Submission
No 13

FORMER URANIUM SMELTER SITE, HUNTER'S HILL

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Australian Government

Australian Radiation Protection and Nuclear Safety Agency

SUBMISSION BY THE AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY

TO THE INQUIRY BY THE NSW LEGISLATIVE COUNCIL GENERAL PURPOSE STANDING COMMITTEE No 5

THE FORMER URANIUM SMELTER SITE IN HUNTER'S HILL

1. Functions and Capacities of ARPANSA

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is an Australian Government statutory agency.

The *Australian Radiation Protection and Nuclear Safety Act 1998* (the Act) established the position of CEO of ARPANSA and gave the CEO the following functions:

> *(a) to promote uniformity of radiation protection and nuclear safety policy and practices across jurisdictions of the Commonwealth, the States and the Territories;*
> *(b) to provide advice on radiation protection, nuclear safety and related issues;*
> *(c) to undertake research in relation to radiation protection, nuclear safety and medical exposures to radiation;*
> *(d) to provide services relating to radiation protection, nuclear safety and medical exposures to radiation;*
> *(e) to accredit persons with technical expertise for the purposes of this Act;*
> *(f) to monitor the operations of ARPANSA, the Council, the Radiation Health Committee and the Nuclear Safety Committee;*
> *(g) to report on the operations of ARPANSA, the Council, the Radiation Health Committee and the Nuclear Safety Committee;*
> *(h) to monitor compliance with Division 1 of Part 5 and make recommendations to the Director of Public Prosecutions;*
> *(i) such other functions as are conferred by this Act, the regulations or any other law.*

The latter two functions include the regulation of the Australian Government's radiation and nuclear activities.

The CEO and Australian Public Service staff assisting the CEO constitute the statutory agency.

The Act relevantly also establishes the Radiation Health Committee. The functions of that Committee are:

> *(a) to advise the CEO and the Council on matters relating to radiation protection;*
> *(b) to develop policies and to prepare draft publications for the promotion of uniform national standards of radiation protection;*
> *(c) to formulate draft national policies, codes and standards in relation to radiation protection for consideration by the Commonwealth, the States and the Territories;*
> *(d) from time to time, to review national policies, codes and standards in relation to radiation protection to ensure that they continue to substantially reflect world best practice;*
> *(e) to consult publicly in the development and review of policies, codes and standards in relation to radiation protection.*

The membership of the Radiation Health Committee includes a 'radiation control officer' from each State and Territory. A 'radiation control officer' is defined as under the Act as a person who holds a senior position in a regulatory body of a State or Territory; and is responsible for matters relating to radiation protection or nuclear safety.

The Commonwealth, the States and the Territories have agreed to work towards national uniformity in radiation protection through the establishment of a National Directory for Radiation Protection. Items to be included in the National Directory, for uniform implementation by all jurisdictions, are first to be agreed by the Radiation Health Committee. A number of Standards, Codes of Practice and Recommendations have been developed through the Radiation Health Committee to provide the basis for nationally uniform radiation protection arrangements.

To support carrying out its functions to provide advice, carry out research and provide services relating to radiation protection, ARPANSA has developed, inter alia, a sophisticated capacity to measure radioactivity in the environment and to carry out the modeling of radiation doses and health effects. ARPANSA staff participate and contribute to the international development of radiation protection standards.

2. Scope of the Submission

This submission aims to provide information to the Committee, drawing upon the expertise and international standing of ARPANSA staff, about ionizing radiation and health and the contemporary national and international framework for radiation protection relevant to the management of a site contaminated with radioactive materials.

In referring to what is known about the contamination at the site, the submission draws on material on the public record. ARPANSA staff did carry out measurement of radiation dose rates at the site in 1999 and these are drawn on generally. The measurements were performed on a contract basis for Egis Consulting Pty Ltd, who had been contracted by NSW Health. ARPANSA would not object to the release of that work to the Committee.

The submission aims to assist the Committee to address its terms of reference. It does not purport to make recommendations as to further study and remediation options for the site.

3. Natural Radioactivity

The rocks and soil of the Earth contain small quantities of the radioactive elements uranium and thorium, together with their radioactive decay products. The radionuclides of interest include long-lived radionuclides such as uranium-238, uranium-235 and thorium-232 and their radioactive decay products, such as isotopes of radium, radon, polonium, bismuth and lead.

This naturally occurring radioactive material is widely distributed. It results in a natural radiation background that varies by approximately two orders of magnitude over the Earth. The world-wide concentrations of some of the naturally occurring radionuclides in the undisturbed environment are given in the reports on the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). For the two most important naturally occurring decay series the average concentrations are: U238: 0.03-0.05 Bg/g; Th 232: 0.04-0.06 Bq/g. A Becquerel (Bq) is the unit of radioactivity; 1 Bq is one radioactive decay per second.

People undertaking normal activities receive a dose of radiation arising from exposure to this naturally occurring radioactivity in two principal ways:

- From direct gamma radiation from the decay of radionuclides in the soil and rock
- By inhaling radon, a radioactive gas that is one of the decay products of uranium 238.

In Australia, the average annual radiation dose received from natural background radiation is around 1.5-2 mSv. This comprises about 0.3 mSv due to gamma radiation from the decay of radionuclides and around 0.6-1.1 mSv from inhalation of radon. (There are also contributions made by cosmic radiation and potassium-40 in the body). The unit of radiation dose is the (milli)Sievert – it measures the energy deposited in the exposed parts of the body modified by the radiosensitivity of the organs exposed and the type of radiation.

4. The Hunter's Hill Site

Following the separation of radium (^{226}Ra) by Pierre and Marie Curie in 1898, and the verification of its usefulness in the treatment of cancer, radium became a very valuable material. Exploration for uranium ores (including radium) were conducted in Australia and useful deposits were found at Mount Painter in South Australia, and at a site which subsequently became known as Radium Hill. Mining operations at Radium Hill were conducted on a small scale, and ore was extracted and concentrated on site. The concentrate was sent to Woolwich (Hunter's Hill) in Sydney. A refinery operated at Hunter's Hill from 1911-1915 (Mudd, 2005), processing the concentrate. A total of approximately 500 tonnes of concentrate of about 1.4 % U_3O_8 were processed at the site, producing 1.8 grams of radium (Gandy, 1982). That is, approximately 67GBq was extracted from the 74GBq of radium in the concentrate and this implies that up to7GBq was left on the site. Gandy estimated 10GBq remained on the site by assuming an extraction efficiency of 86%. From measurements of soil concentrations and volumes, Gandy estimated that he could account for 9GBq of radium.

Surveys have been conducted at Hunter's Hill in 1965-66, 1976-77 and in 1999 and most recently in 2008. These surveys have focused on the properties at numbers 5, 7, 9 and 11 Nelson Parade, Hunter's Hill.

The survey of 1976 looked at external gamma dose rates and radon levels for the properties at No 5, 7, 9 and 11 (Gandy 1982). The house built on the site of the refinery's laboratory (No. 7) was the focus of these investigations. The exposure level inside No 7 was 0.25μSv/h and elevated radon levels were measured. The annual dose to an occupant of the house was estimated to be 1.8 mSv from gamma radiation and 12 -24 mSv from inhalation of radon. Elevated radon levels were not detected in No. 5, No.9 and No.11 and gamma dose rate measurements inside No 5 and 9 were at the level of normal background radiation (0.1μSv/h). Gamma dose rates in the grounds of No 7 and 9 were 0.5μSv/h.

The results of the surveys done over the years are generally consistent, showing external gamma ray dose rates ranging from normal background levels up to 3 μSv/h in isolated places. The contaminated areas total a few hundred square metres of soil contaminated to a level of several Bq/g of ^{226}Ra. Activity concentrations up to 350 Bq/g were reported in a small number of samples.

With elevated levels of radium on the site, the potential exists for elevated levels of radon (^{222}Rn) in the air, particularly in buildings where radon concentrations could build up because of lack of ventilation. Estimates were made of annual doses of 12-24 mSv/y resulting from inhalation of radon for occupants of the house at No7, which was subsequently demolished.

While measurements of external gamma dose rates are relatively easy to make and survey results have been consistent, measurements of radon are subject to many more uncertainties. Not only do radon concentrations vary diurnally, they will also vary from season to season as the climate varies. Radon levels are also very dependent on the construction of the building and the ventilation of the building, which may also depend on the habits of the occupants. Only long term measurements can yield a reliable estimate.

5. Health Effects of Ionizing Radiation

Annex A is a statement describing the established health effects resulting from exposure to ionizing radiation. The Annex is the relevant excerpt from a statement agreed to by the Radiation Health Committee and published in association with current Australian radiation protection standards.

At the level of radiation dose that might be expected to arise from normal activities on a site contaminated at about the level of the Hunter's Hill site, the annexed statement makes it clear that the effects will not be deterministic and result in clear and early harm. Rather, the dose is rather likely to be in the area where the scientific knowledge is still uncertain and contested. Relying on the linear, no-threshold hypothesis and knowing that the dose will be delivered over a long period, the risk overall can be expressed broadly as 1 in 20,000 chance of a fatal cancer per mSv of dose.

6. Radiation Protection Standards

Australia, along with most of the world, bases its radiation protection system on the recommendations of the International Commission on Radiological Protection (ICRP). The ICRP was established by the International Congress of Radiology in 1929. The system of radiation protection currently applied in Australia is based largely on the system set out in 1990 by the ICRP in its publication ICRP 60. The system at that time had a clearly defined scope so that it did not apply to all human activities. Many exposures to naturally occurring radiation sources were excluded.

In the years since 1990 the application of radiation protection standards has evolved and the Commission has modified its recommendations to reflect this evolution. The ICRP intends its new (2007) recommendations (ICRP 103) to be applied to all sources and to individuals exposed to radiation that are classified into the following three types of exposure situations addressing all conceivable circumstances:

- planned exposure situations
- emergency exposure situations
- existing exposure situations

In the new system, exposures to naturally occurring sources are addressed in recommendations relating to existing exposure situations.

If the linear, no-threshold hypothesis is correct, any dose carries some risk. Therefore, measures for control of exposure for stochastic effects seek to avoid all reasonably avoidable risk. This is called optimising protection. However, risk in this sense may often be assessed in terms of risk to a population, and may not ensure sufficient protection of the individual. Consequently, the optimisation approach is underpinned by applying dose limits that restrict the risk to individuals to an acceptable level. The fundamental regulatory philosophy is expressed in three principles, which may be summarised as follows:

- *Justification*: human activities that cause exposure to radiation may be permitted only if they do more good than harm;
- *Optimisation of protection*: exposure to radiation from justified activities should be kept as low as reasonably achievable, social and economic factors being taken into account; and
- *Limitation of individual dose*: doses must not exceed the prescribed dose limits.

Determining what is an acceptable risk for regulatory purposes is a complex value judgement. The ICRP reviewed a number of factors in developing its recommendations, which have in general been internationally endorsed, including by the World Health Organization, the International Labour Organisation and the International Atomic Energy Agency.

The ICRP's recommended dose limits, which apply in Australia, are: for occupational exposure – 20 mSv per year averaged over 5 years with a maximum annual dose of 50 mSv; for members of the public – 1 mSv in a year.

These limits are intended to apply to practices that use radiation or radioactive sources for various purposes. It is important to recognise that the dose limit is not a line between 'safe' exposure and 'unsafe' exposure. The public dose limit has been formulated on the basis of the linear, non-threshold hypothesis, the estimated risk factors described above and a value judgement that such a level of exposure might be allowed as a result of an activity that brings benefit to the community.

It should be recognised that in 1965, when the decision was taken to release the land at Hunter's Hill for residential use, international and national radiation protection standards were changing. This was being driven by epidemiological studies of exposed populations, particularly those exposed as a result of the atomic bombings on Japan, which showed that exposure to ionizing radiation could cause leukaemia and solid cancers. The evidence seemed to suggest that the total dose received was the important factor and it did not matter if the dose was from acute exposure or chronic exposure to low doses over many years.

In 1966 the ICRP issued revised recommendations for a dose limit for occupational exposure of 50mSv per year. For planning purposes, the Commission considered it appropriate to set dose limits for members of the public a factor of ten below those for radiation workers (ie 5 mSv). The Commission stated that 'No undue biological significance should be attached to the magnitude of this factor, as at present the radiobiological information in this respect is inadequate'. The reason for the Commission's caution was that at that time epidemiological, animal and cellular studies were not sufficiently reliable to make risk estimates for cancer induction from radiation exposure. These recommendations were adopted in Australia in 1967 by the National Health & Medical Research Council (NH&MRC).

When ICRP next revised its radiation protection recommendations in 1976, epidemiological studies of the survivors of the atomic bombings on Japan had for the first time yielded quantitative estimates of the risk of fatal cancer resulting from radiation exposure. A fatal risk of 1% per Sievert was adopted by the ICRP for use in setting its radiation protection dose limits. On this basis the Commission continued with its recommendations of occupational and public dose limits of 50 and 5mSv/y respectively (ICRP 26) on the basis that exposures at these levels posed an acceptable excess risk.

By 1990, however, long-term follow-up studies of the Japanese survivors of the atomic bombings had shown that the risk of fatal cancer was approximately 5% per Sievert at low doses. In response to this the ICRP reduced its recommended dose limits from 50mSv/y to 20mSv/y for occupational exposure and from 5mSv/y to 1mSv/y for the public (ICRP 60).

The recommendations in ICRP 60 were adopted by the NH&MRC in 1995. When ARPANSA was created in 1999 it took over the role of publishing national standards for radiation protection and republished the NH&MRC recommendations as Radiation Protection Series No 1.

7. Applying the Radiation Protection System to Remediation and Waste Disposal

The broad aim of remediation of a site that is contaminated with radioactive material is to reduce the doses likely to be received by people to an acceptable level, **taking into account the activities that may be permitted or are likely to take place on the site.** Radiation protection needs to be 'optimised', being as low as reasonably achievable, economic and social factors taken into account. The optimisation may need to consider radiation exposures to workers and the public arising from the remediation itself, as well as the management of any resulting radioactive waste.

There is no relevant uniform Australian guidance on remediation levels. The ICRP in its recent Recommendations (ICRP 103, Section 6.3 'Existing Exposure Situations') offers some guidance . It refers to the possible need 'to take radiological protection decisions concerning existing man-made exposure situations such as residues in the environment resulting from radiological emissions from operations that were not conducted within the Commission's system of protection'.

The approach recommended by the ICRP is as follows:

that reference levels, set in terms of individual dose, should be used in conjunction with the implementation of the optimisation process for exposures in existing exposure situations. The objective is to implement optimised protection strategies, or a progressive range of such strategies, which will reduce individual doses to below the reference level. However, exposures below the reference level should not be ignored; these exposure circumstances should also be assessed to ascertain whether protection is optimised, or whether further protective measures are needed. An endpoint for the optimisation process must not be fixed a priori and the optimised level of protection will depend on the situation.

The ICRP recommends that reference levels be set typically in the 1mSv to 20 mSv band of projected dose. It also notes that:

The main factors to be considered for setting the reference levels for existing exposure situations are the feasibility of controlling the situation, and the past experience with the management of similar situations. In most existing exposure situations, there is a desire from the exposed individual, as well as from the authorities, to reduce exposures to levels that are close to or similar to situations considered as 'normal'. This applies particularly in situations of exposures from material resulting from human actions, e.g., NORM residues and contamination from accidents.

The International Atomic Energy Agency in its Safety Requirements document *Remediation of Areas Contaminated by Past Activities and Accidents* (WS-R-3) suggest that a 'generic reference level' for aiding decisions on remediation is an existing annual effective dose of 10 mSv from all sources, including the natural background radiation.

In summary, the international guidance for remediation implies that an assessment is made of the likely doses to people carrying out activities anticipated on the remediated site and a process of optimisation of radiation protection, taking into account economic and social factors and the full process of remediation and using a 'reference level' of dose judged to be appropriate for the circumstances. This 'reference level' is not the public dose limit of 1 mSv per annum, though that may well be judged to be the appropriate level of protection in certain circumstances.

Turning to the management of radioactive material arising from any further remediation of the site, the material could be readily stored in some appropriately secured site, with it being contained in (say) 205 litre drums. If the average activity concentration in the drums is less than 10Bq/g the dose rates will be less than 1-2 µSv/h near the drum. As the average concentration of the soil is probably about 5Bq/g this should be so for most drums containing material collected from the site. (6.5Bq/g was the average concentration of ^{226}Ra in the 19 soils samples collected for ARPANSA in 1999. These samples were collected from areas where the dose rates were highest.)

Some of the material gathered is likely to be exempt from regulatory control. The activity concentrations and total quantities of radionuclides for exemption from regulatory requirements are specified in the National Directory of Radiation Protection. These levels follow those recommended by the International Atomic Energy Agency in its Basic Safety Standards, BSS 115. This quantitative guidance for exemption levels is limited to "moderate quantities" of material; that is, amounts "at most of the order of a tonne". There are situations for which the exemption of considerably greater amounts than one tonne of material may be appropriate; however exemption for bulk amounts of materials with activity concentrations lower than the guidance exemption levels requires further consideration by the regulatory authorities. Additional guidance is provided by the IAEA in its Safety Guide RS-G 1.7 on the concept of clearance of bulk amounts materials under regulatory control.

For ^{226}Ra, the exemption level recommended by the IAEA and adopted in to the Australian National Directory for Radiation Protection is 10Bq/g, which applies to moderate quantities of material. For clearance of bulk materials, the IAEA recommends an activity concentration of 1Bq/g.

With regard to the potential for ultimate disposal of the bulk of this material, the relevant Australian guidance is contained in the NHMRC document *Code of practice for near-surface disposal of radioactive waste in Australia.* This Code sets out requirements for the disposal of low level radioactive wastes in disposal facilities where the material is deposited within tens of metres of the surface. The upper limit for disposal of bulk materials (including materials arising from downstream processing and contaminated soils) contaminated with ^{226}Ra, uranium or ^{232}Th is 500Bq/g.

Previous surveys indicate that there is approximately one thousand tonnes of contaminated soil on the site with an activity concentration of ^{226}Ra one hundred times the level commonly found in soil. This level is also one hundred times less than the limit for low-level radioactive waste for uranium and thorium (including ^{226}Ra) designated as Category C material in the Near Surface Disposal Code and could be disposed of in a facility applying this Code.

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ANNEX A

Health Effects of Ionizing Radiation

It is well known that high doses of ionizing radiation can cause harm, but there is continuing scientific uncertainty about effects at low doses. At levels of dose routinely encountered by members of the public and occupationally exposed persons, there is little or no epidemiological evidence of health effects. Radiation protection standards recognise that it is not possible to eliminate all radiation exposure, but they do provide for a system of control to avoid unnecessary exposure and to keep doses in the low dose range.

Extreme doses of radiation to the whole body (around 10 sievert and above), received in a short period, cause so much damage to internal organs and tissues of the body that vital systems cease to function and death may result within days or weeks. Very high doses (between about 1 sievert and 10 sievert), received in a short period, kill large numbers of cells, which can impair the function of vital organs and systems. Acute health effects, such as nausea, vomiting, skin and deep tissue burns, and impairment of the body's ability to fight infection may result within hours, days or weeks. The extent of the damage increases with dose. However, 'deterministic' effects such as these are not observed at doses below certain thresholds. By limiting doses to levels below the thresholds, deterministic effects can be prevented entirely.

Doses below the thresholds for deterministic effects may cause cellular damage, but this does not necessarily lead to harm to the individual: the effects are probabilistic or 'stochastic' in nature. It is known that doses above about 100 millisievert, received in a short period, lead to an increased risk of developing cancer later in life. There is good epidemiological evidence – especially from studies of the survivors of the atomic bombings – that, for several types of cancer, the risk increases roughly linearly with dose, and that the risk factor averaged over all ages and cancer types is about 1 in 100 for every 100 millisievert of dose (i.e. 1 in 10 000 per millisievert).

At doses below about 100 millisievert, the evidence of harm is not clear-cut. While some studies indicate evidence of radiation-induced effects, epidemiological research has been unable to establish unequivocally that there are effects of statistical significance at doses below a few tens of millisieverts. Nevertheless, given that no threshold for stochastic effects has been demonstrated, and in order to be cautious in establishing health standards, the proportionality between risk and dose observed at higher doses is presumed to continue through all lower levels of dose to zero. This is called the linear, no-threshold (LNT) hypothesis and it is made for radiation protection purposes only.

There is evidence that a dose accumulated over a long period carries less risk than the same dose received over a short period. Except for accidents and medical exposures, doses are not normally received over short periods, so that it is appropriate in determining standards for the control of exposure to use a risk factor that takes this into account. While not well quantified, a reduction of the high-dose risk factor by a factor of two has been adopted internationally, so that for radiation protection purposes the risk of radiation-induced fatal cancer (the risk factor) is taken to be about 1 in 20 000 per millisievert of dose for the population as a whole.