

Specialist

Study

Radiation

RADIATION IMPACT ASSESSMENT REPORT FOR RYST KUIL SITE



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ACRONYMS

Acronym	Description
ALARA	As low as reasonably achievable
DMRE	Department of Minerals and Energy
EMP	Environmental Management Plan
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
NORM	Naturally Occurring Radioactive Material
NNR	National Nuclear Regulator
RD	Requirements Document
RPP	Radiation Protection Programme
SSRP	Safety Standards and Regulatory Practices

TERMINOLOGY

Term	Explanation
Assessment:	the process, and the result, of analyzing systematically the hazards associated with sources and actions, and associated protection and safety measures, aimed at quantifying performance measures for comparison with criteria;
Average member of the critical group	the individual receiving the Average effective dose or equivalent dose (as applicable) in the critical group;
Characterization	the determination of the nature and activity of radionuclides present in a specified place;
Contamination	radioactive substances on surfaces, or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable, or the process giving rise to their presence in such places.
Critical group	<p>a group of members of the public which is reasonably homogeneous with respect to its exposure for a given radiation source and given exposure pathway and is typical of individuals receiving the highest effective dose or equivalent dose (as applicable) by the given exposure pathway from the given source;</p> <p>With exposure of members of the public it is usually feasible to take account of these sources of variability by the selection of appropriate critical groups within the population provided the critical group is small enough to be relatively homogeneous with respect to age, diet and those aspects of behaviour that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose equivalent</p> <p>The concept is developed further in ICRP Publication 43 “Principles of Monitoring for Radiation Protection of Population” – this addresses the homogeneity criteria for choosing a critical group.</p>

<i>Dose</i>	the sum of the external and internally committed effective dose integrated over the lifetime appropriate to the identified critical group;
<i>Dose limit</i>	the value of effective dose or equivalent dose to individuals from actions authorised by a nuclear installation licence, nuclear vessel licence or certificate of registration, that must not be exceeded;
<i>Exclusion</i>	exclusion from the scope of regulatory control.
<i>Remediation</i>	Any measures that may be carried out to reduce the radiation exposure from existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to humans.
<i>Optimisation</i>	<p>The principle of optimisation of protection requires that the likelihood of incurring exposures, the number of people exposed and the magnitude of the exposures should be kept as low as reasonably achievable, taking into account economic and social factors.</p> <p>The level of protection should be the best under prevailing circumstances and should provide for adequate margin of benefit over harm.</p> <p>The optimisation principle offers means to take a graded approach to management of radiation risks and focuses on achieving an ethically acceptable outcome, within the boundaries of the legal system, based on balancing risks and benefits.</p>

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1. INTRODUCTION

1.1 Background

An environmental assessment examines the physical, biological and human environment in which a project is proposed to be sited, the nature of the project and the anticipated impacts on the environment, with a view to determining mitigating measures for significant impacts and ultimately judging the acceptability of the project, balancing the potential impacts against the benefits.

The assessment process generally includes the production of an environmental impact statement, a document that describes the project, the environment, the anticipated impacts, potential mitigating measures and the costs and benefits of the project.

1.2 Objectives

The purpose of this radiation impact specialist study is to identify and evaluate the likely significance of the potential radiological impacts on identified receptors according to defined assessment criteria. This is used to develop and describe measures that will be taken to avoid, minimise, reduce, or compensate for any potential adverse environmental effects and to report the significance of the residual impacts that remain following mitigation.

To achieve these objectives, the scope of the radiation impact specialist study phase included the following tasks:

- A review of prior project information on site radiation safety.
- A review of legal requirements pertaining to radiation protection.
- A desktop study of the local receiving environment.
- A report summarizing the findings of a desktop study of the potential impact of the proposed site, from a radiation impact perspective.

1.3 Structure

The main text of this report is organised as follows:

- a) Section 1 set out the introduction of the document.
- b) Section 2 presents the South African Regulatory framework as it relates to the National Nuclear Regulator Act, Act 47 of 1999 (herein referred to as the Act) and its associated Safety Standards and Regulatory Practices (herein referred to as SSRP).
- c) Section 3 provides for description of the environment of the study area.

- d) Section 4 details the radiological environmental aspects considered for the assessment.
- e) Section 5 details the types of radiation hazards and modes of exposure. This is much generic and mainly to give context to the dynamics of the risk assessed.
- f) Section 6 describes and contextualises the radiation sources on site during the mining phase.
- g) Section 7 details the significant radiological impacts based on recent studies for remediation activities.
- h) Section 8 provides for future potential radiological impacts during mining phase.
- i) Section 9 details the impact identification and assessment.
- j) Section 10 draws the main findings and conclusions.

1.4 The consultant

The current report was compiled by Mogwera Khoathane:

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Mogwera Khoathane has an extensive knowledge of radiation protection (more than 30 years) and occupational safety. He started as a Scientist at the South African Nuclear Energy Corporation (NECSA) in 1994 in the Occupational Safety Division.

He joined the National Nuclear Regulator in 1996 as a project officer and later was appointed Programme Manager in the Mining and Minerals Processing Department responsible for management and control of over 120 Mining and Minerals Processing CORs in South Africa. He has tackled many diverse specialised projects ranging from the investigation on the uses of depleted uranium to the studies on the radiological contamination of the Wonderfonteinspruit Catchment area.

He is accredited as a Radiation Scientist by South African Council for Natural Scientific Professions. His varied experience in practicing radiation protection in the Nuclear and NORM industry establishments (nationally and internationally), ensures that Zimkile Consulting services can be tailored to meet the needs of all those working with ionising radiation.

Mogwera holds a BSc Honours Degree in Physics from University of North, a Management Development Programme (Project Management) from Unisa, a Postgraduate Diploma in Business Management from University of Natal and a Master of Business Leadership from Unisa School of Business Leadership.

2. REGULATORY FRAMEWORK

2.1 The National Nuclear Regulator Act

For the purpose of this report, the legal and regulatory framework is established through the National Nuclear Regulator Act, Act 47 of 1999 (the Act). Regulations in terms of section 36, read with section 47 of the Act on Safety Standards and Regulatory Practices (SSRP), specifies the situations that are excluded and / or exempted from the scope of regulation.

In terms of section 2 of the SSRP, the Act does not apply where the specific activity is less than 500 Bq per kilogram for naturally occurring radioactive nuclides of uranium and thorium and their progeny except for radon.

The principles and regulatory criteria for exclusion / exemption of sites from regulatory control are mainly determined by the National Nuclear Regulator (NNR) requirements.

2.2 Exposure situations - IAEA

Two types of situations are defined for the purposes of establishing radiation protection principles: planned exposure situations and existing exposure situations.

Planned exposure situations are those human activities that add radiation exposure to those which people normally receive from existing radiation sources, or that increase the likelihood of their incurring exposure.

Existing exposure situations are human activities that seek to reduce the existing radiation exposure, or the likelihood of incurring exposure, and which are not part of a controlled practice.

For planned exposure situations, provisions for radiation protection and safety can be made before its commencement, and the associated radiation exposures and their likelihood can be restricted from the outset. In the case of existing exposure situations, the circumstances giving rise to exposure or the likelihood of exposure already exist, and their reduction can only be achieved by means of protective or remedial actions.

2.3 NNR Guidelines & Requirements

The NNR has developed a guideline document RG-002 for the Assessment of Radiation Hazards to Members of the Public from NORM Activities. This guide provides clarity on the implementation of SSRP section 4.7. on environmental monitoring and surveillance.

3. DESCRIPTION OF THE ENVIRONMENT

3.1 Vegetation and animal life

Ferret (2008) recorded 505 plant species, 339 insect species, 27 species of mammal, 93 bird species and 31 reptiles and frogs on Ryst Kuil. A large range of protected or rare plants and animals were observed in the area, with some of these endemic taxa having been recorded in South Africa less than 6 times. The most obvious of these rare organisms are *Euphorbia decepta*, Barbour's rock mouse (*Petromyscus barbourin*), a hemipteran (*Thaumastella elizabethae*) and a bushhopper (*Laetettix* sp.). Surveys indicated that the biodiversity in the area can be divided into seven distinct biological communities. Of these, the clay pans and drainage lines associated with the Sout River, Amos River and Kariega River systems are by far the most sensitive habitats, followed by the mountainous area of the Winterberg (with a high biodiversity) and the rocky plains (with a high herpetofauna biodiversity). Silty plains, with a relatively low biodiversity and a relatively low ecological sensitivity, constitutes the majority of the study area [12].

According to J Slabbert (2017) study of baseline conditions at Ryst Kuil, the potential contamination of meat products was of concern to the Karoo farming communities. The dose calculation then included the contribution from meat ingestion. The radioactivity concentrations calculated in meat were however negligible compared to natural radioactivity.

3.2 Topography

Ryst Kuil portion 2 is predominantly flat with few distinctive features. The altitude only varies from 840 m above sea level to 853 m above sea level at the Rooikop trig beacon on the most southern border of the property. Remnants of failed agricultural cultivation of land is evident in various areas on portion 2 of Ryst Kuil. The farm is used for small stock grazing [12].

The higher lying parts north of the study area are composed of the Nuweveld Mountain Range, which is capped by sheets or sills of dolerite in places (Campbell, 1977).

3.3 Regional climate

The climate is arid to semi-arid with long periods of insignificant amounts of rainfall. The desert-like environment is reflected in the sparse vegetal cover that comprises mostly varieties of woody shrubs and succulents. Drought conditions are common over the region and periods of up to nine months have recorded no rainfall (Campbell, 1977).

The Central Karoo is a hot, arid region characterised by long dry spells, with very hot summers and cold winters (temperatures can range from -5°C to 43°C. The area is an exposed windy region with annual rainfall of between 100mm and 200mm. Snowfall is often recorded on the mountains during winter [12].

Rain eases the problem of resuspended dust by forcing down the radioactive dust particulates. Thereby, the quality of air becomes drastically better. This phenomenon is called wet deposition. In arid or semi-arid areas like Karoo, this phenomenon will not regularly occur, hence dusty operations could be problematic. However, post remediation of the Ryst Kuil site, the radioactive dust impact has become insignificant as the radioactive NORM material from the exploration activities has been removed [12].

Notwithstanding the above, there are no other significant anthropogenic sources of air pollution in the immediate former exploration site. However, natural sources that also emit air pollutants include wind-blown dust generated by the arid climatic conditions (EIA/EMP, 2016)

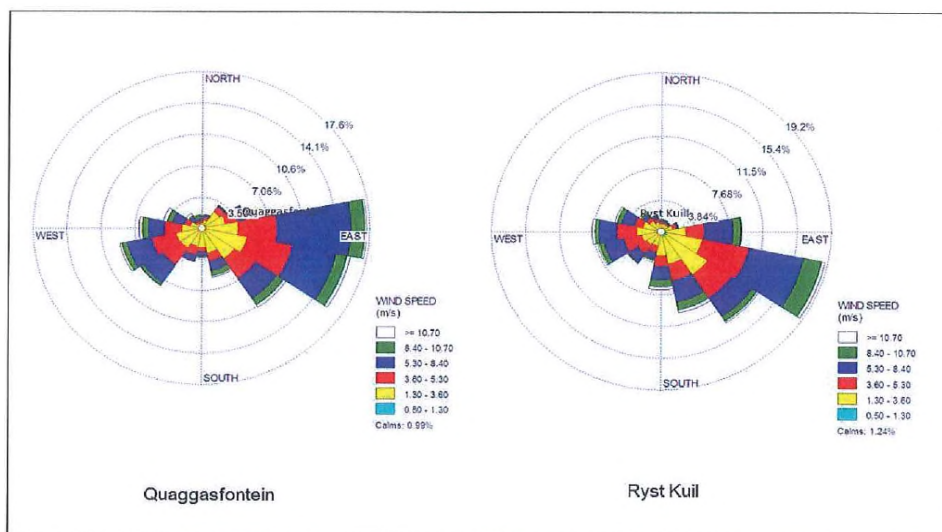


Figure 3-1: Wind roses for Quaggasfontein and Rystkuil - Source [10]

Figure 3-1 depicts wind direction and speed for the Quaggasfontein and Ryst Kuil sites. From the figure, the Ryst Kuil site is characterised by strong winds from South and East direction. Therefore, the greatest impact in case of radioactive dust resuspension will be the North-West. Based on the distribution of critical group from figure 3-1, the most impacted receptors if there is any airborne pollution would be R17 (Retreat); R20 (Saucy's Kuil); R25 (Toomitzkuil), R26 (Hoekskuil) and Quaggafontein site [10].

3.4 Regional Geology

The affected sites are located in south-western part of the Karoo Uranium Province, which forms part of the Main Karoo Basin (Figure 3-2) and extends from the north-eastern part of the Western Cape across the south-eastern part of the Northern Cape and into the Free State as far as Bloemfontein. It also stretches east to Aberdeen in the Eastern Cape and includes a smaller, crescent shaped, satellite area located between Clocolan and Phuthaditjaba (former Qwa-Qwa) (Scholz, 2003).

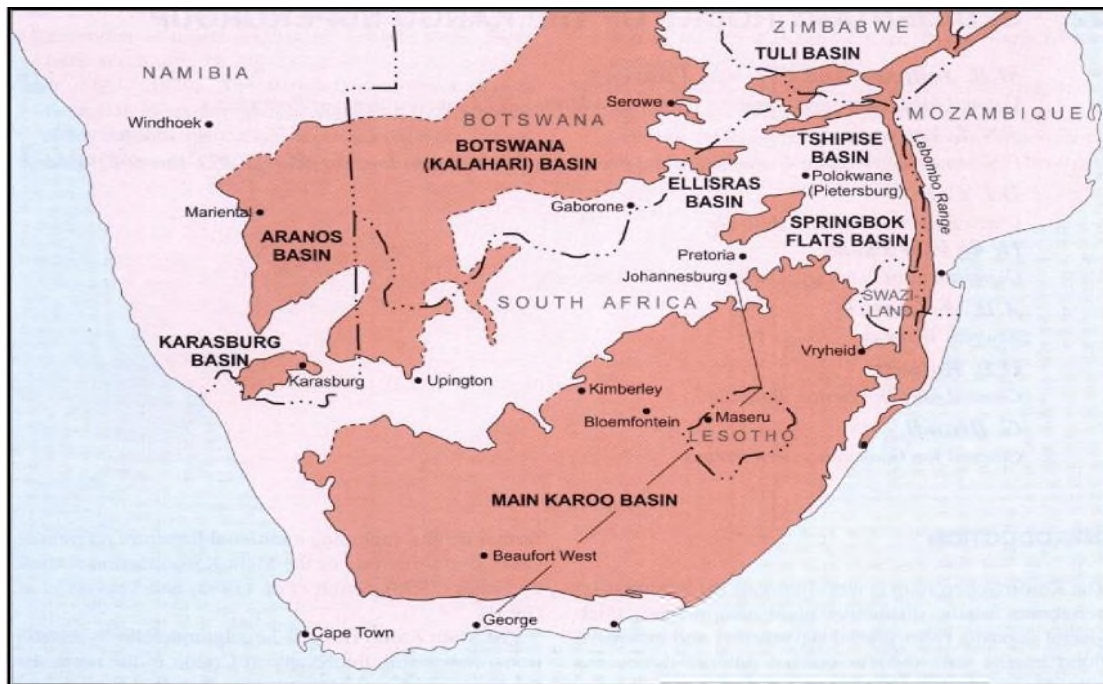


Figure 3-2 Location of Karoo basins of South Africa and adjacent territories (modified after Johnson et al., 1996) Source [12]

Most of the uranium occurrences are situated in fluvial-channel sandstones of the Adelaide Subgroup of the Permo-Triassic Beaufort Group. The mining of uranium ore is a core function of the mine. Hence, the geological profile will be impacted upon.

3.5 Land use

Most of the area is currently used for small stock grazing and the land use potential is limited to either stock grazing or game wilderness. The main commercial activity is sheep farming; however, fruit and olives are also cultivated on the mountain slopes. Some farms have specialized in Angora goats. The Upper Karoo Hardeveld is even grassier, with a greater cover of non-succulent shrubs. Southern Karoo Riviere is a riparian woodland and associated alluvial shrubland is characterized by trees (*Acacia karoo*) and halophytic shrubs [12].

3.6 Critical group

3.6.1 Scenario and impact prior mining

The site is in a remote area with no direct access by local communities. The closest town to the site is Beaufort West and the direct neighbours of the farms are farmers and farm workers. Unemployment levels are high and are expected to increase due to reduced growth in the agriculture sector. No direct impact is expected on any of the farmers, farm workers or people living in Beaufort West [12].

According to J Slabbert (2017), the most sensitive age group for mining activities in the vicinity of Ryst Kuil mine site is the infant age group. The maximum dose (see table 3.1 below) for all potential mining activities calculated for the infant age group is measured against the regulatory dose constraint value of 250 μ Sv/a with no exceedance of the public dose limit expected (i.e. 1mSv/a).

Table 3.1: Maximum potential annual dose for infant age group. Source [10]

Sensitive receptors identified within the Rystkuil mining right area		
Receptor	Area name	Effective dose (mSv/a)
R1	Kat Doorn Kuil	0.085
R2	Kant Kraal	0.127
R3	Klipstawels	0.094
R4	Klipkrans	0.134
R5	Eerstewater	0.092
R6	Ryst Kuil	0.028
R7	Lootsplaas	0.005
R8	Haanekuil	0.006
R29	Kat Doorn Kuil**	0.479
R31	Nuwejaarskuil	0.003
R30	De Pannen	0.001
R50	Neverset	0.001

****Kat Doorn Kuil represents a hypothetical critical group and the only potential receptor location exceeding the NNR dose constraint of 250 μ Sv/a.** Source [10]

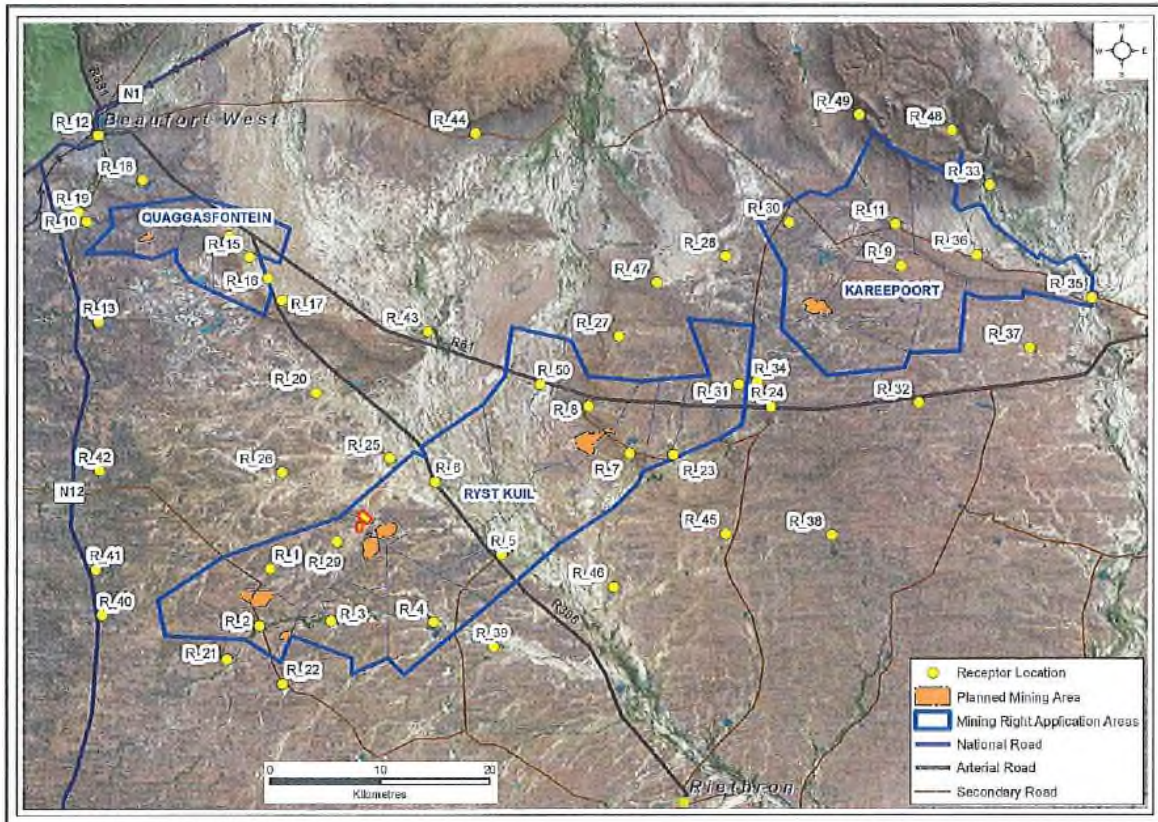


Figure 3.3 Map depicting critical group as per table 3-1. Source [10]

The map in figure 3.3 depicts critical groups as per table 3.1 above.

4. RADIOLOGICAL ENVIRONMENT

4.1 Site characterisation

According to IAEA-TECDOC-1148 (2000), the characterisation of a site is a methodical scientific process used to determine the extent and nature of the contamination as well as the important site parameters, geotechnical characteristics, geological features, and other properties likely to determine the behaviour of the contaminants.

To provide a detailed picture of the nature of the site, this could include:

- Determining the distribution of the contaminants in the various media, e.g whether the contamination is limited to the surface soil, is distributed to significant depths, or whether the ground waters are affected.
- Determine the chemical and physical characteristics of the contaminants and their immediate environment.
- Determining whether the contaminants will be mobile under any of the relevant environmental conditions, and if so, what the likely source term would be.

Against this, a detailed characterisation of the contaminated site and assessment of the consequences of various actions is essential. Section 2 of J Slabbert report, 2017 [10] provides reliable and suitable data regarding the distribution of radioactive contaminants on the Ryst Kuil site. The report is available as reference material and its content will not be repeated here, however, it is important to mention that report covered the following objectives:

- To provide a comprehensive radiological characterisation of the contamination and to characterise the different areas prior to remediation stage.
- To determine how and to what extent radionuclides are moving as a result of runoff, re-suspension, migration, and so on.
- To have a radiological status of the area and use this as a baseline to verify that the activity and dose rate levels in the affected area are within levels acceptable for the purposes for which the area will be used.
- To ensure that dose to the critical group remain within acceptable levels.

4.2 Physical radiological environment

The previous owners of the Ryst Kuil site conducted radiological surveys post remediation. These radiological surveys were undertaken by the previous owners in 2022. The data that was collected include:

- Direct gamma exposure rate.
- Surface contamination measurements.
- Selected specific activity in surface soils.
- Concentration of long-lived alpha concentration (radioactive dust).
- Radionuclide concentration in water.

4.3 Human radiological environment

The human radiological environment relates to the receptor, in this case the critical group. However, the concept of a “critical group” has evolved over time. The original concept was useful as a tool in that in some circumstances it is possible to identify a small, homogenous group of individuals living in proximity to a source of radiative materials (such as uranium mine) that was likely to receive the highest radiation exposure from the source and any others in the vicinity [16].

The situation in places where the existing and future populations of an area are low or considerable distance from the source, and pathways are either non-existent, curtailed or very long, makes it problematic to use the concept of a critical group as a tool to demonstrate good radiation protection principles. Instead, the concept of an “*hypothetical critical group*” has been used. This group is not composed of real people and can be placed anywhere in the environment that is like to receive the greatest exposure resulting from a source of radioactive materials, such as uranium mine and processing plant [16].

4.4 Biological radiological environment

The requirement to assess radiation impact to non-human species (animals and plants), is driven largely by the needs of national regulators and international organisations as part of their initiatives for a sustainable development. There also already exist international conventions and national legal requirements to protect the environment from the harmful effects of radiation.

Currently the NNR regulatory framework applies the basic principles of ICRP's current recommendations and these do not directly address protection of the environment, and the position of the International Commission on Radiological Protection (ICRP) is expressed in paragraph 16 of publication 60 (ICRP, 1990): *"The Commission believes that the standards of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk"*.

4.5 Transport and radiation

Concern is sometimes expressed over the potential for radiation exposure to communities and the environment along the transport route. The transport of radioactive material in South Africa is regulated by the current revision of the *IAEA Regulations for the Safe Transport of Radioactive Material, SSR-6 (rev1), 2018 ed.* Studies of radioactive material transportation highlight the low overall risk, primarily due to stringent regulations and robust packaging.

Radioactive materials are transported in accordance with strict and internationally agreed safety regulations which are the result of permanent and progressive process based on social concern and on the advancement of knowledge provided by research and development. The risks associated with the transport of radioactive material are low and managed in accordance with their actual rather than perceived hazard [23].

5. TYPES OF RADIATION HAZARDS AND MODES OF EXPOSURE

5.1 Types of radiation

The radiation hazards arising post remediation of the site have been assessed; these include gamma radiation and specific activity. Gamma radiation is a very high energy photon (a form of electromagnetic radiation like light) emitted from an unstable nucleus that is often emitting a beta particle at the same time. Gamma radiation causes ionization in atoms when it passes through matter, primarily due to interactions with electrons. Gamma radiation can therefore deliver significant doses to internal organs without inhalation or ingestion.

5.2 Modes of exposure

Irradiation of the body may result from radiation sources located outside the body (external exposure) or from radioactive materials deposited within the body (internal exposure) or simultaneous exposure from both. The methods used to assess dose to the body and its organs differ for these two modes of exposure.

5.2.1 External Exposure

As long as the radiation source remains external, exposure of the individual may be terminated by removing the individual from the radiation field or by removing the source. If the external radiation field is localized, exposure to individuals may be limited readily by shielding or by denying access to the field of radiation or at least to the region of high radiation intensity.

5.2.2 Internal Exposure

Entry of radioactive materials into the body may occur by inhalation, by ingestion, or by absorption through the skin or through a break in the skin. Insoluble materials are usually excreted after ingestion, but after inhalation or entry through the skin, they may remain in the lungs or subcutaneous tissue or may migrate elsewhere in the body depending on the clinical form and particle size. Inhalation and ingestion frequently occur together since large insoluble particles in the tracheo-bronchial tree may be expelled by ciliary action and then swallowed.

Soluble materials, after entering the body, are either excreted or deposited in one or more organs or tissues depending on their chemical and physical form and metabolic pathways in the body. Irradiation of the organs which the radionuclide traverses, or in which it is deposited, continues until the radioactive material is eliminated through translocation, excretion, or radioactive decay. Internal exposure can be avoided only by preventing the entry of radionuclides into the body and this is best achieved by PPE and strict confinement of radioactive materials at work or storage locations.

6. SOURCES – MINING PHASE

6.1 Tailings storage facility

Residual material from mining and associated beneficiation operations are commonly managed by deposition on surface, or by disposal in mine workings excavated below the natural surface of the land. In both cases, the residual material constitutes a potential source of pollution by either wind-borne or water-borne migration of contaminants [22].

Tailings management in South Africa is regulated by law in the Guideline for the Compilation of a Mandatory Code of Practice on Mine Residue Deposits issued by the Department of Mineral Resources (DME) in 2000. This guideline makes

implementation of a code of practice mandatory for each tailings facility with compulsory adherence to the SANS 10286, Code of Practice for Mine Residue Deposits.

6.2 Waste rock & ore stockpiles

Waste rock is frequently made up of very fine particles that contain long lived alpha emitters. When distributed by the wind, this material is dispersed as dust to the environment. Dust emissions can be controlled by maintaining adequate cover or sprinkling with water.

Waste rock is generated from mining development operations, this rock is associated with the uranium reef, hence this may lead to elevated levels of radiation. Waste rock and ore stockpiles will be designed so that all potentially contaminated surface water runoff and seepage from these areas are captured and will be managed to reduce risk of dust generation.

7. RADIOLOGICAL IMPACTS – RECENT STUDIES

The purpose of this section is to provide a summary description of the radiation conditions as observed at Ryst Kuil site post remediation activities. Within the conceptual assessment framework this information would provide input into understanding of the release, distribution and accumulation of radiological contaminants that could be released from the Ryst Kuil site into the environment and associated media.

There are two main categories of exposure pathway; external exposure pathways (the source of exposure remains outside the body) and internal exposure pathways (the source of exposure is incorporated into the body).

The main external exposure pathway considered in this report is direct gamma exposure from source of ionizing radiation. The main internal exposure pathways considered in this report are (i) human inhalation of radionuclides in dust (ii) ingestion of radionuclides in food (iii) inhalation of radon progeny.

The potential exposure pathways for the Ryst Kuil site post remediation phase is discussed in section 7.1 below. In the context of this report, the results of the site remediation will represent a baseline for proposed mining.

7.1 Ryst Kuil remediation phase

7.1.1 Gamma radiation exposure

The post remediation gamma survey conducted on Ryst Kuil sites using a sodium iodide crystal instrument recorded the maximum dose rate of **550.6 nSv/h** which is below the NNR dose limit of 1mSv/a, which is a limit for members of the public.

Therefore, it can be concluded that there is no significant exposure from this pathway. Also, for the public, this is not regarded as a significant impact since the nearest critical group is at about 2km radius of the Ryst Kuil site and gamma radiation intensity reduces with distance from the source [17].

7.1.2 Soil activity concentration

Post remediation surveys done in Sep 2022, the soil monitoring results indicated average specific activity concentrations of **229.94 Bq/kg** for the Ryst Kuil site. This level of radiation is less than the NNR exclusion level of **500 Bq/kg** for NORM [17].

7.1.3 Radioactive dust exposure

The potential dust exposure from the Ryst Kuil site is determined based on the specific activity concentration of soil measurements. The impact from a conservative dust load of 1mg/m³ translated to an on-site potential dose of **24.07uSv/a**, it can be concluded that there is no significant exposure from this pathway [17].

7.1.4. Surface water

No surface water bodies occur near the Ryst Kuil site except for some small earth dams that are used for farming [12]. Due to the aridity of the area and very flat topography, only one surface water sample (about 2.5km north-east of Cameron shaft) could be taken during Scholtz' (2003) assessment.

This site showed copper concentrations above ideal for ecosystems and iron concentrations above ideal for domestic use, which is in line with the natural background levels of these elements found in water for the region. Section 3.3.4 of Scholtz report provides detail on surface and ground water, and accordingly, no other elements of concern were found at elevated concentrations (Scholtz, 2003).

7.1.5 Ground water

The main regional aquifer at Ryst Kuil is a palaeo-channel sandstone fractured rock aquifer, which extends in a northeast-southwest direction across the whole property and has a width of c. 2.5 km, widening to the north-east and south-west. It has a variable thickness of 20 – 40 m at depths of c.100 m below surface but up to c.140 m in places. The uranium ore bodies are hosted within this sandstone, which is frequently interbedded with mudstones. Aquifer transmissivity (c.12 - c.380 m²/day) and borehole yields (c.5 - c.25 L/s), according to test results from purpose-drilled groundwater exploration boreholes, are highest in the south-west and decrease to the north-east. This is a function of sandstone lithology, thickness and structure (SRK, 2017).

According to SRK (2017), seventeen water samples were collected during the 2016 hydrocensus survey and submitted to NECSA laboratory for radio analysis.

Radioactivity concentrations in groundwater samples are mainly from U-238, U-234, and in some cases, Th-230. The other radionuclides in the U-238 and Th-232 decay chains are present at low concentrations. Most of the groundwater samples, although not of ideal radiological quality (i.e. Class 2 Yellow – Marginal Water Quality) except for borehole KDK017 in the Ryst Kuil area. KDK017 recorded a value above the WHO limit of 30µg/l. The water in this borehole is not currently used for human or agricultural purposes [10].

8. POTENTIAL FUTURE RADIATION IMPACTS – MINING PHASE

During the future operation of the mine, the health of members of the public and farmers around the mine should be protected in accordance with the NNR dose optimisation principles. Radiation doses to the public should not exceed the recommended value of 1mSv/a, with a dose constraint of 0,25mSv/a.

Further to the above, the future mining activities must be inherently safe, with no appreciable likelihood of scenarios that could lead to a failure to meet the findings made 7.1 above when optimising radiation safety by adhering to ALARA principle.

Based on the above, the potential significant exposure pathways during the mining phase could be radon and ground water emanating from the TSF. The risks that could result from radon and ground water during the operation of a typical uranium mine are respectively discussed in section 8.1 to 8.2 below.

8.1 Radon

Radon release from tailings material to the environment involves two mechanisms:

- Liberation from the particle in which it is formed, which is characterised by the radon emanation coefficient; and
- Transport through the bulk medium to the atmosphere, which is characterised by the diffusion coefficient in the bulk medium.

In addition, radon release to the environment will be affected by the presence of covering layers and the meteorological conditions. The flux from an uncovered tailings facility is directly related to the Ra-226 activity, the emanation coefficient and the bulk density. If any of these variables increases, then the surface radon flux increases proportionally. The Flux also increases as the diffusion coefficient increases. (IAEA, 1992).

8.2 Ground water

Nuclides contained in the tailings storage facility could migrate into its immediate surroundings and the subsurface of the earth at large, under the influence of molecular diffusion and hydrodynamic dispersion caused by infiltrating surface water.

9. IMPACT ASSESSMENT

9.1 Introduction

The objective of this impact assessment is to identify and evaluate all the significant impacts that may arise as a result of the proposed uranium mining activities at Ryst Kuil site. The impacts identified are evaluated according to an objective set of criteria in accordance with Government Notice R.385, promulgated in terms of section 24 of the National Environmental Management Act, Act 107 of 1998, and the criteria drawn from IEM Guidelines Series, Guideline 5: Assessment of Alternatives and Impacts, published by the Department of environmental Affairs and Tourism (April 1998) as well as the Guideline Document on Impact Significance (DEAT 2002).

9.2 Impact identification and assessment

Exploration conditions do not present any impact to the environment as the site has been remediated by previous owners. The gamma survey done as part of the remediation phase has indicated low level of specific activity, gamma exposure and radioactive dust exposure as discussed in section 7. However, there could be potential radiological impacts associated with the operational phase of uranium mining.

The potential impacts on the environment are associated with gaseous, liquid and solid dispersion of radionuclides into the environment. The impacts identified for Ryst Kuil site are:

- Contamination of surface water with Ra-226 due to accidental spillage into ephemeral rivers (seasonal).
- Seepage of Ra-226 into ground water due to ore stockpiles and tailings material.
- Exposure to radon and its short-lived progenies emanating from the TSF, ore stockpiles and waste rock.
- Discharge of the radium bearing waters into settlement ponds.

9.3 Impact rating criteria

The potential impacts listed above were evaluated according to the following impact rating criteria.

- **Nature:** The nature of the impact refers to the type of effect the potential impact will have on the affected environment.
- **Intensity:** This is relative evaluation of the extent to which the receiving environment is affected as a result of the identified impacts.
- **Extent:** Extent refers to the spatial scale of the potential impact.

- **Duration:** The impact criteria provided describe the “duration” assessment norm as the expected lifespan of the potential impact.
- **Impact on the irreplaceable resources:** The resources potentially affected by the identified impacts are expected to cover over time.
- **Consequence:** The consequence and significance of impacts are derived values based on the values selected for the foregoing criteria.
- **Probability of occurrence:** Probability of occurrence is a description of the probability of the impact occurring.
- **Significance:** The significance of an impact is decided by evaluating the magnitude, duration and likelihood of an impact occurring within a context. Significance is a value judgement and depends on the nature of impact.

The potential impacts are evaluated with and without mitigation. The mitigation measures accounted for are as follows and must be adhered to:

- The design of the mine must consider releases of radium contaminated water and radon gas and must ensure that releases are managed to be ALARA.
- The settlement ponds where radium bearing water is dumped must be engineered in such a way to prevent seepage into ground water and possible discharge into rivers.
- Stockpiling of uranium ore should be done considering prevention of runoff water and seepage of water into underground aquifer.
- Dust control measures – this can be achieved by implementing appropriate dust control measures

9.4 Results of impact assessment

The results of the impact assessment of radioactive discharges associated with uranium mining and processing are presented in Table 9.1.

Table 9.1: Results of the impact assessment of radioactive discharges associated with Ryst Kyl

Impact	Nature	Intensity	Extent	Duration	Irreplaceable resources	Probability	Significance
Contamination of surface water with Ra-226 due to accidental spillage into perennial rivers.							
Without mitigation	Negative	Low	Low	Medium	Low	Low	Medium
With mitigation	Negative	Low	Low	Low	Low	Low	Low
Seepage of Ra-226 into ground water due to uranium ore stockpiles.							
Without mitigation	Negative	Medium	Medium	Medium	Low	Low	Medium
With mitigation	Negative	Low	Low	Low	Low	Low	Low
Exposure to radon and its short-lived progenies in underground working places.							
Without mitigation	Negative	Medium	Medium	Medium	Low	Low	Medium
With mitigation	Negative	Low	Low	Low	Low	Low	Low
Increased gamma radiation exposure in the surrounding environment due to dust deposition.							
Without mitigation	Negative	Low	Low	Low	Low	Low	Medium
With mitigation	Negative	Low	Low	Low	Low	Low	Low
Discharge of the radium bearing waters into settlement ponds.							
Without mitigation	Negative	Medium	Medium	Medium	Low	Medium	Medium
With mitigation	Negative	Low	Low	Low	Low	Low	Low

10. MAIN FINDINGS AND CONCLUSIONS

- a) Based on the surveys done on site post remediation in 2022, the projected radiation exposures at Ryst Kuil site currently presents low levels of radiation, therefore the current radiological impact to members of the public and the environment is lower than the NNR public dose limit of 1mSv/a.
- b) Without mitigation, radon and ground water contamination could result in radiation impact to the environment due to uranium mining activities.
- c) It should be noted that radon was not extensively sampled as part of the exploration activities, hence it is recommended that Lukisa Invest should undertake radon baseline studies at the Ryst Kuil site during the mining operations. The broad scope for the investigations is as follows:
 - (i) Baseline investigations to assess the concentration of radon and radon decay products.
 - (ii) Definition and modelling of the radiation exposure pathways from all mining activities for both workers and public.
 - (iii) Exposure estimates to estimate annual average exposure of the Hypothetical Critical Group.

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