COSMIC RADIATION – A LEGAL AND MEDICAL ISSUE IN AVIATION

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Abstract: Research into the effects of different effects of radiation on human health has only recently been brought to light while the events in Hiroshima and Nagasaki have revived the interest in the research into the effects of ionizing radiation on organisms. The man has to live with radiation regardless of the risk. Protection efficiency is related with proper understanding of dangers coming from radiation and radiological contamination and protection methods. Knowledge in radiation protection is an important tool in the battle for survival on our planet. Our public today still seems insufficiently informed when it comes to hazards brought about by natural sources of radiation. Based on the published results it seems that the cosmic radiation hazard to passengers in contemporary air transport is nonexistent. Nevertheless, for some air crew categories (frequent intercontinental flights) it is possible that annual absorbed doses are quite close to the doses absorbed by workers handling radiation sources, even the possibility of exceeding the prescribed levels is not inconceivable.

Keywords: radiation, air transport, danger, air crew, protection.

1. Introduction

The discovery of the nucleus almost 100 years ago changed the world, and in the spring of 1911 Ernest Rutherford announced to the Royal Society that he had discovered the nucleus as a result of interpretation of the experiment performed by Geiger and Marsden (who had under his direction experimented with alpha particles passing through gold foil for years). The nuclear age in the history of mankind is thought to have begun then even though ever since 1910 Emile Laude, the Belgian jurist, has talked about "the new law, the outer space law".

Dr Vladimir Mandl, the Czech jurist penned the book "Space law" in 1932 examining the outer space issues. Space law encompasses legal norms regulating legal relations of people and space aircraft in outer space (outer space law, droit supra-atmospherique, Weltraumrecht, межпланетное право). In the atmosphere ionization occurs under the influence of radioactive, cosmic radiation. Ionizing radiation is known to be electromagnetic or particle radiation which can ionize matter and cause damage to the cells of living organisms. The Earth's magnetic field shields the people on Earth from the most dangerous cosmic radiation. Nevertheless, natural radiation man adjusts to over the years has become 50 times greater over the last 60 years.

The issue of exposure to cosmic radiation during high altitude flights is one of the

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problems which coincided with the cosmic technology and aviation development. In 1961 Foelshea from Langley Research Center carried out the first study which tackled this issue and which was subsequently completed. In the 60s and 70s a greater number of studies on supersonic transport were conducted from the radiobiological point of view. One of the first ones is the report of Commitee 1 of the ICRP Task Group on the Biological Effects in High-Energy Radiations.

2. Radioactivity and Cosmic Radiation

The phenomenon we call "radioactivity" is a natural phenomenon on our planet. There are many natural radionuclides some of which, the long living ones, have been around since the formation of the planet Earth while others are continually being created. Thus, under the influence of the neutron component of cosmic rays spontaneous reactions occur in the higher layers of the atmosphere with micrometeorites and other air dust creating natural radionuclides: hydrogen H-3, beryllium (Be-7), carbon (C-14), sodium (Na-22), silicon (Si-32), phosphorous (P-32), Ar-39, chromium (Cr-81) and others (Kljajic et al. 1995).

Natural sources of ionizing radiation may include: cosmic radiation, radionuclides from the Earth's crust and radionuclides that are absorbed and kept in the body through inhalation and nutrition. Human exposure may be "external" due to irradiation from the source outside the body or "internal", that is, "inner" due to the disintegration of radionuclides taken into the body, through ingestion or inhalation (Pavlovic and Nikezic, 1995).

Table 1 of the International Atomic Energy Agency shows radiation exposure during every day activities (IAEA Bulletin, 2006).

Table 1

Radiation Exposure During Every Day Activities

Source /Activity	Average dose/year
5-hour flight	30 microsieverts
Construction materials	40 microsieverts
Chest x-ray	80 microsieverts
Cosmic radiation	300 microsieverts
Terrestrial radiation	350 microsieverts
Mammography	1,38 millisieverts
Radon	2,0 millisieverts
Computerized tomography (scanner)	25 millisieverts
Smoking 20 cigarettes a day	53 millisieverts
Cancer treatment	50 sieverts

The terms "cosmic radiation" and "cosmic rays" refer to the primary high-energy particles which originate from outside the Earth and which enter the Earth's atmosphere, and to secondary radiation which stems from their interactions in the atmosphere.

Primary cosmic rays originate from outer space and are generally found at altitudes higher than 25 km, and are usually composed of protons (over 90 %), alpha particles and other nuclei, while secondary cosmic rays are produced by the interaction between primary rays and the Earth's atmosphere and they pervade near the Earth's surface.

Cosmic rays are examined by means of various nuclear radiation detectors which are located on high mountains, in balloons and rockets. Data collected from the Earth's surface and particularly measurements from outside the Earth's atmosphere, for example, the Moon, give an increasing amount of information on cosmic rays and phenomena in our galaxy.

Cosmic radiation may be classified, according to the origin, into: trapped particle radiation, galactic cosmic radiation and solar particle radiation.

Trapped particle radiation is mostly composed of electrons and protons trapped by the Earth's magnetic field in orbit and even though it may pose a radiation risk to astronauts at ground level, it does not contribute to any dose.

Galactic cosmic radiation is mostly composed of protons, with a certain amount of helium and heavier ions, it originates from outside the solar system, and it is the most important element of the exposure on the ground and airplane. When penetrating the atmosphere, high-energy primary particles from the universe interact with nuclei in the air (nitrogen, oxygen, argon) and produce neutrons, protons, muons, pions and kaons and different products of reactions, with H-3, Be-7 and Na-22 being significant from the dosimetric standpoint. The resulting secondary cosmic radiation has enough energy to provoke an entire cascade of events.

Solar cosmic radiation originates from the Sun while low-energy radiation is emitted continually and during geomagnetic storms that happen approximately once in a decade the high-energy component is created. This type of radiation is less significant for the exposure on the ground since it does not have enough energy to penetrate the Earth's magnetic field. Its significance is seen in the modulation of galactic cosmic radiation intensity.

For estimating the dose from exposure to cosmic radiation it is necessary to take into consideration the effects of above mean sea level, geographic latitude and shielding, that is, buildings acting as shields. The Decision on established and withdrawn Serbian standards and related documents (Official Gazette of the Republic of Serbia, 2011/A/) stipulates that for the protection against radiation, inter alia, Serbian Standard SRPS ISO 20785 (en) on dosimetry of exposure to cosmic radiation in civil aviation shall be imposed, with Basic Measuring Principles as Part 1.

Due to the effects of AMSL on the intensity of cosmic radiation, passengers and crew on commercial flights are exposed to higher levels of ionizing radiation. The intensity of the effective dose during commercial flights is about 3 $\mu Sv\ h^{-1}$, and viewed globally, the average annual individual effective dose received from air travel is 2 μSv while in North America this value is 10 μSv.

On commercial passenger flights the protection of passengers> and air crew>s life and health represents the main prerequisite. It is in this regard that the issue of exposure to ionizing radiation is considered and safety analyses are done determining the maximum equivalent doses at the utmost unfavourable combination of other conditions.

The research carried out by the Finnish airline (Finnair) in the period of 1940 to 1992 showed that flight attendants have twice the risk of developing breast cancer compared to an average air passenger. One such analysis was conducted for the "Yugoslav Airlines (JAT)" personnel. Theoretical models were used to estimate the dose of the air crew together with the literature data on the change in cosmic radiation with height, geographic latitude and solar activity. All flights selected pilots – samples took in the course of one year were processed (Antic, 1995).

Towards the end of October 2004 the British airline (British Airways) announced the results of the study revealing that 411 of its pilots had developed melanoma, bowel cancer or lung cancer due to cosmic radiation exposure. Some studies were conducted for airport purposes since airplanes are used to transport radioactive materials and sources

(the reference was made as part of the study of six major airports in the USA, Luszynski et al. 1978).

The Law on Air Traffic (Official Gazette of the Republic of Serbia, 2010) stipulates that work hours of air crew members on scheduled flights and regarding other commercial activities, flight duration, a period of time when a member of air crew is released of all duties, annual leave of air crew members on scheduled flights and concerning other commercial activities and a period of paid leave of air crew for the purpose of maintaining good psycho-physical shape shall closely be set forth by the minister responsible for traffic affairs.

A degree of human exposure to cosmic radiation depends on AMSL (more precisely, on the thickness of the Earth's atmosphere layer above it), geographic latitude and solar activity. As AMSL rises the annual equivalent dose increases approximately exponentially so that the intensity of the equivalent dose at altitudes of air corridors for commercial flights amounts to 1-4 micro Sv/h. The permissible annual dose for persons who are not occupationally exposed to sources of ionizing radiation equals 5 mSv, which means that a pilot (or a crew member) might reach it in case he accumulates several hundred hours of flights at higher altitudes (12-13 km). A sample of 17 pilots was selected, with 4 or 5 pilots classified into four groups and every group matches one of JAT airplanes. The samples were selected randomly from the group of pilots who had flown the usual number of hours the previous year. All pilots had the usual number of flying hours and route structure in the course of the analyzed year (Antic, 1995).

The existing JAT flight plans lay down the condition that pilots on intercontinental routes cannot in the course of one year be exposed to cosmic radiation that would exceed the permissible level for individuals who do not professionally deal with sources of ionizing radiation (5 mSv a year). The estimated doses for flight personnel indicate a low level of passenger exposure to high-level radiation on annual basis since only in exceptional cases of businessmen and diplomats can annual number of flying hours be comparable to the time flight personnel spend in the air. However, it would be interesting to estimate the collective doses for JAT passengers in the next phase of the research and most likely the obtained results would be in agreement with the results of such analyses given in the literature. Annual doses from 1 to 2 mSv represent a quite acceptable range but they are comparable with doses of numerous cases of professional work with ionizing radiation sources making this issue suitable for further consideration. In this regard, there is an array of possibilities of using JAT occupational medicine data from longer intervals of the past. Occupational medicine findings from the Institute of Nuclear Sciences "Vinča" could be transferred to the analysis of data on health surveillance of pilots and crew collected over the course of many years (Antic, 1995).

3. The Role of Legal Framework and the Issue of Cosmic Radiation

Research into the effects of different effects of radiation on human health has only recently been brought to light while the events in Hiroshima and Nagasaki have revived the interest in the research into the effects of ionizing radiation on organisms. Ever since 1956 the dose of 5 rems has been considered to be an acceptable dose of a worker's exposure to radiation. It was an "official dose limit" used by the Nuclear Regulatory Commission and it was considered relatively safe compared

to other industrial risks. Recent studies have shown that an annual dose limit of 1 rem can generally be met in the radiation industry within the ALARP principle ("as low as reasonably practicable"). This is why this limit is widely accepted.

First, the International Commission on Radiological Protection, which has a status of a private organization, provided recommendations in the field of radioactive radiation protection on an international scale only for numerous international organizations to follow suit and contribute to the approximation of protection measures on an international scale by their guidance and recommendations, and to influence the decisions adopted in internal legislation. The approximation of decisions on ionizing radiation protection was attained especially in internal legislation of EU member states and is based on the main Euratom rules.

Since the very beginning the purpose of legal regulation of ionizing radiation protection issues has been to provide the safe operation of nuclear plants and all other activities which presuppose the handling of nuclear materials by humans in the workplace. The guidelines on radiation protection were designed in this respect and laid down by the European Atomic Energy Community (Euratom) on 1 June 1976 for the purpose of attaining nuclear safety, especially the utmost reliability of plants and health protection of workers and population within the impact zone of the plants and the radioactive material usage (Cok, 1982).

The International Commission on Radiological Protection as a specialized United Nations organization laid down the conditions, norms and criteria of radiation protection as well as maximum radiation doses for food, water, air and medications. Some of the measures include priority designation of contaminated areas and decontamination by specialized teams, then, denying access to population to these places or determining the length of stay, banning consumption of contaminated food and water and introducing stringent controls on radioactivity content in foodstuff. Our country accepted these recommendations whereby it introduced regulations concerning the protection of people against radiation. This was our way to protect ourselves against radioactive radiation and minimize the risks as much as possible.

According to regulations concerning the limits of ionizing radiation exposure (Official Gazette of the Federal Republic of Yugoslavia, 1998), the basic natural radiation level /phon/ for a given location shall equal overall ionizing radiation from natural sources in the soil and cosmic radiation up to a level that has not been significantly raised by human activities. Still, man has to live with radiation regardless of the risk. Protection efficiency is related with proper understanding of dangers coming from radiation and radiological contamination and protection methods as well as with impeccable discipline of people working with radioactive substances.

As far back as 2 February 1959 the European Council adopted directives establishing the main safety standards for the protection of workers' and public's health against dangers arising from ionizing radiation only to be amended by Directives 80/836/Euratom and 84/467 Euratom.

Pursuant to Article 24 of Directive 80/836/Euratom, all member states shall ensure that exposed workers receive adequate information on protection against radiation while Article 45 of the same Directive shall provide for each member state to envisage, in case of an accident, emergency levels and

measures taken by competent authorities as well as indispensible personnel resources and equipment for taking actions on maintaining and looking after public health.

Council Directive 89/618/Euratom of 27 November 1989 on notifying the public of health protection measures being implemented and steps taken in case of radiological danger (Council Directive 89/618/Euratom, 27 November 1989/A/) is supposed to define, at the level of Community, common goals with regard to measures and procedures for informing the public for the purpose of improving operational health care which is provided in case of radiological danger. The cited Directive does not affect the right of member states to implement or adopt measures designed to provide additional information in respect of those called for by this Directive (Council Directive 89/618/Euratom, 27 November 1989/B/).

According to the Law on Environmental Protection (Official Gazette of the Republic of Serbia, 2004, 2009/A/) protection against radiation shall be provided by implementing a system of measures preventing harm to the environment and human health from radiation effects coming from ionizing and non-ionizing sources and eliminating the effects of emissions that radiation sources emit or can emit (Official Gazette of the Republic of Serbia, 2004, 2009/B/). The Law on Protection against Ionizing Radiation and Nuclear Safety which was passed recently (Official Gazette of the Republic of Serbia, 2009/A/) sets forth the measures aimed at protecting (Official Gazette of the Republic of Serbia, 2009/B/) life, human health and the environment against adverse effects of ionizing radiation and shall regulate the conditions of pursuit of professional activities with sources of ionizing radiation and nuclear material as well as managing radioactive waste (Official Gazette of the Republic of Serbia, 2009/C/).

According to the Law on Occupational Health and Safety (Official Gazette of the Republic of Serbia, 2005/A/) the employer shall inform the employee during vocational training about all types of risks at jobs he shall be assigned to and about concrete measures aimed at safety and health in the workplace in accordance with the risk assessment act (Official Gazette of the Republic of Serbia, 2005/B/). The fact that cosmic radiation issues are taken seriously is suggested by regulations concerning the assessment of medical fitness of flight crew in civil aviation (Official Gazette of the Republic of Serbia, 2008) which envisage 2 lessons in cosmic medicine (radiation, spacecraft) within an advanced course in aviation medicine.

Regulations concerning conditions and procedures for issuing training certificates for the pursuit of activities in air transport (Official Gazette of the Republic of Serbia, 2008, 2009, 2010, 2011) are laid down by OPS.1390 - Cosmic radiation according to which the airline shall take into account the cosmic radiation exposure of crew members during flight while they are on duty (including the positioning) and take the following measures when the crew is exposed to radiation which exceeds 1 millisievert a year:

1. estimate the crew's exposure to cosmic radiation,

2. consider the estimated radiation exposure of crew members when drawing up the working schedule in order to reduce the radiation dose of crew members who have already been exposed to high-level of radiation,

3. familiarize crew members, those to whom it applies, with health risks related to the pursuit of their professional activities,

4. ensure that working schedule for female crew members once they have been notified that they are pregnant keep the foetus exposed to radiation as little as possible and ensure that the dose does not exceed 1 millisievert for the remainder of the pregnancy,

5. keep records on each individual and especially on crew members who are exposed to higher doses of radiation. Crew members have to be informed about the cosmic radiation doses every year and upon retirement.

Similarly, an airline shall not conduct flights at altitudes above 15 000 m (49 000 ft) unless the equipment specified in OPS 1.680(a)(1) is serviceable or unless the procedure prescribed in OPS 1.680 (a)(1) is complied with; and the commander of an aircraft or the pilot to whom conduct of the flight is delegated has to initiate a descent as soon as possible when the limit values of cosmic radiation dose rate specified in the Operations Manual are exceeded (see OPS 1.680(a)(1)).

For the purposes of estimating exposure levels to ionizing radiation of occupationally exposed persons, patients and population prescribed measurements are carried out in accordance with the Law on Protection against Ionizing Radiation and on Nuclear Safety. Serbian Radiation Protection and Nuclear Safety Agency prescribes types, method and time intervals of measurements in order to estimate ionizing radiation exposure levels and limits to occupationally exposed individuals, persons receiving schooling, and population (Official Gazette of the Republic of Serbia, 2009/D/).

Regulations concerning the terms and procedure for the issuance of an Air Operator Certificate (Official Gazette of the Republic of Serbia, 2008, 2009, 2010, 2011) govern the application procedures for cosmic or solar radiation detection: equipment application and reading records, including measures that need to be taken in case limit values specified in the operations manual are exceeded; procedures in case a decision has been made about a descent or route change, including procedures of air transport service providers (ATS). The procedures in case of emergency situations refer to: exceedance of the limit values of cosmic radiation rates and data on cosmic and solar radiation doses are kept for 12 months after a crew member has left the job at the airline.

Regulations concerning devices and equipment which have to be installed in the aircraft dependent on the aircraft category and purpose (Official Gazette of the Republic of Serbia, 1984) cease to be valid by regulations concerning invalidation of regulations concerning devices and equipment that have to be installed in the aircraft dependent on the aircraft category and purpose (Official Gazette of the Republic of Serbia, 2011/B/). Article 21 of the above-mentioned Regulations laid down that "an aircraft which flies at altitudes over 15 000 metres must have a cosmic radiation indicator installed".

Within the ministry responsible for labour the Administration for Health and Safety at work which is in charge of public administration affairs with the aim to improve and develop occupational safety and health, that is, decrease occupational injuries, occupational diseases and work-related illnesses. This Administration, inter alia: surveys and assesses the condition of health and safety at work and prepares paragraphs for the uniform regulation of the occupational health and safety measures;

provides professional assistance in the field of safety and health of the employees; prepares methodologies for surveillance and research in the field of occupational health and safety; investigates causes and occurrences that result in occupational injuries, occupational diseases, and work-related illnesses; collects and analyzes data on occupational injuries, occupational diseases and work-related illness and occurrences that affect the health of the employees; organizes counselling, provides education to the employees, employers, persons in charge of occupational health and safety, inspectors and others, publishes various materials and informs the public about the state of occupational health and safety; encourages education and development of workplace culture in the field of occupational health and safety (Official Gazette of the Republic of Serbia, 2005/C/).

There are many challenges, for instance towards the end of May 2001 the Serbian airline "JAT Airways" cancelled its flights to Copenhagen and Gothenburg because of an ash cloud from Iceland's Grimsvotn volcano which covered Scotland and Northern Ireland. Volcanic ash composed of large particles found in the air, radiation as well as other factors of the environment we live in are significant and should not be overlooked. The cosmic radiation issue has rarely been considered and is relatively unknown to the general public even though the impacts of this radiation are more than significant, which is confirmed by past research in this area.

4. Conclusion

At the beginning of 21st century the world is confronted with significant social, economic and environmental changes. Knowledge in radiation protection is an important tool in the battle for survival on our planet. Seneca wrote that no life is more secure than any other and that no one is safe for tomorrow.

Our public today still seems insufficiently informed when it comes to hazards brought about by natural sources of radiation. However, state authorities, the autonomous province authorities, the local self-government authorities, authorized and other organisations are obliged to inform the public on regular basis, in time, fully and objectively about the state of our natural environment, that is, about the phenomena that are surveyed within the monitoring of the level of polluting substances and emissions, and about precautionary measures or about the progress of pollution which can prove to be hazardous to life and human health in compliance with the Law on Environmental Protection and other regulations. Similarly, the public has a right of access to prescribed inventories or records containing information and data in accordance with this law (Official Gazette of the Republic of Serbia, 2004, 2009/C/).

Based on the published results it seems that the cosmic radiation hazard to passengers in contemporary air transport is nonexistent. With the exception of some professions such as diplomats, sales representatives, athletes, most passengers spend less time on an airplane in the course of one year than air crew, while flying schedules for air crew generally meet the condition regarding radiation exposure below prescribed levels. Nevertheless, for some air crew categories (frequent intercontinental flights) it is possible that annual absorbed doses are quite close to the doses absorbed by workers handling radiation sources, even the possibility of exceeding the prescribed levels is not inconceivable.

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KOSMIČKO ZRAČENJE – PRAVNI I MEDICINSKI PROBLEM U VAZDUHOPLOVSTVU

Nataša Tomić-Petrović

Sažetak: Izučavanje posledica najrazličitijeg zračenja na zdravlje ljudi novijeg je datuma, a događanja u Hirošimi i Nagasakiju aktuelizovala su proučavanje dejstva jonizujućeg zračenja na organizme. Čovek mora živeti sa zračenjem bez obzira na rizik. Efikasnost zaštite povezana je sa dobrim poznavanjem opasnosti od zračenja i radiološke kontaminacije, kao i načinom zaštite. Znanja o zračenjima i veštine da se od njih zaštitimo su važan instrument u borbi za opstanak na našoj planeti. Naša javnost danas je, izgleda, još uvek nedovoljno informisana kada su opasnosti koje prirodni izvori zračenja nose u pitanju. Na osnovu do sada objavljenih rezultata čini se da opasnost od kosmičkog zračenja po putnike u savremenom avio saobraćaju ne postoji. Ipak, za neke kategorije letačkog osoblja (česti interkontinentalni letovi) postoji mogućnost da godišnje primljene doze budu sasvim bliske dozama koje primaju radnici koji rade sa izvorima zračenja, a nije isključena ni mogućnost prekoračenja propisanih nivoa.

Ključne reči: zračenje, avio-saobraćaj, opasnosti, letačko osoblje, zaštita.