# 11 POTENTIAL ENVIRONMENTAL IMPACT ASSOCIATED WITH PULVERIZED FUEL ASH

## 11.1 Introduction

As part of the WENT Landfill Extension would be built on the existing ash lagoons at Tsang Tsui near Nim Wan, the potential health risk induced by radon emissions associated with Pulverized Fuel Ash (PFA) arising from the construction and operation of the WENT Landfill Extension is required to be evaluated.

According to Clause 3.4.9 of the EIA Study Brief, an assessment shall be conducted to assess the potential environmental impacts associated with the disturbance of the PFA.

This section presents the literature review and assessment for the health risk associated with radon emissions from PFA during the construction and operation phases of the WENT Landfill Extension.

## 11.2 Health Hazard of Radon

Radon-222 exists as a naturally occurring radioactive inert gas with a half-life 3.82 days and is a decay product of radium-226, which is present in geological materials (rocks, soil, etc.) and concrete at natural levels.

Radon naturally decays into a series of radioisotopes as illustrated in the “radon progeny”. Each radioactive element on the list gives off either alpha or beta radiation, and sometimes gamma radiation too – thereby transforming itself into the next element on the list.

Radon is an indoor air quality concern because the radium family is present in most building materials. The presence of these radioisotopes in the building materials causes external exposure to the people that occupy the building. Inhalation of gaseous radon as well as its short-lived progeny also leads to internal exposure of the respiratory tract to alpha particles.

In living lung tissue, if the DNA in one of the cells adjacent to an inhaled radioactive particle is damaged by the emitted radiation, it may later become a cancer cell that may spread through the lung, perhaps causing death of the individual.

The Relative Risk Model (Yu *et al*., 1988 [11-2]), which takes into account various factors, such as age and sex, has been used to estimate the excess lung cancer deaths due to radon. It has been found that, around the year 1988, about 300 (about 13%) of the lung cancer deaths each year are attributable to radon in Hong Kong.

In addition, chronic exposure of human beings to low doses of ionizing radiation can cause health damages which may appear 5-30 years after the exposure. The most critical damage which can result from such exposure is an increase in the probability of contracting malignant diseases by the person who was exposed.

It is believed that the radon health risk also increases with the dose, and the probability of the appearance of damage is greater when the exposure starts at a younger age.

## 11.3 Radon Characteristics of the Project

### 11.3.1 Radon Sources

Radon gas may be liberated from PFA contained in the ash lagoon. PFA is a by-product of the combustion process of an electric utility plant. Coal contains uranium-238, which is the parent element of the uranium series. After the combustion process, the concentration of the radioactive content in the PFA may increase and consequently, the radon concentration as well as its health risk potential may also increase.

Suspended particulate, including fine dust from PFA, may also be an incremental source of radiation. Re-suspension of materials from surfaces is affected by the nature of the surface and the strength of the wind or other disturbing agents.

As mentioned in Section 11.2, radon also occurs naturally as an inert gas. Cautiously speaking, the worldwide, population-averaged radon concentration is estimated to be 10 $Bq/m^3$ in an ambient outdoors condition. However, this content is not considered in the assessment but only involved in estimated of the total annual effective dose in Green's Study as illustrated in Section 11.4.

### 11.3.2 Pathway Exposure

Radon gas will emanate from the PFA to the air above the ask lagoon. Cracks on the walls and floors would also facilitate the ingress of radon gas from the PFA into the building structures located on top of the PFA. Radon flux from the PFA mainly depends on the emanation power of PFA. The pathway exposure also includes inhalation of suspended material containing radionuclide.

### 11.3.3 Target Sensitive Receivers

It is anticipated that the workers during the construction and operation stages would be exposed to higher radon health risks. Particularly, the workers in an indoors environment or confined space could be affected by elevated radon concentration.

Regarding truck drivers, who would visit the Project site occasionally, there may also be a risk potential from radon. However, as the risk level is dependent on the duration of exposure, it is considered that the target sensitivity should be lower than that of the workers on site.

## 11.4 Risk Assessment of Radon Emission Associated with PFA

As addressed in the literature research, the health risk due to radon emission due to construction and operation of WENT Landfill Extension is considered insignificant. In this section, the results of these previous relevant studies are discussed to demonstrate an insignificant health risk. Alpha particles and gamma ray dose are both taken into account in the evaluation of annual effective dose.

A study on radiological significance of the utilization and disposal of coal ash from power stations was conducted by Dr. B M R Green [11-1] from Central Electricity Generating Board in 1986 (Green, 1986).

The objectives of the study were to assess the radiological significance of utilization of PFA as building materials and activities of workers and the general public on disposal sites, under both indoor and outdoor environment. The significance was calculated on the basis of actual field study, laboratory study and mathematical models.

Field measurements were taken at three coal ash disposal sites in the United Kingdom (UK). Radionuclide content, porosity, radon emanating fraction and exhalation rates of building blocks containing PFA were also analyzed. Mathematical models were used to estimate the exposure to gamma-ray dose rates and radon concentrations under the tested conditions:

- Exposures from building materials
- Exposures from disposal sites under outdoors and indoors conditions.

From the field studies, it was found that there is an increase of radionuclide content from coal to PFA. The result agrees with that from the assessment conducted by the Environmental Protection Department (EPD) and Royal Observatory (RO) in co-operation with the China Light & Power (CLP) in 1989. The specific activity of samples of PFA, FBA (fuel bottom ash) and coal from the Castle Peak Power Stations was assessed. The results have been extracted and shown in Table 11.1 after conversion to radium equivalent activities. The data indicate an increased activity from unburned coal, FBA to PFA.

A number of observations were noted when predicting flux for various thicknesses of PFA and of soil cover in the field studies. It was noted that increasing the thickness of PFA layer beyond 5m makes little impact on the surface radon flux. The flux would be reduced by a factor of two if 30cm of soil cover is provided on top of the PFA.

**Table 11.1 Radium Equivalent Activities of PFA, FBA and Coal from the Castle Peak Power Station**

| Coal Source | Date of Sample Collection | Radium equivalent activity (Bq/kg) | | |
|---|---|---|---|---|
| | | Coal | PFA | FBA |
| Columbia | 22/02/89 | | 233 | 255 |
| Australia | 22/02/89 | | 373 | 347 |
| Australia | 02/03/89 | | 532 | 163 |
| South Africa | 07/03/89 | | 407 | 343 |
| South Africa | 08/03/89 | | | |
| South Africa | 10/03/89 | 72 | 423 | 382 |
| South Africa | 15/03/89 | 66 | 443 | 335 |
| Australia | 19/03/89 | 27 | 211 | 197 |
| Sampled by RO | 1987 | | 377[a] | |
| Source not specified | 1987 | | 378[a] | |

Remark: [a]Data from RO

Radon concentration under indoor and outdoor environment above an ash lagoon is estimated by mathematical models in Green's Study [11-1]. As expected, the radon level and associated effective dose under outdoor condition is of low significant level. The contribution from the PFA is calculated to be 1 $Bqm^{-3}$ and it may reduce to less than 0.5 $Bqm^{-3}$ if there is a soil cover of 50cm over the PFA.

Regarding an indoors environment, the radon concentration inside a reference all-brick dwelling built on an ash disposal site was estimated. Two scenarios were considered: on ash with a covering of 50cm of soil and on ash without soil cover. It was found that the radon concentration in a dwelling built on an uncovered ash disposal site was calculated to be 28 $Bqm^{-3}$ and this value reduces to 13 $Bqm^{-3}$ if the ash is covered with 50cm of soil. As a result, the annual effective dose to an occupant of the all-brick house on a covered ash disposal site was calculated to be 360µSv and this value increased to 780µSv if the ash is uncovered. The study also provided the corresponding values for heavy and light block houses on covered and uncovered ash disposal sites.

A mass-loading approach was used to predict the airborne activity levels due to dust particle suspension. It was assumed that particulates in air had the same activity per unit mass as the surface material. Besides, a dust loading of 100$\mu gm^{-3}$ over a PFA disposal site and an annual intake of dust of about 0.84g was assumed. The committed effective dose from the annual intake of thorium, uranium and their long lived decay products was calculated to be 35µSv.

Table 11.2 provides the summary of the estimations of the effective dose under the above conditions in the study.

**Table 11.2 Summary of Estimates of Annual Effective Dose**

| Situation | Normal Ground | | | PFA disposal site 50cm soil cover | | | PFA disposal site no soil cover | | |
|---|---|---|---|---|---|---|---|---|---|
| | From γ | From Rn | Total | From γ | From Rn | Total | From γ | From Rn | Total |
| **Indoors** | | | | | | | | | |
| All-brick dwelling | 0.740 | 0.260 | 1.000 | 0.750 | 0.360 | 1.110 | 0.760 | 0.780 | 1.540 |
| Heavy block dwelling | 0.700 | 0.290 | 0.990 | 0.710 | 0.400 | 1.110 | 0.720 | 0.820 | 1.540 |
| Light block dwelling | 0.530 | 0.340 | 0.870 | 0.540 | 0.440 | 0.980 | 0.560 | 0.860 | 1.420 |
| **Outdoors** | | | | | | | | | |
| Workers such as farm or disposal site laborer (2000 hrs in a year) | 0.056 | 0.057 | 0.113 | 0.070 | 0.060 | 0.130 | 0.130 | 0.060 | 0.190 |
| Members of the public (500 hrs in a year) | 0.014 | 0.007 | 0.021 | 0.018 | 0.008 | 0.026 | N/A | N/A | N/A |
| **Inhalation of Re-suspended Dust** | | | | | | | | | |
| (8,760 hrs in a year) | | | 0.011 | | | | | | 0.035 |

Note: Estimated Values (including values from gamma ray dose γ and radon Rn) were rounded to two significant figures

N/A: Not applicable

All units in mSv

The estimation indicates that there is no significant radiological hazard to workers working out of doors or near either restored or working ash disposal sites. The annual effective dose to a worker spending 2000 hours outdoors on an ash filled lagoon is about 0.19mSv and is not of great radiological significance level when compared with an annual limit of 1 mSv for general public suggested by the International Commission on Radiological Protection (ICRP). Since the risk imposed on workers with direct radon exposure is not significant and that there will be no off-site disposal of PFA under this Project, the risk on off-site sensitive receivers will also be insignificant as well.

It was found that there is a potential increase in the radiation exposure of occupants in dwellings built over ash disposal sites from increased radon flux out of the ground. The annual effective dose induced by radon in an indoors environment on an ash disposal site with 50cm soil cover is similar to that on a normal area but there is an increase on an uncovered ash field. Nevertheless, the annual effective dose of about 1.5mSv in an indoors environment on an uncovered ash field, which includes contribution from gamma ray dose and radon concentration. 1.5mSv is not of great radiological significance level when compared with 10mSv, the exposure limit for indoor radon in dwellings and workplaces with reference to International Commission on Radiological Protection (ICRP). In fact, according to a previous study (Yu et al., 1992, 1996), the annual effective dose from indoor radon for Hong Kong were 0.65 – 1.09 mSv, and that from indoor gamma radiation was about 1.17 mSv. Hence, the annual effective dose (due to radon and gamma) exposure in indoors environment of Hong Kong is about 2.26 mSv. In other words, the predicted dose of 1.5mSv is lower than the HK average dose of 2.26 mSv. As such, although the predicted 1.5mSV is higher than the limit for public (1mSv) under the Radiation Health Ordinance, the staff of the WENT Landfill Extension should not be exposed to a significant level of health risk.

There may be some differences in the working habits, ambient radon levels and radiological characteristics of PFA in the ash lagoon of the Project from the study cases in the reviewed literature. However, it is anticipated that these differences should hardly elevate the health hazard to an unacceptable level.

## 11.5 Recommended Measures to Control Radon Health Risk

As discussed in the health risk assessment conducted by Green [11-1], there is no significant radiological hazard to the workers at the proposed part of the WENT Landfill Extension on an ash lagoon during construction, operation and restoration period. However, recommended measures/ good practices shall be considered during the design, construction, operation and restoration of the WENT Landfill Extension.

For buildings within the WENT Landfill Extension, prevention of radon of at least 1m from the PFA to the buildings is preferred. A soil cover can be provided beneath the buildings on top of ash lagoon prior to construction works because it reduces the level of radon influx significantly. Slab-on-grade can be an option on foundation design. In addition, soil suction can also prevent radon from entering the buildings by drawing the radon from below the buildings and venting it through a pipe, or pipes, to the air above the buildings.

Sufficient ventilation should be provided at the interior of the buildings within the WENT Landfill Extension. Forced and natural ventilation should be introduced properly to enhance air exchange rate in the buildings. If basement is provided, pressurization by using a fan to blow air into the basement areas from outdoors is suggested. This would create enough pressure at the lowest level indoors to prevent radon from entering into the buildings.

Regular maintenance should be provided for the floor slabs and walls. Cracks and other openings in the foundation should be properly sealed to reduce radon ingress. Sealing the cracks limits the flow of radon into the buildings thereby making other radon reduction techniques more effective and cost-efficient. It also reduces the loss of conditioned air.

Prior the occupation of the buildings, radon concentration shall be measured by professional persons in accordance with EPD ProPECC Note PN 1/99 Control of Radon Concentration in New Buildings [11-3] *Appendix 2, "Protocol of Radon Measurement for Non-residential Building"* to ensure the radon concentration is in compliance with the guidance value.

## 11.6 "What if IWMF not proceed"

The feasibility of IWMF is still being conducted and there is no decision on the implementation programme and site selection. In case the IWMF is not located at the middle ash lagoon, the boundary of the WENT Landfill Extension would be further expanded to include the middle lagoon. Since there would not be any sensitive receivers within that area and the recommended measures will also be applied to this extended area, additional impacts are not anticipated.

## 11.7 Conclusions

An evaluation of previous health risk assessments of radon emission from PFA is provided in this section. Based on the findings from various literature researches, the radon health risk for construction, operation, restoration and aftercare of the WENT Landfill Extension is concluded to be of insignificant level.

Recommended measures/ good practices are recommended to be considered during the design, construction, operation, restoration and aftercare of the WENT Landfill Extension to control radon health risk.

## 11.8 Reference

[11-1] Green, B.M.R. (1986). Radiological Significance of the Utilization and Disposal of Coal Fly Ash from Power Stations Report for Central Electricity Generating Board. National Radiological Protection Board, UK.

[11-2] Yu, K.N., Young, E.C.M. and Stokes, M.J. (1988). The Radon-induced Lung Cancer Mortality in Hong Kong Deduced from a Relative Risk Model.

[11-3] EPD (1999) ProPECC Note PN 1/99 Control of Radon Concentration in New Buildings