RADIATION EXPOSURE AND CONTROL

1.1 INTRODUCTORY CONCEPTS

Humans have evolved in the presence of ionising radiation from natural sources, including from cosmic radiation, radioactive terrestrial sources, air, food and water. Since more than five decades now, a variety of man-made sources emitting ionising radiation have made additional contributions to this perpetual sea of background radiation.

Today, some such sources of man-made radiation are from uranium mines. Here, radioactive ores are brought to the surface and are crushed, milled and concentrated. Through ore dumps, waste rock, tailings and process facilities, radioactive materials are exposed to the environment, and also contribute to an enhancement of atmospheric radon exhalations and the addition and uptake of inhalable radioactive dust into the atmosphere.

The International Commission on Radiological Protection (ICRP) has put forward a conceptual model of the processes causing human exposures to ionising radiation [ICRP, 2007]. The model views exposure processes as a network of events and situations with each part of the network starting from a specific source of radiation. This radiation, or the radioactive source material giving rise to such radiation, passes through environmental or other pathways, and in this way exposes individuals. Such exposure to radiation or radioactive materials then leads to exposure doses to individuals.

In what is today commonly referred to as the source-pathway-receptor model of exposure to radiation, radiation protection can be achieved by taking action at the source of radiation, or at the various points along the exposure pathways, and if possible, by changing the location, behaviours and protective measures used by exposed individuals. Radiation protection includes all measures, processes and controls applied to minimise the potential exposure to radiation, and such measures are therefore most effectively implemented at the source(s), in the pathway(s) and at the receptor(s).

Although not fully fortified by empirical data for low exposure doses, it is generally assumed that there exists a proportional relationship between an increment of exposure dose and an increment of the associated risk of such an exposure. The assumption is further that there exists no low-radiation threshold for the onset of such risks. This so-called linear no-threshold assumption and the associated view that radiation risk increases linearly as the

dose increases underpins the formulation of separate radiation protection measures for each source, pathway and receptor, while enabling the radiation protection officer to identify those parts of the exposure chain that are most relevant and amenable to the application of effective exposure controls. Separating the total exposure dose into its various contributing parts therefore allows targeted action for each such contributing element.

It is recognised that individuals are subject to several types and categories of exposure, each of which can be dealt with separately. For example, a worker at a uranium mine who is occupationally exposed because of the particular work that is being undertaken is also exposed to naturally occurring environmental sources of ionising radiation. Similarly, a member of the public is exposed to the ionising radiation from the natural background radiation, plus an incremental contribution due to other sources in his/her immediate environment, such as radioactive dust, radon and radon progeny entering the environment from nearby uranium mines.

Radiation protection measures are most effective when applied in the immediate environment in which risks to exposure exist. For example, the occupational exposure by a worker at a uranium mine needs to be minimised at the place of work where particular exposure dose limits apply for such an occupational settings. Similarly, the incremental dose that ordinary members of the public may be exposed to as a result of the operations of a uranium mine needs to be minimised to such a degree as to ensure that such potential exposure does not exceed the dose limit applicable for this particular group. As far as regulatory controls are concerned, each distinct exposure group, such as for example the occupational group or members of the public, are treated separately and are subject to separate regulatory provisions. And because potential occupational and public exposure categories require different control approaches, separate control measures and dose limits apply to each exposure category.

Radiation protection practices in the uranium mining industry focus on minimising the so-called stochastic effects of ionising radiation. Stochastic effects are not associated with a particular exposure threshold, in contrast to non-stochastic or deterministic effects which are certain to occur if and only if a certain exposure dose exceeds a threshold dose. Stochastic effects are probabilistic in nature, and may ensue if a cell (for example in the body of a worker) and with it the genetic make-up of the affected cell is modified rather than killed. Such modified cells may, after some delay, develop into cancer. In most cases, the body's repair and defence mechanisms active at the cellular level make it very unlikely that cells are irreparably modified when irradiated with small exposure doses, such as those that are typical in an occupational setting at a uranium mine. Nevertheless, there is no evidence that a threshold dose exists below which cancerous growth will no longer form. While the probability of occurrence of such cancers is higher for higher doses, the severity of any cancer that may result from irradiation is independent of the dose that has caused it.

This implies that all potential exposures of members of the public or workers have to be kept as low as reasonably achievable, and certainly below the regulatory dose limit specified by the national regulator for the relevant exposure group.

In Namibia, the Atomic Energy and Radiation Protection Act, Act No. 5 of 2005, describes the statutory and regulatory radiation protection and control measures. By virtue of this Act, the National Radiation Protection Authority (NRPA) has been established, and is responsible for setting and overseeing the criteria applicable to radiation protection in Namibia. In October 2010, draft regulations are available from the NRPA, and are expected to become enacted soon [NRPA, 2010]. In parts, the draft regulations are based on international guidelines and the recommendations by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA). The Namibian draft regulations distinguish between occupational dose limits, and those that apply to members of the public.

The occupational exposure of any worker is to be controlled to ensure that the following limits are not exceeded [NRPA, 2010, refer to Schedule 2]:

a) an effective dose of 20 mSv per year averaged over five consecutive years;
b) an effective dose of 50 mSv in any single year;
c) an equivalent dose to the lens of the eye of 150 mSv in a year; and
d) an equivalent dose to the extremities (hands and feet) or the skin of 500 mSv in a year.

In special circumstances, a temporary change in the dose limitation requirements may be granted by the NRPA [NRPA, 2010].

For members of the public, the inferred average exposure dose of the relevant critical group(s) of members of the public may not exceed the following limits [NRPA, 2010, Schedule 2]:

a) an effective dose of 1 mSv in a year; in special circumstances, an effective dose of up to 5 mSv in a single year provided that the average dose over five consecutive years does not exceed 1 mSv per year;
b) an equivalent dose to the lens of the eye of 15 mSv in a year; and
c) an equivalent dose to the skin of 50 mSv in a year.

1.2 RADIOLOGICAL PROTECTION STANDARDS

The draft regulations of the Namibian National Radiation Protection Authority are largely based on the recommendations for the radiological protection standards of the International Atomic Energy Association (IAEA), as defined in the IAEA Basic Safety Standards [IAEA, 1996].

Accordingly, the Mining project will have to comply with the national regulatory requirements for radiological protection, which are underpinned by the following elements: justification of practices, exposure dose limits, optimisation of protection and safety, and dose constraints. These principal elements of the radiological protection standards are summarised below.

1.2.1 Justification of practices

As indicated above, the NRPA draft regulations applicable to the Mining project are the *"Regulations for protection against ionizing radiation and for the safety of radiation sources"* [NRPA, 2010]. In regard to the justification of practices, Chapter 3, regulation 9 of the draft regulations states (quoted verbatim from [NRPA, 2010]):

1. *"No practice or source within a practice may be licensed or registered unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation harm that it might cause, taking into account social, economic and other relevant factors.*
2. *The applicant for the license or registration must provide sufficient information to the authority relating to the benefits and the harm to support the justification of the practice.*
3. *For the purposes of sub-regulation (1), the following practices are deemed not to be justified whenever they would result in an increase, by deliberate addition of radioactive substances or by activation -*
   a) practices involving food, beverages, cosmetics or any other commodity or product intended for ingestion, inhalation or percutaneous intake by, or in relation to, a human being; or
   b) practices involving the frivolous use of radiation or radioactive substances in commodities or products such as toys and personal jewellery or adornments."

1.2.2 Dose limitation

In regard to the dose limitation applicable to the Mining project, Chapter 3, regulation 10 of the NRPA's draft regulations state (quoted verbatim from [NRPA, 2010]):

1. *"The normal exposure of individuals must be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from all practices, exceeds any relevant dose limit specified in Schedule 2 except in the special circumstances contemplated in Regulation 11*[1]*.*
2. *Sub-regulation (1) does not apply to medical exposures from licensed practices."*

The dose limits referred to in the draft regulations (Schedule 2) are summarised in section 1.1 above.

1.2.3 Optimisation of protection and safety

In regard to the optimisation of protection and safety as is applicable to the Mining project, Chapter 3, regulation 12 of the draft regulations state (quoted verbatim from [NRPA, 2010]):

1. *"In relation to exposures from any particular source within a practice, radiation safety must be optimised in order that the magnitude of individual doses (except for the volume of interest in cases of therapeutic medical exposures) the number of people exposed and the likelihood of incurring exposures must be kept as low as reasonably achievable, economic and social factors being taken into account, within the restriction that the dose to individuals delivered by the source be subject to dose constraints, as specified in the license condition imposed by the Authority.*
2. *The licensee must use, to the extent practicable, procedures and engineering controls based upon sound radiation safety principles to achieve this objective."*

1.2.4 Dose constraints

In regard to dose constraints as are applicable to the Mining project, Chapter 3, regulation 13 of the draft regulations state (quoted verbatim from [NRPA, 2010]):

1. *"Except for medical exposure, the optimisation of the radiation safety measures associated with a given practice must satisfy the condition that the resulting doses to the individuals of the critical group do not exceed dose constraints which are equal to the dose limits specified in or any lower values established by the Authority.*
2. *In case of any source that can release radioactive substances to the environment, the dose constraints must be established so that the prospective annual doses to members of the public, including people distant from the source and people of future*

[1] Regulation 11 describes special circumstances under which the regulator may grant approval for the temporary exceedance of applicable dose limitations.

generations, summed over all exposure pathways, including contributions by other practices and sources, are unlikely to exceed the dose limits specified in Schedule 2 or any lower values established by the Authority."

The dose limits referred to in the draft regulations are given in section 1.1 above.

1.3 OCCUPATIONAL EXPOSURE TO IONISING RADIATION

The International Commission on Radiological Protection (ICRP) defines occupational exposure "as all radiation exposure of workers incurred as a result of their work", and limits the use of the term occupational exposure to "radiation exposures incurred at work as a result of situations that can reasonably be regarded as being the responsibility of the operating management" [ICRP, 2007].

1.3.1 Sources of radiation exposure

In the uranium mining sector one distinguishes between three main pathways for the delivery of radiation doses to the human body [von Oertzen, 2010b], i.e.

1. external irradiation by gamma radiation originating from radioactive materials found and/or used in the mining and concentration processes,
2. internal radiation by way of inhalation of radon and radon decay products (radon progeny), and of long-lived radionuclides contained in airborne dust, and
3. internal radiation by way of ingestion of radionuclides, e.g. when coming in contact with contaminated surfaces, applying poor hygiene standards, consuming contaminated food or water, or otherwise causing radionuclides to enter the body's digestive tract.

1.3.1.1 Gamma radiation

A uranium mine concentrates naturally occurring radioactive source materials through a process of uranium extraction. In such an occupational setting, the main sources of gamma radiation are mainly due to exposure to the

- uranium ore body,
- uranium-bearing materials contained in ore stockpiles, waste rock dumps, pulps and sludge, and tailings facilities,
- final product, i.e. uranium oxide,

- radioactive deposits and contaminants building up in pipes and process equipment, and
- sealed sources containing specific radionuclides, for example those frequently used in density and flow meters.

1.3.1.2 Radon and radon progeny

Radon (Rn^{222} and Rn^{220}, which is also called thoron) are radioactive gases arising in the decay of radium (Ra^{226} and Ra^{224} respectively). Radon emanates from the crystal lattice in which the parent radionuclide radium was embedded, and travels into the pore space of the substrate material from where it diffuses to the surface of the ore to escape into the atmosphere. The flux of radon from the soil surface, rocks and tailings facilities is called radon exhalation. The crushing and milling operations undertaken in most uranium mining environments enhances the natural exhalation of radon, and ore stockpiles, tailings facilities, the pit area and waste rock dumps containing radium are the main sources of such radon and thoron.

Radon is a decay product of the uranium decay chain, whereas thoron is a decay product of the thorium chain. The presence of thoron therefore depends on the abundance of thorium in the soil and ores. In addition, the very short half-life of thoron (55 seconds) limits the ambient concentrations of thoron – on average therefore, radon concentrations are about 10 times higher than the thoron concentration, and hence thoron is often disregarded relative to radon. The present assessment does not take thoron into account.

The exposure to radon and radon daughters in an open pit uranium mine depends on prevailing weather conditions. Low-lying atmospheric inversion layers and still-air conditions may trap radon close to where it is exhaled from the source. As temperatures increase after sunrise and natural thermal air movements commence, radon is dispersed into the surrounding atmosphere and transported away from the source.

1.3.1.3 Radioactive dust

Geophysical analyses of the ore body in the Mining project indicate that uranium concentrations in the ore are between 200 and 360 parts per million (ppm) [Deep Yellow, 2010]. The mining process generates atmospheric dust, which contains radionuclides, which can be inhaled and/or ingested by humans and also cause the contamination of exposed surfaces with particulates containing radionuclides. Main dust-generating activities include exploration drilling, blasting, mining, transport of ores on haul trucks, crushing, milling, conveying, general vehicle movements on unsealed roads, and the eventual storage on tailings facilities, all of which enhance the natural concentration of airborne dust.

Airborne dust originating from drilling, blasting, crushing and milling has average uranium concentrations which are very similar to the mined ores. In addition, the production of the final product, and in particular the drying and packaging process involving uranium concentrate in the form of yellow cake are other sources of radioactive dust that may be inhaled and/or ingested.

1.3.1.4 Contaminated surfaces

Airborne dust is characterised by the concentration of total suspended particulates, and the concentration of the inhalable fraction of the dust. Both types of airborne dust are eventually deposited on exposed surfaces, and will then become available for human and animal ingestion. Such ingestion can be direct, i.e. by way of a direct intake, or indirect by way of consuming food or water that is contaminated by such dust. The mining environment offers opportunities for intense surface contamination, as are typically found at drill rigs and crushers. In addition, dust which is transported away from the source will eventually settle out and is deposited on objects.

1.3.2 Managing the occupational exposure to radiation

Under the Namibian Atomic Energy and Radiation Protection Act, Act No. 5 of 2005, the National Radiation Protection Authority (NRPA) is the country's radiation protection regulator. The NRPA has issued guidelines for how practices that potentially give rise to exposure to ionising radiation are to develop and implement a Radiation Management Plans [NRPA, 2009].

Section 1.4.1 below summarises the main components that the Radiation Management Plan (RMP) for the Mining project will have to include. In regard to ensuring that occupational exposure doses of workers are kept as low as reasonably achievable, the RMP will be guided by the stipulations as currently contained in the draft regulations issued by the NRPA [NRPA, 2010].

Chapter 6 of the NRPA's draft regulations are of relevance to occupational exposure protection, in particular regulation 21 (2) pertaining to **general responsibilities** (quoted verbatim from [NRPA, 2010]):

"Licensees must ensure for all workers engaged in activities that involve or could involve occupational exposure, that –

a) *occupational exposures are limited as specified in Schedule 2;*
b) *radiation safety is optimised in accordance with these regulations;*
c) *policies, procedures and organisational arrangements for occupational protection and safety are established to implement the relevant requirements of these*

regulations, and the resulting decisions on measures to be adopted for this purpose are recorded and made available to relevant persons, including workers, through their representatives where appropriate;

d) *suitable and adequate facilities for radiation safety are provided, including personal protective devices and monitoring equipment, and arrangements are made for their proper use;*
e) *radiation safety and health surveillance services are provided through qualified experts;*
f) *arrangements are made to facilitate consultation and co-operation with workers, through their representatives where appropriate, about measures which are needed to achieve adequate radiation safety by effective implementation of these regulations; and*
g) *necessary conditions are provided and arrangements are made to promote a safety culture in the work force and achieve adequate training of workers on radiation safety matters."*

In regard to monitoring the workplace, Chapter 6, regulation 29 of the draft regulations states that (quoted verbatim from [NRPA, 2010]):

1. *"Licensees, in co-operation with employers if appropriate, must establish, maintain and keep under review a programme for the monitoring of the workplace commensurate with the nature of and the risks associated with all relevant sources.*

2. *The nature and frequency of monitoring of workplaces must –*
    a. *be sufficient to enable –*
        i. *the evaluation of the radiological conditions in all workplaces;*
        ii. *the assessment of the exposure of workers in controlled areas and supervised areas; and*
        iii. *the review of the classification of controlled and supervised areas; and*
    b. *depend on the levels of ambient dose equivalent and airborne and surface activity concentration, including their expected fluctuations and the likelihood and magnitude of potential exposures.*

3. *The programmes for monitoring of the workplace must specify –*
    a. *the quantities to be measured;*
    b. *where and when the measurements are to be made and at what frequency;*
    c. *the most appropriate measurement methods and procedures; and*
    d. *reference levels of the measured quantities and the actions to be taken if they are exceeded.*

4. *Licensees must keep appropriate records of the findings of the workplace monitoring programme, which must be made available to workers and where appropriate their representatives."*

In regard to work areas, Chapter 6, regulation 23 of the draft regulations states that (quoted verbatim from [NRPA, 2010]):

1. *"Licensees must designate as a **controlled area** any area in which specific protective measures or safety provisions are or could be necessary for –*
   a) *controlling normal exposures or preventing the spread of contamination during normal working conditions; and*
   b) *preventing or limiting the extent of potential exposures.*

2. *Licensees must –*
   a) *determine the boundaries of any controlled area on the basis of the magnitude and likelihood of expected exposures and the nature and extent of the required protection and safety measures;*
   b) *delineate controlled areas by physical means or, where this is not reasonably practicable, by some other suitable means;*
   c) *where a source is brought into operation or energised only intermittently or is moved from place to place, delineate an appropriate controlled area by means that are appropriate under the prevailing circumstances and specify exposure times;*
   d) *display a warning symbol, recommended by the International Organisation for Standardisation (ISO) , and appropriate instructions at access points and other appropriate locations within controlled areas;*
   e) *establish occupational protection and safety measures, including local rules and procedures that are appropriate for controlled areas;*
   f) *restrict access to controlled areas by means of administrative procedures, such as the use of work permits, and by physical barriers, which could include locks or interlocks, the degree of restriction being commensurate with the magnitude and likelihood of the expected exposures; and*
   g) *provide at entrances and exits of controlled areas appropriate means for change of clothing, contamination monitoring and personal decontamination."*

In regard to supervised work areas, Chapter 6, regulation 24 of the draft regulations states that (quoted verbatim from [NRPA, 2010]):

1. *"Licensees must designate as a supervised area any area not already designated as a controlled area, but where occupational exposure conditions need to be kept under review even though specific protection measures and safety provisions are not normally needed.*
2. *Licensees must delineate and identify the supervised areas by appropriate means, taking into account the nature and extent of radiation hazards in those areas.*
3. *Licensees must periodically review conditions to determine the possible need to revise the protection measures or safety provisions, including the boundaries of controlled and supervised areas."*

The draft regulations also contain descriptions of the regulations for

- conditions of service of workers who are potentially exposed to ionising radiation
- local rules and supervision of workers
- personal protective equipment
- management of overexposure
- monitoring of the workplace
- health surveillance
- approval of dosimetry services, and
- records of worker exposure

which, in the interest of brevity, will not be reproduced here, but are discussed in further detail in section 1.4 below.

1.3.3 Determining the occupational exposure dose

The occupational exposure of workers is determined from the results of the occupational monitoring program. As described in section 1.3.2, the occupational exposure program will be presented in detail in the to-be-developed Radiation Management Plan, which will be prepared for the Mining project.

The occupational radiation exposure of workers is based on the dose attributable to gamma radiation, the dose attributable to the inhalation of radionuclides contained in dust, and the dose attributable to the inhalation of radon and radon progeny. It is noted that the ingestion pathway is ignored in the present study as this pathway is most easily managed (and thereby almost eliminated) if proper hygiene and behavioural measures are put in place. Under these assumptions, the individual occupational dose is expressed as:

Equation 1: $$E_T = H_p(d) + h_\alpha I_\alpha + h_{Rn}$$

where E_T resultant annual effective dose in $mSv.a^{-1}$,

$H_p(d)$ whole-body external exposure dose from gamma radiation,

$h_\alpha I_\alpha$ whole-body internal dose from inhaled long-lived alpha emitters in dust,

h_{Rn} whole-body internal dose from inhaled radon/radon progeny,

where the exposure dose along each pathway is expressed in $mSv.a^{-1}$.

1.3.3.1 Monitoring exposure to gamma radiation

Worker exposure to external gamma radiation will be monitored using electronic personal dosimeters or thermo-luminescent dosimeters. Such dosimeters will be individually assigned, and the duration and number of assignees per work area will depend on the expected exposure in a specific work area, the relevant exposure group, and the number of members per such exposure group.

The details of how dosimeters will be assigned will be described in the to-be-developed Radiation Management Plan, which will be prepared for the Mining project. For the purposes of this section it suffices to mention that the whole-body dose equivalent from external gamma radiation will be determined using individually assigned dosimeters, yielding an external exposure dose for a specific worker $H_p(d)$ measured in units of mSv per annum ($mSv.a^{-1}$).

1.3.3.2 Monitoring exposure to radioactive dust

The committed effective dose from the inhalation of long-lived alpha emitting radionuclides contained in airborne dust, $h_\alpha I_\alpha$ (in $mSv.a^{-1}$), is estimated using the following equation:

Equation 2: $$\mathbf{h_\alpha I_\alpha = V_{Rate} \times AC_\alpha \times DCF \times ET}$$

where V_{Rate} is the hourly breathing rate for workers, which is assumed to be 1.2 $m^3.h^{-1}$ as per the recommendations by the ICRP for adult workers [ICRP, 1995],

AC_α is the average long-lived alpha activity concentration expressed in $Bq.m^{-3}$, and measured in air using a personal air sampler, or inferred from an area air sampler,

DCF is the dose conversion coefficient, which is expressed in $mSv.Bq^{-1}$, and

ET is the exposure time, which is expressed in hours per annum ($h.a^{-1}$).

Appropriate dose conversion coefficients DCF are chosen and depend on whether the airborne dust is mainly due to uranium-bearing ore dust, or the final uranium oxide product. In the present study, and as per the Namibian regulator's draft regulations, the DCFs as provided by the IAEA guidelines [IAEA, 2004, Annex, p. 79 for uranium ore dust] are used.

1.3.3.3 Monitoring exposure to radon/radon progeny

The exposure dose from inhaled radon and radon daughters, h_{Rn} (in $mSv.a^{-1}$), is estimated using the following equation:

Equation 3: $$h_{Rn} = AC_{Rn} \times CF_{Rn} \times ET$$

where AC_{Rn} is the average radon activity concentration, which is expressed in $Bq.m^{-3}$, and measured using a personal radon/radon progeny monitor, or inferred from an area radon sampler,

CF_{Rn} is the conversion factor, which is expressed in $mSv / Bq.h.m^{-3}$, and

ET is the exposure time, which is expressed in hours per annum ($h.a^{-1}$).

The present study uses the conversion factors CF_{Rn} as provided in the ICRP guidelines [ICRP, 1994].

1.4 RADIATION MANAGEMENT

1.4.1 Introduction

Under the Namibian Atomic Energy and Radiation Protection Act, Act No. 5 of 2005, the National Radiation Protection Authority (NRPA) is the country's radiation protection regulator. Recently, the NRPA has issued draft regulations to be applicable for entities dealing with radioactive substances [NRPA, 2010], and has also made available guidelines on how organisations that potentially expose their employees and/or members of the public should develop a Radiation Management Plan (RMP) [NRPA, 2009].

This section summarises the main components that the RMP for the Mining project will have to include, based on the requirements stipulated in the draft regulations [NRPA, 2010]. It is to be noted however that the present summary is not intended to comprehensively address all aspects that will have to be covered in the Mining project RMP.

The Mining project RMP is to comprise of the following main elements:

a. **Background**, which is to include
   - a description of the technical nature of the operation
   - physical plan of the site
   - expected sources of radiation
   - types of radioactive materials that will be used
   - overview and assessment of radiation hazards, and
   - description of the principal exposure pathways.

b. **Pre-Operational Safety Assessment**, which is to include
   - a summary of the main outcomes of all assessments carried out prior to operations
   - description of applicable risk, remediation/rehabilitation assessments and risk management plans, and
   - a summary of the radiation-related Environmental Management Plan.

c. **Organisational Arrangements**, which is to include
   - a description of the main responsibilities within the organisation, and
   - specification of the functions and responsibilities of the designated Radiation Safety Officer(s).

d. **Occupational Radiation Protection Program**, which is to include
   - a description of the program and activities undertaken to protect workers in the occupational setting.

e. **Medical Exposure Control**, which (if applicable) is to include
   - a description of all relevant medical measures taken to minimise individual doses.

f. **Public Exposure Monitoring Program**, which is to include
   - a description of the programs and methods to monitor the potential public exposure pathways, and
   - minimise any accidental exposure caused by operations.

g. **Waste Management Program**, which is to include
   - a description of how radioactive waste materials, both in form of sealed and unsealed radioactive sources, contaminated materials and effluents arising from operations will be managed.

h. **Emergency Preparedness and Response Plan**, which is to include
   - a description of the emergency management plan to be enacted after accidental exposure to radiation.

i. **Transport Plan**, which is to include
   - a description of how radioactive materials will be transported, including the labelling, packing and controlling of transport processes involving radioactive materials.

j. **Safety and Security of Radiation Sources**, which is to include
   - a description of the controls and measures to ensure the safety of sources of radiation.

The sections below summarise the key requirements of the following sections of the to-be-developed RMP:

- occupational radiation protection program (refer to section 1.4.2)
- public exposure monitoring program (refer to section 1.4.3)
- safety and security of sources (refer to section 1.4.4)
- transport requirements (refer to section 1.4.5)
- emergency intervention (refer to section 1.4.6), and
- waste management program (refer to section 1.4.7).

The sections below are guided by the stipulations of the Namibian draft regulations as have been made available in October 2010 [NRPA, 2010]. It is noted that these draft regulations, and therefore the elements described below, are only to be considered as a guide and

cannot as yet be seen as being prescriptive in nature. Once the regulations have been promulgated, which is expected in late 2010 or early 2011, the sections below will have to be reviewed and updated where required.

1.4.2 Elements of the occupational radiation protection program

In regard to the occupational radiation protection program to be implemented at the Mining project, chapter 6 of the draft regulations include the following main elements based on the regulations which are summarised below [NRPA, 2010]:

Regulation 21: General responsibilities

This regulation stipulates that an entity that employs workers who are engaged in activities that involve or could involve occupational exposure are responsible for the protection of their workers against any such occupational exposure. The regulation then further defines the conditions for such occupational exposure control, including the required policies, procedures and organisational measures to be applied.

Regulation 22: Conditions of service

This regulation stipulates that the conditions of service of workers must be independent of the existence or the possibility of occupational exposure, and that the employer may not offer or grant any special compensatory arrangements or preferential treatment with respect to salary or otherwise as substitutes for the provision of radiation protection measures. The regulation then further stipulates that female workers must be advised to notify the employer of pregnancy, upon which the employer must adapt the working conditions to ensure that the embryo or foetus is afforded the same broad level of protection as required for general members of the public.

Regulation 23: Controlled areas

This regulation stipulates that an entity must designate work areas as a controlled area to control exposures or prevent the spread of contamination under normal working conditions. The regulation then further stipulates that an entity must also determine the boundaries of any controlled area on the basis of the magnitude and likelihood of expected exposures, and the nature and extent of the required protection measures, and delineate controlled areas by physical means and display warning symbols as per the recommendations of the International Organisation for Standardisation (ISO), and issue appropriate instructions at access points and other appropriate locations within such controlled areas.

Regulation 24: Supervised areas

This regulation stipulates that an entity must designate work areas as a supervised area where occupational exposure conditions need to be kept under review, even though specific protection measures and safety provisions are not normally needed. Such supervised areas must be suitably delineated and identified, taking the nature and extent of radiation hazards in those areas into account.

Regulation 25: Local rules and supervision

This regulation stipulates that an entity must, in consultation with workers, establish rules and procedures to ensure adequate levels of protection and safety, and ensure that any work involving occupational exposure is adequately supervised, and all reasonable steps are taken to ensure that the rules, procedures, protective measures and safety provisions are observed. The regulation then further states that employers must provide workers with adequate information on the health risks due to their occupational exposure, as well as provide instruction and training on protection and safety, and provide to female workers who are liable to enter controlled areas or supervised areas appropriate information on the risk to the embryo or foetus due to exposure. Records of the training provided to individual workers need to be kept.

Regulation 26: Personal protective equipment

This regulation stipulates that an entity must minimise the need for relying on administrative controls and personal protective equipment (PPE) for protection and safety during normal operations by providing suitable controls and working conditions, and ensure that workers are provided with suitable PPE. The regulation then further states that PPE is to be regularly tested and maintained, taking into account the medical fitness of workers to sustain physical effort while using such PPE, and additional work time, inconvenience or additional non-radiological risks associated with the use of such PPE.

Regulation 27: Exposure assessment

This regulation stipulates that an entity must arrange for the assessment of the occupational exposure of workers and must ensure that adequate arrangements are made with appropriate dosimetry services under an adequate quality assurance programme. The regulation then further states that any worker who is normally employed in a controlled area, be individually monitored, or, where not feasible, that occupational exposure of the workers is assessed on the basis of the results of workplace monitoring. For a worker who is normally employed in a supervised area or who enters a controlled area only occasionally,

the occupational exposure must be assessed, where such an assessment may be on the basis of the results of monitoring of the workplace or of individual monitoring.

Regulation 28: Management of overexposure

This regulation stipulates that an entity who suspects or has been informed that a person is likely to have received an overexposure as a result of work carried out by that employer must determine whether there are circumstances that such overexposure could have occurred. The regulation then further states that in case such an overexposure has occurred, the entity must as soon as practicable possible notify the NRPA and the appointed medical practitioner of the affected person.

Regulation 29: Monitoring of workplace

This regulation stipulates that an entity must establish, maintain and keep under review a program to monitor the workplace, commensurate with the nature and risks associated with all relevant sources. The regulation then further states that the nature and frequency of monitoring of workplaces must be sufficient to enable the evaluation of the radiological conditions in all workplaces, and the assessment of the exposure of workers in controlled areas and supervised areas, while allowing for the review of the classification of controlled and supervised areas. The workplace monitoring program must specify the quantities, timing, methods and reference levels to be measured, and the entity must keep appropriate records of such workplace monitoring.

Regulation 30: Health surveillance

This regulation stipulates that an entity must make arrangements for appropriate health surveillance based on the general principles of occupational health, and designed to assess the initial and continuing fitness of workers for their intended tasks. The regulation then further states that an employer must ensure that a health record in respect of each employee is made and maintained, and that that record or a copy thereof is kept until the person to whom the record relates has or would have attained the age of 75 years, but in any event for at least 50 years from the date of the last entry made in it.

Regulation 31: Approval of dosimetry services

This regulation stipulates that the NRPA may approve a suitable dosimetry service, and may carry out a re-assessment of any approval granted.

Regulation 32: Records of worker exposure

This regulation stipulates that an entity must maintain records of exposure for each worker for whom an assessment of occupational exposures is required, and include information on the general nature of the work resulting in exposure, the doses and intakes at or above the relevant exposure levels, the data upon which the dose assessments are based, and the periods of employment with different employers and the corresponding doses and intakes in each period of such employment. The regulation then further states that an entity must provide for access by workers to information in their own exposure records, and upon request from the NRPA or other persons / organisations with a demonstrated need for such records, provide access to such worker exposure records. Exposure records for each worker must be retained by the entity (or the NRPA if the entity ceases activities) and such records must be preserved at least until the worker attains or would have attained the age of 75 years, and for not less than 30 years after the termination of the work involving occupational exposures.

1.4.3 Elements of the public exposure monitoring program

In regard to the public exposure monitoring program to be implemented at the Mining project, chapter 8 of the draft regulations include the following elements which are briefly summarised below [NRPA, 2010]:

Regulation 42: General responsibilities

This regulation stipulates that an entity must apply the requirements of the regulations to any public exposure delivered by a practice or source for which they are responsible, unless such exposure is excluded or exempted from the regulations. The regulation then further states that an entity is responsible for the establishment, implementation and maintenance of radiation safety policies, procedures and organisational arrangements for the control of public exposure and measures for ensuring the optimisation of the protection of members of the public whose exposure is attributable to such sources, and the limitation of the normal exposure of the relevant critical group in order that the total exposure is not higher than the relevant dose limit for members of the public. An entity is responsible to ensure that suitable and adequate facilities, equipment and services for the protection of the public are available, and that appropriate radiation safety training is undertaken, and retraining of the personnel responsible for the protection of the public is provided, and that monitoring equipment and surveillance programmes are in place to assess public exposure. Records of such surveillance and monitoring exercises are to be established.

Regulation 43: Control of visitors

This regulation stipulates that an entity must ensure that visitors to any controlled area are accompanied by a person knowledgeable about the radiation safety measures for that area. The regulation then further states that adequate information and instruction is provided to visitors before they enter a controlled area, and that adequate control over entry of visitors to a supervised area is maintained, and that appropriate signs are posted in such areas.

Regulation 44: Sources of external irradiation

This regulation stipulates that an entity must ensure that, if a source of radiation can cause exposure to the public, the floor plans and equipment arrangement for all new installations and all significant modifications to existing installations utilising such sources of radiation are reviewed and approved by the NRPA. The regulation then further states that specific dose constraints for the operation of such a source are established to the satisfaction of the NRPA, and that shielding and other protective measures are provided as appropriate for restricting public exposures.

Regulation 45: Radioactive contamination in enclosed spaces

This regulation stipulates that an entity must ensure that for sources for which they are responsible, measures that are optimised are taken to restrict public exposure in areas accessible to the public, and that specific containment provisions are established for the construction and operation of such sources in order to avoid or minimise spread of contamination in areas accessible to the public.

Regulation 46: Monitoring of public exposure

This regulation stipulates that an entity must establish and carry out a monitoring program which is sufficient to ensure that the requirements of the regulations are satisfied, and to assess the exposure of members of the public from sources of radiation and discharges of radioactive substances into the environment. The regulation then further states that appropriate records of the results of the monitoring program are to be kept by the entity, and that a summary of the monitoring results is to be provided to the NRPA at intervals as stipulated in the specific authorisation to the entity.

Regulation 47: Consumer products

This regulation stipulates that an entity must ensure that consumer products capable of causing exposure to radiation may not be supplied to members of the public unless such

exposure is excluded from the regulations, or such products are authorised by the NRPA. An entity that imports such exempted consumer products for sale and distribution must include in the application to the NRPA a copy of the license or authorisation issued by the Authority in the country of manufacture or origin, which authorises distribution of the product concerned to members of the public in that country. The regulation then further states that an entity that imports consumer products for sale and distribution as exempt products must ensure that legible labels are visibly and firmly affixed to each consumer product and its package, stating that the product contains radioactive material, and the sale of the product to the public has been authorised by the NRPA. The entity is to also provide information and instructions on the precautions of use and disposal of the product.

1.4.4 Elements of safety and security of sources

In regard to the safety and security of sources program to be implemented at the Mining project, chapter 9 of the draft regulations include the following requirements [NRPA, 2010]:

Regulation 48: General responsibilities

This regulation stipulates that an entity must ensure the safety and security of the sources under their responsibility, from the moment of their acquisition throughout their entire operational life and up to their final disposal. The regulation then further states that for this purpose, licensees must ensure that a multilayer system of provisions for protection, safety and security of sources, commensurate with the magnitude and likelihood of the potential exposures involved, is applied to the sources under their responsibility, such that a failure at one layer is compensated for or corrected by subsequent layers, for the purposes of (a) preventing accidents that may cause exposure; (b) preventing unauthorised access or damage to, and loss of, theft of or unauthorised transfer of the source; (c) mitigate or minimise the consequences of any such accident or incident should it occur; and (d) restoring sources to safe and secure conditions after any such accidents or incidents. The regulation then also states that licensees must ensure that, as applicable and appropriate, the location, design, construction and assembly, commissioning, operation and maintenance, and decommissioning of sources are based on sound engineering practice which (a) takes into account approved codes and standards and technical and scientific developments; (b) is supported by reliable managerial and organisational features, with the aim of ensuring protection, safety and security throughout the life of the sources; (c) includes adequate safety margins in the design, construction and operation of sources, to ensure the reliable performance during normal operation, taking into account quality, redundancy and inspectability, with emphasis on preventing accidents, and mitigating their consequences and restricting any future exposures.

Regulation 49: Accountability and security of sources

This regulation stipulates that a licensee must conduct and keep verified a physical inventory of all sealed sources annually or as specified in the licence by the NRPA. The regulation then further states that the records must contain the following information: (a) the identity of each sealed source (serial number and model); (b) radionuclide and its activity on a specified date; (c) location of each sealed source; (d) receipt or transfer or disposal of the source; (e) the date of the inventory and signature of the Radiation Safety Officer. The regulation also states that licensees must make arrangements for the sources under their responsibility to be kept secure by ensuring that (a) control of a source is not relinquished without compliance with all relevant requirements specified in the license and

without immediate communication to the NRPA of information regarding any decontrolled, lost, stolen or missing source; (b) a source may not be transferred unless the receiver possesses a valid authorisation; (c) records are maintained of source inventory, including records of receipt, transfer and disposal of sources; and (d) a periodic inventory of sources is conducted at intervals specified in the license to confirm that they are in their assigned locations and are secure; (e) all sources are marked with legible and durable labels, which include as a minimum serial numbers, model, activity and date of activity, warning signs, supplier and manufacturer name, name and contact details of the Radiation Safety Officer; (f) sources are appropriately secured to the site of operation so as to minimise the likelihood of unauthorised access or removal. Licensees must immediately notify the NRPA, in case of loss of control of sources, unauthorised access to, or unauthorised use of a source, malevolent acts threatening authorised activities, or failures of equipment containing sources which may have security implications, and the discovery of unaccounted sources.

Regulation 50: Design and safety of sources

This regulation stipulates that a licensee, in specific co-operation with suppliers whenever appropriate, must ensure, on procurement of new equipment containing radiation generators or sources, that such equipment and sources conform to applicable standards of the International Electrotechnical Commission (IEC) and the International Standards Organisation (ISO), or equivalent standards as may be approved by the NRPA. The regulation further states that except for IEC and ISO standards, other standards applied in the country of origin of such equipment and sources must have the specific approval of the NRPA to (a) ensure that sources and equipment are tested to demonstrate compliance with the appropriate specifications; (b) conduct a safety assessment, either generic or specific, for the sources for which they are responsible, in accordance with the requirements of regulation; (c) ensure that performance specifications and operating and maintenance instructions, including protection and safety instructions, are provided in English and in compliance with the relevant IEC and ISO standards with regard to accompanying documents; (d) ensure that, where practicable, the operating terminology and operating values are displayed on operating consoles or other control systems in English. The regulation also states that where a radioactive substance is used as a source of ionising radiation, the radiation employer must ensure that (a) whenever reasonably practicable, the substance is in the form of a sealed source; (b) the design, construction and maintenance of any article containing or embodying a radioactive substance, including its bonding, immediate container or other mechanical protection, is such as to prevent the leakage of any radioactive substance; (c) suitable tests are carried out bi-annually to detect leakage of radioactive substances from any sealed source, and retain the record of each such test for inspection.

Regulation 51: Storing and moving sealed sources

This regulation stipulates that every employer must ensure that any radioactive source under his/her control which is not for the time being in use or being moved, transported or disposed of is (a) kept in a suitable sources container; and (b) kept in a suitable storage site. The regulation then further states that every employer who causes or permits a source to be moved (otherwise than by transporting it) must ensure that, so far as is reasonably practicable, the substance is kept in a suitable source holder, and suitably labelled while it is being moved. The regulation also states that nothing of the above applies in relation to a radioactive substance while it is in or on the live body or corpse of a human being.

Regulation 52: Records

This regulation stipulates that a licensee must maintain and annually submit to the NRPA records of tests, safety assessments, inventory of sources, source certificates, as well as any other necessary information to allow retrospective assessments of the doses received by third parties.

1.4.5 Elements of the transport requirements

In regard to the transport requirements to be implemented at the Mining project, chapter 10 of the draft regulations includes the following [NRPA, 2010]:

Regulation 53: Transport requirements

This regulation states that no radioactive material may be offered for transportation by rail, ship, aircraft or road vehicle unless the radioactive material is packed, shielded, marked and labelled in accordance with the Regulations for the Safe Transport of Radioactive Material, as drawn up by the International Atomic Energy Agency, details of which are obtainable from the NRPA. The regulation then further states that any container of radioactive material imported from recognised foreign suppliers must be deemed to comply with provisions of the conditions relating to the packing, marking and labelling of radioactive material if it is packed, marked and labelled in accordance with the law in that connection in force in the country of origin.

1.4.6 Elements regarding emergency interventions

In regard to the emergency intervention measures to be implemented at the Mining project, chapter 11 of the draft regulations include the following elements which are briefly summarised below [NRPA, 2010]:

Regulation 54: Responsibilities of licensees

This regulation states that if an authorised practice or source within a practice has a potential for accidents which may provoke an unplanned exposure of any person, the licensee must ensure that an emergency plan appropriate for the source and its associated risks is prepared and is kept operational. The regulation then further states that if an authorised source is involved in an accident or incident, the licensee is responsible for taking such protective actions as may be required for the protection of occupationally exposed workers undertaking intervention, and for the protection of the public from exposure as set forth in the licence application and emergency plans approved by the NRPA, or as might otherwise be required by the NRPA to protect against, mitigate or remedy a hazardous situation involving the licensed sources.

Regulation 55: Licensee emergency response planning requirements

This regulation states that a licensee responsible for sources for which prompt intervention may be required must ensure that the emergency plan defines on-site responsibilities and takes account of off-site responsibilities of other intervening organisations appropriate for implementation of the emergency plan. The regulation then further states that such emergency plans must, as appropriate (a) characterise the content, features and extent of a potential emergency taking into account the results of any accident analysis and any lessons learned from operating experience and from accidents that have occurred with sources of a similar type; (b) identify the various operating and other conditions of the source which could lead to the need for intervention; (c) describe the methods and instruments for assessing the accident and its consequences on and off the site; (d) provide for protection and mitigation actions, and assignment of responsibilities for initiating and discharging such actions; (e) provide for rapid and continuous assessment of the accident as it proceeds and determining the need for protective actions; (f) allocate responsibilities for notifying the relevant authorities and for initiating intervention; (g) provide procedures, including communication arrangements, for contacting any relevant intervening organisation and for obtaining assistance from fire-fighting, medical, police and other relevant organisations; (h) provide training to personnel involved in implementing emergency plans and ensure that these are rehearsed at suitable intervals in conjunction with designated authorities; and (i) provide for periodic review and updating of the plan.

Regulation 56: Implementation of intervention

This regulation states that the licensee must ensure that the protective or remedial actions aimed at reducing or averting accidental exposures are only undertaken when they are justified, taking into account health, social and economic factors. The regulation then further states that the form, scale and duration of any justified intervention must be optimised so as to produce the maximum net benefit under the prevailing social and economic circumstances. The regulation then states that subject to Section 32 of the Act, licensees must promptly notify the NRPA when an accidental situation requiring intervention has arisen or is expected to arise, and must keep them informed of (a) the current situation and its expected evolution; (b) the measures taken to terminate the accident and to protect workers and members of the public; and (c) the exposures that have been incurred and that are expected to be incurred.

Regulation 57: Protection of workers undertaking intervention

This regulation states that no worker undertaking an intervention may be exposed in excess of the maximum single year dose limit for occupational exposure specified in the regulations, except for (a) the purpose of saving life or preventing serious injury; or (b) if undertaking actions to prevent the development of catastrophic conditions. The regulation then further states that when undertaking interventions under the circumstances in sub-regulation (1), all reasonable efforts must be made to keep doses to workers below twice the maximum single year dose limit, except for life saving actions, in which case every effort must be made to keep doses below ten times the maximum single year dose limit in order to avoid deterministic effects on health. The regulation also states that workers undertaking actions in which their doses may approach or exceed ten times the maximum single year dose limit must do so only when the benefits to others clearly outweigh their own risk. Workers who undertake actions in which the dose may exceed the maximum single year dose limit must be volunteers and must be clearly and comprehensively informed in advance of the associated health risk, and must, to the extent feasible, be trained in the actions that may be required. Once the emergency phase of an intervention has ended, workers undertaking recovery operations, such as repairs to equipment and buildings, waste disposal or decontamination must be subject to the full system of detailed requirements for occupational exposure specified in the regulations. All reasonable steps must be taken to provide appropriate protection during the emergency intervention and to assess and record the doses received by workers involved in the emergency intervention. When the intervention has ended, the doses received and the consequent health risk must be communicated to the workers involved. Workers may not normally be precluded from incurring further occupational exposure because of doses received in an emergency

exposure situation. Qualified medical advice must be obtained before any such further exposure of a worker, if that worker has during emergency exposure receives a dose exceeding ten times the maximum single year dose limit, or if a worker who was subject to emergency exposure, at that worker's request.

Regulation 58: Responsibilities of the Authority

This regulation states that pursuant to Section 24 (1) of the Act, the NRPA may initiate any action and take any measures necessary to the public interest to prevent, eliminate and ameliorate the adverse effects on and to restore the environment. The regulation further states that the NRPA must ensure that (a) emergency plans are prepared and approved for any practice or source which could reasonably give rise to a need for emergency intervention; (b) emergency plans are periodically reviewed and updated; (c) provision is made for training personnel involved in implementing emergency plans and the plans rehearsed at suitable intervals in conjunction with designated authorities; and (d) prior information is provided to members of the public who could reasonably be expected to be affected by an accident.

Regulation 59: Clean-up and removal operations

This regulation states that the NRPA in consultation with the Board must determine (a) the procedures for clean-up and removal operations in the event of an emergency exposure; (b) the method of storage and disposal of any radioactive substance or of any object, plant, animal, or any part of the environment removed in a clean-up or removal operation or otherwise affected by an exposure.

1.4.7 Elements of the waste management program

In regard to the management of radioactive waste materials at the Mining project, chapter 12 of the draft regulations include the following elements which are briefly summarised below [NRPA, 2010]:

Regulation 62: Application

This regulation describes the sources, substances, materials and objects within authorised practices which are above the exemption levels specified in Schedule 1 of the regulations, and defines the users of sources of ionising radiation which include the fields of medicine,

industry, teaching, research, agriculture, hydrology, geology and other fields of human activity.

Regulation 63: Radioactive waste classification

This regulation categorises radioactive waste according to its physical form and composition as (i) solid waste; (ii) liquid aqueous waste; (iii) liquid organic waste; (iv) gaseous waste; (v) sealed radiation sources; (vi) biological waste (e.g. animal carcasses which might undergo decomposition if not properly treated and stored); (vii) medical waste (e.g. syringes, bed linen and contaminated clothing from a hospital environment). The regulation then further categorises waste according to the activity concentration and half lives of radionuclides contained therein as

(i) category I, which is low level radioactive waste (e.g. the activity is less than 10 MBq), containing short-lived radionuclides only (e.g. with half-life less than 50 days) that will decay to clearance levels within one year after the time of its generation;
(ii) category II, which is low and intermediate level radioactive waste, containing the radionuclides with half-life less than 30 years and restricted long-lived radionuclide concentrations and that is not expected to decay to clearance levels within one year from the time of its generation (limitation of longer lived alpha emitting radionuclides to 4,000 Bq/g in individual waste packages and to an overall average of 400 Bq/g per waste package);
(iii) category III, which is low and intermediate level radioactive waste, containing the radionuclides with half-life greater than 30 years and concentration of alpha emitters exceeding the limitations for category II, for which the regulation stipulates that such waste needs to be disposed of in deep geologic facilities only;
(iv) category IV, which is termed high level radioactive waste, with thermal power above 2kW/m^3 and concentration of alpha emitters exceeding the limitations for category II (e.g. spent fuel from research reactors), for which the regulation stipulates that such waste needs to be disposed of in deep geologic facilities only.

Regulation 64: General responsibilities

This regulation defines the primary responsibility for the safe management of radioactive waste as resting with the waste generator, who is to take all necessary actions to ensure the safety of radioactive waste unless the responsibility has been transferred to another person or organisation as approved by the NRPA. The regulation then further stipulates that the waste generator is responsible for on-site segregation, collection, characterisation, and temporary storage of the radioactive waste arising from activities and discharge of exempt waste. The regulation states that no person or organisation may dispose of any radioactive

waste unless the disposal facility designed and constructed specifically for this purpose is available, and an authorisation has been obtained for such disposal.

Regulation 65: Licence application

This regulation states that proposals from applicants to generate radioactive waste are to specify the nature and purpose of the proposed facility and equipment that generates radioactive waste, suggested operational procedures, taking into account reduction of radioactive waste generation to the extent practicable, quantity, type and characteristics of the radioactive waste to be generated, proposed destination for the radioactive waste, assessments of the safety and environmental impact of the facility under normal and accident conditions, decommissioning procedures, availability of competent staff and provisions for its further training, systems for records keeping and reporting, proposed quality assurance programme, contingency plans in the event of an emergency, proposals for discharge and environmental monitoring as needed, supporting research and development proposals as needed, and other details as may be specified by the NRPA. The regulation also states that an applicant will pay the fees as prescribed by the NRPA to cover the cost of the authorisation procedures, and that the holder of an authorisation is to comply with all limits and conditions specified in the authorisation including the amounts and characteristics of waste which may be generated, treated, conditioned and stored, and any specific radiation protection and physical security measures.

Regulation 66: Radiation Safety Officer (RSO)

This regulation states that each waste generator must appoint a technically competent person with the appropriate independence and authority to implement the provisions of the regulations, who may be the same person as appointed for other purposes. The regulation further states that the RSO must establish, maintain and keep an up to date inventory of radioactive materials and generated waste, make and maintain contact with all on-site persons using radioactive materials, and provide an authoritative point of advice and guidance, liaise as needed with the NRPA, establish and maintain a record-keeping system in such a manner as to facilitate identification, characterisation, collection and storage of radioactive materials that become waste, ensure that on-site transfer of radioactive materials and waste is carried out in accordance with written safety procedures, ensure appropriate shielding, labelling, physical security and integrity of waste packages, ensure that any discharge of effluents is made within clearance levels or limits specified as a condition for granting an authorisation for the disposal in question, ensure that the activity or activity concentration of waste to be disposed of in a municipal landfill are below clearance levels, report on accidents and inappropriate waste management practices to the

management and the NRPA, maintain up to date knowledge of the characteristics of the site sewerage system, local municipal landfills, available incinerators for non-radioactive waste and other facilities relevant to the organisation of waste management practices, and return sources to supplier.

An entity that applies to import a sealed source containing radioactive material which ten years after purchase will have an activity greater than 100 MBq must require the supplier, as a condition of any contract for purchase or as acceptance of any gift, to receive the source back after its useful lifetime within one year of the recipient requesting such return, request to return the source to the supplier not later than 15 years after purchase, submit to the NRPA a copy of relevant parts of the contract or acceptance document and obtain its written agreement prior to entering the contract in force or accepting the source, and return the source to the supplier within 15 years, or if later, ensure that the source is conditioned, stored and disposed of at the cost of the waste generator.

Regulation 67: Segregation, collection and characterisation

This regulation states that the waste generator must keep control on waste generation to the minimum level practicable, and must segregate, collect and characterise waste as far as practical at the point of origin, in accordance with the categories specified in regulation 63, in order to facilitate subsequent treatment, conditioning, storage and disposal. The regulation then further states that after separation, each waste category must be kept separately in a suitable container. Sufficient numbers of containers must be made available by the waste generator where radioactive wastes are generated. The waste containers must be easy to handle, be strong enough to withstand normal handling, and not be affected by the waste content. Waste requiring treatment and conditioning must be further segregated by the waste generator as stipulated in the licence or registration depending of the availability of treatment and conditioning facilities.

Regulation 68: Container labelling

This regulation states that a licensee must ensure that each container containing radioactive waste bears a durable, clearly visible label bearing the radiation symbol. The label must be legible for the whole period of storage and must provide the following information: (a) nature of the waste generated; (b) date of waste generation; (c) commencement date of storage; (d) major radiologically significant radionuclides; (e) external surface dose rate; waste category; (f) biological, chemical or other hazardous materials if exist; (g) name of a person responsible for the waste generation; (h) identification number; and (i) any particular information that may be required by the NRPA in the authorisation for the

disposal in question. The regulation further states that a licensee must, prior to removal of empty containers to unrestricted areas, which after measuring have proved to be uncontaminated, remove or deface the label or otherwise clearly indicate that the container no longer contains radioactive waste. A licensee must prior to its disposal remove the label from containers holding waste with the activity concentrations or activity levels below the exemption levels specified in Schedule 1 of the regulations.

Regulation 69: Discharge of radioactive substances to the environment

This regulation states that a licensee must ensure that radioactive waste is not discharged or released to the environment unless (a) the waste activity or concentration is confirmed to be below exemption levels specified in Schedule 1; or (b) such discharge is within the limits specified in the licence and is carried out in a controlled fashion using authorised methods. The regulation further states that before initiating the discharge to the environment of any solid, liquid or gaseous radioactive waste considered to be within discharge limits, a licensee must, as appropriate (a) determine the characteristics and activity of the material to be discharged, and the potential points and methods of discharge; (b) determine by an appropriate pre-operational model study, all significant exposure pathways by which discharged radionuclides can deliver public exposure; (c) assess the doses to the critical groups due to the planned discharges; (d) submit this information to the Authority as an input to the establishment of authorised discharge limits and conditions for their implementation. Also, a licensee, during the operational stages of radioactive waste management, must (a) keep all radioactive discharges below discharge limits imposed as a condition for the discharge in question; (b) monitor the discharges of radionuclides with sufficient detail and accuracy to demonstrate compliance with the authorised discharge limits and to permit estimation of the exposure of critical groups; (c) record the monitoring results; (d) report the monitoring results to the NRPA annually; and (e) report promptly to the NRPA any discharges exceeding the authorised discharge limits.

Regulation 70: Discharge of cleared waste

This regulation states that waste of Category I (refer to regulation 63) that is expected to decay below clearance levels within one year from its generation, must be stored safely on site, and after confirmation by measurements or other means that the exemption levels specified in Schedule 1 have been reached, must be appropriately discharged or released by the waste generator. The regulation then further states that a licensee may discharge the cleared liquid effluents into sanitary sewerage only if the material is readily soluble or is readily dispersible in water. A licensee may release the cleared solid waste into a municipal waste incinerator or landfill. The regulation notes that nothing in the regulations is

construed as relieving any person from any duty imposed by any law dealing with the disposal of hazardous waste contaminated with toxic compounds or infectious agents.

Regulation 71: Release of specific waste

This regulation states that a licensee may release the following material as if it were not radioactive: (a) 1.85 kBq, or less of Hydrogen-3 or Carbon-14 per gram of medium used for liquid scintillation counting; and (b) 1.85Bq, or less of Hydrogen-3 or Carbon-14 per gram of animal tissue, averaged over the weight of the entire animal. The regulation further states that a licensee may not dispose of tissue under sub-regulation (1) in a manner that would permit its use either as food for humans or as animal feed.

Regulation 72: Waste Storage

This regulation states that a licensee must provide for interim storage of radioactive waste prior to its clearance, discharge or disposal. The regulation then further states that the interim storage facility must be properly designed and constructed with at least one physical barrier between the radioactive waste and other material in the store. The store must be large enough to hold all generated and anticipated waste in an orderly manner and keep different categories separated. The store design must provide for (a) adequate shielding of the radioactive waste; (b) prevention of deterioration of the waste packages; (c) handling and retrievability of the waste packages; (d) adequate ventilation if volatile radioactive substances may be present in the waste; (e) conventional safety; and (f) physical protection. The regulation states that the radioactive waste store must so far as is practicable not contain or be located close to any corrosive, explosive or flammable material, and be clearly and legibly marked with the radiation symbol and details of the Radiation Safety Officer of the waste generator.

Regulation 73: Transport of Radioactive Waste

This regulation states that a licensee must ensure that radioactive waste is prepared for transport, when so required, and is regarded as a radioactive source for transport in accordance with these regulations.

Regulation 74: Treatment

This regulation states that a waste generator must treat the radioactive waste in order to reduce its volume and to facilitate further conditioning. The regulation then further states that the treatment method must be suitably selected for the radioactive waste, depending

on such factors as the volume and type of the radioactive waste, the discharge requirements for liquid effluents and additional conditioning requirements.

Regulation 75: Conditioning

This regulation states that the radioactive waste for long-term storage, transportation and disposal must be properly conditioned. The regulation then further states that waste packages produced by a conditioning process must be fully characterised with regard to important physical, chemical, radiological, mechanical and biological properties. Radium sources must be conditioned for storage by encapsulating the source in a welded stainless tube, placing the tube in a lead shielding container following emplacement of the container inside a 200 liter mild steel drum filled with concrete. Provisions for the retrieval of the encapsulated radium sources from drums and transportation to a disposal facility must made.

Regulation 76: Quality assurance

This regulation states that a licensee must ensure that all radioactive waste management operations are carried out in accordance with a suitable quality assurance programme commensurate with the scope of activities and approved by the NRPA. The regulation further states that the quality assurance programme must be designed to ensure that the facilities and equipment are designed, constructed and operated in accordance with specified requirements for safe operation, all regulations and conditions in a licence or registration are complied with. Each licensee must develop and maintain an accurate and complete documentation system to cover all stages of radioactive waste management, from its generation to disposal. The quality assurance programme must provide for controlled approval, receipt, retention, distribution and disposition of all records important for safety. Records, such as letters, drawings, specifications, etc. must include all pertinent information, such as stamps, initials, and signatures. Each record must be legible throughout the specified retention period. The licensee must retain the records until the NRPA terminates each pertinent licence or registration requiring the record. The licensee must maintain adequate safeguards against tampering with and loss of records. The effectiveness of the quality assurance programme must be verified by independent audits to ensure that a radioactive waste management programme meets specific requirements, is covered by procedures, and that implementation is adequate.

Regulation 77: Physical protection

This regulation states that waste generators must ensure adequate physical protection measures to prevent any unauthorised access to the radioactive waste management facilities.

Regulation 78: Reporting to Authority

This regulation states that a licensee must prepare and maintain an inventory of existing and anticipated radioactive waste containing radionuclides with half lives above 50 days and an activity greater than 10 MBq, and submit it to the NRPA annually and whenever significant changes in radioactive waste amounts or characteristics occur. The regulation then further states that the inventory must be based on the classification system specified in regulation 67, including information on important physical, chemical and radiological characteristics in addition to the quantity of the radioactive waste. Each licensee must report to the NRPA immediately after its occurrence becomes known any lost, stolen or missing radioactive waste under such circumstances that it appears to the licensee that an exposure could result to persons in unrestricted areas. Within 30 days after such occurrence, the licensee must then issue a written report with a description of the radioactive materials involved, its probable disposition, the circumstances under which the loss or theft occurred, and actions that have been taken. Each licensee or registrant must immediately report to the NRPA any event involving radioactive waste possessed by the licensee that may have caused or threatens to cause the release of radioactive material, inside or outside of a restricted area. The licensee must submit to the NRPA annually a report that specifies details of quantities and types of (a) the cleared waste disposed of at a municipal landfill, discharged into a public sewerage system or to the atmosphere; (b) the effluents discharged into the environment within authorised release limits; (c) the conditioned radioactive waste in storage; (d) the spent radiation sources sent to suppliers.

Regulation 79: Emergency preparedness

This regulation states that a licensee must establish and implement an emergency response and preparedness plan in compliance with requirements specified in Chapter 12 (i.e. the chapter describing the waste management program).