
4	SVA976	B744	03/06/12	22:06	Lagos Nigeria – Riyadh Saudi Arabia	406	0.221
5	MEA572	A332	06/06/12	15:03	Lagos Nigeria – Beirut Lebanon	364	0.185

**Table 4: Computed effective dose received by passengers and crew members on flights to Europe from MMIA in June, 2012**

S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu$ Sv)
1	VIR652W	A346	01/06/12	09:47	Lagos Nigeria – Heathrow London UK	375	0.211
2	DHK082	B763	01/06/12	14:48	Lagos Nigeria – Brussels Belgium	396	0.224
3	KLM588	A332	01/06/12	21:01	Lagos Nigeria – Amsterdam Netherlands	408	0.230
4	DLH565	EA33	01/06/12	22:09	Lagos Nigeria – Frankfurt Germany	391	0.222
5	LMJ619	DA90	06/06/12	19:00	Lagos Nigeria – Paris France	381	0.215

**Table 5: Computed effective dose received by passengers and crew members on flights to Africa from MMIA in June 2012**

S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu\text{Sv}$ )
1	SAA061	A346	01/06/12	21:27	Lagos Nigeria – Johannesburg SA	366	0.283
2	ARA116	CRJ9	02/06/12	01:43	Lagos Nigeria – Luanda Angola	181	0.091
3	RWD314	B738	02/06/12	13:54	Lagos Nigeria – Kigali Rwanda	263	0.171
4	SKK040	B737	02/06/12	16:09	Lagos Nigeria – Libreville Gabon	101	0.049
5	ETH3910	B752	03/06/12	12:47	Lagos Nigeria – Entebbe Uganda	277	0.165

**Figure 2: Comparison of dose received by passengers and crewmembers on flights from the different Continents**



**Table 6: Computed effective dose received by passengers & crew members on flights to America from MMIA in December 2011**

S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu$ Sv)
1	ARA107	A345	02/12/11	17:11	Lagos Nigeria – New York USA	660	0.387
2	DAL55	A332	01/12/11	21:49	Lagos Nigeria – Atlanta GA USA	731	0.455
3	CO143	B777	01/12/11	22:24	Lagos Nigeria – Houston TX USA	811	0.479
4	ACX3527	B744	27/12/11	23:00	Lagos Nigeria – Ciudad Del Este Paraguay	568	0.313
5	UAE4930	B744	01/12/11	03:08	Lagos Nigeria – Campinas Brazil	506	0.299

**Table 7: Computed effective dose received by passengers and crew members on flights to Asia from MMIA in December, 2011**

S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu$ Sv)
1	UAE784	B773	01/12/11	14:59	Lagos Nigeria – Dubai UAE	470	0.229
2	QTR593	A333	01/12/11	14:13	Lagos Nigeria – Doha Qatar	442	0.216
3	THY624	A333	01/12/11	01:19	Lagos Nigeria – Istanbul Turkey	371	0.200
4	SVA976	B744	02/12/11	17:04	Lagos Nigeria – Riyadh Saudi Arabia	406	0.223
5	MEA572	A332	05/12/11	15:00	Lagos Nigeria – Beirut Lebanon	364	0.187

**Table 8: Computed effective dose received by passengers and crew members on flights to Europe from MMIA in December 2011**

S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu$ Sv)
1	VIR652W	A346	01/12/11	10:44	Lagos Nigeria – Heathrow London UK	375	0.214
2	DHK082	B763	01/12/11	14:31	Lagos Nigeria – Brussels Belgium	396	0.226
3	KLM588	A332	01/12/11	22:45	Lagos Nigeria – Amsterdam Netherlands	408	0.232
4	DLH565	EA33	05/12/11	22:14	Lagos Nigeria – Frankfurt Germany	391	0.224
5	AFR3051	B773	01/12/11	22:58	Lagos Nigeria – Paris France	381	0.217

**Table 9: Computed effective dose received by passengers and crew members on flights to Africa from MMIA in December 2011**

S/N	ARC NAME	ARC TYPE	DATE	ATD	FLIGHT ROUTE	FLIGHT TIME (mins)	EFFECTIVE DOSE ( $\mu$ Sv)
1	ARA103	B738	01/12/11	22:00	Lagos Nigeria – Johannesburg SA	366	0.285
2	ADB2710	AN124	01/12/11	12:13	Lagos Nigeria – Luanda Angola	181	0.091
3	RWD313	B738	02/12/11	16:49	Lagos Nigeria – Kigali Rwanda	263	0.172
4	DHV130	B722	01/12/11	16:14	Lagos Nigeria – Libreville Gabon	101	0.049
5	ETH3910	B752	15/12/11	12:59	Lagos Nigeria – Entebbe Uganda	277	0.166

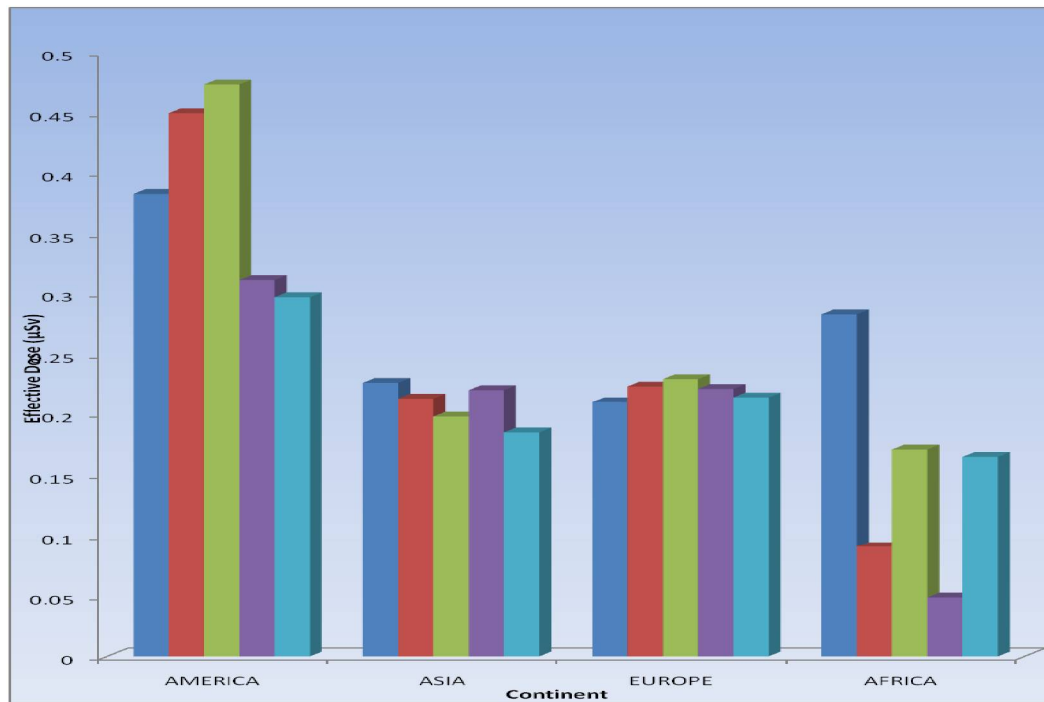


Figure 3: Pictorial summary of Tables 6 – 9

## CONCLUSION AND RECOMMENDATION

This work has shown the direct relationship between time of flight and effective dose. The more time spent in the air, the more exposed an individual becomes. It is observed that flights from MMIA to places in America spend more time in the air (about 11 hours) than flights to other places in Asia, Europe or Africa. This is why exposures on these routes are more than those of other routes. Also, it was discovered that travelling to west makes one more exposed to cosmic radiation (East-West Effect). This is established with more radiation on flights travelling to America than flights travelling to Asia. Another fact also established from this work was that cosmic radiation dose was more at the poles than at the equator

and this is clearly shown with the figures obtained for South Africa, Gabon and Uganda.

Doses received by aircrew members on annual basis can be monitored with the aid of CARI 6M. To achieve this, there must be adequate records of employee work schedules. Work schedules and flight routes must be planned to ensure that a worker's annual effective dose does not exceed 6 mSv (Aspholm et al., 1999). The flight schedule of a pregnant woman must be organized so that the equivalent dose received by the fetus will be as low as reasonably achievable. The equivalent dose during the remainder of the pregnancy must not exceed 1 mSv. If the effective dose received by the woman is less than 1 mSv, then the equivalent dose received by the fetus will be assumed to be less than 1 mSv. To achieve this, the worker

must notify the responsible party of her pregnancy immediately the pregnancy is verified.

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