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Cosmic Ionizing Radiation Exposures on Aircraft and Its Impact Depending on Some Definite Selected Paths

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Abstract
The assessment of the exposure to cosmic radiation onboard aircraft is one of the preoccupations of bodies responsible for radiation protection. Cosmic particle flux is significantly higher onboard aircraft than at ground level and its intensity depends on the solar activity. The dose is usually estimated using codes validated by the experimental data. In this paper, a comparison of the radiation dose on 30 one-way flights between Kuwait and Egypt was organized. A survey meter IMI Inspector Alert model (IA-V2) Geiger Counter, as well as personal dosimeter detectors [(EPD) and (RAD-60S / RADOS)], were used in this work. Good agreement was observed for instruments determining the different components of the radiation field; the mean ambient dose equivalent for the one-way flying was 8.4 µSv and Absorbed Dose rate was 3.6 µSv/hr. The agreement of values obtained for the total dose obtained by measurements and by calculations is very satisfying.

Keywords: Cosmic Rays, Electronic Personal dosimeter, Passengers, Aircraft crew, Hazards, Equivalent Dose Rates, Commercial Aviation, Radiation Protection, Ionizing radiation, Human Risks, Air Travel, Radiation Exposure

1. Introduction

You would possibly guess that a common traveler’s radiation dose is coming from the airport security checkpoints, with their body scanners and baggage x-ray machines, however you’d be wrong. The radiation doses to passengers from those protection approaches are slight.

The flight itself is the primary source of radiation exposure from air travel. This is because the air becomes thinner at higher altitudes. The number of molecules of gas per volume of space decreases as one moves away from the Earth's surface. Thinner air means fewer molecules to block cosmic rays, or radiation from space. With less atmospheric shielding, there is more exposure to radiation.

Ionizing radiation, which includes x-rays, gamma rays, and ultraviolet waves, is characterized by high frequencies and energies strong enough to knock electrons out of their atoms [1].

When ionizing radiation interacts with the human body, it can disrupt the molecular architecture of human cells and tissues, resulting in life-threatening illnesses. Avionics and communication devices on aircraft may potentially be compromised [2].

1.1 Radiation's Influence on Altitude and Latitude

The great majority of radiation sources on the Earth's surface are non-ionizing, and even ionizing sources generate very little non-hazardous radiation Crew and passengers who fly at cruising altitudes above 30,000 feet, on the other hand, are exposed to solar radiation and galactic or cosmic radiation, both of which are kinds of ionizing radiation. At 35,000 feet above sea level, the radiation level could be up to ten times higher than at sea level [3].

The magnetospheric shielding of the Earth, which shields against solar radiation, is strongest at the equator and declines with rising latitude until becoming feeble at the poles; thus, radiation impacts worsen with increasing latitude.

Because of these consequences, the United Nations assessed in

2000 that working in an airline exposed people to more radiation than working in a nuclear power plant. Radiation exposure threatens not only passengers and crew members, but also aircraft systems and other equipment when flying at high altitudes [4].

1.2 Human Risks
Ionizing radiation exposure causes cancer and reproductive difficulties, including miscarriages. It can also result in genetic abnormalities and ocular problems such as cataracts.

Cancer is predicted to kill 200 persons per 1,000 in the United States alone, but for airline crew members, radiation exposure from 20 years of high-altitude flying boosts the risk to 225 per 1,000 according to the World Health Organization's (WHO) International Agency for Research on Cancer (IARC) [5].

1.3 Passengers and Flight Crew
The International Commission on Radiological Protection (ICRP) is the primary body in charge of radiation protection and recommends an individual's effective dose limit of 20 mSv per year, averaged over defined 5-year periods (100 mSv in 5 years), with the additional restriction that the effective dose not exceed 50 mSv in any single year.

Furthermore, pregnant crew members should get 1 mSv from the time of pregnancy discovery until birth, with a monthly limit of 0.5 mSv. For the general public (passengers), the annual limit is 1 mSv [6].

Pregnant passengers and Flight Crew members might consider trip-trading or delaying a flight to reduce their risk of miscarriage. Miscarriage risk increases when women are exposed to cosmic radiation of at least 0.36 mSv during the first trimester, according to a National Institute for Occupational Safety and Health (NIOSH) study [7].

Furthermore, the Personnel Licensing Regulation Part 138 requires pregnant pilots and cabin crew to be evaluated and barred from flying duties between the time of pregnancy discovery and the end of the 12th week of gestation, as well as between the end of the 26th week of gestation and delivery, to protect them from the effects of radiation exposure and other effects [8].

1.4 Airlines and Aircrafts
After receiving a solar radiation alerts, airlines adopt a route and altitude that lowers radiation exposure for moderate, intense, and severe transient solar radiation occurrences (20 µSv/hr and above).

A solar radiation alert is broadcast worldwide and is accompanied by a message containing radiation level estimations at altitudes ranging from 20,000ft to 80,000ft at specified latitudes [9].

In addition, using a downloadable computer program called CARI-6 or CARI-6M developed at the FAA's Civil Aerospace Medical Institute; an individual can determine the effective dosage of ionizing radiation received in each flight.

According to ICAO Annex 6, Provision 6.12, all aircraft built to fly over 15,000m (49,000ft) must carry technology that can monitor and continuously display the dosage rate of all cosmic radiation received as well as the cumulative dose for each trip.

The operator is required by ICAO Annex 6 regulation 4.2.11.5 to maintain track of all flights exceeding 15,000 meters (49,000 feet) in order to compute the cumulative cosmic radiation dosage received by each crew member over a 12-month period [10, 11].

1.5 Amount of Radiation Can I Get From Flying
The amount dose of radiation you receive when flying is modest, but it varies on a few factors.
These quantities of radiation are insignificant and unlikely to harm human health.

- **The Flight's Duration**

The longer you remain in the air, the more radiation you will receive.

- **Altitude**

The higher the altitude, the greater the exposure of radiation. This is due to the atmosphere's lower ability to screen cosmic radiation at higher altitudes.

- **Latitude**

The farther north or south you are from the Equator, the more radiation you will receive. The Earth's magnetic field deflects some cosmic radiation away from the equator and toward the North and South poles.

Whether you fly or not, the average dose from cosmic radiation is 0.33 mSv (33 mrem), or 11% of our total yearly radiation exposure from all natural sources [12].

2. Experimental Part and Results
The radiation dose on 30 flights between Kuwait and Egypt was recorded and as shown in the map of Fig. (2). In this study, the authors used a digital Survey meter and personal dosimeter with high sensitivity and accuracy [survey meter IMI

Inspector Alert model (IA-V2) Geiger counter, as well as personal dosimeter detectors (EPD) and (RAD-60S / RADOS)] to determine the actual radiation dose throughout the entire flight from the time of take-off to landing.

Most flights between Egypt and Kuwait were organized at an altitude of approximately 36,000 feet, with short-haul flights of up to 3 hours in duration at different times of the year. Example of calculation of dose from cosmic radiation used by computer codes as shown in Fig. (1). The Doses and flights information were recorded as shown in Table (1).

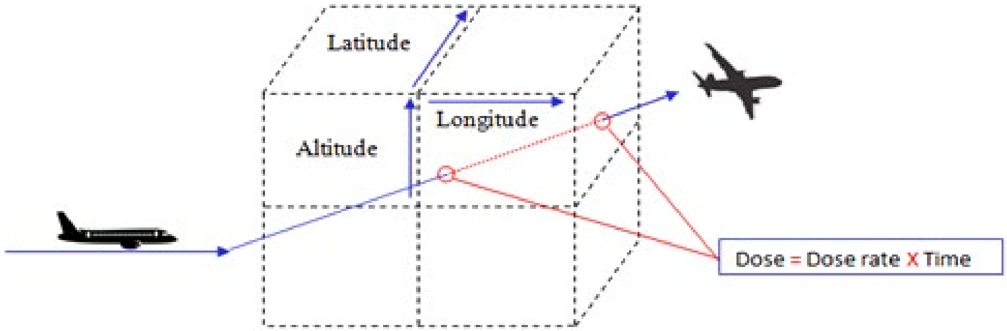

Figure 1: Computer Code Estimation of Exposure from Cosmic Radiation [13].

Flight Details		Flight Duration	Dose (μSv)	Absorbed Dose Rate (μSv/hr)
From	To			
Cairo (CAI), Egypt	Kuwait (KWI), Kuwait	2:30	8.101	3.522
Assiut (ATZ), Egypt	Kuwait (KWI), Kuwait	2:40	8.750	3.646
Kuwait (KWI), Kuwait	Cairo (CAI), Egypt	2:30	8.301	3.609
Kuwait (KWI), Kuwait	Cairo (CAI), Egypt	2:30	7.887	3.429
Sphinx (SPX), Cairo, Egypt	Kuwait (KWI), Kuwait	2:40	8.700	3.625
Kuwait (KWI), Kuwait	Alexandria (HBE), Egypt	2:50	9.228	3.691
Sharm elSheikh (SSH), Egypt	Kuwait (KWI), Kuwait	2:25	7.832	3.481
Kuwait (KWI), Kuwait	Cairo (CAI), Egypt	2:30	8.163	3.549
Assiut (ATZ), Egypt	Kuwait (KWI), Kuwait	2:40	8.750	3.646
Cairo (CAI), Egypt	Kuwait (KWI), Kuwait	2:30	8.121	3.531
Sphinx (SPX), Cairo, Egypt	Kuwait (KWI), Kuwait	2:40	8.839	3.683
Kuwait (KWI), Kuwait	Alexandria (HBE), Egypt	2:50	9.380	3.752
Kuwait (KWI), Kuwait	Cairo (CAI), Egypt	2:30	7.974	3.467
Cairo (CAI), Egypt	Kuwait (KWI), Kuwait	2:30	8.018	3.486
Luxor (LXR), Egypt	Kuwait (KWI), Kuwait	2:25	7.783	3.459
Kuwait (KWI), Kuwait	Cairo (CAI), Egypt	2:30	8.059	3.504
Kuwait (KWI), Kuwait	Sharm elSheikh (SSH), Egypt	2:25	7.810	3.471
Cairo (CAI), Egypt	Kuwait (KWI), Kuwait	2:30	8.202	3.566
Assiut (ATZ), Egypt	Kuwait (KWI), Kuwait	2:40	8.762	3.651
Kuwait (KWI), Kuwait	Assiut (ATZ), Egypt	2:40	9.221	3.842
Kuwait (KWI), Kuwait	Luxor (LXR), Egypt	2:25	7.880	3.502
Cairo (CAI), Egypt	Kuwait (KWI), Kuwait	2:30	7.659	3.33
Kuwait (KWI), Kuwait	Sphinx (SPX), Cairo, Egypt	2:40	8.801	3.667
Cairo (CAI), Egypt	Kuwait (KWI), Kuwait	2:30	7.887	3.429
Kuwait (KWI), Kuwait	Cairo (CAI), Egypt	2:30	7.930	3.448
Assiut (ATZ), Egypt	Kuwait (KWI), Kuwait	2:40	8.808	3.67
Cairo (CAI), Egypt	Kuwait (KWI), Kuwait	2:30	7.953	3.458
Alexandria (HBE), Egypt	Kuwait (KWI), Kuwait	2:50	9.285	3.714
Kuwait (KWI), Kuwait	Cairo (CAI), Egypt	2:30	7.956	3.459

Kuwait (KWI), Kuwait	Alexandria (HBE), Egypt	2:50	9.343	3.737

Table 1: The Ionizing Radiation Absorbed Dose Rate Received By Passengers and Aircrew During Direct Airplane Travel.

Figure 2: A Map Depicting Flights Between Kuwait and Egypt, As Well As Airport Locations In Both Countries.

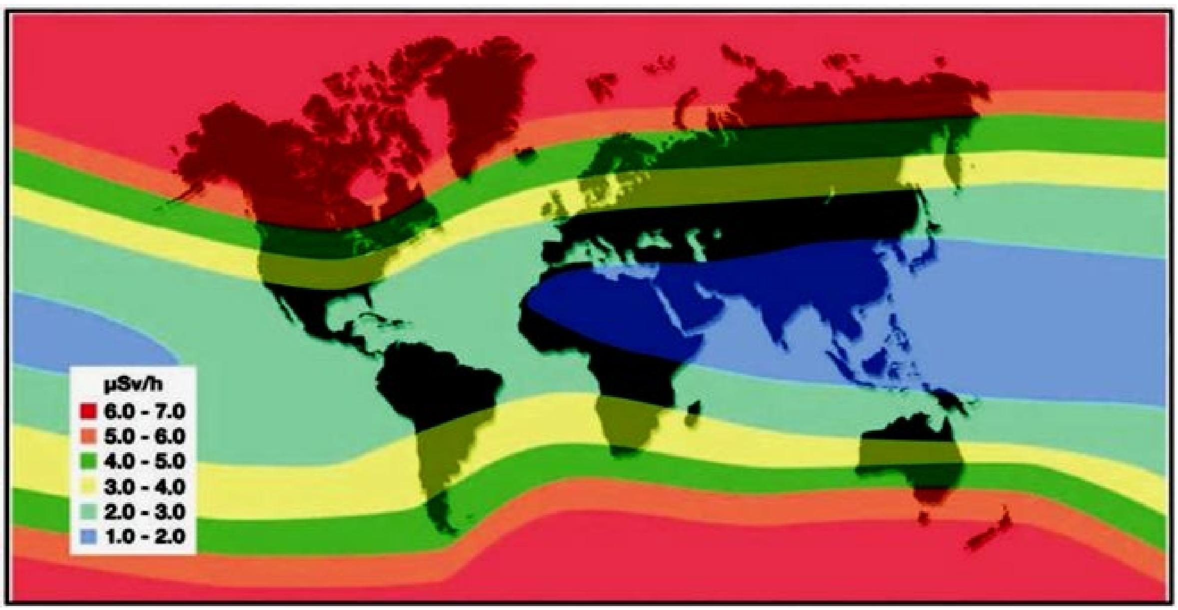

Figure 3: Ambient Dose Rate by Latitude and Longitude at an Altitude of 11 km in December 2002 [13, 14].

3. Discussion and Conclusion

Aircrew and frequent flyers receive higher radiation doses from cosmic radiation than the general public. Astronauts receive even higher radiation doses. Depending on the altitude reached and time spent there.

From the results in table (1), we conclude the following:

The mean ambient dose equivalent for the one-way flying was 8.4 µSv and Absorbed Dose rate was 3.6 µSv/hr. The agreement of values obtained for the total dose is very satisfying, and very similar to its global counterpart in the field of cosmic radiation exposure in short-haul flights.

Taking into account the preventive safety measures for passengers and aircrew, we should clarify that:

1- The extent of additional radiation exposure on a flight depends primarily on duration, altitude, route of the flight and the solar activity.

2- For people who fly only occasionally, as most holiday travelers do, the additional radiation exposure from flying is very low and has no adverse health effects; this applies also to pregnant women and infants.

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