Assessment of Population Dose Exposure in Taiwan

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ABSTRACT

The source terms of population dose in Taiwan were divided into natural radiation, fallout, occupational exposure, medical exposure, nuclear facilities and miscellaneous. The exposures from natural radiation and fallout are homogeneous in nature and resulted in annual per caput dose of 1.62 mSv.y^{-1} and 6×10^{-3} mSv.y^{-1} respectively. The other exposure source terms are heterogeneous in nature and the collective dose thus incurred is 1.73×10^{4} man Sv.y^{-1} which is equivalent to annual per caput dose of 0.82 mSv .y^{-1}. The total population dose in Taiwan is 2.44 mSv. y^{-1}, where 66.3% from natural radiation and 33.3% from medical exposure. Contribution from other source terms is only 0.4%. As compared with the assessment of UNSCEAR 1993 report, the population dose from natural radiation is 33% lower than the world average and the medical exposure dose is 16% lower than that of health care level I countries.

1. INTRODUCTION

The man-made and natural radiation dose in the environment are of much concern recently. Some of the developed countries have made detailed assessment. The recent world average was assessed by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1933).[1,2] the population dose may differ from different locations and living styles. The world average of natural radiation is around 2.4 mSv·y^{-1}, but the maximum may be higher than 100 mSv · y^{-1}. The world average of medical exposure is around 0.3 mSv·y^{-1}, but in some developed countries it may be as high as 2.2 mSv · y^{-1} which is 7 times higher than the average. [2] Hence, it is necessary to assess the population dose so as to support the radiation protection policy.

The Radiation Monitoring Center (RMC) of AEC, R.O.C. initiated a 6-year project to assess the population dose in Taiwan. The source terms include natural radiation, radio-fallout, occupational exposure, medical exposure, nuclear facilities and miscellaneous. The materials of this paper are taken from literature review of surveillance in recent 20 years in Taiwan and reports from Japan, U.S.A., U.K., and UNSCEAR.[1- 22]

2. RESULTS

2.1 Natural Radiation Dose

Natural radiation is the most important radiation source of human being. It can be divided into internal and external sources. External sources include cosmic ray and terrestrial gamma ray, while internal sources include inhalation of air and intake of natural food stuffs. The RMC performs a series of natural radiation surveillance and dose assessment programs since 1980. The summarized reports shown as follows. [8 ,9]

2.1.1 Cosmic- Ray

The RMC carried out a cosmic-ray measurement project all over Taiwan in 1985 by using a 21-L normal pressure ion chamber and 76.2 mm ϕ Na I (TL) spectrometer. The measured dose rate for sea level cosmic-ray near Kaohsiung (22° N, 120° E) is 0.026 μGy . h^{-1}, while in the ground level around Taiwan is 0.027 μ Gy . h^{-1}. The cosmic-ray dose rate is doubled at 2,100 m a.s.l. which was measured in Mountain Ali. [9-12]

The neutron component of cosmic ray was measured by Jiang et al. of National Tsing- Hua University in 1995 by using a BF_3 detector. The measured dose rate is 3.3 n Sv . h^{-1} at sea level. [13] To assess the population dose from cosmic ray, the LUIN computer code was used and verified. The calculated dose rate was in good agreement with that of measured data by considering the altitude, population distribution and shielding effect of buildings, the average per caput dose from cosmic-ray is 250 μSv . y^{-1} , where 235 μSv . y^{-1} from ionizing component and 15 μSv . y^{-1} from neutron component. [14]

2.1.2 Terrestrial Gamma Radiation

The terrestrial gamma radiation is originated from U-238 , Th-232 series and ^{40}K in soil and rock. In 1980, the RMC carried out an in-situ measurement project by using a 25.4 mm ϕ Na I (TL) survey-meter measured at 1 m high above ground. There were 153 towns which were selected for this project based on the distribution of population and geology. The absorbed dose rate ranged from 0.02 to 0.089 μGy . h^{-1} with an average of 0.053

μGy . h^{-1} . By using the dose conversion factor of o.8 Sv/Gy , the effective dose equivalent rate is 0.045 μSv . h^{-1} . [14]

In 1993 , RMC measured the terrestrial γ dose rate around Taiwan by using a 25.4 mm $\phi \times$50.8 mm Na I (TL) survey-meter in a train. [12] The γ dose rate along the railroad ranged from 0.026 to 0.068 μGy . h^{-1} , with an average of 0.0 5 μGy . h^{-1} , which is very close to the result of in-situ measurement performed in 1990. ([12]

During 1987 and 1990, RMC measured the indoor γ dose rate for 85 houses by using TLD $CaSO_4$(Tm) . The average γ dose rate is 0.101±0.015 μGy . h^{-1} . As compared with the outdoor data, the indoor/outdoor ratio is about 1.9 which is higher than other countries owing to the concrete house structure. The indoor and outdoor occupancy factors were assumed to be 0.8 and 0.2 respectively , the per caput effective dose from terrestrial γ is 0.64 mSv . y^{-1} .

2.1.3 Internal Exposure

According to the UNSCEAR 1988 report, the major internal radionuclides are ^{3}H , ^{7}Be , ^{14}C , ^{40}K ,^{87}Rb , ^{210}Pb ,^{3}H and ^{210}Po, and their dose contribution is 0.31 mSv . y^{-1}. [1] The ^{40}K content in Taiwanese was measured by whole body counter. Data from 388 men and 176 women show that the ^{40}K contents are 54 ±8 and 46 ±5 Bq . kg^{-1} respectively. Adopting the rounded dose conversion factor of 3 μ S v . y^{-1} per Bq . kg^{-1} , the annual effective dose equivalent from ^{40}K in a Taiwanese subject is 0.154 mSv for adults.

2.1.4 Radon and Its Progeny

The indoor radon measurement was carried out for 250 homes all over Taiwan by using the passive cellulose nitrate film during 1988 and 1990. The long-term measurement gave an average indoor concentration of 10 ±4 Bqm^{-3}. The equilibrium factor for 43 homes showed an average of 0.49 ±0.12 and 0.57±0.30 indoors. Adopting the new dose conversion factor given in the UNSCEAR 1993 report, the radon-induced dose was calculated to be 0.36 mSv . y^{-1}. There are no reliable data of ^{220}Rn in air and tap water in Taiwan, the authors adopted the data provided in the UNSCEAR 1993 report, which is 0.07 mSv . y^{-1}.

2.2. Radio-fallout

2.2.1 External exposure from fallout

The major radionuclides from fallout are ^{14}C, ^{90}Sr, ^{137}Cs, ^{239}Pu and ^{240}Pu. The ^{137}Cs are the most important nuclide from the view point of external exposure due to surface deposited nuclides. Suppose the ^{137}Cs content in surface soil (5cm depth) is homogenous, the surface concentration of ^{137}Cs in soil was calculated to be 320Bq/m^2 . By adopting the dose conversion factor of 8 nSv.y^{-1}/Bq.m^{-2}, the calculated external dose rate at 1m high above ground is 2.6 μ Sv.y^{-1}.[7] Assuming that the indoor occupancy factor and shielding factor are 0.8 and 0.4 respectively the external effective dose from ^{137}Cs is 1.1 μ Sv . y^{-1}. Following the Chernobyl nuclear accident, from May to August 1986, the ^{137}Cs content in fallout ever increased 86 times but it decreased to normal level within several months.[18]

2.2.2. External exposure from fallout

Except the worldwide radionuclide ^{14}C, the other fallout deposition rate in Taiwan is about 1/3 of Japan. Thus, the internal dose from fallout in Taiwan is calculated to be 5 μ Sv . y^{-1}.[7] From the above data, the total effective dose equivalent from in external and external fallout radionuclides is 5 μ Sv . y^{-1} and 1.1 μ Sv . y^{-1} respectively. The total dose is 6.1 μ Sv . y^{-1}.

2.3 Occupational exposure

There are 25,200 occupational workers in Taiwan and 87% of them are exposed to man-made radiation. The collective effective dose from man-made sources is around 19 man Sv . y^{-1}. About 64% of them are from nuclear power plants. The per caput dose is 1.95 mSv . y^{-1}. The other 36% are from industry, hospitals and research institutions.

About 2,200 air-crew members and 1,000 coal miners are exposed to natural radiation.[11,19] The collective effective dose is about 5 man Sv.y^{-1} with an average per caput dose of 1.0 mSv . y^{-1}.

Thus, the population dose from occupational exposure is 1.14 μ Sv . y-1, of which 21 % from natural radiation and 79 % from man-made radiation exposure.

2.4 Medical Exposure

According to the annual report of AEC R.O.C., there are 3,472 clinical χ-ray machines, 5,256 dental x-ray machines, 138 nuclear medicine departments, 36 linear accelerators, 4 therapy x - ray machines, 102 sealed sources and 36 non-sealed sources.

On average, there are 0.16 x - ray machines per 1,000 people, which is close to the world average of 0.14. We have 3,089 licensed radiological doctors in total, i.e., 0.15 doctors per 1,000 people, which is lower than the world average of 0.21.

During 1992 and 1994, the RMC carried out a nationwide survey of medical exposure. The estimated clinical x-ray exposures were 10,445,700 y^{-1} with an individual average of 0.493 y^{-1}. The collective effective dose was about 15,100 man Sv.y^{-1} . About 63% was from bone examination. The calculated population dose from medical exposure was about 0.71 mSv . y^{-1}. Dental and nuclear medicine exposures are referred to UNSCEAR 1993 report which are 0.01 and 0.09 mSv . y^{-1} respectively. The medical dose is around 0.81 mSv . y^{-1}.

2.5 Miscellaneous

The miscellaneous sources include TV receivers, luggage examination, luminescent dials, smoke detectors and airplane traveling etc. The assessed collective dose is about 67.7 man Sv . y^{-1} and 99.5% from airplane traveling, while the other sources are negligible. [7,9,21] The induced population dose is about 3.2 μ Sv . y^{-1}.

2.6 Nuclear Facilities

Nuclear facilities include nuclear power plants, research reactors, radwaste storage sites and accelerators. The major exposure source is from the liquid and gaseous effluent of nuclear power plant.[22] According to the AEC annual report of environmental monitoring, the average collective dose around nuclear power plants is about 0.19 man Sv . y^{-1}, of which the population dose is about 0.85 mSv . y^{-1}.

3. CONCLUTION

In conclusion, the population dose in Taiwan is mainly from natural radiation source, which is 1.62 mSv . y^{-1}. The contribution of each natural source is shown in Fig.1. Terrestrial radiation is the most important natural source. It is 39% higher than world average owing to the concrete buildings. The dose from radon and its progeny is lower as compared with world average. High air exchange rate in Taiwan due to warm weather makes the indoor radon concentration lower.

The population dose from medical exposure is 0.81 mSv . y^{-1} that is close to the average of health level I, i.e., 1.0 mSv . y^{-1}. The main medical exposure source is from clinical x-ray, which is 0.71 mS v . y^{-1}.

The total population dose from different radiation sources is shown in Table 1 and Fig.2. About 99.6 % of population dose is from natural and medical exposure, the other sources such as radiofallout, occupational exposure, miscellaneous and nuclear facilities are negligible.

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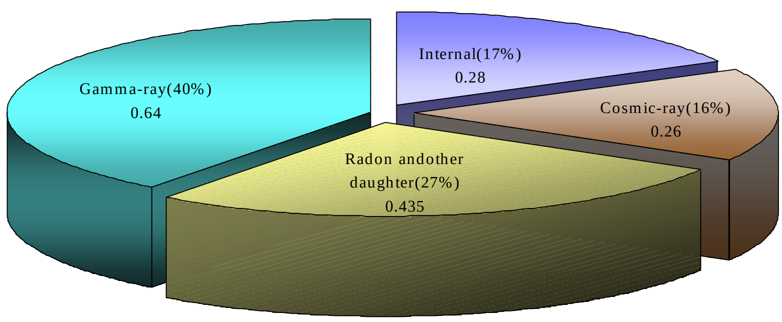
Table 1. Estimated total effective dose of the people in Taiwan

Source	Mean annual effective dose rates (mSv . y^{-1})	Percent (%)
Natural radiation	**1.62**	**66.4**
Cosmic ray	0.26	10.66
Gamma ray	0.64	26.33
Radon and daughter	0.44	18.03
Internal	0.23	11.48
Artificial radiation	**0.82**	**33.6**
Fallout	6.0×10^{-3}	0.25
Miscellaneous	3.2×10^{-3}	0.13
Occupational	1.1×10^{-3}	0.05
Nuclear facility	8.5×10^{-7}	0.00003
Medical	0.81	33.2
Total	**2.44**	**100**

Unit : mSv/y



total: 1.62 mSv/y

Fig. 1 Average annual effective dose for adults from natural backgrund Radiation in Taiwan.

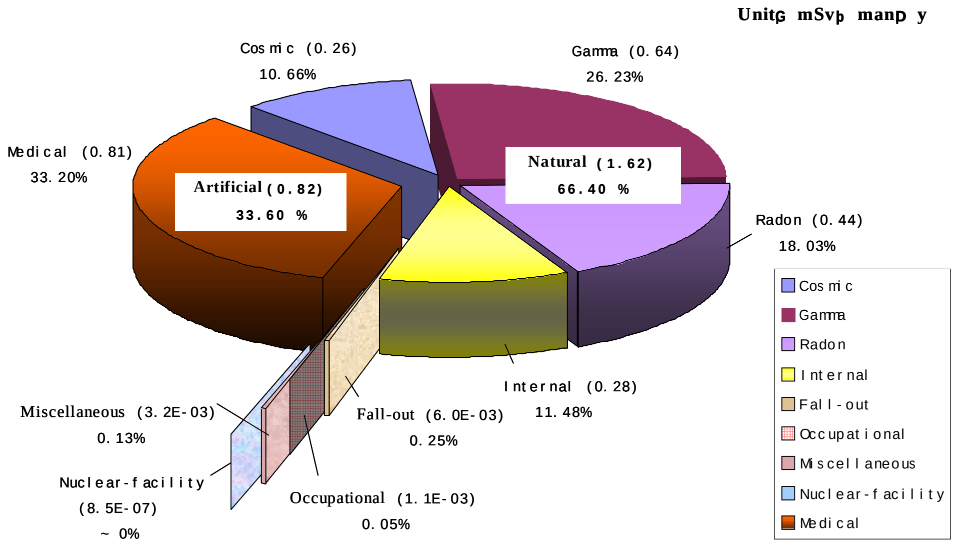


Fig 2 Population Dose Chart in Taiwan : total 2.44 mSv per annum