Calytrix Consulting Pty Ltd

Uranium Exploration

Safety, Environmental, Social and Regulatory Considerations

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Contents

Executive summary

The main purpose of the document is to summarise issues pertinent to uranium exploration in Western Australia and to initiate the discussion of relevant matters between all stakeholders.

The report:

- Provides background information on uranium and radioactivity, possible pathways of radiation exposure, and methods of radiation measurements;
- Explains the current scientific uncertainty in regard to the effects of low level radiation;
- Describes the stages of mineral exploration, drilling techniques and methods for the minimisation of the generation of dust;
- Details the general legislative framework of radiation protection and its applicability to the exploration of uranium;
- Examines the possible effects of uranium exploration on human health and the environment, and the applicability of the WA Contaminated Sites Act 2003;
- Provides comments on the relationship between exploration and mining companies and members of the general public, particularly the Aboriginal population,
- Analyses the legal requirements for an exploration/mining company to show a degree of compliance sufficient for the successful demonstration of statutory compliance in regard to uranium exploration in Western Australia.

It is concluded that uranium exploration and subsequent mining are acceptable activities, provided that:

- Each exploration and mining company complies in full with the standards of radiation protection and relevant guidance documents – both in regards to the protection of human health and the protection of the environment. No special exemptions should be available to exploration and mining companies from any State or Federal Law or Regulation. Additionally, radiation management plans approved prior to 2008 may need to be amended to include the requirements arising from new WA guidelines for radiation protection in mining and mineral processing (2008).
- Effective control over the management of radiation protection at exploration and mining sites is exercised by the relevant government departments. To facilitate this process a system of inspections and monitoring of uranium exploration sites (and mining sites, in the future) should be introduced as soon as possible. It is suggested that the system be based on the model used in Australia's Northern Territory where such inspections are carried out with the involvement of both representatives from government departments and representatives of the interests of Traditional Owners, with appropriate modifications to reflect the differences between NT and WA regulatory systems.
- Education programs dealing with uranium exploration and mining and aimed at the general public (both in population centres and in remote areas) are developed and presented jointly by the industry, government and non-government organisations. It is noted that a high degree of cooperation between all stakeholders will be required for any education program to succeed.

1. Uranium, radioactivity and pathways of radiation exposure

1.1. Uranium

The recent resurgence in uranium exploration is explained by the significant increase in the price of uranium on the world market[1,2,3,4,5,6], from under US$10/lb of uranium concentrate (historically called 'yellowcake'[A]) in the 1990-s to around US$50/lb in 2008; making the exploitation of low grade uranium deposits (at and below 0.05% uranium) viable. The recent change of Government in Western Australia has opened the way for uranium mining to commence in the State.

Detailed descriptions of uranium resources[1,7] and current exploration[1] activities in Australia indicate that vast reserves of uranium are available to be recovered at a relatively low cost to mining companies.

1.2. Uranium – radioactivity

Uranium is the heaviest naturally occurring element and is radioactive. Uranium atoms may contain 92 protons, 92 electrons and different number of neutrons. For example, uranium-238 nucleus contains 146 neutrons and uranium-235 nucleus – 143 neutrons. The atoms of an element containing the same number of protons but different number of neutrons are called *isotopes* of the particular element.

Atoms of uranium strive to become stable and during this process (called radioactive transformation or decay) they break down and give up the excess energy in different forms, such as emitting subatomic particles and/or electromagnetic waves.

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[1] Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006, pp.54-56

[2] Uranium: Global Market Developments and Prospects for Australian Exports, W Mollard, C. Rumley, K. Penney, R Curtotti, Australian Bureau of Agricultural and Resource Economics (ABARE) Research Report 06.21, November 2006

[3] Uranium Industry Framework: Report of the Uranium Industry Framework Steering Group (September 2006), p.25

[4] Why Australia has so much uranium? AusGeo News, Geoscience Australia, issue 80, December 2005

[5] Nuclear Power: Winds of Change, American Association of Petroleum Geologists (AAPG) Energy Minerals Division, Uranium Committee Annual Report of 2007, March 2007

[6] Environmental consequences of uranium mining, P Diehl, World Information Service on Energy Uranium Project, November 2006

[A] *"Yellowcake" was the term used for ammonium di-uranate, which is bright yellow and was produced by uranium miners in the 1950's and 1960's. Most companies at the present time produce U_3O_8, which is a khaki-grey in colour, several companies also produce UO_4 which is light yellow.*

[1] Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006, pp.73-139

[7] Australia's Uranium: Resources, Geology and Development of Deposits, A D McKay and Y Miezitis, AGSO – Geoscience Australia, Mineral Resource Report 1, 2001

The particles, which are emitted, are *alpha* (α) *particles* (which are the same as the nucleus of helium atom, consisting of two protons and two neutrons), *beta* (β) *particles* (electrons), and neutrons.

The electromagnetic waves called *gamma* (γ) *rays* are similar to radio waves or light but are typically emitted with much higher energies.

These emitted particles and waves are known collectively by the general name of *radiation*.

There are two forms of radiation: *ionising* and *non-ionising*. Ionising radiation includes alpha, beta, and gamma radiation, neutrons and X-rays. Examples of non-ionising radiation are heat, light, microwaves and radio waves. The name 'ionising radiation' originates from the fact that it can *ionise* different compounds and atoms by breaking the chemical bonds between atoms in molecules, thus changing the composition of the original atoms themselves.

The rate of radioactive decay is usually described in terms of the *half-life*. The half-life is the time required for one half of the atoms in a sample to decay. For instance, if the half-life of the particular isotope is 1 day and the given amount of atoms in the sample is 1000, in one day 500 atoms of an original isotope will remain in the sample and in a week the number of atoms of original isotope in the sample will be reduced to 8.

Uranium occurs in two natural *decay series*, headed by uranium-238, and uranium-235. In nature, the radionuclides in these two series are approximately in a state of secular equilibrium, in which the activities of all radionuclides within each series are nearly equal. Natural uranium contains approximately 0.71% of uranium-235 and 99.29% of uranium-238. During the industrial process called *enrichment* the proportion of uranium-235 is increased to 3–5% for uranium reactor fuel. Weapons-grade uranium requires much more significant enrichment, usually to more than 90% of uranium-235.

Due to the very low percentage of uranium-235 in natural uranium and relatively low concentrations of uranium in ores, uranium-238 and its decay products (sometimes called *daughters*) are more radiologically significant.

The figure on the following page[8] shows the various stages of the radioactive decay of uranium-238, the type of radiation emitted at each step and the half-life for each particular radioisotope.

Alpha radiation (α) consists of positively charged and relatively heavy particles which themselves consist of two protons and two neutrons. These particles do not have the ability to travel very far and can be stopped by a sheet of paper. Even in air alpha particles can travel only few centimetres. For this reason they present no real *external*

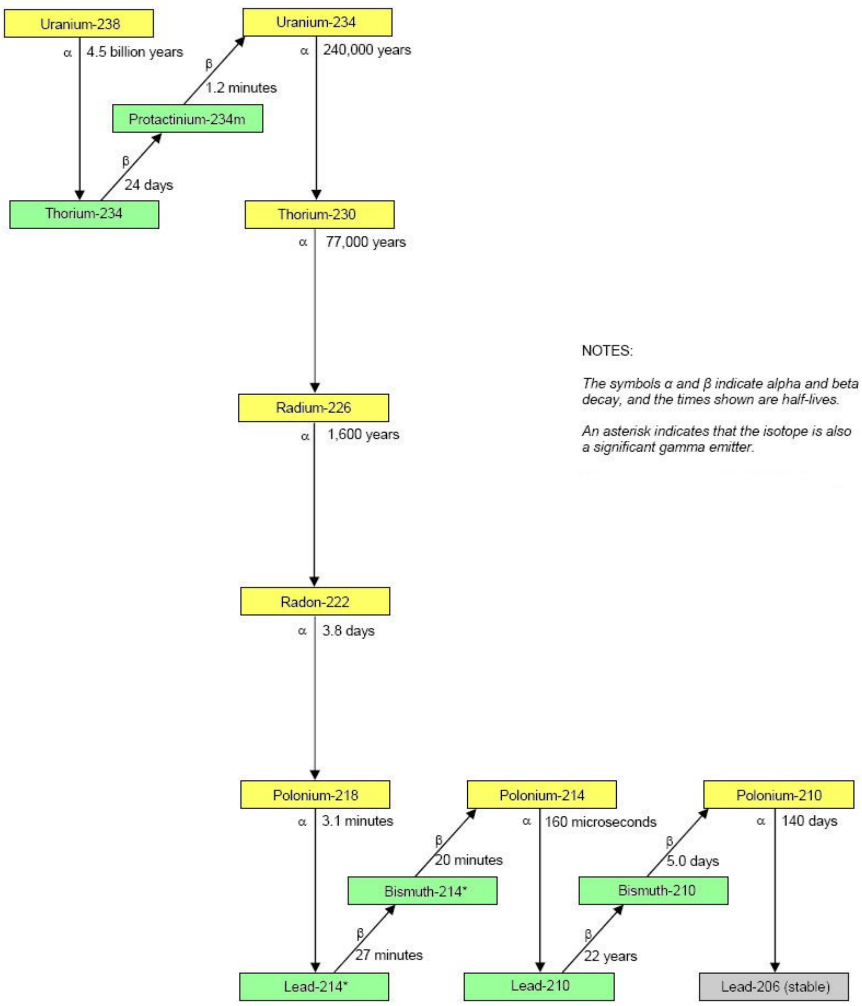
[8] Natural Decay Series: Uranium, Radium, and Thorium, Argonne National Laboratory, USA, Human Health Fact Sheet, August 2005

radiation hazard. Due to its mass and high energy alpha radiation is an *internal* radiation hazard, since, if taken into the body by inhalation, ingestion or through an open wound, all the radiation energy emitted is absorbed in a small volume of tissue.

Beta radiation (β) consists of high-speed electrons and is more penetrative than alpha, but can be stopped by a thin sheet of aluminium. Beta radiation usually does not penetrate far beyond the skin. Therefore, most of the dose from this type of radiation is considered as a 'skin dose'. Beta radiation energy is absorbed in much larger volumes of tissue, and the relative risk of beta radiation in the uranium-238 decay series is considered to be insignificant in comparison with the risk from alpha radiation.

Gamma radiation (γ) is much more penetrative than alpha and beta. Comparatively thick layers of dense material, such as concrete or lead, are needed to stop it. Gamma radiation is an electromagnetic radiation with no negative or positive charge. It is similar to radio waves and light, but is much more energetic and penetrating. Because of its penetrating power it is considered an *external* radiation hazard.

Neutrons have no charge and are very penetrating. In the atomic energy industry neutrons are used to produce radioactive isotopes.



1.3. Units of measurements

The activity of a sample of radioactive material is its rate of disintegration, i.e. the number of atoms decaying per unit of time. Isotopes with a short half-life have high activity, because they are decaying more rapidly than isotopes with a long half-life. The unit of activity is one disintegration per second and is named *Becquerel* (Bq). Since this unit is comparatively small, different prefixes are used: kilo 1 KBq = 1,000 Bq, mega 1 MBq = 1,000,000 Bq, and giga 1 GBq = 1,000,000,000 Bq.

In practical situations the measure of radioactivity of a substance is typically expressed in terms of *specific activity*, which is also sometimes called *activity concentration*. The specific activity of a radionuclide in a liquid or air is calculated by dividing the activity of the radionuclide in a sample (in Bq) by its volume (in L or m^3). The specific activity of a solid material is determined in a similar way, by the division of the activity of the radionuclide by a measure of weight. Most commonly, the specific activity is measured in Bq/m^3 (air), Bq/L (liquid), and Bq/g (solid).

For example, if it is established that specific activity of radium-226 in water is 2 Bq/L – this means that 2 atoms of radium-226 disintegrate in each little of this water every second. Similarly, if the result of a laboratory assessment indicated that uranium content in a core sample is 8 Bq/g – this means that eight atoms of uranium disintegrate in each gram of this sample every second.

When a material other than air is exposed to radiation, the amount of energy deposited in the material will be different from that deposited in air which has been exposed to the same quantity of radiation.

For a particular type of radiation of a specific energy, the amount of energy deposited depends on the properties of the material. It is, therefore, not sufficient to know just the quantity of incident radiation involved when discussing an effect on a material; the amount of energy actually absorbed by unit mass of the material must also be known, and this is called *absorbed dose*. The SI unit of absorbed dose is the joule per kilogram. The special name given to this unit is the *Gray* (Gy) where 1 Gy = 1 Joule/kg of material.

However, for radiation protection purposes it is also important to interpret the amount of radiation received by a person in terms that express the likelihood of harm. In order to do this, a *radiation weighting factor* is introduced, which represents the relative amount of damage likely to be caused to living cells by the same amount of different types of radiation.

Tissue weighting factors for different organs of human body are also taken into account when only a particular organ is exposed to radiation. The absorbed dose is then modified using both radiation and tissue weighting factors to give the amount of radiation now expressed as an effective dose.

The SI unit for effective dose is also joule per kilogram, the same as that for absorbed dose, because factors referred to above are only correction values. The special name given to this unit is the *Sievert* (Sv) where 1 Sv = 1 Joule/kg of material. Since this unit is comparatively large, different prefixes are used: milli 1mSv = 0.001 Sv, and micro 1μSv = 0.000001 Sv.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in its 2000 Report has used "a coefficient of 0.7 Sv Gy^{-1} to convert absorbed dose in air to effective dose equivalent and effective dose."[9] However, due to the potential complexity involved in the interpretation of data obtained with a particular radiation monitoring instrument and calibration uncertainties the use of any conversion factors should be avoided without prior approval from the Appropriate Authority (in Western Australia – Resources Safety Division of the Department of Mines and Petroleum and/or Radiological Council), and in order to ensure the degree of conservatism in the dose assessments, the results of monitoring are usually interpreted as follows: 1 mSv = 1 mGy.

1.4. Background radiation

Everyone is exposed to natural background radiation because almost all objects around us are radioactive to some extent, and because of cosmic radiation. The level of background radiation varies with geographic location, diet and lifestyle and numerous information booklets describe the components of this exposure in detail[10,11,12,13,14,15] (terrestrial radiation, food and drink, cosmic rays, other sources such as air travel and naturally occurring radioactive materials in enhanced concentrations).

As reported by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the worldwide average annual exposure to natural radiation sources generally varies between 1 and 10 mSv with an average of 2.4 mSv[16].

1.5. Radiation effects

The energy of ionising radiation is sufficient to break the chemical bonds between atoms in molecules. In most cases, these breaks are quickly repaired or do not lead to any harm. However, if breaks occur in complex organic molecules regulating

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[9] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000 Report to the UN General Assembly, Annex A: Dose assessment methodologies, p.29
[10] We live in a Sea of Radiation, Australian Nuclear Science and Technology Organisation (ANSTO), 1996
[11] Around us all the time… Radiation, American Nuclear Society, USA, 2000
[12] Radiation Booklet for Workers, National Nuclear Regulator, Republic of South Africa, not dated
[13] Natural Radiations through Naked Eyes, Chubu Atomic Conference, Japan, not dated
[14] Radioactivity in the Environment [in French], French Society for Radiation Protection, France, not dated
[15] Radiation: Doses, Effects, Risks [in Spanish], Argentinean Society for Radiation Protection, Argentina, not dated
[16] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000 Report to the UN General Assembly, Annex B: Exposure from natural radiation sources, p.111, 121, 140

behaviour of a certain cell, this cell may start to behave anomalously. There are two possibilities:

- The cell could die. Then there are usually many more cells of the same kind and the death of several of them will not affect the correct functioning of a certain body organ. A severe dose of radiation is required for the destruction of a relatively large percentage of cells.
- The cell may start working destructively, and this could result in cancer. If the damaged cell is used in reproduction, there is a chance that the damage may be passed on to children.

Therefore, in normal situations, the main types of damage that could be caused by radiation are cancer and genetic effects.

High radiation doses are more likely to result in cancer or genetic effects than low doses. Radiation accidents, medical therapy and various studies on both humans and animals provide evidence that cancer could be caused only by a large dose of radiation.

The evidence for the effects of low radiation doses is very difficult to collect and estimate for the following reasons:

- Radiation is only one of numerous agents that can cause cancer and genetic effects,
- Everyone receives some radiation dose from the natural sources, and
- There is no certain scientifically credible level of radiation dose above which cancer and genetic effects will definitely take place.

On the current level of scientific knowledge it is impossible to determine if there exists a dose threshold below which radiation does no harm. For this reason the Linear No Threshold (LNT) hypothesis is used in radiation protection. From the precautionary point of view it is assumed that harm due to the radiation is directly proportional to the amount of radiation received, or dose.

A system of radiological protection is based on three central requirements[17] developed by the International Commission on Radiological Protection (ICRP). Each of these involves social and economic considerations — explicitly in the first two and implicitly in the third — so there is considerable need for the use of judgement.

1. *Justification of a practice*: No practice involving exposure to radiation should be adopted unless it produces at least sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes.

2. *Optimization of protection*: In relation to any particular source of radiation within a practice, the dose to any individual from that source should be below an

[17] Radiation, People and the Environment, International Atomic Energy Agency, Vienna, 2004

[1] Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

appropriate dose constraint, and all reasonable steps should be taken to adjust the protection so that exposures are "as low as reasonably achievable" (ALARA), economic and social factors being taken into account.

3. *Application of individual dose limits*: A limit should be applied to the dose received by any individual as the result of all the practices (other than medical diagnosis or treatment) to which he or she is exposed.

The scientific and general communities are bitterly divided in regards to the possible effects of low levels of radiation on human health and the environment. This controversy is clearly illustrated by contradictory statements in submissions to the Australian House of Representatives Standing Committee on Industry and Resources Inquiry into the Developing Australia's Non-Fossil Energy Industry[1].

Opponents of uranium mining and exploration argued that there is "no known safe level at which radiation does not damage DNA and initiate cancer"[18,19]. It has also been alleged that the reports by United Nations organisations and national governments describing the consequences of the incident at the Chernobyl nuclear power plant in Ukraine in 1996 deliberately and severely underestimate the number of deaths attributed to the accident, in order to favour the nuclear industry.[20,21]

On the other hand, other submitters argued that low doses of radiation may in fact have beneficial consequences for human health and questioned the validity of the application of the Linear No Threshold hypothesis in the development of radiation protection requirements.[22,23]

The key messages from the committee are, among others[1]:

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[18] Submission No.10, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[19] Submission No.74, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[20] Committee Hearing, 19 August 2005, Melbourne, p.26, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[21] Committee Hearing, 16 September 2005, Sydney, pp.2-6, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[22] Submission No.24, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[23] Submission No.34, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[1] Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

- Claims by some submitters that many thousands of people have already died as a result of the Chernobyl accident are massively exaggerated and are possibly intended to generate fear and further opposition to nuclear power. Whatever the motive, such claims are irresponsible and reflect poorly on the credibility of those individuals and groups making such claims.

- The total average effective dose received by the world population from natural sources of radiation (i.e. 'natural background radiation') is 2.4 milliSieverts (mSv) per year. In contrast, the total average effective dose to monitored workers across the whole nuclear fuel cycle (including uranium mining and milling) is 1.75 mSv per year. Aircrew in civil aviation are exposed to an average 3.0 mSv and radon exposure in some above ground workplaces is estimated to average 4.8 mSv.

- The maximum average annual radiation dose allowed for a uranium miner is currently set at 20 mSv. The actual dose received by workers at Australian uranium mines is well under half this level. The radiation exposure for the public in the vicinity of the mines is a small fraction of the prescribed limit for members of the public, which is 1 mSv.

- There is a clear need for improved public understanding of the nature of radiation and the actual exposures to the public from the nuclear industry's operations.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) stated that there is some epidemiological evidence that there are risks to health from lower doses of radiation, down to about 20 mSv[21]. While the evidence of health effects from doses lower than this is uncertain, ARPANSA submitted that the "safest view is that the effect is linear down to very low levels." That is, that the LNT hypothesis is the most prudent basis for radiation protection policy[24] and the limits for radiation exposure established in Australia in accordance with international recommendations (1 mSv per year for members of the public and 20 mSv per year, averaged over 5 years, for occupational exposure) are appropriate.

Australasian Radiation Protection Society specifies that where the annual exposure of a person is in the range between 0.1 and 10 mSv per year neither harmful nor beneficial effects of ionising radiation can be ruled out, but, "using the ethical position of caution in the face of uncertainty", endorses the established limits.[25]

[21] Committee Hearing, 16 September 2005, Sydney, pp.76, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[24] Submission No.32, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[25] Risks from Exposure to Low Levels of Ionising Radiation, Australasian Radiation Protection Society (ARPS) Position Statement, adopted at the Annual General Meeting, 16 November 2005

It should be noted that in some areas of the world annual radiation exposures from natural background radiation can be very high, but apparently without noticeable risks to human population.

For example in the city of Ramsar in the northern Iran some inhabitants receive annual doses from natural background that can be up to 260 mSv per year – thirteen times higher than the limit of 20 mSv per year for occupational exposure.

It was found that "inhabitants of high background radiation areas had about 56% the average number of induced chromosomal abnormalities of normal background radiation area inhabitants following this exposure."[26]

In another situation, recycled steel accidentally contaminated with the radioactive isotope cobalt-60 was formed into construction steel for more that 180 buildings in Taiwan.

Approximately 10,000 people occupied these residential buildings and received an average radiation dose of 400 mSv, during a 9–20 years period. They "did not suffer a higher incidence of cancer mortality, as the LNT theory would predict. On the contrary, the incidence of cancer deaths in this population was greatly reduced – to about 3 per cent of the incidence of spontaneous cancer death in the general Taiwan public. In addition, the incidence of hereditary malformations was also reduced—to about 7 per cent of the incidence in the general public".[27]

On the other hand, others claim that low levels of radiation are extremely dangerous, for example that –

"one third of men who have, in the past, mined uranium around the world have died of lung cancer,"[21] and

"low dose ionizing radiation may well be the most single cause of cancer, birth defects and genetic disorders. There cannot be a 'safe' dose of radiation; there is no 'safe' threshold. Knowing this, then any permitted radiation is a permit to commit murder."[28]

Most members of the public that could be exposed to radiation associated with uranium exploration and mining are representatives of indigenous communities in the vicinity of a mining/exploration site, and many of them are fearful that the bush food and land will be contaminated, and that people living downstream of a mine may face risks from contamination:

[26] M Giassi-nejad, SMJ Mortazavi et al, Very High Background Radiation Areas of Ramsar, Iran: Preliminary Biological Studies, Health Physics, vol.82, No.1, January 2002, pp.87-93

[27] W L Chen et al, Effects of Cobalt-60 Exposure on Health of Taiwan Residents Suggest New Approach Needed in Radiation Protection, Dose-Response, vol.6, pp.63-75.

[21] Committee Hearing, 16 September 2005, Sydney, pp.2-6, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[28] Submission No.2, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

"A fundamental concern …is that uranium mining, both during operation and after rehabilitation, could lead to increased concentrations and loads of radionuclides released in the environment compared to pre-mining conditions, as well as possibly higher radiation rates due to the operations undertaken."[29]

These concerns are not unfounded, as, in comparison with Iranian and Taiwanese studies referred to above, other scientific data indicates that, despite an apparent reduction of the risk per unit of radiation dose by factor of 2 or 3 in the extrapolation from high doses to low doses –
"…it has been shown that the risk of cancer is increased even at doses below 100 mSv,
"…most of the risk of radiation-induced leukaemia appears to have been expressed within about 40-45 years of the exposure,
"…research data is consistent with a linear no-threshold hypothesis at low doses,
"…raised risks of childhood cancer have been associated with doses received *in utero* that averaged 10-20 mSv."[30]

Also, it was concluded that scientific studies confirm the applicability of linear dose-response relationship at low to intermediate doses and that "…analysis of the combined cohort of radiation workers showed a statistically significant trend in the risk of leukaemia… with external dose", and
"…comparative studies of groups exposed to differing levels of natural background gamma radiation have not demonstrated any significant effects on cancer incidence", noting that "…the estimation of cancer risks associated with exposure to low doses poses particular problems" as "the size of the study population required to detect a raised risk is usually much larger than that required for the high-dose studies."[31]

It is clear that, in the view of uncertainty surrounding the effects of exposure to ionising radiation at low doses, caution is necessary both in developing regulatory requirements and applying them to 'low level' exposure situations.

1.6. Radiation protection – other considerations

Uranium industry argues that it "has demonstrated that it can mine its uranium in a safe and environmentally responsible way, safe for the workers directly involved in the industry and safe and with minimal environmental impact for the wider community"[20] and that "…uranium mining companies have taken active steps to reduce possible radiation risk below international standards. Australian companies have voluntarily adopted the most recent international recommendations on safe radiation levels,

[29] Submission No.44, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[30] Low dose ionizing radiation and cancer risk, Radiation Protection 125, European Commission, 2001

[31] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000 Report to the UN General Assembly, Annex G: Biological effects at low radiation doses, pp.118-121

[20] Committee Hearing, 19 August 2005, Sydney, p.89, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

published by the International Commission on Radiological Protection (ICRP), without waiting for a revision of the 1987 Health Code in Australia. Maximum actual exposure levels at Australian mines are about half those specified, and average levels are little more than from natural background."[32]

The main causes of the difference of opinions appear to be uncertainty and misunderstandings about the nature of radiation and the risks associated with exposures to it at low levels. The greatest concern about ionising radiation is its potential to cause malignant diseases in people exposed to it and possible inherited defects in later generations. Human senses cannot detect radiation, making this risk seem more sinister than others.

It was suggested that the Australian public "has been subject to campaigns of gross misinformation on nuclear matters over the past three decades, by individuals, and by organizations such as Greenpeace, the ACF, Friends of the Earth, Movement against Uranium Mining, various Trade Unions, and much of the media (including women's magazines). Any little incident overseas gets sensational headlines, but benefits get no mention."[33]

This situation can be illustrated by the comparison of two submissions to the Australian House of Representatives Standing Committee on Industry and Resources inquiry into the development of the non-fossil energy industry in Australia.

The submission from the Uranium Information Centre industry urged governments at all levels "to ensure that they do not impose reporting requirements on the industry, that mitigate against public understanding of industry impacts. For example, some operations are required to publicly report spills that have no environmental or safety significance. Such reporting can lead to unnecessary public concern or misrepresentation of operational impacts. If corresponding requirements were placed on other industries handling hazardous materials there would be an outcry.
"The right of the public to be informed about matters that can affect safety or the environment is acknowledged but this needs to be balanced with the right of the industry to have its reputation protected from exaggerated or misleading public comment about its operations."[34]

The submission from the Western Australian Branch of the Medical Association for Prevention of War states "the record indicates a lack of care in an industry that can afford no mistakes. Examples are:

[32] Submission No.20, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006
[33] Submission No.07, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006
[34] Submission No.12, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

- The spate of radioactive spills at Olympic Dam in 2003 (five incidents in that year). The last of these saw 145,000 litres of waste liquid (containing 36 parts per million of uranium) escape from a failed plastic pipe…
- In June 2002, at Southern Cross Resources' Honeymoon mine in South Australia, there was a spill of around 30,000 litres of basal groundwater (~1,000 ppb). This spill was kept quiet by the company."[35]

Whilst the concentration of 36 ppm of uranium in water is, of course, a matter of concern; the mentioning and reporting of a spill of water with concentration of 1 part per million (1,000 ppb) of uranium at the Honeymoon mine appears to be unnecessarily alarmist. One part per million of uranium corresponds to the radioactivity concentration of 12.5 mBq per gram, or 12,500 mBq/kg. Whilst the level is elevated, it is still within the range of the naturally occurring levels of uranium in *drinking* water in the world[16].

The potential radiation exposure from drinking this water can be estimated with the help of a relevant dose conversion factor for the ingestion of uranium-238, which is 0.045 microSievert for each Becquerel ingested[16].

Typical consumption of drinking water by the member of the general public is estimated at 700 L per year, and a theoretical annual exposure in a purely hypothetical extreme case when only this water is used for drinking throughout the whole year would be:
12.5 Bq/L $\times$ 700 L $\times$ 0.045 microSv/Bq = 394 microSv, or less than 40% of the annual exposure limit for members of the general public.

The need for improvements and simplification of the regulations applicable to the mining industry in general were also highlighted in the submissions[36,37] to the Australian Productivity Commission's five-year "Review of Regulatory Burdens on Business".

The National Competition Policy review of radiation protection legislation was carried out in Australia in 2000-2001, and it appears that so called *performance-based* regulatory approach is inappropriate to regulate activities that require a high level of safety, particularly to an activity that usually a subject of frequent public scrutiny.

[35] Submission No.08, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[16] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000 Report to the UN General Assembly, Annex B: Exposure from natural radiation sources, p.125, 127

[36] Minerals Council of Australia, Submission: Annual Review of Regulatory Burdens on Business, June 2007

[37] Australian Uranium Association, Submission: Annual Review of Regulatory Burdens on Business – Primary Sector, 4 July 2007

The general view in the submissions to the Issues Paper[38] was that leaving it to the industry to demonstrate compliance would not work as private firms are profit motivated and would invariably select low cost control systems and compromise on safety standards.

This is of particular concern in radiation safety, as the effects of ionising radiation exposure cannot necessarily be traced to a particular source, and have a long latency period of 10 to 15 years. It was noted that "defining acceptable levels of exposure and putting in place legislation to ensure that such levels are not exceeded might be a safer approach"[38].

The Council of Australian Governments (COAG) calls on regulators to move away from overly prescriptive standards towards performance-based standards but makes reference to the fact that the prescriptive approach may be unavoidable in regulations that deal with public health and safety.[39] Regulations applicable to the Australian uranium mining industry are detailed in the 'mining paper' by the Uranium Information Centre.[40]

Apart from the assumption that low levels of radiation may be very dangerous to human health, a number of organisations and individuals oppose uranium mining not only for safety and environmental reasons, but also in principle[41,42,43,44,45,46,47,48] – mostly due to the fact that it is a part of nuclear fuel cycle and could eventually lead to nuclear proliferation.

The problem with regulation of radiation protection is very complex; as it has to take into account not only *health* and *environmental*, but also *social* and *economic* factors.

Dose limits that are set in regulations can be open to criticism from both sides of the 'low dose' debate – from those who feel that the limits are too low, and from those who claim they are too high. This can be partially explained by the apparent

[38] National Competition Policy Joint National Review of Radiation Protection Legislation, Issues Paper, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), October 2000
[39] National Competition Policy Review of Radiation Protection Legislation, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), Final Report, May 2001
[40] Regulation of Australian Uranium Mining, Uranium Information Centre Mines Paper 9, March 2006
[41] Yellowcake Country? Australia's uranium industry, A Beyond Nuclear Initiative publication (a collaboration between the Poola Foundation, Friends of the Earth, and the Australian Conservation Foundation), 2006
[42] Uranium in Queensland, Briefing Paper, Friends of the Earth, May 2006
[43] Labour's policy challenge: The impacts and failures of the uranium industry, Australian Conservation Foundation, 24 April 2007
[44] Uranium Mining Policy, The Wilderness Society, current
[45] A Nuclear Free Western Australia, Anti-Nuclear Alliance of Western Australia, 2007
[46] Giz Watson, Uranium Mining (Implementation Of Government Commitments) Bill 2007: Second Reading Speech (Draft), WA Legislative Council, 4 April 2007
[47] Uranium Mining (Implementation of Government Commitments) Bill 2007 as tabled by Giz Watson, 4 April 2007
[48] Uranium Mining (Implementation of Government Commitments) Bill 2007 - Explanatory Memorandum as tabled by Giz Watson, 4 April 2007

inconsistency in applying the specified dose and/or concentration limits in different circumstances.

For example, there are different limits for:

- workers and the public,
- nuclear power, medicine, radon, and exposure from naturally occurring radioactive materials,
- transport and processing/storage of the same material, and
- accidents and routine situations.

The characteristic issue that affects the debate is associated with extreme positions of different groups of people. At the international seminar on ethical issues in radiation protection[49] these groups were classified as "anarchists" and "autocrats".

"*Anarchists* believe that no one should have the right to make radiation regulations that affect them, unless they individually have consented to the regulations." Two arguments are typically used: 'zero tolerance argument' and 'vested interests argument':

a) Zero tolerance argument: any additional low-dose exposures to ionising radiation are rejected on the grounds that "they have not consented to them, and they draw no personal benefits from them. The major flaw in their argument… is that …in a democracy, not everyone's opinion can be conclusive, although everyone's interests ought to be considered. If everyone reserved the right to control all societal decisions, no decisions could ever be made."

b) Vested interests argument: "no nuclear expert and no industry scientist ought to be believed… because all such persons have vested interests." But "the very assumption of bias on the part of others is itself biased" and "anarchists fall victim to the very vested interests that they attribute to radiation experts."

"*Autocrats* believe that they have the right to set radiation standards in such a way that they define all low-dose exposures as negligible. They presume that they have the right to decide what risks may be imposed on others without their consent, precisely because the risks are allegedly negligible. Two arguments are also generally used: 'paternalistic argument' and 'comparative risk argument':

a) Paternalistic argument: "because the public does not understand radiation… the public ought not to make decisions about radiation." However, "although the public may be wrong in its fear of radiation, and even irrational, nevertheless the public has the right to be wrong, at least to some degree, in a democracy."

[49] Ethical Issues in Radiation Protection – an International Workshop, Swedish Radiation Protection Institute Report 2000:08, 2000

b) Comparative risk argument: "people should accept low-dose ionizing radiation exposures… because, for example, they receive more radiation from a year of frequent airline flights". It is, however, wrong to assume "that there are no ethical differences between involuntary risks like those from a nuclear reprocessing centre, and voluntary risks, like flying"[49] – particularly in situations when there is no one independently available to check a particular exposure level.

The use of *procedural justice* is suggested as the way of possible resolution of the above-mentioned problem. Main principles are:

- All stakeholders should participate in making a decision, and
- "No member of the decision-making group has information that was not shared and made available to all members of the group." For example, if "information… came from groups either promoting or rejecting nuclear energy, it would be necessary to have alternative information, prepared with alternative methodological assumptions, also available, so that the information was balanced and so that everyone had full access to all data."[49]

It seems appropriate that the decisions on the future uranium mining in Western Australia are taken with the involvement of such a group that will have representatives from:

(a) Relevant government departments,
(b) Industry and its representative bodies (Chamber of Minerals and Energy, Association of Mining and Exploration Companies, Australian Uranium Association, etc), and
(c) General public and its representative bodies (Local Councils, Traditional Owners' organisations, non-government environmental organisations, etc).

Generally, it is suggested that the following main questions are answered in the process of assessment of allowing a particular practice to proceed:

- "Do the benefits outweigh the costs?
- Is the distribution of risk and benefit equitable?
- Has the person [people] given consent to the risk?
- Have people been involved in the decision making process?
- Is there a viable alternative to the imposition of risk?
- Does the person [people] have control over the risk?
- Has the person [people] been compensated for the risk?"[49]

[49] Ethical Issues in Radiation Protection – an International Workshop, Swedish Radiation Protection Institute Report 2000:08, 2000

A number of publications analyses the positions of different groups on radiation protection[50], as well as ethical and other non-radiological factors affecting the making of decisions on different aspects of radiation protection[51,52,53,54,55].

The suggestions for the process of an assessment of a particular practice cited above describe a 'general' situation. Typically, exploration and mining companies enter into discussions with Traditional Owners (through a Land Council intermediary) to seek to obtain an access agreement. The purpose of these negotiations is to reach a mutually beneficial agreement that provides some certainty for the company and meets company's social responsibility obligations; while at the same time allowing recognition of cultural values, sacred sites and containing an obligation to provide employment opportunities and other benefits. On the question of compensation, under the Mining Act in WA, mining companies are technically required to compensate freehold landowners and the State only through payments of royalties. In practice, however, some sort of mutually acceptable arrangement is typically a component of an agreement with the Traditional Owners.

Radiation protection measures providing mechanisms that are available to mining companies to guard against radiation hazards in Western Australia at the moment of the publication of the current version of this report are described in Part 3.

1.7. Pathways of possible radiation exposure

Several possible pathways of radiation exposure can be considered in the estimation of the radiation dose to a particular group of people:

- External radiation exposure to gamma radiation,
- Inhalation of dust,
- Inhalation of radon and its decay products,
- Surface contamination,
- Ingestion of drinking water,
- Incidental ingestion of dust and soil,
- Ingestion of fruits and vegetables,
- Ingestion of meat, milk, and locally caught aquatic organisms.

[49] Ethical Issues in Radiation Protection – an International Workshop, Swedish Radiation Protection Institute Report 2000:08, 2000

[50] H K Florig, An Analysis of Public Interest Group Position on Radiation Protection, Health Physics, vol.91, No.5, November 2006, pp.508-513

[51] G Silini, Ethical Issues in Radiation Protection, presented at the congress of International Radiation Protection Association (IRPA), Montreal, Canada, 1992

[52] D Schwarz, Ethical Issues in Radiation Protection, Continued, Health Physics, vol.75, No.2, August 1998, pp.183-186

[53] Ethical considerations in protecting the environment from the effects of ionizing radiation, International Atomic Energy Agency (IAEA) TECDOC-1270, February 2002

[54] Non-technical factors impacting on the decision making process in environmental remediation, International Atomic Energy Agency (IAEA) TECDOC-1279, April 2002

[55] Socio-economic and other non-radiological impacts of the near surface disposal of radioactive waste, International Atomic Energy Agency (IAEA) TECDOC-1308, September 2002

In different situations of exposure different pathways may need to be analysed.

For example, for the workers in a plant processing minerals with elevated concentrations of natural radionuclides only external radiation exposure and inhalation of dust need to be assessed, which is complemented (where necessary) by the assessment of the exposures from the inhalation of radon and surface contamination.

However, the assessment of the potential radiation exposure of the members of the general public living (or working) in the vicinity of this plant will be much more complex, as it may involve the assessment of most (if not all) of the pathways listed above.

1.8. The measurement of radiation

External gamma radiation can be measured directly with the help of small radiation monitors worn by a person for a certain period of time. Some of these monitors are sent to a laboratory for analysis (such as thermo luminescent “badges” – TLD), others (such as electronic dosimeters) provide an instantaneous reading and typically can be set to sound an alarm at a pre-determined level of exposure.

The possible dose of gamma radiation could be estimated at once: dose rate is determined with a calibrated radiation monitoring instrument and the reading (typically in microSieverts per hour) is multiplied by a number of hours that a person needs to spend in a particular area.

It is not possible to measure the *alpha radiation* dose from the inhalation of dust and/or radon directly. The method involves the determination of the radioactivity of the source (dust/air). The exposure from the inhalation of dust and radon is estimated with the help of dust and/or radon monitors (that may be either worn by a person or placed at a specified location) and analysing the collected samples. The data obtained by this monitoring is used to calculate the radiation dose to a person, following several assumptions on factors such as breathing rate, hours spent in a particular area, the size of dust particles, etc.

Potential exposure to alpha and beta radiation that may arise from the contamination of surfaces is estimated on the basis of measurements carried out with a specifically designed surface contamination monitor, or by wiping the surfaces and sending the ‘wipes’ to a laboratory for analysis.

In order to assess potential radiation exposure from the *ingestion* pathway the samples of the medium that is suspected to be contaminated (water, plants, meat, etc) are analysed in the laboratory and results are compared with the samples of the same medium from the same/similar area that are known not to be contaminated by a specific activity. In cases where such contamination may be possible, ‘baseline samples’ should be collected and analysed prior to the commencement of the activity that may cause this contamination – for the comparative analysis in the future.

2. Mineral Exploration – General Considerations

2.1. Stages of mineral exploration

There are several stages in the mineral exploration process:

The initial stage involves collection of new and evaluation of already available geological data that is gathered remotely with the help of satellite and/or aerial surveys.

The second stage may involve random sampling in selected areas and some investigative drilling. Typically, access to a particular site will be necessary and some ground disturbance (although relatively minor) would occur.

The third stage is typically a detailed exploration for the assessment of mineral deposit. This may result in a substantial ground disturbance due to drilling, development of new access tracks and also due to the presence of an exploration camp. During this stage the removal of bulk samples of materials may also take place.

The potential environmental impact of exploration activities on a particular area may be classified as follows:

Stage 1: Zero impact – satellite-sensed imagery or high-level aerial photography,

Stage 2: Minimal impact – low-flying aircraft, some disturbance to the environment due to the use of vehicles and rubbish that may be left on site (sample bags, fuel drums, etc).

Stage 3: Medium or major impact (depending on the length and the extent of a particular exploration program, size of the camp, etc). The detailed exploration will typically have a visible impact on the local environment by the way of surface scarring (drill holes and/or trenches, tracks, and camp site), flora and fauna in the immediate vicinity may also be damaged. However, this stage is in most cases restricted to a comparatively small area and will only result in a medium impact, particularly due to the fact that area will need to be rehabilitated at the end of the operation.

2.2. Drilling methods

Various methods of drilling to obtain mineral samples have been developed. These methods fall into two general categories:

a) Various types of percussion drills which break up the rock as the hole is drilled producing rock chips like coarse sand which are flushed to the surface by circulating fluids or by compressed air, and
b) Core drilling methods that recover a more or less continuous rock core from the drill hole by grinding, or cutting, an annular ring of rock from around the

central core and recovering the core by a system of retaining core barrels or tubes.[56]

More detailed description of the current drilling methods is as follows[57]:

Rotary Air Blast (RAB) drilling is typically used for the initial 'scout' drilling. The rigs are small, mounted on light vehicles and can work with minimal disturbance to soil and vegetation. The majority of RAB drilling is carried out 'dry', without water injection. Depending on the type of sample system used, dry RAB drilling can result in significant or little dust generation.

The newer 'heavy' RAB rigs have been altered to become multi-purpose that may include drilling of angle holes and water injection. These rigs are fitted onto much heavier vehicles than previous RAB rigs and require use of a larger support vehicle to carry water, drill rods and fuel.

Rotary percussive drilling rigs are of a heavy construction, usually supported by a truck carrying fuel, water and auxiliary equipment and are often unable to reach a difficult drilling site without some road works. Rotary percussive rigs are typically used as a follow up to RAB rigs.

Percussion drilling uses steel bits of various designs to break up the rock while drilling. The bit is rotated and the hammer action of the drill is transmitted through a string of drill rods, which have a relatively small centre hole through which compressed air (in the case of dry ground), or water (in the case of wet ground), is passed. The air (or water) exits through the centre of the bit and forces the drill cuttings up the hole through the space between the drill rods and the drill hole wall. At the surface the drill cuttings are passed through a sample splitter (typically cyclone separator) and a sample of the material is collected. Percussion drill holes are efficient to depths of about 100 meters.

Reverse circulation technique is an adaptation of the rotary percussive method. This system is designed to combine the fast drilling of percussion drilling with better control of the collection of the drill samples. To achieve this, the drill rod of the percussion drill is replaced by a drill stem of concentric pipes which allow the compressed air or water to be forced down an inner pipe, exiting near the centre of the drill bit, flushing the drill cuttings up the side of the bit assembly and into slots in the drill stem above the bit. The cuttings are then forced up the space between the inner drill rod and the outer drill pipe. At the surface the rapidly moving rock cuttings and drill fluid are passed through a cyclone, which vents most of the compressed air and drops the drill cuttings through a splitter, which collects a preset fraction of the cuttings as a sample for assay.

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[56] Mineral Exploration Primer, Association for Mineral Exploration British Columbia, Canada, not dated

[57] R. Stephens, Drilling Practices for Minimal Environmental Impact, in: "Mineral Exploration in an Environmentally Conscious Society", Australian Institute of Geoscientists, Bulletin No.11, 1991, pp.103-105

In the more refined centre hole recovery systems, the air (or water) is forced down the hole between the inner and outer drill pipes, exits around the outer face of the drill bit, and carries the drill cuttings back into the drill stem through a centre hole in the drill bit – to be carried to surface through the inner pipe of the drill stem. This method prevents contact of the sample material with any part of the drill hole wall. Reverse circulation drill systems can drill to depths of 300 meters or more but are more commonly used for holes to about 150 meters.[56,57]

Core drilling provides the most accurate sample of all types of drilling methods. The hole is drilled using a hollow drill bit with the face that is set, or impregnated, with small diamonds. The bit is attached to a string of rotated hollow drill rods. Drilling fluids, usually just water, are forced down the inner side of the drill rods, out around the drill bit face and returned up the hole between the drill rods and the drill hole wall carrying the drill cuttings (sludge) which have been produced by the face of the drill bit.

The typically water-based 'drilling fluid' may also contain cutting oil and other conditioners. The contaminated fluid flows into pits/sumps dug in the ground, or tanks, where the fine particles are allowed to settle, before the remainder of the fluid is returned to the system. When the rig moves to a new site, new settling pits/sumps are again required. Most commonly used modern drill fluids are bio-degradable.

The best practice is that "all drilling fluids containing chemical additives will be contained in lined sumps or tanks; these can be pumped out on completion of the hole, removed from the site and the residues disposed of at an authorised waste disposal site".[58] In case of uranium exploration this may be problematic and an additional consultation on this issue with the 'appropriate authority' may be necessary prior to the commencement of the drilling program.

The drill core consists of the column of rock remaining in the centre of the bit as it cuts a circular hole. As the borehole progresses, the drill core stands within the bit and within the following core tube, which is usually about 3.5 meters in length. When the core tube is full, the shock breaks off the core near the bottom of the hole. The core is prevented from slipping out of the core tube by retaining springs. In the old style 'standard' drilling method, the drillers would have to pull the whole string of rods, rod by rod, to recover the core tube and empty out the drill core. With modern 'wire line' systems, a retrieving device is dropped down the hole, within the drill rods, using a wire line cable. This device snaps unto the core tube, unlocks it from the core barrel, and pulls the core tube up to surface to be emptied into the core box.

[56] Mineral Exploration Primer, Association for Mineral Exploration British Columbia, Canada, not dated
[57] R. Stephens, Drilling Practices for Minimal Environmental Impact, in: "Mineral Exploration in an Environmentally Conscious Society", Australian Institute of Geoscientists, Bulletin No.11, 1991, pp.103-105
[58] S Kerber, Environmental Policy and Code of Practice: An Example, in: "Mineral Exploration in an Environmentally Conscious Society", Australian Institute of Geoscientists, Bulletin No.11, 1991, pp.137-143

Drill core, after being placed in the core box, is usually marked with the drill hole number and depth of each drill 'run'. The geologist 'logs' the core by recording the rock type, alteration, mineralization, etc. and, commonly, the core is photographed. If the core possibly contains uranium it is common that the geologist also uses a radiation monitor and records its reading as well. The core is then usually sent for assay in a laboratory. The core is typically split lengthwise using a core splitter or a diamond saw; one half is bagged for each sample section and the other half is retained for future reference. Diamond drill holes can be drilled to depths of 3,000 meters or more but holes exceeding 1,000 meters are relatively uncommon.[56,57]

Other drilling methods that need to be mentioned are *Aircore* and *Sonic* methods, which are increasingly being used by explorers for shallow deposits, partially because of better quality and more representative samples, but also due to enhanced dust control methods.

Aircore method allows exploration to depths of up to 100 metres. Compressed air is forced down between the inner and outer drill rod to operate a venturi vacuum system at the face of the drill bit. The samples are carried up through the inner tube to the cyclone which distributes cuttings at the bottom of the cyclone and releases the air into the atmosphere.

Sonic drilling is a relatively new exploration technique that provides continuous samples in a wide range of soil types, including 'difficult' unconsolidated ground, where efficient sampling by many other techniques deemed to be impractical. The system consists of a large diameter core wrapped in a sealed plastic sleeve for quality/integrity of sampling, and uses virtually no water as it produces so little dust. The drill stem and sampler barrel are vibrated vertically at frequencies between about 50 and 180 Hz (hence the name 'sonic'), such that the sampler barrel normally advances by slicing through the soil. This method is promoted as producing 80% less waste (dust) and it is sought after for "shallow" uranium exploration.

To minimise environmental damage from drilling the following processes must be addressed[57]:

1. *Collection of the sample from the drill hole*: many drill rigs are equipped to collect the sample material from the drill hole in a closed system (e.g., reverse circulation rigs), on some occasions holes may be drilled with the system open at the hole. The chips and dust flow from the drill hole for collection in open trays. If a hole is drilled through surface material of no value or interest, the open-hole method is sometimes used for expediency and management of generated dust may be necessary.

[56] Mineral Exploration Primer, Association for Mineral Exploration British Columbia, Canada, not dated
[57] R. Stephens, Drilling Practices for Minimal Environmental Impact, in: "Mineral Exploration in an Environmentally Conscious Society", Australian Institute of Geoscientists, Bulletin No.11, 1991, pp.103-105

2. *Disposal of the water from wet samples*: where wet drilling is carried out, the water is separated from the sample and should be collected in sumps prior to subsequent reuse, rehabilitation and/or disposal in an approved manner.
3. *Collection of soil and water from the outside circulation hose*: water and sample mixtures from the outside circulation hose should be collected for later disposal. If the drill holes are dry, fitting a second cyclone separator to the open end of the hose can help to contain the chip/dust mixture.
4. *Removal of all samples from drill sites*: In contrast with exploration for other minerals the samples from uranium exploration should not be heaped next to the hole and left for a period of time prior to final rehabilitation of a site. They must be either placed back in the hole or removed from the site.
5. *Restoration of mud pits/sumps*: Core drilling mud pits are dug as required in positions adjacent to drill holes. In contrast with exploration for other minerals, it is recommended that that pits be cleaned of any radioactive residue and then backfilled with soil material. In this case the surface will not need to be compacted and there will be no impediment for vegetation growth. Where this is not possible, mud pits containing material from uranium exploration should be covered with at least 1-meter thick cover of compacted soil.
6. *Capping and/or filling drill holes*: Temporary capping of drill holes should be carried out immediately after the completion of the hole. Permanent closure should be in accordance with any regulatory or company requirements e.g. grouting the hold to the surface, fitting a buried plug etc.

The best practice for the environmental rehabilitation of a drill site includes:

- Cutting of the casing to a minimum of 30 cm below ground level,
- Backfilling the holes with all cuttings that are not required for analysis,
- Fitting an approved cap (PVC plug or concrete plug), and
- Filling and levelling the area above the hole.

Any holes emitting flowing water should be permanently sealed unless instructed otherwise by the land owner / title holder or relevant government authority.

Where an aquifer has been encountered in the drill hole the bore should preferably be grouted to the surface (backfilled with cement slurry) after completion of the field work to return the conditions underground as close as possible to those which existed before the exploration program commenced.

This is important in order to avoid:

a) Cross contamination of aquifers which might affect water quality for existing or future beneficial users, or
b) Problems of water inflow into mine workings should an old exploration bore cross the line of an underground excavation during mining. There have been instances in the past where workings have been flooded due to ingress of water from old exploration holes.

A further issue may arise where a tool sting (the long linked drill rods) has been lost in a drill hole and could not be recovered to the surface. This should be carefully logged so that in the event of any future underground development miners would be aware that they may encounter this drill rod during tunnelling at a particular location.

Damage that may have occurred away from drill sites should also be taken into account and rehabilitation of the camp site, roads and tracks that were used for the vehicle access should be carried out.[58]

2.3. Drilling – dust generation

Comprehensive studies of dust generation during different drilling processes have been carried out from the early 20th century. The summary on dust control[59] provides information that different designs of wet drills were used to reduce dust generation as early as in 1916 (for the purpose of preventing miners getting silicosis in the mines of the Witwatersrand in South Africa).

For dust control in dry drilling it was established that:

"The application of local exhaust ventilation to the dry rock drill provides a direct means for controlling the dust exposure of the drill operator. As with other dust exhaust systems, the apparatus required includes hoods at the drills, connected by flexible hose to a suitable source of suction and a dust collector. Unlike a permanent ventilating system in a factory, the exhaust system for rock drills must be compact and transportable to permit its being moved as the rock-drilling operations are shifted.

"The dust holding capacity of the collector must be sufficient to provide for at least four hours of continuous drilling at rates encountered in actual work. A highly efficient filter is required to allow for recirculation since the apparatus may be located in a confined area and the maximum filter resistance must be limited to prevent the rate of air flow from dropping dangerously between cleaning periods."

For dust control in wet drilling:

"In comparison with uncontrolled dry drilling the wet drill greatly reduces dust production. The efficiency of dust control varies with the design of the wet drill" and the conclusions reached are as follows:

1. The dust concentration decreases with increasing water flow and with decreasing air flow through the drill steel.
2. Efficiency of dust control is least during collaring of the hole and increases with depth of hole.
3. Efficiency of dust control is greatest when drilling vertically down and decreases when the drill departs from this position."[59]

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[58] S Kerber, Environmental Policy and Code of Practice: An Example, in: "Mineral Exploration in an Environmentally Conscious Society", Australian Institute of Geoscientists, Bulletin No.11, 1991, pp.137-143

[59] L. Greenburg, T.F. Hatch, W.J. Burke, W.B. Harris, "Dust Control in Rock Drilling", American Journal of Public Health and National Health, Vol.3, No.5, May 1940, pp.463-476

Current USA regulations require that: "holes shall be collared and drilled wet, or other effective dust control measures shall be used, when drilling non-water-soluble material. Effective dust control measures shall be used when drilling water-soluble material."[60]

The requirement that all drilling rigs should be fitted with some form of engineered dust control is also contained in other 'best practice' guidelines[61,62].

There have been various successful methods of dust suppression and numerous physical and mechanical factors can determine the effectiveness of each method. One common element of all dust suppression methods is the use of a dust boot or skirt of some type that seals the area around the drilled hole. This boot/skirt does not allow dust to escape into the working environment in the vicinity of the drill rig.

It is recognised that the methods of control are only limited by a company's ingenuity and some simple methods for the control of dust during surface drilling are available; for example the use of a bucket with the cut out bottom to minimise dust generation when uneven bench conditions exist (in these cases the dust skirt usually does not reach the ground, resulting in a lack of sealing that permits drill dust to escape into the work environment). Basically, the bottom of a plastic bucket is cut to create a cylinder. When drilling through this cylinder, the air carries the cuttings higher under the table allowing the collection system to function more efficiently, eliminating dust from being exhausted under the skirt.[63]

[60] USA Code of Federal Regulations, Mine Safety and Health Administration and Labor, 30CFR § 72.620 – Drill dust control at surface mines and surface areas of underground mines

[61] Dust Control, Best practice environmental management in mining, Australian Department of Environment, 1998

[62] Dust Suppression on Seismic Drilling Rigs, Canadian Association of Geophysical Contractors, Best Practices guideline, 2006

[63] Controlling Drill Dust With A Bucket, Mine Health and Safety Administration, US Department of Labor, Occupational Illness and Injury Prevention Program Health Idea AP2002-H0010, 2002

3. Uranium Exploration – Western Australia

3.1. General

The exploration for minerals in Western Australia is governed by the WA Mining Act (1978)[64] that clearly states, in Sections 63 and 63AA, that –

63. Condition attached to exploration licence

Every exploration licence shall be deemed to be granted subject to the condition that the holder thereof will explore for minerals and —

- *(a) will promptly report in writing to the Minister all minerals of economic interest discovered in, on or under the land the subject of the exploration licence;*
- *(aa) will not use ground disturbing equipment when exploring for minerals on the land the subject of the exploration licence unless —*
  - *(i) the holder has lodged in the prescribed manner a programme of work in respect of that use; and*
  - *(ii) the programme of work has been approved in writing by the Minister or a prescribed official;*
- *(b) will fill in or otherwise make safe to the satisfaction of a prescribed official all holes, pits, trenches and other disturbances to the surface of the land the subject of the exploration licence which are —*
  - *(i) made while exploring for minerals; and*
  - *(ii) in the opinion of the prescribed official, likely to endanger the safety of any person or animal;*

and

- *(c) will take all necessary steps to prevent fire, damage to trees or other property and to prevent damage to any property or damage to livestock by the presence of dogs, the discharge of firearms, the use of vehicles or otherwise.*

63AA. Conditions for prevention or reduction of injury to land

- *(1) On the granting of an exploration licence, or at any subsequent time, the Minister may impose on the holder of the licence reasonable conditions for the purpose of preventing or reducing, or making good, injury to the natural surface of the land in respect of which the licence is sought or was granted, or injury to anything on the natural surface of that land or consequential damage to any other land.*
- *(2) A condition imposed under this section may be cancelled or varied by the Minister at any time.*
- *(3) A condition imposed in relation to a license under this section —*
  - *(a) may, either in full or with sufficient particularity as to identify the recommendation or other source from which it derives, be endorsed on the license, for which purpose the holder of the license shall produce the license on demand; and*
  - *(b) whether or not so endorsed, on notice of the imposition of the condition being given in writing to the holder of the license shall for all purposes have effect as a condition to which the license is subject.*

[64] Mining Act (1978), Western Australia

The situation with uranium exploration in Australia in general was described at the technical meeting organised by the International Atomic Energy Agency (IAEA) in 2004[65], where it was demonstrated that Australia showed the greatest disparity between exploration expenditures (3% of worldwide exploration expenditure) and relatively low-cost known resources (38%).

It was concluded at the time that "the question of why Australia has not attracted more exploration dollars may find its answer in politics and a well organized environmental community opposed to uranium mining" and that "the combination of uncertainty surrounding development of Jabiluka and the potential cloud hanging over uranium mining in Western Australia could partially explain the seeming disparity between exploration expenditures and low-cost known resources."[65]

One of the uranium exploration companies operating in Australia is of the opinion that "Australia's current regulatory system is inconsistent and the policy favours three large established producers over all other potential producers in Australia." It was further noted that "the two beneficiaries of this system are the three established Australian producers and the Canadian uranium industry. The cost is the lack of the investment in uranium exploration, limited competition, loss of employment and wealth creation opportunities in other areas and States of Australia and a loss of a major contribution to Australia's economic well being without delivering any benefits. The regulatory system is illogical and permits uranium mining in one State and Territory in Australia and prohibits it across a border in neighbouring States."[66]

Over twenty companies actively explore for uranium in South Australia, as the South Australian Government "has made clear that it openly and actively supports exploration for uranium in South Australia, realising that it has a clear advantage over some states that are still not prepared to grant exploration licences for uranium exploration.
"The State and national interest is that we want to see this ore body (Olympic Dam) developed. It will create thousands of jobs. It also means, of course, a massive export future for the industry." (Mike Rann, SA Premier ABC's "The 7:30 Report", 2 February 2005). "I believe the current national ALP policy is anachronistic and therefore likely to be changed." (Mike Rann, SA Premier, The Advertiser, Wednesday 29 March 2006)[67]. It should be noted that the 'three mines' policy was overthrown by the ALP nationally before the general election in 2007.

There are numerous known uranium deposits in Western Australia[68] and current exploration activities would, most likely, lead to the discovery of other deposits.

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[65] Recent developments in uranium exploration, production and environmental issues, International Atomic Energy Agency (IAEA) TECDOC-1463, IAEA, September 2005, pp.68-69
[66] Submission No.15, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006
[67] Uranium in South Australia, Information Sheet M50, March 2006, Division of Minerals and Energy Resources, Department of Primary Industries and Resources of South Australia
[68] Western Australian Uranium Map, Anti-Nuclear Alliance of Western Australia, 2000

In November 2008 new Premier of WA Colin Barnett announced the lifting of the ban on uranium mining in Western Australia. As the Information Circular from the WA Chamber of Minerals and Energy specified:

"…mining leases would be granted to cover all minerals, including uranium, unlocking tens of millions of dollars in royalties revenue, employment opportunities and allowing the state to play a greater role in the fight against climate change.

"Like other mining operations in the state, the mining of uranium will be subject to strict environmental, safety and security provisions including:

- meeting all the necessary international safeguards in relation to the safe and peaceful use of uranium resources,
- that environmental approvals are obtained in relation to the mining of uranium and the transport of uranium oxide, and
- ensuring a safe workplace for all employees involved in the mining and the transport of uranium oxide.

The Premier said these provisions were fair, balanced and in accord with international standards."[69]

3.2. WA and other jurisdictions

At the moment mineral exploration in general is regulated in accordance with Division 1 of Part 16 of the WA Mines Safety and Inspection Regulations (1995)[70].

In regards to radiation protection, regulation 16.7 states:

16.7. Preparation of radiation management plan

(1) Each responsible person at a mine must ensure that a plan for the safe management of radiation at the mine that complies with subregulation (2) is prepared —

(a) in the case of an existing mine, as soon as is practicable after the commencement day; or

(b) in any other case, before mining operations (other than exploration operations) commence at the mine.

It appears, therefore, that the preparation of a radiation management plan is not required in the case of uranium exploration. In practice, however, this appears not to be the case.

It is expected that regulation 16.7.(1)(b) will be amended in the near future and all uranium exploration companies in Western Australia are already working with an approved radiation management plan (RMP).

This is confirmed in the official publication of the Resources Safety Division of the Department of Consumer and Employment Protection[71].

[69] Information Circular No.29, 18 November 2008, Chamber of Minerals and Energy of Western Australia Inc

[70] Mines Safety and Inspection Regulations, Western Australia, 1995

[71] Uranium – the new gold?, 'Mine Safe' publication of the Resources Safety Division of the Department of Consumer and Employment Protection (DoCEP) of WA, Vol.14, No.4, December 2005, p.18

The requirement for exploration companies to provide some proposals for radiation management on a prospective site is also contained in one of the guidelines of the WA Department of Industry and Resources (DoIR). In the paragraph 5 this guideline specifies that "before commencing any mining operation the Mining Company must submit a Notice of Intent (NOI) to DoIR for approval. In the NOI the Mining Company must give DoIR information about:
"18) Hazardous materials (including radiation) + hazard risk management (safety & environment)"[72]

Additional guidance documents are available for specific situations. In cases where there exploration is planned in areas adjacent to national parks or within nature reserves, additional requirements may be imposed on exploration companies[73] and special conditions also exist for the protection of water resources[74].

Relevant guidelines dealing with exploration, mining and rehabilitation are available from the Department of Primary Industries and Resources of South Australia[75,76]. These guidelines refer the miner/explorer to the State Radiation Protection and Control Act[77] in cases where the materials that are classified as radioactive are present – as detailed in relevant regulations[78] (currently defined as > 200 parts per million (ppm) uranium and/or > 500 ppm thorium).

It appears that if the grade of uranium ore is less than 0.02% the radiation protection requirements may not apply to a particular exploration activity. It is, however, proposed[75] to reduce the regulatory level for uranium to 80 ppm (0.008%); in this case the requirement of SA Radiation Protection and Control Act will apply to virtually all uranium exploration activities. The value of 80 ppm corresponds to the internationally-accepted level for the specific activity of material containing natural uranium (1 Bq/g), when radiation protection measures for a particular activity may become necessary. Further information is provided in International Atomic Energy Agency (IAEA) documents listed in Part 3.3 below.

The same definition of 'radioactive ore' (over 0.02% uranium) appears to exist in the Northern Territory and in New South Wales[79].

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[72] Mineral Exploration and Productive Mining – Approvals and Responsibilities Required by the Government, Guideline, Department of Industry and Resources of WA, March 2003

[73] Mining Environmental Management Guidelines – Mineral Exploration and Mining within Conservation Reserves and other Environmentally Sensitive Lands in Western Australia, Guideline, Department of Industry and Resources of WA, 1998

[74] Guidelines for the Protection of Surface and Ground Water Resources during Exploration Drilling, Department of Industry and Resources of WA, November 2002

[75] Guidelines for the Preparation of a Mining and Rehabilitation Program (MARP), Department of Primary Industries and Resources of South Australia, 2006

[76] Preparation of a Mining Lease Proposal or Mining and Rehabilitation Program (MARP), Department of Primary Industries and Resources of South Australia, 2007

[77] South Australian Radiation Protection and Control Act 1982

[78] Regulations under the Radiation Protection and Control Act 1982, No.194 of 2000, South Australian Government Gazette, 24 August 2000.

[79] Radiation Control Regulations, New South Wales, 2003 [only draft is available at the time]

Further potentially relevant guidelines are available from the Queensland Resources Council[80,81]. Similarly to the situation in South Australia, both documents refer the miner/explorer to the State Radiation Protection Act[82] and Regulations[83], which classify material as 'radioactive' if uranium specific activity exceeds 1 Becquerel per gram (approximately 0.008%) but appear to exclude the material from being classified as such if it is located within the boundaries of land that is the subject of a mining lease, mineral development license or exploration permit. It is possible that in most cases the mineral will be classified as 'radioactive' when uranium concentration in it exceeds 0.008%.

The regulatory system in Queensland is now appears to be complete, as in addition to the documents described above, the new comprehensive guidance note addressing radiation protection aspects of exploration for minerals within the boundaries of a mining lease has been issued by Queensland Department of Mines and Energy in 2008[84].

3.3. Guidance documents

Many guidance documents are available in regard to the environmental management at exploration sites in general[85,86].

The need for dust control at exploration sites is one of the necessary requirements and not only during drilling, but also during the handling of core samples.

In the process of drilling: "sampling in dusty environments, particularly around percussion rigs, can cause breathing problems, wear personal protective equipment".

In the process of core samples handling:

- "The use of a rock saw in a closed space exposes personnel in that space to fine silica dust, which is very damaging to the lungs. Rock saws should be operated only with a water-misting or lubricating device, the room should be vented with an exhaust fan, and a mask or respirator should be worn by the operator—as the dust level requires.
- Pay special attention to the storage of radioactive samples, as radon gas is given off by these samples and may become concentrated in poorly ventilated areas.

[80] Technical guidelines for the environmental management of exploration and mining in Queensland, Queensland Resources Council, 1995

[81] Mineral Exploration Safety Guidance Note, Queensland Resources Council, 2004

[82] Queensland Radiation Safety Act, 1999

[83] Queensland Radiation Safety Regulations, 1999

[84] Radiation protection from naturally occurring radioactive material (NORM) during exploration, Guidance Note QGN12, Queensland Department of Mines and Energy, April 2008

[85] Environmental Guidelines for Construction and Mineral Exploration Companies, Newfoundland Department of Environment and Labour, Canada, not dated

[86] Safety Guidelines for Mineral Exploration in Western Canada, Association for Mineral Exploration British Columbia, Canada, 2006

- If working with X-ray equipment (e.g. XRF analyzer), operators are required by the regulations of the Canadian Nuclear Safety Commission to be equipped with a dosimeter and to file data on exposure."[86]

It is not known if any uranium exploration companies operating in Western Australia use or intend to use portable or semi-portable X-ray analyzers on exploration sites. If this is the case, the equipment must be registered with the WA Radiological Council and operator should be appropriately qualified in accordance with Western Australian Radiation Safety Regulations[87,88,89].

The information on the methods and tools that may be used at exploration sites for core assays and for down-hole electric logging techniques is available in the chapter 'Uranium' of the Canadian guideline describing the methods of the estimation of mineral reserves[90] and in one of the industry publications[91].

Additional insight into the regulatory requirements applicable to uranium exploration in Canada is also available in two government documents[92,93].

Numerous national and international publications dealing with the issue of uranium exploration and mining or referring to it are available and it is important that best practice standards contained in them are implemented in Western Australia.

In addition, it is essential that regulations and, particularly, technical guidelines are regularly revised and updated to ensure that they reflect the current best practice international standards.

Notable publications that are relevant include several published by the International Atomic Energy Agency (IAEA). The IAEA produces a hierarchy of documents. This starts with Requirements which lead to Safety Guides (Standards) and then Safety Reports, (which provide examples of best practices and methods). In particular the following IAEA publications are applicable to uranium exploration, mining and processing:

- International Atomic Energy Agency Safety Guide on occupational radiation protection in the mining and processing of raw materials[94], providing

[86] Safety Guidelines for Mineral Exploration in Western Canada, Association for Mineral Exploration British Columbia, Canada, 2006
[87] Radiation Safety Act, Western Australia, 1975
[88] Radiation Safety (General) Regulations, Western Australia, 1983
[89] Radiation Safety (Qualifications) Regulations, Western Australia, 1980
[90] Estimation of Mineral Resources and Mineral Reserves – Best Practice Guidelines, Canadian Institute of Mining and Metallurgy and Petroleum (CIM), 2003
[91] Uranium Exploration – A Guide for the Uninitiated, in 'Earth Explorer', Geosoft Inc, February 2007
[92] Record of Proceedings, Including Reasons for Decision in the Matter of Cameco Corporation; Application for Revocation of Mining Facility Removal License for the Dawn Lake Project", Canadian Nuclear Safety Commission, 22 March 2002
[93] Questions concerning uranium exploration in Quebec, Ressources naturelles et Faune, Québec, 2007
[94] Safety Guide RS-G-1.6, Occupational Radiation Protection in the Mining and Processing of Raw Materials, International Atomic Energy Agency (IAEA), Vienna, 2004

recommendations and guidance on meeting the requirements for the establishment of occupational radiation protection programs in mining and processing of raw materials.

- International Atomic Energy Agency Safety Guide on application of the concepts of exclusion, exemption and clearance[95], reviewing and expanding on the concepts of exclusion, exemption and clearance defined earlier in the Basic Safety Standards for radiation protection[96].
  The Safety Guide is accompanied by two Safety Reports presenting detailed exposure scenarios and parameters that were used in calculations[97] and providing information on industrial activities, materials and expected exposure levels to ensure that application of control measures is commensurate with the characteristics of the operation and potential radiation exposures[98]; in cases where levels specified in the Guide are exceeded.

- International Atomic Energy Agency Safety Guide on environmental and source monitoring for purposes of radiation protection[99], providing recommendations and guidance on setting environmental monitoring programs, technical considerations and the interpretation of the obtained data.

- International Atomic Energy Agency Requirements[100] and Safety Guide[101] on the near surface disposal of radioactive waste, providing recommendations and guidance on the near-surface disposal of radioactive waste, safety assessments and confidence building.

- International Atomic Energy Agency Safety Guide on management of radioactive waste from the mining and milling of ores[102], detailing administrative framework and strategies for waste management and providing recommendations and guidance on the protection of human health and the environment.

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[95] Safety Guide RS-G-1.7, Application of the Concepts of Exclusion, Exemption and Clearance, International Atomic Energy Agency (IAEA), Vienna, 2004

[96] International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), International Atomic Energy Agency (IAEA) Safety Series No. 115, 1996

[97] Safety Report No.44, Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance, International Atomic Energy Agency (IAEA), Vienna, 2005

[98] Safety Report No.49, Assessing the Need for Radiation Protection Measures in Work Involving Minerals and Raw Materials, International Atomic Energy Agency (IAEA), Vienna, 2006

[99] Safety Guide RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection, International Atomic Energy Agency (IAEA), Vienna, 2006

[100] Safety Requirements WS-R-1, Near Surface Disposal of Radioactive Waste, International Atomic Energy Agency (IAEA), Vienna, 1999.

[101] Safety Guide WS-G-1.1 Safety Assessment for Near Surface Disposal of Radioactive Waste, International Atomic Energy Agency (IAEA), Vienna, 1999

[102] Safety Guide WS-G-1.2, Management of Radioactive Waste from the Mining and Milling of Ores, International Atomic Energy Agency (IAEA), Vienna, 2002

This Safety Guide is accompanied by the Report providing technical information on the development of effective monitoring and surveillance programs[103].

- International Atomic Energy Agency Safety Guide on regulatory control of radioactive discharges to the environment[104], setting up responsibilities (both general and operational) and describing the process of authorising discharges for a new practice or source.

- International Atomic Energy Agency Requirements[105] and Safety Guide[106] on remediation of areas affected by past activities and accidents, providing an overview of environmental remediation requirements and describing planning and operational aspects of remediation and post-remediation management.

- International Atomic Energy Agency Safety Guide on the release of sites from regulatory control[107], providing an overview of regulatory and legal framework and describing the development and implementation of cleanup activities for the release of a site.

- International Atomic Energy Agency Handbook on Nuclear Law[108], describing in detail a structured legal framework that is necessary for meeting the technical and management requirements designed to protect public health, safety and the environment and stating that –
  "mining is part of a chain of activities that starts with prospecting, continues with exploration and then the actual mining operations, and, once the mine has been closed, ends with decommissioning and the rehabilitation of the landscape. Prospecting, the initial search aimed at detecting the presence of radioactive ores, does not as a rule expose prospectors to radiological hazards. By contrast, exploration commonly involves trenching and drilling, which can release radioactive dust and sludge (the drill cores may also represent a radiological hazard). Although exploration does not always lead to the development of a mine, it must at least be monitored."

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[103] Safety Report No.27, Monitoring and Surveillance of Residues from the Mining and Milling of Uranium and Thorium, International Atomic Energy Agency (IAEA), Vienna, 2002

[104] Safety Guide WS-G-2.3, Regulatory Control of Radioactive Discharges to the Environment, International Atomic Energy Agency (IAEA), Vienna, 2000

[105] Safety Requirements WS-R-3, Remediation of Areas Contaminated by Past Activities and Accidents, International Atomic Energy Agency (IAEA), Vienna, 2003

[106] Safety Guide WS-G-3.1, Remediation Process for Areas Affected by Past Activities and Accidents, International Atomic Energy Agency (IAEA), Vienna, 2007

[107] Safety Guide WS-G-5.1 Release of Sites from Regulatory Control on Termination of Practices, International Atomic Energy Agency (IAEA), Vienna, 2006

[108] Handbook on Nuclear Law, International Atomic Energy Agency (IAEA), Vienna, 2003

- In regards to the regulation principles and methods, the measures to achieve an independency of a regulatory body are described in another IAEA document[109].

- In addition, out of many documents describing uranium, its mining and processing and subsequent land reclamation two US documents[110,111] should be noted for information and reference.

All of the above documents were taken into account in the process of the development of the new Western Australian guidelines for radiation protection in mining and mineral processing, in 2008. These documents are described below, in part 3.4, with the guideline addressing development of radiation management plan for an exploration site being of a particular importance.

It is also beneficial to compare licensing regimes applicable to uranium exploration in Western Australia with the ones in other Australian States and Territories and in overseas jurisdictions.

For example, detailed requirements exist in the USA for the issuance of leases to permit the exploration for and mining of deposits containing uranium and requiring that "…the lessee will be required to conduct operations so as to minimize adverse environmental effects, to comply with all applicable State and Federal statutes and regulations and to the extent stipulated in the lease agreement, will be held responsible for maintenance or rehabilitation of affected areas in accordance with plans submitted to and approved by DOE"[112].

In another example, if the application to explore for uranium is approved in Finland, claims can remain in force for some time, given that the period from the beginning of uranium exploration to the beginning of mining operations may span several years. A rule is maximum 5 years and a possible continuation of three years before entering the mining certificate phase. It appears that in this situation a mining company has a maximum of eight years from the beginning of the exploration program to the commencement of mining operations. It should be noted that, similarly to Australia, in Finland "the local, regional and national critics of uranium exploration or mining have seen even a possibility of uranium mining impossible to accept"[113].

[109] Independence in Regulatory Decision Making, INSAG-17, International Atomic Energy Agency (IAEA), Vienna, 2003

[110] Extraction and Beneficiation of Ores and Minerals, Vol.5: Uranium, Technical Resource Document, U.S. Environmental Protection Agency, 1995

[111] Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining, Volume 1: Mining and Reclamation Background, US Environmental Protection Agency, 2006

[112] Code of Federal Regulations, Department of Energy, 10CFR § 760 – Uranium leases on lands controlled by DOE. (Domestic Uranium Program Circular No. 760.1, formerly (AEC) Domestic Uranium Program Circular 8, 10 CFR 60.8)

[113] Status of Uranium Exploration in Finland, Ministry of Trade and Industry, 2007

3.4. Australian legislative framework

The legislative process is quite complex, but simplistically it could be described as follows:

Results of worldwide scientific research into ionising radiation and its effects on humans and the environment are considered by two international bodies, namely: non-governmental scientific organisation International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR). Both bodies publish reports and recommendations that are used by another United Nations body (International Atomic Energy Agency – IAEA) to establish international radiation protection standards and guidelines. Most important standards are developed by the IAEA in collaboration with other relevant international organizations, such as, for example, World Health Organisation, International Labour Organisation, Food and Agriculture Organisation, UN Environment Program, etc.

National 'appropriate authorities' may then adopt these international documents into national regulatory frameworks. The current regulation of radiation protection worldwide is mainly based on the International Atomic Energy Agency Basic Safety Standards for radiation protection[96], which adopt the ICRP Recommendations issued in 1991[114].

The new ICRP recommendations[115] were published in 2007 and the IAEA Basic Safety Standards[96] are also currently under review but no major changes in radiation protection principles and limits are anticipated.

In some cases relatively minor changes are inserted into a particular national regulation but the most important internationally accepted principles and limits are usually kept. Specific documents providing guidance in the application of radiation protection regulations for important sectors of national industries are usually produced by national regulatory authorities[116,117,118].

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[96] International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), International Atomic Energy Agency (IAEA) Safety Series No. 115, 1996

[114] Recommendations of the International Commission on Radiological Protection, International Commission on Radiological Protection (ICRP) Publication 60, 1991

[115] Recommendations of the International Commission on Radiological Protection, International Commission on Radiological Protection (ICRP) Publication 103, 2007

[96] International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), International Atomic Energy Agency (IAEA) Safety Series No. 115, 1996

[116] Radiation protection requirements at mining operations where radiation exposure of workers, members of the public and environment are possible, Guideline by the Czech State Office for Nuclear Safety, 2003 [in Czech]

[117] Methodical guideline for radiation measurements and assessment of effective dose at workplaces where significant exposures from natural sources are possible, Czech Office for Nuclear Safety, 2007 [in Czech]

[118] Radiation Safety in Practices Causing Exposure to Natural Radiation, Radiation Safety and Nuclear Safety Authority, Finland, 2005

As uranium exploration activities are typically only a very small part of the scope of radiation protection regulations, the general principles are always followed, sometimes supplemented by explanatory guidelines.

Where a specific guideline does not exist (as, for example, in the Republic of South Africa) – the 'general' radiation protection regulations[119,120] are applied to the exploration of uranium. The South African regulations apply to any action that is "capable of causing nuclear damage", which appears to include uranium exploration and, therefore, the protection measures against radiation exposures to be incurred during exploration activities are necessary.

As in other countries, in Australia international recommendations and guidelines are considered by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which develops Codes of Practice and Safety Guides relevant to Australian conditions.

The principal radiation protection document in Australia is the National Directory for Radiation Protection[121]. The principle of applying uniform radiation protection regulations throughout Australia is detailed in this document and is based on the decision of the Australian Health Ministers' Conference (AHMC) that "agreed that upon consideration and approval of the provisions of the Directory, the regulatory elements of the Directory shall be adopted in each jurisdiction as soon as possible, using existing Commonwealth/State/Territory regulatory frameworks". The first edition of the Directory, however, is not applicable to the mining and mineral processing industries.

The Australian Code of Practice for radiation protection in mining and mineral processing[122] has been developed and will form a part of the second edition of the National Directory that is expected to be published in the near future.

This Code of Practice will be adopted into the Western Australian legislative framework: with the implementation of the second edition of the National Directory, or earlier – into both Radiation Safety Regulations[88,89] and Mines Safety and Inspection Regulations[70].

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[119] National Nuclear Regulator Act, 1999, Republic of South Africa Government Gazette No.1537, Vol.414, 23 December 1999, No.20760

[120] Regulations in Terms of Section 36, read with Section 47 of the National Nuclear Regulator Act, 1999 on Safety Standards and Regulatory Practices, Republic of South Africa Government Gazette No.8454, Vol.490, 28 April 2006, No.28755

[121] National Directory for Radiation Protection – Edition 1.0, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), Radiation Protection Series No.6, 2004

[122] Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing, Radiation Protection Series No.9, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2005

[88] Radiation Safety (General) Regulations, Western Australia, 1983

[89] Radiation Safety (Qualifications) Regulations, Western Australia, 1980

[70] Mines Safety and Inspection Regulations, Western Australia, 1995

It should be noted that, in accordance with the paragraph 4 “Application of regulations” of the Radiation Safety Regulations:
“In the event of an inconsistency between these regulations and —
- (a) the Radiation Safety (Transport of Radioactive Substances) Regulations 2002; or
- (b) any regulations relating to the mining or milling of radioactive ores made under the Mines Regulation Act 1946 2 or the Nuclear Activities Regulation Act 1978,

the regulations referred to in paragraph (a) or (b), as the case requires, shall prevail to the extent of the inconsistency.”[88]
Therefore, at mining and exploration sites the provisions of Part 16 – Radiation Safety of the Mines Safety and Inspection Regulations[70] are the primary regulatory instrument.

These regulations are supported by the set of guidelines detailing methods acceptable to the Resources Safety Division of the Department of Mines and Petroleum for implementing specific regulations.
Most of the earlier guidelines were developed in early 1990-s and there was a clear need to review and update them to reflect contemporary industry practice, current scientific knowledge, new developments in monitoring methods and international best practice in radiation protection. The review of the radiation safety guidelines was carried out in 2006–2008 period as a joint initiative between the Resources Safety Division at (then) the Department of Consumer and Employment Protection and the Radiation Protection Working Group of the Chamber of Minerals and Energy of WA.

The new guidelines adopt the current national approach to radiation protection and radioactive waste management in mining[122] and were published in 2008[123,124]. The suite of fourteen guidelines consists of the following documents:

1. Applying the system of radiation protection to mining operations

2. *Two guidelines describing radiation management plans:*
   2.1. Preparation of a radiation management plan – exploration
   2.2. Preparation of a radiation management plan – mining and processing

3. *Five ‘monitoring’ guidelines:*
   3.1. Pre-operational monitoring requirements
   3.2. Operational monitoring requirements
   3.3. Air monitoring strategies

[88] Radiation Safety (General) Regulations, Western Australia, 1983
[70] Mines Safety and Inspection Regulations, Western Australia, 1995
[122] Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing, Radiation Protection Series No.9, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2005
[123] Managing NORM – new guide, MineSafe Vol.17, No.1, May 2008 – Resources Safety Division of the WA Department of Consumer and Employment Protection
[124] Guidelines can be downloaded from: http://calytrix.biz/radlinks/tenorm/guidelines/index.htm and http://www.dmp.wa.gov.au/6745.aspx

   3.4. Airborne radioactivity sampling
   3.5. Measurement of particle size

4. *Three 'control' guidelines:*
   4.1. Dust control strategies
   4.2. Management of radioactive waste
   4.3. Transport

5. Radiation dose assessment
6. Reporting and notifying
7. Boswell – assessment and reporting database

These documents reflect the latest international best practice in radiation protection and are expected to form a foundation on which mining and exploration companies will base their radiation protection programs.

An additional important radiation protection document dealing with exposures to Naturally Occurring Radioactive Material (NORM) that may need to be consulted has been issued by ARPANSA in 2008[125].

Prior to the publication of the new WA guidelines the primary source of information for mineral exploration companies in Western Australia was a Draft Guide on Radiation Safety in Uranium Exploration from the Resources Safety Division of the Department of Consumer and Employment Protection of WA[126].

The document contained a number of the assumptions and values that were not entirely correct and it is strongly advised that radiation management plans of uranium exploration companies that were approved prior to 2008 are reviewed and amended to reflect the current requirements – particularly in regards to the radiation levels acceptable for the clean up of exploration sites and their final rehabilitation. Further discussion of this document is presented in Part 8.2.5.

Several guidelines need to be expanded in view of the possibility of uranium mining in WA, particularly documents addressing operational monitoring, airborne radioactivity sampling, dust control strategies and waste management. 'Boswell' (assessment and reporting database) will also need to be expanded to account for radon measurements.

The most important guideline that must be considered in management of radioactivity in the process of uranium exploration is the one describing the development of a radiation management plan for a uranium exploration site.

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[125] Safety Guide: Management of Naturally Occurring Radioactive Material (NORM), Radiation Protection Series No.15, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2008

[126] Radiation Safety in Uranium Exploration, Draft – version 6, Department of Consumer and Employment Protection of WA, 2007

In addition to the part describing elements to be included in the plan and to the 'check list' it also contains:

- Description of applicable government regulations and codes of practice,
- Basic principles of radiation safety and limits of radiation exposure,
- Guidance for the essential monitoring program and types of required monitoring,
- Control of radiation exposure in general and in regards to storage and handling of core and other mineral samples such as rock chips,
- Handling of potentially contaminated equipment, and
- Environmental management.

The last point requires specific attention due to the applicability of the WA Contaminated Sites Act to mining exploration site, as described below, in part 6.

There are several other guidelines applicable for the exploration of uranium:

- Queensland[84];
- Australian Northern Territory[127]
- Canada[128] (the Canadian guideline is a supplementary document to the other guidelines for the management of Naturally Occurring Radioactive Materials[129] that details the levels of radiation exposure for workers at which different levels of radiation protection measures and monitoring are applicable); and
- Argentina[130] (an adoption of the Canadian guideline);
- It is also known that the South Australian Environmental Protection Agency of SA has developed a specific document addressing radiation protection in mineral exploration. The official publication of this guideline is expected in a very near future.

It is believed that the 2008 Western Australian guide and the guideline from the EPA of South Australia (when published) are the most comprehensive and up-to-date documents. The latest (2008) Queensland guidance note is also worth noting but it, unfortunately, addresses only exploration activities undertaken within a boundary of a mining lease.

It should be borne in mind that not all available national and international guidelines describe the best practice. For example, the environmental, health and safety guidelines developed by the International Finance Corporation[131] recommend that

84 Radiation protection from naturally occurring radioactive material (NORM) during exploration, Guidance Note QGN12, Queensland Department of Mines and Energy, April 2008

127 Uranium Exploration – Health, Safety and Environment Management Guideline, Department of Primary Industry, Fisheries and Mines of the Northern Territory, 2006

128 Radiation Protection Guidelines for Uranium Exploration, Occupational Health and Safety, Saskatchewan Labour, Canada, 2006

129 Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM), Health Canada, 2000

130 Guideline on Radiation Safety and Protection [in Spanish], Energía Mineral S.A., Bases y fundamentos, Seguridad Radiológica, Argentina, 2007

131 "Environmental, Health and Safety Guidelines for Mining" by the International Finance Corporation (World Bank Group), 2007

where results are expected to show uranium or thorium mineralization in a grade of 0.15 percent by weight or greater, the recommended mitigation measures should be the implementation of a radiation dosimetry monitoring program for any areas where workers may be expected to receive whole body doses of greater than 6 milliSieverts in a year.

Whilst the principles of the guideline are correct, the numerical values appear to be too high. It appears that if the uranium grade is about 18 Bq/g (less than 0.15%) and people are expected to be exposed to 5.9 mSv/year there is no need to do anything at all. This is in direct contradiction with legislative documents such as, for example, WA Mines Safety and Inspection Regulations (1995) that state that radiation protection will need to be addressed at the site if there is a potential for workers to be exposed to radiation in excess of 1 mSv/year[70].

3.5. A separate issue – transport of exploration samples

It is generally unclear what regulations are applicable to the transport of uranium exploration samples and at which uranium concentration and/or volume the package needs to be labelled as 'radioactive material'.

The regulations applicable in Western Australia are the WA Radiation Safety (Transport of Radioactive Substances) Regulations 2002[132], which adopt the Australian Code of Practice[133].

A specific provision is available in current regulations, which are not applicable to:
"natural material and ores containing naturally occurring radionuclides, which have been processed, where the physical or chemical processing was not for the purpose of extracting radionuclides, provided the activity concentration of the material does not exceed 10 times the values specified in paras 401-406."

It is generally assumed this "10-times" exemption is applicable to the uranium exploration samples; however no reference to any statutory document was available until the review of Australian 'Transport' Code of Practice in 2008. The situation is, however, still not entirely clear and the uncertainty of the applicability of Transport Code to the transport of uranium (and other) exploration samples remains.

This new Australian Code of Practice[134] adopts the latest (2005) Transport Safety Regulations issued by the International Atomic Energy Agency[135] and the exemption clause referring to 'natural material' has now been changed to:

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[70] Mines Safety and Inspection Regulations, Western Australia, 1995

[132] Radiation Safety (Transport of Radioactive Substances) Regulations, Western Australia, 2002

[133] Code of Practice: Safe Transport of Radioactive Material Radiation Protection Series No.2, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2001

[134] Code of Practice: Safe Transport of Radioactive Material Radiation Protection Series No.2.1, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2008

[135] Safety Requirements TS-R-1, Regulations for the Safe Transport of Radioactive Material, International Atomic Energy Agency (IAEA), Vienna, 2005

"The Regulations do not apply to natural material and ores containing naturally occurring radionuclides that are either in their natural state, or have been processed only for purposes other than for the extraction of the radionuclides, and that are not intended to be processed for use of these radionuclides, provided that the activity concentration of the material does not exceed 10 times the values specified in para 401(b), or calculated in accordance with paras 402–406."

Additionally, the latest Safety Guide accompanying new Australian Code of Practice includes Annex B (Exemption Levels for Transport of Ores and Concentrates Containing Uranium or Thorium) that clearly states that ores and concentrates containing uranium are exempt from the transport requirements if the uranium content is less than 800 ppm (10 Bq/g uranium), provided that processing intended to remove radionuclides has not, and will not be undertaken.

There is an opinion that the exemption for 'natural material' cited above does not apply to uranium exploration samples because the ultimate outcome is to have a uranium mine that does extract uranium from the ore. As cited previously, "mining is a part of a chain of activities that starts with prospecting, continues with exploration and then the actual mining operations"[106]. Therefore, uranium mining would include uranium prospecting, uranium exploration and the actual mining operations; and the '10-times' exemption appears not to be applicable to exploration samples.

Additional argument is that the main test at a laboratory is the determination of the ore grade and will, therefore, involve 'processing' for the purpose of 'extraction of radionuclides'. On the other hand, even if the 'extraction of radionuclides' takes place in a laboratory, this 'processing' is certainly not undertaken 'for the use of these radionuclides' and the exemption appears to be applicable.

Additional complication arises from the fact that the exact uranium content in exploration samples cannot be determined at an exploration site and the WA Radiation Safety (Transport of Radioactive Substances) Regulations 2002 explicitly prohibit displaying 'radioactive' labels on packages/containers that do not contain radioactive material.

It is hoped that a clear regulatory guidance is provided on the matter of transport of uranium exploration samples in the near future.

The situation is much more clear in case of transport of uranium concentrate for processing (removal of radionuclides), where the limit of 80 ppm (1 Bq/g) will be applicable.

Additional uncertainly is associated with the requirement of the new Code of Practice that "conveyances" be added to the list of items that should be checked for surface contamination prior to transport (amended regulation 509). Whilst this is a common

[106] Handbook on Nuclear Law, International atomic Energy Agency (IAEA), Vienna, 2003

practice at uranium mining sites, it is not clear if it will be applicable to mining exploration companies, which may not be fully aware of this additional requirement.

Based on the information available and practical considerations, it is suggested that the '10-times' exemption provided in the Transport Code is, indeed, applicable to all exploration samples. Therefore, shipment of these samples should not be signposted as 'radioactive' unless there is a certainty that the grade of the ore is 0.08% or above.

It is, however, very important to note the applicability of <u>both</u> Radiation Safety (General) Regulations[88] and Radiation Safety (Transport of Radioactive Substances) Regulations[132] to the transport of uranium exploration samples.

As suggested above, Transport Regulations and the Code would not apply to exploration samples containing less than 0.08% uranium whilst they are being transported. However, WA Radiation Safety Regulation 28A(1)(b) states that the exemption from registration and licensing *for storage* can only be granted in a material is stored at a location for less than 24 hours. Therefore, if a shipment of exploration samples is awaiting transportation at a location different from an exploration site (storage depot, wharf, etc) for 24 hours or more – a company would need to apply for the license to 'store radioactive material', as legally this material is no longer considered to be 'in transport' and the '10-times' exemption no longer applies.

[88] Radiation Safety (General) Regulations, Western Australia, 1983
[132] Radiation Safety (Transport of Radioactive Substances) Regulations, Western Australia, 2002

4. Uranium Exploration – health effects

As mentioned above, most members of the public that could be exposed to radiation associated with uranium exploration are representatives of indigenous communities in the vicinity of a mining/exploration site. It is believed that exploration for uranium conducted in accordance with all relevant regulatory requirements and guidelines, cannot affect the health and safety of Aboriginal people any more than exploration for other minerals; and any health and safety effects are unlikely to be associated with radiation.

As detailed in a document of the Department of Consumer and Employment Protection of WA, "recently at a major WA exploration site where hundreds of thousands of tonnes of uranium ore were moved that involved 44 workers, the doses ranged from 0 to 0.33 mSv. The highest dose of 0.33 mSv was received over 786 hours."[126]

This value of *worker's* exposure is significantly lower than the limit of radiation exposure for members of general *public*. Even in a hypothetical case when the highest observed level of exposure is extrapolated for the complete working year (2000 hours), the value is expected to be below the 'public limit' of 1 mSv/year.

Two main pathways of radiation exposure from the list presented in part 1.7 that may be applicable are exposure to external gamma radiation and the inhalation of radioactive dust.

When modern drilling methods described in parts 2.2 and 2.3 are used in uranium exploration it is very unlikely that large amounts of dust will be generated. It is also unlikely that this dust will be dispersed by the wind far from the drilling site.

Furthermore, the concentrations of uranium in the dust are typically relatively low and accidental inhalation of such dust for short periods of time (several hours) is very unlikely to result in a detriment to human health. In fact, the internal exposure to the potentially radioactive dust generated in uranium exploration for several hours would be, in most cases, very difficult to quantify.

It also appears unlikely that members of the public may be exposed to external gamma radiation in excess of the natural background during the normal course of exploration, unless they visit drilling sites and sample storage areas whilst the exploration takes place. In these cases the data obtained by the monitoring of workers can be used for the assessment of possible doses received by visitors.

It is, therefore, concluded that any potential measurable radiation exposure for members of the public may only be caused by an unsuccessful and/or partial rehabilitation of the drilling site, after the exploration activity ceases.

[126] Radiation Safety in Uranium Exploration, Draft – version 6, Department of Consumer and Employment Protection of WA, 2007

5. Uranium Exploration – environmental impacts

Due to the fact that the indigenous population is likely to be the one most affected by uranium exploration and mining it is of utmost importance that not only occupational but all possible environmental impacts of uranium exploration are identified by both mining exploration companies and regulatory authorities.

It has been recognised internationally that – "Aboriginal groups are in some countries an integral part of dynamic ecosystems, for whom to separate 'man' from 'nature' is a convention with little meaning when dealing with environmental impact. The native cultures stress 'seven generations' as a reference for accountability. Science and all forms of knowledge are useful and desirable, but human experience and wisdom accumulated through generations remain the basis for judgement."[136]

The current view of the International Commission on Radiological Protection (ICRP) is that "that the standards of environmental control needed to protect the general public would ensure that other species are not placed at risk…"[115]

There was no international guidance as to how radiological protection of the environment should be implemented, particularly in situations where humans are not present. Examples of these situations are:

- Deep sea water, and
- Extremely remote areas of Western Australia where a group of people may only 'pass through' once every 10-20 years, or so.

Other similar situation is the case where the distribution of radionuclides in the environment is such that the exposure to humans would be minimal, but other organisms in the environment could be considerably exposed.

In recent years there has been an extensive discussion and many scientific conferences and workshops were held on the issue[137,138,139,140,141,142].

[136] Communications on nuclear, radiation, transport and waste safety: a practical handbook, International Atomic Energy Agency (IAEA) TECDOC-1076, April 1999

[115] Recommendations of the International Commission on Radiological Protection, International Commission on Radiological Protection (ICRP) Publication 103, 2007

[137] Effects of Ionizing Radiation on Terrestrial Plants and Animals: A Workshop Report, Publication No. 4494, ORNL/TM-13141, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA, December 1995

[138] Stakeholders' Conference on Approaches to the Management of Environmental Radioactivity, December 2002, Luxembourg, Radiation Protection Issue No.138, European Commission, 2002

[139] Radiation Protection of the Environment: The Path Forward to a New Policy? Workshop Proceedings, Nuclear Energy Agency (NEA), Organisation for Economic Co-operation and Development (OECD), 2002

[140] Radiological Protection of the Environment, Summary Report of the Issues, Nuclear Energy Agency (NEA), Organisation for Economic Co-operation and Development (OECD), 2003

[141] Protection of the Environment from Ionising Radiation: The Development and Application of a System of Radiation Protection for the Environment, proceedings of the Third International Symposium on the Protection of the Environment from Ionising Radiation held in Darwin, Australia, 26 July 2002, International Atomic Energy Agency (IAEA), Vienna, 2003

[142] Protection of the Environment: Current Status and Future Work, Report 03, International Union of Radioecology (IUR), 2002

A survey of environmental radiation protection in the law was also carried out.[143]

An improvement in the system of radiation protection was clearly necessary and in 2003 ICRP issued Special Recommendations for assessing the impact of radiation on the environment[144].

When the principles of the radiation protection of non-human species become available, it is expected that it will take a considerable amount of time for them to 'flow through' into the Australian legislative framework.

It appears, however, that a limited amount of monitoring of the effects of radiation on the environment is already being carried out at some uranium mining operations in Canada[145] and Australia[146].

It should be noted that Annual Reports of the Office of the Supervising Scientist[143] in Australia's Northern Territory detail, among other issues, the results of inspections of the sites where mineral exploration for uranium occurs. The inspection program involves representatives of the Office of the Supervising Scientist, the Northern Territory Department of Business, Industry and Resource Development and the Northern Land Council (acting on behalf of the Aboriginal Traditional Owners). Operational, recently completed and rehabilitated drill sites as well as various camp sites, water collection/pumping points, helicopter landing pads and roads associated with the campaigns were inspected. It was concluded that "…the level of environmental management performance generally being very good. There has been a significant improvement in the companies' environmental management over the past few years, such that the present standard is high."

It is deemed essential that a similar system of inspections addressing environmental management at uranium exploration sites in Western Australia be established as soon as possible.

The decision in regard to the success of the environmental rehabilitation of a particular site should not be based on the mining company's reports alone, but confirmed by independent measurements and assessments, preferably by a government department or an independent specialist, or both.

From the theoretical point of view, the potential impacts of radiation on the non-human species are similar to the impacts on humans and a summary is presented below:

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143 Environmental Radiation Protection in the Law, Nuclear Energy Agency, Organisation for Economic Co-operation and Development (OECD), 2007

144 A Framework for Assessing the Impact of Ionising Radiation on Non-human Species, International Commission on Radiological Protection (ICRP) Publication 91, 2003

145 Saskatchewan Uranium Mining: Public Consultation 2004, AREVA and Cameco companies, Canada, 2004

146 Supervising Scientist Annual Report 2000-2001, Part 2 – Environmental Assessments of Uranium Mines in the Alligator Rivers Region, 2001

- Flora (plants):
  - external gamma-radiation;
  - surface contamination (absorption of dust settling on leaves and branches and radon);
  - waterborne radioactivity (uptake of radionuclides via the root system).

- Fauna (animals and insects):
  - external gamma-radiation;
  - airborne radioactivity (inhalation of dust and radon);
  - waterborne radioactivity (ingestion of radionuclides);
  - surface contamination (on direct contact with a contaminated material);
  - ingestion of contaminated flora.

- Ground/soil/groundwater – subterranean organisms:
  - external gamma-radiation;
  - waterborne radioactivity (ingestion of radionuclides).

- Surface water – aquatic organisms (flora):
  - immersion – exposure to external gamma-radiation;
  - uptake of radioactivity from both sediments (via roots) and water itself.

- Surface water – aquatic organisms (fauna):
  - immersion – exposure to external gamma-radiation;
  - ingestion of aquatic flora.

- Atmosphere (fauna):
  - airborne radioactivity (inhalation of dust and radon);
  - ingestion of contaminated flora and fauna.

Having particular regard to Aboriginal practices, the exposure to radiation may be a result of not only *direct* pathways of radiation exposure such as external gamma-radiation, inhalation of dust/radon, and ingestion of drinking water, but also several *indirect* ones, such as:

- Ingestion of contaminated flora (both surface and aquatic),
- Ingestion of contaminated fauna (both surface, air and aquatic),
- Incidental ingestion of dust and soil (particularly for children).

The number of pathways of radiation exposure from the list presented in part 1.7 that may be applicable (and therefore may need to be monitored) should be determined on a case-by-case basis, depending on the local environment, the scale (both area- and time-wise) of exploration operations, and on the life style and practices of a particular community.

As almost no processing of samples (chemical or otherwise), apart from occasional core cutting, usually takes place at uranium exploration sites, the most common case would be the monitoring of the following media:

- Ground/soil – external gamma radiation and, in some cases, radon emanation rates;
- Air – concentrations of radioactivity in airborne dust and, in some cases, concentrations of radon and its decay products;
- Water – concentrations of radionuclides (typically uranium-238 and radium-226) in surface and/or ground water.

In certain cases samples of local flora and fauna should also be collected for future reference and comparison.

The results of the 'post-exploration' monitoring should be compared with the data obtained prior to the exploration operations taking place – to assess if the levels of radioactivity in any of the measured media are elevated and, if they are, to what degree. The general description of possible 'baseline monitoring' is given in the WA 2008 guideline on pre-operational monitoring requirements.

It is important to note that a broad monitoring program needs to be undertaken and all anomalies in radionuclides concentrations should be identified prior to the commencement of exploration activities. For example, it is possible that concentration of radium-226 in ground water would be 'naturally' elevated in areas of uranium mineralisation (in comparison with ground water in areas adjacent to the exploration lease). If this anomaly is not identified during the pre-operational stage, it may be attributed to the exploration (or future mining) operations of a company and a costly remediation program may subsequently be required.

A theoretical assessment of the radiation exposure to the members of the general public is then carried out and results are compared with appropriate limits.

It is expected that the result of this assessment will be used in the determination if a particular site is 'contaminated', as defined in the Western Australian Contaminated Sites Act 2003[147], in accordance with the criteria described in the following Part.

In the case of uranium mining operation the monitoring of environmental media (particularly water and air) should be carried out at a frequency that will allow for the early identification of any unusual increases in concentrations of radionuclides. Whilst the environment may, to some degree, become affected – the exposures to the members of the general public would be significantly reduced or avoided all together through the use of such an 'early warning system'.

[147] Contaminated Sites Act 2003, Western Australia

6. *Uranium Exploration – contaminated sites*

In relation to a particular site, the WA Contaminated Sites Act defines 'contaminated' as: having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value[147].

The Western Australian Department of Environmental Conservation classifies all known or suspected contaminated sites as follows:[148]

1. Report not substantiated
2. Possibly contaminated – investigation required
3. Not contaminated – unrestricted use
4. Contaminated – restricted use
5. Remediated for restricted use
6. Contaminated – remediation required
7. Decontaminated

The application of the WA Contaminated Sites legislation to sites potentially contaminated with radioactive material was presented at the meeting of the Radiation Protection Working Group of the Chamber of Minerals and Energy of WA on 18th of May 2007 and was later incorporated into the 2008 WA guideline on the management of radioactive waste:

1. **Report not substantiated:** there is no information to indicate the presence of contamination on the site.
2. **Possibly contaminated – investigation required:** there are grounds to indicate the presence of contamination at the site, but more information is required to confirm or dismiss the possibility of contamination.
3. **Not contaminated – unrestricted use:** after the investigation, the site was found not to be contaminated. The mean dose to a member of the critical group of the members of the general public is below the dose constraint of 0.3 mSv/y.
4. **Contaminated – restricted use:** the site is contaminated but suitable for restricted uses (e.g. the site may be suitable for the industrial, but not the residential use; or the site may be suitable for any land use, but restrictions on excavation and/or ground water use may apply). The mean dose to a member of the critical group of the general public is above the dose constraint of 0.3 mSv/y, but below the annual limit for the radiation exposure of 1.0 mSv/y.
5. **Remediated for restricted use:** the site that was contaminated has been remediated so that it is suitable for restricted use. The mean dose to a member of the critical group of the general public is above the dose constraint of 0.3 mSv/y per year, but below the annual limit for the radiation exposure of 1.0 mSv/y.

[147] Contaminated Sites Act 2003, Western Australia

[148] Contaminated Sites Fact Sheets 1-15, Department of Environmental Conservation (DEC), Western Australia, 2007

6. **Contaminated – remediation required:** the site is contaminated and remediation is required to ensure it does not present a risk to human health, the environment or any environmental value. The mean dose to a member of the critical group of the general public is above the annual limit for the radiation exposure of 1.0 mSv/y. In some very rare cases the value at which remediation is necessary may be increased to 3.0 mSv/y.
7. **Decontaminated:** The site has been remediated, is suitable for all uses and does not pose a risk to the environment or any environmental value. The mean dose to a member of the critical group of the members of the general public is below the dose constraint of 0.3 mSv/y.

Summary of Classifications (Action Levels)

Classification is based on the comparison of the level of radiation exposure of the members of the critical group of the members of the general public with both annual dose *limit* of 1 mSv/year and a dose *constraint* of 0.3 mSv/year.

- Unrestricted use: 0.0 mSv/y < DOSE < 0.3 mSv/year
- Restricted use: 0.3 mSv/y < DOSE < 1.0 mSv/year
- Remediation necessary in most cases: 1.0 mSv/y < DOSE < 3.0 mSv/year
- Remediation necessary in all cases: DOSE > 3.0 mSv/y

It is believed that the values selected in the guideline are appropriate:

- The highest possible value of exposure (3.0 mSv/year) under which environmental remediation of a site may not be necessary (naturally, only in extraordinary circumstances) is the same as the “the dose criterion for the designation of radioactively contaminated land”, that is applicable in the United Kingdom[149].

- In typical situations, the level for the classification of the site as ‘contaminated’ is the same as the limit of radiation exposure for the members of the general public, 1.0 mSv/year.

- The dose constraint of 0.3 mSv/year is in line with current recommendations of the International Atomic Energy Agency: “For the unrestricted use of a site, it should be ensured… that the effective dose to a member of a critical group is kept below the dose constraint of 300 microSv in a year. For the restricted use of a site it should be ensured that, with restrictions in place, the effective dose should not exceed the dose constraint of 300 microSv in a year and that if the restrictions were to fail in the future the effective dose should not exceed 1 mSv in a year.”[107]

In the practical application of these values (having a particular regard to Aboriginal culture and practices) it may be necessary to carry out additional radiation protection

[149] Dose Criteria for the Designation of Radioactively Contaminated Land, RCE-2, Advice from the Health Protection Agency, United Kingdom, March 2006

[107] Safety Guide WS-G-5.1 Release of Sites from Regulatory Control on Termination of Practices, International Atomic Energy Agency (IAEA), Vienna, 2006

studies, particularly in situations where the distribution of radionuclides in the environment is such that the exposure to humans would be minimal, but other organisms in the environment could be considerably exposed.

It will also be necessary to determine if all radionuclides in the uranium decay chain stay in secular equilibrium to confirm that different elements (such as radium-226 and lead-210) are not leaching into the ground water or concentrating in the food chain.

As described in Part 5 above, higher than "usual" radium concentrations in ground water may be expected in the areas of uranium mineralisation and it is in the best interest of the exploration company to obtain 'baseline' values of these concentrations *prior* to the commencement of exploration. In this case elevated radium levels in ground water will not be mistakenly attributed to the exploration activities.

In the estimation of the level of potential radiation exposure the applicability of all possible pathways of radiation exposure (listed in part 1.7) must be assessed and the exposure through those pathways identified as applicable, measured and assessed.

The detailed guideline addressing the classification of contaminated sites is expected to be published by the Radiological Council of Western Australia in early 2009.

7. Exploration, mining and Aboriginal population – general comments

This document would be incomplete without a discussion of the relationship between exploration and mining companies and the Aboriginal population, both in general terms and with a specific emphasis on uranium.

This issue is, unfortunately, not usually of a high priority to many people. A clear illustration of this fact is the poll on uranium mining and the 135 comments received on the Perth Internet site 'Perth Now'[150], immediately following the announcement of the WA Government's change in policy on uranium mining. Out of a total 882 votes in the poll (as on 25th of November 2008) 58% agreed with the lifting of the ban and 42% disagreed. An analysis of all comments showed a similar (60/40) split between readers but what is disappointing is that not one out of 135 comments mentioned a potential impact of uranium mining on Aboriginal populations that would be affected.

The main recommendation of the International Institute on Environment and Development report on encounters between indigenous peoples and mining industries is to extend the environmental precautionary principle to the impact of mining on indigenous peoples: "Non-indigenous stakeholders in mining shall use the precautionary approach to protect the indigenous peoples and the environment that supports them. Mining cannot take place on indigenous lands without their prior informed consent and participation in their self-defined indigenous development. Where there are threats of serious or irreversible damage, scientific and economic uncertainty shall not be used to postpone cost-effective measures to avoid and mitigate risks to indigenous livelihoods and cultures."[151]

Specific issues associated with the impact of uranium mining on Aboriginal communities were identified in the Australian House of Representatives Report in 2006[1] and four main ones are:

1) Social impact and its monitoring,
2) Consultation practices and processes,
3) Employment and training opportunities, and
4) Limitations of the Aboriginal Land Rights Act.

A number of guidelines exist in Australia, describing recommended approaches for mining companies in working with Aboriginal communities, both by State[152,153] and Federal[154] Governments.

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[150] 'Perth Now', http://www.news.com.au/perthnow/, 18-19 November 2008

[151] Downing, Theodore E. *et al.*, Indigenous Peoples and Mining Encounters: Strategies and Tactics, International Institute for Environment and Development Report No.57, April 2002

[1] Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[152] Manual for Applicants for Exploration Tenements, Native Title Procedures, Mineral Resources Act 1989, parts 12,15,16,18 & 19, Department of Mines and Energy, Queensland, September 2000

[153] Working with Aboriginal communities: A practical approach, Department of Industry and Resources of WA, 2005

[154] Guidelines for Indigenous Participation in Natural Resources Management, Commonwealth of Australia, 2004

In Western Australia, one of the guidelines developed by the Department of Industry and Resources (DoIR) specifies, "the provisions of the Aboriginal Heritage Act 1972 (WA) are endorsed on all tenements. The Department of Industry and Resources (DoIR) gives companies a set of guidelines… to help them comply with the legislation."[72]

The document referred to in the quote above[155] details the legislative requirements and describes methods for a mineral exploration company to consult with Aboriginal organisations. As a supplement, several flow charts were also developed[156,157,158].

Indigenous perspectives of uranium mining and exploration are presented in the Aboriginal Law Bulletin[159] and in submissions to the Australian House of Representatives Standing Committee on Industry and Resources inquiry into the development of the non-fossil energy industry in Australia. There were submissions from the Northern Land Council[160,161] and from the Gundjeihmi Aboriginal Corporation[29], which should be read in conjunction with the corrections provided by the Department of the Environment and Heritage[162]; as well as in the resolution of the Indigenous World Uranium Summit in 2006[163,164] and in another paper from Western Australia[165].

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[72] Mineral Exploration and Productive Mining – Approvals and Responsibilities Required by the Government, Guideline, Department of Industry and Resources of WA, March 2003

[155] Guidelines for Consultation with Indigenous People by Mineral Explorers, Department of Industry and Resources of WA, 2004

[156] Native Title Act 1993 (Commonwealth) Future Act Provisions, Right to Negotiate Process for Mining Lease Applications, Department of Industry and Resources of WA, 2004

[157] Native Title Act 1993 (Commonwealth) Future Act Provisions, Right to Negotiate Process for Onshore Petroleum Title Applications - Exploration Permit, Drilling Reservation, Retention Lease and Production Licence, Department of Industry and Resources of WA, 2004

[158] Native Title Act 1993 (Commonwealth), Expedited Procedure for Mineral Exploration Licence Applications, Department of Industry and Resources of WA, 2004

[159] Uranium Exploration in the Rudall River National Park: An Aboriginal Perspective, Aboriginal Law Bulletin, 1987

[160] Submission No.78, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[161] Submission No.78-1, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[29] Submission No.44, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[162] Submission No.55-1, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[163] Uranium Hype Hits Indigenous Opposition Globally, Provokes Conflict in the North, The Indigenous World Uranium Summit, Mine Watch Canada, 7 February 2007

[164] Declaration of the Indigenous World Uranium Summit, 2 December 2006

[165] R. Williams, Normandy Poseidon Ltd, "Mineral Exploration Activities and Aboriginal Heritage Sites: Finding the Right Approach with Balance", in: "Mineral Exploration in an Environmentally Conscious Society", Australian Institute of Geoscientists, Bulletin No.11, 1991, pp.35-39

It is also interesting to note that, as a result of the large number of uranium mines on their land, special government agencies were created by the Navajo Nation in the USA to deal with reclamation and remediation activities, as well as environmental protection on their Tribal lands; a brief description is available in one of the documents of the US Environmental Protection Agency[111].

Industry viewpoints on uranium mining and exploration are presented in the submissions to the abovementioned Australian Parliamentary inquiry from the Uranium Information Centre[34] and the Minerals Council of Australia[166], and were highlighted in the process of inquiry's hearings – by Cameco Corporation[167], Heathgate Resources[20], Compass Resources[21], and Nova Energy[168].

Additional information is available in chapter 7 of the 'Uranium Industry Framework' report[3] and in a detailed report from Canada on Aboriginal Participation in Mining[169].

More information that may be of relevance is available in the report for the Environment Centre Northern Territory and the Australian Conservation Foundation, describing the exploration of uranium in West Arnhem Land and commenting that "Aboriginal concerns about uranium need to be seen within the context of past actions by the mining industry and government, the bulk of which have ignored the basic land and human rights of the indigenous people"[170].

This fact was recognised as valid by the Chief Executive Officer of the Minerals Council of Australia, M. Hooke, who stated that: "…the criticism of the industry's performance in that area of a decade and a half ago is quite valid. You will find that the industry will

[111] Technologically Enhanced Naturally Occurring Radioactive Materials from Uranium Mining, Volume 1: Mining and Reclamation Background, US Environmental Protection Agency, 2006, pp.AVI13-AVI14

[34] Submission No.12, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[166] Submission No.36, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[167] Committee Hearing, 11 August 2005, Canberra, p.2 and 5-6, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[20] Committee Hearing, 19 August 2005, Melbourne, p.96,99-100,102, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[21] Committee Hearing, 16 September 2005, Sydney, pp.66, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[168] Committee Hearing, 23 September 2005, Perth, p.80, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

[3] Uranium Industry Framework: Report of the Uranium Industry Framework Steering Group (September 2006), pp.43-48

[169] Report on Aboriginal Participation in Mining, Sub-committee of the Intergovernmental Working Group on the Mineral Industry, Canada, September 1993

[170] Uranium Exploration in West Arnhem Land, Report for the Environment Centre Northern Territory and the Australian Conservation Foundation, November 2001

tell you that it is quite valid. If you had to pick something that has been a paradigm shift in the operations of the Australian minerals industry, I suspect that would be right up the top. …We have not only proclaimed our respect for rights, cultures, interests and special connections to land and waters but also practised and performed it."[171]

It is important to note the Australian Parliamentary Committee finding that –
"Despite professing concern that Indigenous groups be consulted, environmental groups revealed that, should Traditional Owners approve a mining development, they would still oppose uranium mining. This seems to support the observation made by one submitter who remarked that Aboriginal groups are being used by some 'no development' groups to support their opposition to uranium mining. Traditional Owners' views are clearly *not* to be respected if they happen to support resource development."[1]
The above argument is based on the statements made by the representatives from 'Friends of the Earth' during one of the hearings of the Parliamentary Committee.[20]

It is, however, not less important to note that, whilst some individuals may hold such an opinion, 'Friends of the Earth' and several other non-government organisations overall have clearly argued and campaigned for increased Indigenous land control and decision-making rights. A clear example is the work against the special legislation covering the operations at the copper-uranium mine at Olympic dam in South Australia that overrides the SA Aboriginal Heritage Protection Act. In addition, it appears that non-government organisations would continue working with Aboriginal communities even if the consultation process results in a particular community supporting a certain exploration and/or mining project – which this non-government organisation opposes.

The Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) prepared a document of a particular interest dealing specifically with health hazards to Aboriginal communities[172].

The main conclusions of the document are that –

"…a significant overall increase in the incidence of cancer among people in the Kakadu region which is ninety percent greater than would be expected" was identified, and

[171] Committee Hearing, 5 September 2005, Canberra, p.32, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006
[1] Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006, p.567
[20] Committee Hearing, 16 August 2005, Melbourne, pp.66, Australia's uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006, pp.63-63 and 59-60
[172] Aborigines and Uranium: Monitoring the Health Hazards, Research Discussion Paper Number 20, Australian Institute of Aboriginal and Torres Strait Islander Studies, December 2006

"…existing data sets are not adequate to identify a definitive cause for the increased cancer incidence. There could be reasons for the high cancer rates other than proximity to uranium mining and milling".

It is concluded, "there is an urgent need for continued, comprehensive monitoring of health wherever uranium mining occurs, and for at least twenty years after mines cease operation."

As the authors of the document themselves state, the results have to be regarded as a preliminary finding only and further investigation is required.

The conclusion about the increase in cancer occurrence in the Kakadu population in 1994-2003 was made by comparison of the number of *actual* cases with the *expected* values. It was not considered appropriate to use rates of cancer incidence of predominantly non-Aboriginal populations (such as total Australian or total Northern Territory rates) in calculations concerning an exclusively Aboriginal population. The comparison principle appears to be correct, but it would be very useful to have the cancer rates compared with other populations as well, at least for reference purposes.

It also not entirely clear from the document how the overall value was calculated and why it is 90% higher than the expected number of cases. It is noted that –

- the actual number of lung cancer cases was slightly higher but not statistically significant,
- the actual number of thyroid cancer cases was slightly lower than expected but also not statistically significant,
- there were no more than two cases of any particular cancer diagnosed in Aboriginal persons in the Kakadu Region in this ten-year period and none or only one case for most cancers, including thyroid (no cases), leukaemia (no cases) and lymphoma (one case),
- the excess of all cancers combined is not due to an excess of any particular cancer.

The document does not specify how the value of 27 actual cancer cases was calculated (describing what particular types of cancer were taken into account) and how the value of 14.4 expected cancers was estimated. If table 1 of the document were to be expanded, the reasons for the main conclusion of the report would be much clearer.

If an increase in cancer rates for the Aboriginal population is confirmed, there will be, indeed, a need for some monitoring. It is likely, however, that it will be necessary to link particular cancers with particular possible radiation exposures.

As it is correctly pointed out in the report, the "environmental monitoring program focuses on water quality guidelines, monitoring radiation accumulation in local aquatic flora and fauna, and modelling the hypothetical contribution to human radiation dose accumulation."

Monitoring of actual radiation exposures for members of the general public is, on many occasions, very difficult since the equipment used in monitoring of ionising radiation has certain minimum detection limits, there are many varieties of this type of equipment and calibration facilities, and it is likely that even the best gamma radiation monitor would have a systematic error of about 5 to 10 percent (meaning that, for example, several consecutive readings taken with the same monitor at the same location may differ by 5-10%).

It is, therefore, important to have the environmental monitoring data available, so when the exposure cannot be measured, it can be at least estimated with a reasonable degree of accuracy. Also, as mentioned above, monitoring of the impacts of radiation on the environment is as important as monitoring of the impacts of radiation on humans.

The application of the precautionary principle in this case may be warranted, but probably after (and if) the higher incidence of cancer in Kakadu population is confirmed, either by additional data from the research already conducted, or by undertaking further studies.

The implementation of the precautionary principle to situations involving radiation exposure is different to many other similar situations. It is evident that there is a scientific uncertainty in regards to the effects of exposures to low levels of ionising radiation (as described in part 1.5) and, *as a precaution*, a Linear No Threshold theory is applied in radiation protection – assuming that at low doses the risk of health effects, whilst almost negligible, still exists.

Therefore, it is very important to bear in mind that the *compliance* with radiation protection legislation by not exposing workers and members of the public above specified limits *is already an application of the precautionary principle*.

Therefore, acceptable uranium exploration and mining could be defined by:

- Strict compliance by each company with the standards of radiation exposure for both workers and the members of the general public (including keeping these exposures not “just below the limit”, but also “as low as reasonably achievable”);

- Assessing, where applicable, the impacts of ionising radiation on the local environment – both during the exploration process and upon the completion of the drilling program (in case of exploration), and throughout the life of the mine and beyond (for mining operations); and

- Effective control over the management of radiation protection at an exploration/mining site by the relevant government department – by both providing regulatory directions and advice and by carrying out regular inspections of the level of compliance with best practice radiation protection guidelines.

The relevant legislation is currently in place (as described in part 3.4) and would only require minor adjustments, on a guideline level. However, as a significant expansion of uranium exploration in Western Australia is expected to be followed by the opening of one or more uranium mines within the next few years the third principle requires urgent attention.

It is imperative that WA government provides for sufficient resources (mainly qualified personnel) to be allocated for the control of uranium exploration and mining, as soon as possible. The fact that during inspections in November 2007 it was discovered that there was an "82 percent failure rate in obeying environmental conditions"[173] by exploration and mining companies serves as illustration. It is also essential that inspections by the government departments are carried out promptly, particularly of the exploration sites that have been rehabilitated and would have to be fenced off as a 'restricted access area' until such inspection is carried out and the success of rehabilitation is confirmed.

As the mining process is still some time in the future, there is an opportunity at the moment to employ local technically qualified people (preferably without pre-conceptions about radiation and its effects) and train them over the next few years, to ensure that when the first uranium mine opens in the State there are sufficient resources to control all the relevant processes. Alternatively, interstate and/or overseas personnel that might not be fully aware of the specifics of WA mining will be required to provide the skills and service on a "short notice basis" and, of course, at quite considerable expense.

[173] Renegade miners could lose tenements, K. Campbell, The West Australian, Wednesday, November 14, 2007, p.11

8. Radiation and the law

8.1. General remarks

Several publications dealing with the legal aspects of exposures to ionising radiation are available. A general overview was presented by the US Atomic Energy Commission to the International Radiation Protection Association meeting in 1973[174] and is also available in several publications from both USA[175,176,177,178] and UK[179,180] sources.

It appears that, in the majority of cases in the USA, it was found that the standard of ALARA (As Low As Reasonably Achievable) is not a "standard of care" and that "numerical federal permissible dose limits provide the sole standard".

It is also interesting to note that in one recent court case in the USA[181] it was found that a person could sustain 'compensable injury' simply from fear of radiation. This particular case was a result of a truck driver's contact with a leaking container that was mistakenly labelled as radioactive waste. Although the driver suffered no physical injuries and was not actually exposed to radiation, the court determined that the driver's post traumatic stress disorder, depression, fatigue and anxiety were rationally connected to his contact with the hazardous material; and are, therefore, compensable under Tennessee's Workers Compensation Act.

8.2. Uranium exploration – Western Australia

One recent case of importance to all uranium exploration companies in Western Australia is *Wilma Freddie and Others*[182], as paragraph 21 of the National Native Title Tribunal determination lists five conditions that appear to be sufficient for a mining company to guard against the hazards, both environmental and human health related, associated with uranium exploration – from a legal perspective. These conditions are addressed in detail below.

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174 C.F. Eason, N.Y. St Denis, The Law and Low Level Radiation, presented at the congress of International Radiation Protection Association (IRPA), Washington, USA, 1973

175 D. Wiedis, D. E. Jose, K. Komer, An Overview of the Current State of Radiation Litigation, Health Physics, vol.81, No.3, September 2001, pp.253-259

176 D. Wiedis, D. E. Jose, K. Komer, A Radiation Litigation Causation Analysis which Achieves Fairness to Both Litigants, Health Physics, vol.81, No.3, September 2001, pp.260-264

177 S.E. Mervin, D.W. Moeller, W.E. Kennedy, M.P. Moeller, Application of the Supreme Court's *Daubert* Criteria in Radiation Litigation, Health Physics, vol.81, No.6, December 2001, pp.67-677

178 J. Masten, J. Strzelczyk, Admissibility of Scientific Evidence Post-*Daubert*, Health Physics, vol.81, No.6, December 2006, pp.678-682

179 W.J. Leigh, R. Wakeford, Radiation Litigation and the Nuclear Industry – The Experience in The United Kingdom, Health Physics, vol.81, No.6, December 2001, pp.646-654

180 S.R. Jones, J.A. Coote, A.J. Shittleworth, A Claim for Damage to Property by Radioactivity, presented at the congress of International Radiation Protection Association (IRPA), Montreal, Canada, 1992

181 Saylor v. Lakeway Trucking S.W.3d 2005 WL 3163521 (Tenn., November 29, 2005)

182 *Wilma Freddie and Others* on behalf of the Wiluna Native Title Claimants/ Western Australia/ Globe Uranium Ltd, [2007] NNTTA 37 (14 May 2007)

8.2.1. Relevant legislation

The grantee party undertakes to be bound by relevant legislation and to work according to relevant guidelines regarding radioactive substances as defined by authorities such as the Australian Radiation Protection and Nuclear Safety Agency.

a) The fact that ARPANSA has issued a Code of Practice for a particular activity does not mean that this Code is immediately applicable to this activity in Western Australia. As described above in part 3.4, the ARPANSA Code for mining and mineral processing[122], whilst used by both government and industry in the development of guidelines and radiation management plans, is legally not in force in the State of Western Australia until such time as the relevant regulations have been officially amended to include the Code.

It could be argued that there is no necessity for the Code to be incorporated into regulations, as appropriate provisions can be made under existing WA laws, such as the Mining Act, Mines and Safety Inspection Act and Environmental Protection Act; through the approvals of Programs of Work, Mining Proposals, Radiation Management Plans and the imposition of tenement/licence conditions. These measures, however, would address only specific parts of mining and minerals processing industry in Western Australia (or specific companies) and, therefore, any legal references to the Code should be treated with caution.

It would be more appropriate for the company to be bound by the WA Mining Act, WA Mines Safety and Inspection Regulations (Part 16 – Radiation Safety), and associated guidelines (2008), administered by the WA Department of Mines and Petroleum; and by the WA Radiation Safety and Radiation Safety (Transport of Radioactive Substances) Regulations, administered by the WA Radiological Council.

b) It appears that the statement by the company that it is "complying with the Radiation Safety Manual and Uranium Guidelines" may not be sufficient in all cases. It is further explained in paragraphs 24 – 26 (of *Wilma Freddie and Others*), that the actual reference is to the Radiation Management Plan as defined in WA Mines Safety and Inspection Regulations. As described in part 3.4 above, it is strongly advised that radiation management plans of uranium exploration companies that were approved prior to 2008 are reviewed and amended to reflect the current requirements – particularly in regards to the radiation levels acceptable for the clean up of exploration sites and their final rehabilitation.

It is also highlighted (in the Conclusion of the *Wilma Freddie and Others*) that:
"…It also appears that the protection relating to the 'critical groups' of the general public is based on the existence of such persons in permanent communities in the vicinity of the exploration activity and not persons who may exercise their native

[122] Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing, Radiation Protection Series No.9, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2005

title rights and interests by travelling through the area… There is no mechanism or requirement to consult with native title claimants who may visit the area where exploration is taking place”[179].

This concern has now been alleviated (at least to some degree), after the publication of the new WA guideline on the requirements for pre-operational monitoring. Among other requirements, the guideline recognises that in some cases identification of the ‘critical group’ may not be possible. The guideline specifies that in this situation, there still will be a need for a mining company to demonstrate that the impact of the particular activity on the local environment is minimal or negligible; and a reference plant/animal may need to be selected for the study (after consultation with an appropriate authority). This requirement brought the application of radiation protection in Western Australia in line with best practice in environmental protection from ionising radiation.

8.2.2. Radiation safety officer

The grantee party undertakes to have a trained Radiation Safety Officer (as defined by the Australian Nuclear Science and Technology Organisation training standards) on site at all times.

a) This comment may be incorrect as it appears that Australian Nuclear Science and Technology Organisation (ANSTO) did not set a specific training standard for radiation safety officers in the area of mining and mineral processing.
It is also not clear how many specialists with extensive *practical* experience of radiation management in mining and mineral processing environment capable of providing this type of training are working in ANSTO at present (or proposed to be employed for this purpose in the near future). The training programs that are based mainly on theoretical knowledge, whilst useful, are unlikely to provide sufficient information for site radiation safety officers that require ‘hands-on’ knowledge.

b) The current shortage of radiation safety officers was mentioned in the Australian Parliamentary report on Australian uranium[1] and detailed in the Uranium Industry Framework as follows:
“There is a shortage of radiation safety officers (RSO’s) available to work in the uranium industry to ensure that uranium operations meet radiation health and safety requirements. This shortage is expected to become a major barrier if there is a significant expansion in uranium production.
“RSO’s will also be required to work in a regulatory role for various government departments. While radiation courses related to medical and occupational hygiene are available, there are currently no existing training courses in the specific skills

[179] *Wilma Freddie and Others* on behalf of the Wiluna Native Title Claimants/ Western Australia/ Globe Uranium Ltd, [2007] NNTTA 37 (14 May 2007), para [87]

[1] Australia’s uranium – Greenhouse friendly fuel for an energy hungry world, The Parliament of the Commonwealth of Australia, House of Representatives, Standing Committee on Industry and Resources, Canberra, November 2006

required by uranium mine operators and regulators. The development of an accredited course would assist in defining standards and skills in this industry.
"Previous Mining Code guidelines have required RSO's to have tertiary qualifications, preferably in the physical sciences, and at least five years experience in radiation protection in the mining industry. Senior RSO's also require site experience. There are few skilled personnel in Australia who can meet these requirements. A graded approach depending on the scale of the operation is recommended in the Mining Code's safety guide."[3]

There are, indeed, a very limited number of persons in Australia who can qualify to be a radiation safety officer for mining and mineral processing and it appears that there are no training opportunities that provide education to a required standard.

c) As described above, there are currently no existing courses in Australia that provide specific skills required for both the industry and the government in the area of mining and processing of radioactive materials. Short one-day courses and workshops[183] are not expected to provide training sufficient for the RSO level.

The most relevant event so far is the five-day training course that is regularly conducted by one of the radiation protection consultants[184]. Another company also appears to be planning to conduct such a course[185], but no additional information in regard to its contents and the qualifications of presenters is currently available.

Both of these 5-day courses, however, do not match the requirements specified in the Uranium Industry Framework Report, which states that "it is expected that participants in the course would have relevant qualifications, industry experience, or both, and that a short course (a few weeks) followed by six to 12 months of on-site training under the guidance of a mentor would be required before a final assessment".[3]

d) A number of other documents, both from Australia[186] and other jurisdictions[187,188] specify that a radiation safety officer must be, indeed, tertiary qualified and have some years of experience in radiation protection; and the general requirements for

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[3] Uranium Industry Framework: Report of the Uranium Industry Framework Steering Group (September 2006), p.29

[183] Radiation Protection in Uranium Exploration Seminar, 14 September 2007, Adelaide, Australasian Radiation Protection Society (ARPS)

[184] Theory & Practice of Radiation Safety in Uranium, Mineral Sands, and Rare Earths Mining and Processing, Radiation Advice & Solutions Pty Ltd, 2009

[185] Radiation Safety Officer (RSO) full course, Mining Radiation Safety, 2008

[3] Uranium Industry Framework: Report of the Uranium Industry Framework Steering Group (September 2006), p.32

[186] Draft Radiation Guideline: Radiation Safety Officers and Radiation Safety Committees, Environmental Protection Authority, New South Wales, 2002

[187] Safety Guide RS-G-1.4, Building Competence in Radiation Protection and the Safe Use of Radiation Sources, International Atomic Energy Agency (IAEA), Vienna, 2001

[188] The Swedish Radiation Protection Institute's General Advice on the Competence of Radiation Protection Experts; SSI FS 2000:6, Swedish Radiation Protection Institute, (SSI), 2000

obtaining full qualifications are available from a training course designed by the International Atomic Energy Agency[189].

e) In Western Australia the only legal requirement for the person to become a radiation safety officer for mining and mineral processing is to comply with the requirements of the Mines Safety and Inspection Regulation 16.7(2), which states "to be eligible for appointment as a radiation safety officer a person must have qualifications and experience satisfactory to the State mining engineer."[70]

   Further guidance describing the required qualifications and experience is available in the new guidelines supporting the Regulations. The general requirement is that a radiation safety officer will need to have between 6 and 18 months of on-site training under the guidance of a mentor prior to the official appointment, depending both on the qualifications and experience of the person and on the level of radiation hazard at a particular operation. Tertiary qualifications and the successful completion of both 'surface ventilation officer' and five-day 'radiation safety officer' courses are also pre-requisites for the RSO's official appointment.

The education courses currently available[184,185] appear to be adequate for the training of radiation safety officers for uranium exploration, and an external consultant may be employed by a company to develop specific plans and procedures, for the cases where complex dose assessments (including the exposures to biota) need to be carried out, and when a 6–18 months' mentorship of a site's future RSO is required. There is also a clear need for the development and delivery of a specific training course for radiation safety officers in mining and mineral processing, and it may be possible that such course will be available in Western Australia in 2009.

Currently 'Government Skills Australia' is conducting a series of workshops across the country, with an aim to develop mutually agreed units of competency for those working in fields that involve radiation protection. Two of the "national industry consultation" topics are 'uranium and mineral sands mining' and 'radiation safety officers' and it is expected that relevant industry standards will be developed.

8.2.3. Education of employees and general safety

The grantee party undertakes that all employees on site will receive general radiation safety training and that it will maintain a safe working environment for all employees.

It is expected that the education could be provided for employees at a relatively low cost (typically a one day course); other courses may be developed in the future

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[189] Training Course Series No.18, Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources, Standard Syllabus, International Atomic Energy Agency (IAEA), Vienna, 2002

[70] Mines Safety and Inspection Regulations, Western Australia, 1995

[184] Theory & Practice of Radiation Safety in Uranium, Mineral Sands, and Rare Earths Mining and Processing, Radiation Advice & Solutions Pty Ltd, 2009

[185] Radiation Safety Officer (RSO) full course, Mining Radiation Safety, 2008

(including the ones that may be run either off-site or 'in-house' by a qualified consultant).

It is also expected that the safe working environment will have to be maintained at the exploration site, in line with applicable regulations and guidelines. It should be borne in mind that radiation is only one (relatively minor) element of the occupational health and hygiene program at a drilling site. In addition to complying with general safety requirements, a company will also need to ensure that the workers are protected from excessive noise and heat, for example.

8.2.4. Dust reduction measures

The grantee party undertakes to establish procedures that ensure there is as little exposure as possible of the workforce and of the public to dust contaminated with radioactive material during exploration.

As described in part 2.3, numerous methods for the reduction of the levels of dust are available and it is likely that in some situations workers will not need to wear any respiratory protection – particularly when they are instructed not to stay downwind when the cyclone is being 'blown' (cleaned) and dust is likely to be generated. It is also not expected that dust from drilling will travel far from the drill hole, particularly when water is regularly used for dust suppression.

8.2.5. Environmental rehabilitation

The grantee party undertakes to return any site of ground disturbance to a condition prescribed by relevant regulatory guidelines for environmental rehabilitation to its original state or so that it poses no radiation threat to the public.

a) Unfortunately, the earlier DoCEP guideline[126] contained the suggestion that "drill sites must be cleaned to 1 microSievert per hour at a height of 1 meter (excluding any natural mineralized outcrops in the area)" that was in direct contradiction with the requirement of the return of the site to its original state.

b) The use of the clean up criterion of "less than 1 microSievert per hour" would result in an unacceptable radiation exposure to members of the general public. Even when only the exposure to external gamma radiation is considered in a dose assessment (not taking into account any other exposure, such as inhalation of dust and ingestion of soil and flora/fauna), the dose constraint of 0.3 mSv/year that is used for classification of contaminated sites (part 6) will be reached in less than two weeks (300 hours or twelve and a half days) of the permanent occupation of the site.

[126] Radiation Safety in Uranium Exploration, Draft – version 6, Department of Consumer and Employment Protection of WA, 2007

The possibility of Aboriginal people camping on the particular former drilling site for about two weeks or more cannot be ruled out. Therefore, the criterion mentioned above is unacceptable and emphasises the requirement for all radiation management plans approved prior to 2008 to be re-assessed and amended where necessary, as soon as possible.

8.2.6. Additional comments

The requirements for qualifications and experience of a person to become a radiation safety officer for mining and mineral processing in Western Australia are described in an appendix to the first of 'NORM' Guidelines issued in 2008 by the WA Department of Consumer and Employment Protection (now Department of Mines and Petroleum) and the Chamber of Minerals and Energy of WA[124].

As clearly stated in the Foreword, –
"The guideline is not a substitute for regulations and compliance with it is not mandatory. However, to the extent practicable, industry is encouraged to follow this publication to ensure uniformity in radiation safety management."

Therefore, it is expected that all companies would follow this guideline and contact the WA Department of Mines and Petroleum *prior* to the appointment of a radiation safety officer whose qualifications and experience are significantly different from those detailed in the document.

A typical requirement is for a radiation safety officer is either to be located on site or to be easily reachable; and a possible rejection of a statutory appointment due to insufficient qualifications and/or experience of a person may delay the commencement of the exploration program.

It is not uncommon for exploration and mining companies to employ contract radiation safety officers and engage other 'consulting' companies in relevant training, monitoring and the management of radiation in general.

If this option is considered, it is strongly advised that no 'contract' person or a company is engaged unless it is clearly demonstrated that their qualifications and experience are relevant and sufficient to carry out the tasks to the required standard:

- It should be ensured that the monitoring is undertaken in accordance with all relevant Australian Standards and using properly calibrated equipment – to guarantee that the results of this monitoring are technically and legally valid and, therefore, acceptable for the purpose of statutory reporting.

[124] Guidelines can be downloaded from: http://calytrix.biz/radlinks/tenorm/guidelines/index.htm and http://www.dmp.wa.gov.au/6745.aspx

There have been cases of people not previously involved in any way with mining and mineral processing industry and/or particular chemical and thermal mineral processing techniques undertaking measurements, carrying out training and providing advice to companies on the management of radiation; both overseas and in Australia – with abysmal results.

It is likely that the 'general' theoretical knowledge of radiation and relevant monitoring methods only would be insufficient in mining and mineral processing industry.

The requirements for an additional knowledge that a radiation protection specialist / adviser in mining and mineral processing industry is expected to possess vary and would typically include:

- Exploration – drilling methods and equipment;
- Mining – mining methods and equipment, ventilation;
- Processing – chemical engineering and thermodynamics;
- Overall – basic psychology and dealing with the media, non-government organisations and the general public (including Traditional Owners, where required), particularly on:
    a) Emotional issues surrounding uranium exploration and mining, and
    b) Health and environmental effects of ionising radiation.

It is also known that, on many occasions, the role of radiation safety officer is assigned to a company's 'technical' person (geologist, laboratory manager, process engineer, safety and environmental specialist), who has many other duties that often precede the management of radiation.

Whilst this practice is usually acceptable for exploration and some mining sites, it is important to ensure that, –

- Both the appointed person and the management of a company are fully aware of their legal obligations,
- A company has access to qualified advice on radiation management from either a relevant government department of a qualified 'contract' specialist,
- Sufficient resources (including equipment, personnel and time allocation) are provided at a site.

Additionally, in order to carry out statutory acceptable atmospheric sampling in Western Australia a person must possess the qualification of a 'ventilation officer' or 'technician', as required by the WA Mines Safety and Inspection Regulation 9.4.(2)[70]. Apart from the possibilities of potential errors in sampling undertaken by an unqualified person, it is likely that the results of the monitoring will technically be unacceptable and, if any legal issues arise, it may be deemed that a company did not carry any statutory monitoring at all.

[70] Mines Safety and Inspection Regulations, Western Australia, 1995

Conclusions

It is concluded that uranium exploration and subsequent mining are acceptable activities, provided that:

- Each exploration and mining company complies in full with the standards of radiation protection and relevant guidance documents – both in regards to the protection of human health and the protection of the environment. No special exemptions should be available to exploration and mining companies from any State or Federal Law or Regulation. Additionally, radiation management plans approved prior to 2008 may need to be amended to include the requirements from new WA guidelines for radiation protection in mining and mineral processing (2008).
  It should be noted that the word 'acceptable' must not be misinterpreted and does not imply in any way that, in contrast with other branches of mining and mineral processing industry, should one uranium exploration company fail to meet any obligation, the whole uranium industry would become 'unacceptable'.

- Effective control over the management of radiation protection at exploration and mining sites is exercised by the relevant government departments.

- A system of inspections and monitoring of uranium exploration sites (and, if needed in the future, mining sites) is introduced as soon as possible. It is suggested that the system be based on the model used in the Australia's Northern Territory where such inspections are carried out with the involvement of both representatives from government departments and representatives of the interests of Traditional Owners.

- Education programs dealing with uranium exploration and mining and aimed at the general public (both in population centres and in remote areas) are developed and presented jointly by the industry, government and non-government organisations. It is noted that a high degree of cooperation between all stakeholders will be required for any education program to succeed.

Final note and acknowledgements

The author first summarised issues relevant to uranium exploration in a relatively short document, following a request received in 2007.

The current document has not been commissioned by any government department, company or organisation and no payment of any kind was received from any organisation or person. There was no financial or any other incentive to reflect some particular points of view and the document is solely the description of author's views on the subject of uranium exploration and mining and associated issues, with a reflection on the present situation in author's home State of Western Australia.

It is hoped that the report will be useful as a reference for all stakeholders in uranium exploration: government departments, exploration and mining companies, non-government organisations and the general public – particularly to the Traditional Owners of the land where exploration of uranium often takes place.

The current version of the document is in no way final, the intension is to keep it 'live' as several other author's publications. Therefore, any clarifications, amendments and additions to the current version (2.0) will be very much appreciated.

Most useful comments were received from the International Atomic Energy Agency (IAEA) in Vienna. The comments from several Australian companies and organisations were particularly helpful in the development of the current version of the report and author would like to express his gratitude to:

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- Toro Energy Ltd,
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The summary of the report will be presented at the 2009 Safety and Health Conference in Perth in March 2009 and it is anticipated that the next version of the report will be developed in April – May 2009.

NOTE:
If you did not receive this version directly from the author and would like to obtain subsequent versions of the document, please contact the writer via Internet (www.calytrix.biz) or e-mail (nick@calytrix.biz).

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