Cosmic Ray Exposure in Aircraft and Space Flight

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1. INTRODUCTION

The exposure from cosmic ray radiation to the workers and public is a new aspects of exposures that was caused by the development of science and technology. This relation is no more than the developing procedure of the ICRP activities from X-ray and radium control to nuclear reactors, fuel recycling facilities, radioactive wastes and large accelerators. High technology of the 20th century accomplished not only the development of airplane but also the space vehicles. We accepted the benefit of a high speed transportation of the jet flight and the adventurous space mission. But for the exposure of cosmic ray radiation is not so clearly recognized as a risk source.

In recent years the peoples concern to the environmental risk is becoming high. Some groups are beginning to say the risk from the practice of flight in air or space. And several groups have a real fear to the exposure from cosmic ray radiation. Also several reports on the epidemiology on the pilots and cabin crew in airplane companies are saying there may be a raise of cancer risk by the exposure from the flight. Based on these circumstances several surveys and reporting were done; e.g. EU report, UN report, NCRP report. US Academy of science did a symposium on the Cosmic Ray Exposure 31 May-1April 1998, in Washington. In this symposium the wide range people did a discussion including, radiation protection specialists, radiation measurement specialists, air regulation authority, pilots union and cabin crew union. The real risk communication began. In 1- 3 July 1998, Dublin the same meeting lead by EURADOS (European Radiation Dosimetry Group) was also held.

The difficulty of this problem lies in the following points; a big number of general public relates to the air flight as passengers, the exposure of workers (pilots and cabin crew) of the international flights are clearly over 1 mSv/y, the astronauts staying in the space station are also clearly over 50 mSv/y. And the most difficult point is not-so-clear recognition of the exposure and the level of risk. For the clarification of these situations, discussions are expected.

2. THE EXPOSURE OF PUBLIC AND WORKERS

The basic principles on the exposure of public and workers are summarized in ICRP Publication 60 (1990). In paragraph (109) the exposures are classified into three categories; occupational exposure, medical exposure and public exposure. The exposure received from the work is classified to the occupational exposure. In this meaning the exposure of pilots and cabin crew are classified to the occupational exposure. Then how is the monitoring? The exposure below 5 mSv/y is the boundary to the ordinary personal monitoring. This range covers almost all air crew cosmic ray exposure situations. In case of the pregnant woman, what kind of pragmatic way exist to keep the dose limitation of fetus (1 mSv/y)?

Some discussion on the occupational exposure to cosmic radiation can be seen in ICRP Publication 75.

(163) ...... The Commission does not consider it necessary to treat the exposure of business passengers as occupational exposure. The principal occupational group exposed to elevated levels of cosmic rays is air crew.

(164) The exposure of jet air crew should be treated as occupational exposure. The annual effective doses should be derived from the flying time and typical effective-dose rates for the relevant routes. Since there are no other practical control measures, there is no need to consider the use of designated areas. It is likely that the existing restrictions on the flying time of air crew will provide sufficient control of exposures. Pregnant members of air crew are usually relieved of flying duties well before the end of pregnancy. The Commission believes that this practice will adequately achieve its objectives given in Section 3.3.6. and therefore sees no reason to invoke further protective measures for the conceptus.

For general public one mSv/y is a dose limit. Then what is the recommendation of frequent flying passengers?

3. THE RELATED EXISTING GUIDANCE OF ICRP

The basic principle of the control over natural radiation in ICRP has changed depending on time. In early stage, natural radiation was excluded from the control of doses. The only one concern to the natural radiation was the technically enhanced radioactivity, and its risk was recognized in the recommendation.

In ICRP Publication 26 (1977);

(83) In relation to dose-equivalent limits, the dose equivalent shall not be held to include contributions from "normal" natural radiation.
(88) Man-made modifications of the environment and man's activities can increase the "normal" exposure to natural radiation.
(89) In radiation protection the Commission's recommended dose-equivalent limits have not been regarded as applying to, or including, the "normal" levels of natural radiation, but only as being concerned with those components of natural radiation that results from man-made activities or in special environment. ...... Clearly, however, there is no sharp dividing line between levels of natural radiation that can be regarded as "normal" and those that are more elevated owing to human activities or choice of environment. There will therefore be instances in which judgment will have to be exercised as to whether the component of increased natural radiation should or should not be subject to the Commission's recommended system of dose limitation.
(235) Examples of the practices that may increase the level of exposure from the natural background of radiation include:

the use of certain materials in the construction of buildings and roads;
high-altitude flying;
the consumption of water and foodstuffs in which the concentration of natural radio-elements is unusually high because of their origin or has been enhanced, for example by the use of fertilizers.

But this attitude had slightly changed in ICRP Publication 39 (1983), taking in the discussion on the public exposure of
radon . In this the new proposal was presented by considering the controllability of sources.

In ICRP Publication 39 (1983);
(9) This advice is now expanded and significantly modified. The Commission had already drawn attention to the difficulty of distinguishing between normal and enhanced levels of exposure. It has now concluded that this distinction is unhelpful and bases its new advice in a different approach in which the emphasis is on the extent to which the exposure to the source is controllable.

The outline is the principle proposed in ICRP Publication 39 as follows: The exposure situation is divided into two categories, existing and future. For the existing exposure situation, the action has to be remedial. For the future exposure situation, the limitation and control can be considered at the stages of decision and planning.

There are some description on the natural radiation, mainly concerned about radon exposure, in the reports of ICRP Publication 47 "Radiation Protection of Workers in Mines" and ICRP Publication 50 "Lung Cancer Risk from In Door Exposures to Radon Daughters".

The Committee stated firstly in ICRP Publication 60 that some kinds of exposure to natural sources should be included as part of occupational exposures.
(135) Of the components of exposure to natural sources, those due to potasslum-40 in the body, cosmic rays at ground level, and radionuclides in the earth's crust are all outside any reasonable scope of control. Only radon in workplaces and work with materials containing natural radionuclides can reasonably be regarded as the responsibility of the operating management. Furthermore, there is some exposure to radon in all workplaces, and it is important not to require the use of a formal system of separate decisions to exempt each individual workplace where controls are not needed. They should be excluded from the control of occupational exposure by some general system. Considerable knowledge and judgement is needed to define such a system. The Commission recommends that exposure to radon and the handling of materials containing traces of natural radionuclides should be regarded as excluded from occupational exposure and treated separately, unless the relevant regulatory agency has ruled otherwise, either in a defined geographical area or for defined practices.
(136) To provide some practical guidance, the Commission recommends that there should be a requirement to include exposures to natural sources as part of occupational exposure only in the following cases:
(a) Operations in workplaces where the regulatory agency has declared that radon needs attention and has identified the relevant workplaces.
(b) Operations with and storage of materials not usually regarded as radioactive, but which contain significant traces of natural radionuclides and which have been identified by the regulatory agency.
(c) Operation of jet aircraft.
(d) Space flight.

The definition of quantified specifications for cases (a) and (b) will depend on the local circumstances; but, as a very general guide, operations in spas, in most uranium mines, including open-cast *mines, in many other underground mines and caves, and in some other underground workplaces are likely to constitute examples of case (a). Case (c) will relate principally to the aircraft crew, but attention should also be paid to groups such as couriers who fly more often than other passengers.*

4. THE OTHER ACTIVITIES

Epidemiological surveys were done in Canada[PIE96], Finland[PUK95] and Denmark[LYN96]. Canada's case covered 2680 pilots (62449 person-years) and clarified the statistically significant excess for acute myeloid leukemia (AML). Finland's case is 1577 female cabin attendants (22000 person-years) and 187 male cabin attendants (2500 person-years). It found out a significant excess of breast cancer (standardized increase ratio 1.87(95% confidence interval 1.50 to 2.23)) and bone cancer (15.10(95% confidence interval 1.82 to 5.40)) among female workers. Denmark's case is 915 female cabin attendants, 362 male cabin attendants and 620 male pilots. The result of the standardized incidence ratio for breast cancer for female cabin attendants was 1.61(0.9 to 2.7). All these epidemiological survey could not clearly say the final conclusion in this stage.

On the discussions for the guidance to the real situation, the activities in EU and US are continuing. One is the summary report on "Exposure of air crew to cosmic radiation: Radiation Protection 85"[MCA96]. EURADOS(European Radiation Dosimetry Group) held a symposium on this problem in Dublin On 1 - 3 July 1998. On the other hand NCRP has already published several documents; NCRP Report No.98 (1989) "Guidance on Radiation Received in Space Activities", NCRP Commentary No.12 (1995) "Radiation Exposure and High-Altitude Flight", NCRP Symposium (1996) "Acceptability of Risk from Radiation --- Application to Human Space Flight". On 31 May to 1 April 1998, NCRP held a symposium on "Cosmic Ray Exposure to Air line Crews, Passengers and Astronauts" as an annual meeting of NCRP in Washington.

The International space flight project exists between US, Russia, EU and Japan. In the real situation the internationally harmonized guideline of radiation doses for astronauts is needed.

5. DISCUSSION POINTS

The discussion points on cosmic ray exposure in aircraft and space flight are the follows: (1) characteristics of cosmic radiation (2) jet air plane flight (3) supersonic air plane flight (4) space flight. To each item we would like to mention the discussion frame.

5.1. Characteristics of cosmic radiation

On the real measurement of cosmic ray the developments of measuring methods are needed for the reasons of the special characteristic of cosmic ray. One is the high energy characteristic and the rich of heavy ion fluence. The definition of radiation dose under cosmic ray exposure will be difficult for the following reasons.

(a)Ineffectiveness of radiation weighting factor in the high energy region over 100MeV.

(b) What is Q-L relationship? Especially in case of space flight, the problem will be serious.
HZE (high-Z and high energy) particles contribution is big and the knowledge of these biological effects is less. The characteristics of cosmic ray radiation field are different from the general radiation works. Those high LET radiation contribution lies between 1/3 and 2/3 of total effective dose. On the other hand those high LET contribution is only (for external) about 2% of total dose for the general workers.

(c) Definition of dose will become difficult for the internal radiation cascade. This causes the usefulness of selection of effective dose equivalent than effective dose. (The use of radiation weighting factor will become difficult.)

(d) Several cases of estimation on radiation dose, e.g., the case of astronauts in space station, will become difficult for the modeling consideration between man and space vehicle shielding system, in which the radiation cascade showers in the shielding wall increase man's receiving radiation.

5.2.Jet air plane flight

(a) Air crew as radiation workers

The individual annual dose levels (about 4mSv/y) and risks of jet air plane crew are about three times higher than those of nuclear power plant workers (about 1.5mSv/y in Japan). This requires the introduction of the radiation protection system to these workers as occupational radiation workers. The consideration of education, radiation monitoring and radiation dose recording will be requested. In the real situation the radiation dose estimation will be done through the calculation by doing an accumulation of (flight route dose x staff rosters).

(b) Woman's radiation worker

The characteristic of exposed population of cosmic ray exposure in a jet air plane is special. The fraction of man and woman is roughly 50/50. And these women are young in usual. The fraction of man and woman in general radiation works are 90/10 and women are older than this case. Accordingly, the pregnant woman's dose limitation will become important.

(c) Epidemiological survey

Some reports of epidemiological survey say the sensitivity of cancer increase after the cosmic ray exposure through the work. But in theses analysis the following factors like the synergism of low air pressure and electromagnetic fields in cockpit, the circadian rhythm affects and aircrew's atypical life style etc. are not included. In this stage to introduce any conclusion is a little difficult.

(d) Public exposure

The cosmic ray exposure of general public as an air plane passenger will not be so big concern, because of the quite low vale than 1 mSv and the unameanability of control of cosmic ray exposure. But this information passage to them will be requested. Especially in case of higher dose of frequent fling passengers these actions will be inevitable.

(e) Dose modeling depending to each flight course and the development of dose estimation methodology will become important to grasp the doses of workers. Then the handling and operation of higher dose situation like solar flare had to be considered.

5.3.Supersonic air plane flight

The high altitude fly at over 15 km (50,000 ft) and the long hours flight by a supersonic air plane will give high dose rate to the crew and the passengers. In this case more careful considerations will be requested. In the Concorde Supersonic Air Plane the radiation monitor has already set. But the operation of real radiation protection system in this field is not still established.

5.4.Space flight

In case of space flight, especially in case of staying in the space station, the receiving radiation dose will be over 50mSv/y. In case of this kind of voluntary scientific work, special guideline is usually prepared to the astronauts. On the risk estimation, "what is an acceptable risk?" is a point. US did this discussion in NCRP-98 and introduced the lifetime dose limits based on the 3% lifetime risk of cancer death as a stochastic effect dose limit. (e.g., for man 0.8Sv(25 years old), 1.4Sv(35y), 2.0Sv(45y), 3.0Sv(55y), for women 0.5Sv(25y), 0.9Sv(35y), 1.2Sv(45y), 1.7Sv(55y)) The dose limitation system will also include the deterministic effect dose limit of gonad, eye lens, red bone marrow and skin (in the Japanese discussion).

Special attention will be paid to the unusual situation like solar flare and extra-vehicle (out of the vehicle) activity. These will give a higher dose to the astronauts. In these radiation dose estimation the special attention should be paid to the performance of high energy particles.

6. CONCLUSION

Here the former activities on the cosmic ray exposure in aircraft and space flight are reviewed. The discussion points on this issue are considered and classified.

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