

REVIEW OF THE RELEASE OF RADIOACTIVE MATERIAL FROM THE RIO TINTO/QMM MINE MADAGASCAR



By
Stella Swanson, Ph.D.

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Commissioned by the Andrew Lees Trust (ALT UK)

SUMMARY REPORT

**The full report is available on request from the Andrew Lees Trust
Please contact: info@andrewleestrust.org**

Introduction

This independent review of the release of radioactive material from the QIT Madagascar Minerals S.A. (QMM) ilmenite mine was commissioned by the Andrews Lees Trust (ALT UK).

The overall aim was to conduct an independent expert review of all available, relevant information pertaining to the release of naturally occurring radioactive material to the environment due to the activities of the QMM mine in Anosy, southern Madagascar, and the subsequent exposure of members of the public. This review does not include consideration of radiation doses to QMM workers.

The objectives of this review are:

- To review the scientific methods and approach involved in the monitoring and management of the radioactive materials generated by the QMM mine;
- To determine whether the levels of naturally occurring radioactive material (NORM) in the environment that result from the operation of the QMM/Rio Tinto mine in Anosy, southern Madagascar, are within international exposure limits; and,
- To determine whether the pathways of radionuclides and radioactive by-products are managed to internationally recognized standards for the protection of local citizens.

Caveat: The review of radioactivity is based on data and information provided by QMM and Rio Tinto, and the study has not been sufficiently resourced nor remitted to undertake separate field studies, measurements, or verification processes on the QMM mine site in Anosy.

Acknowledgements

Exposure Pathways - graphics production by: Alan Hunns (Hunns Graphics). Images of Anosy provided by: Mbola Mampiray Miandrito, Retsivery, Barry Ferguson, Antonie Kraemer, and the Andrew Lees Trust.

Note: *Images provided for this study have been sourced from local and international researchers; the people displayed have not been involved in this study and their views are not reflected in its content.*

Contact Details

Swanson Environmental Strategies: stellastrat@gmail.com; <http://swansonenviro.ca/>
The Andrew Lees Trust: info@andrewleestrust.org
For all enquiries please call: Yvonne Orengo, Mob: +44 (0)7905 406 303
See related reports at: www.andrewleestrust.org/andrew.htm

Statement from the Andrew Lees Trust

The Andrew Lees Trust (ALT UK) is hugely grateful to Dr. Stella Swanson for the time and expertise she has dedicated to this study, with very limited resources from ALT UK to sustain almost two years of exchange, research, dialogue and management of the process required to see this report into the public domain.

ALT UK is committed to the full disclosure of information in recognition of citizens' rights and the promotion of corporate transparency and accountability. ALT UK cannot be held responsible for how scientific facts and research findings are managed by other parties, including local stakeholders, journalists, media, etc. Ultimately, Rio Tinto/QMM is responsible for managing the impacts of the QMM mine in Madagascar, and effectively and responsibly communicating its operational impacts.

The report deals with a sensitive and complex area of environmental hazard. For this reason, in 2017, as part of a framework agreement with Rio Tinto, ALT UK insisted that a communications component be developed to accompany the release of the independent radioactivity review by Swanson.

The Trust has provided a six-page document to Rio Tinto for framing and advancing a communications process at the local level, as well as the possibility for developing community level monitoring expertise (e.g., around water quality).

In addition to identifying changes needed to improve QMM's monitoring practices, specifically to identify and minimise any risks to local people from radiation, ALT UK and Swanson believe this report also highlights two significant opportunities for QMM to meet key **Sustainable Development Goals (SDGs)**:

(1) **Safe drinking water**, which requires Rio Tinto/QMM (a) to accept that management of the risk associated with QMM mine-related uranium concentrations in receiving waters is a priority; (b) to develop and implement a monitoring program that is sufficiently rigorous to discriminate between natural background uranium and mine-related uranium concentrations in water; (c) to manage uranium effluent releases to the receiving environment adaptively, in response to monitoring information; and, (d) to demonstrate that it recognizes the multiple benefits of the provision of safe drinking water to nearby communities in accordance with its corporate commitment to management of human rights risks, including risks to water resources, and to directing benefits to those affected by mining activities (Rio Tinto 2017 Sustainable Development Report – see: http://www.riotinto.com/documents/RT_SD2017.pdf)

(2) **Equitable inclusion** of local stakeholders and affected communities, which includes developing local staff and community capabilities in communications, social engagement and environmental monitoring skills in order to increase understanding among community members, contribute to informed and inclusive decision making, and provide independent monitoring of the mine's radiation levels over the project lifetime, and beyond.

See also findings/recommendations below and in the main technical report.

Local Context



The Anosy region is one of the ecologically most diverse regions of Madagascar, but also one of the poorest and most isolated (Vincelette et al. 2008). Per capita income is very low and literacy ranges from 25% to 50%. Environmental zones range from littoral forests along the coastline, to humid and transitional forest, marshlands and wooded bush.

Nine communes, including eight rural and one urban, border QMM's three mining concessions (Rio Tinto 2016). People in these communes are heavily dependent on ecosystem services and the natural resource base for subsistence and income needs. About 15,000 people live within a few kilometres of the current QMM site in Ampasy Nahampoana and Mandromondromotra (Rio Tinto 2016).

About 80% of the population is engaged in subsistence agriculture, including rice, manioc, vegetable, and fruit cultivation (Vincelette et al. 2008, Panos London 2009). Coastal areas of Anosy are largely populated by fisherfolk and their families. Most of the rural population relies on forest resources during times of food shortage, but also year-round for firewood and wood for construction (Rio Tinto 2016). Forests also provide medicinal plants, vines for weaving, and honey.



Mandromondromotra and Ampasy Nahampoana have high levels of in-migration with recent in-migration due, in part, to prolonged drought in southern Madagascar. The in-migration often results in unequal land access and resource use between long-established residents and recent migrants. Access to land and natural resources within the QMM mining concession is addressed by a social contract (DINA).

The QMM Mine

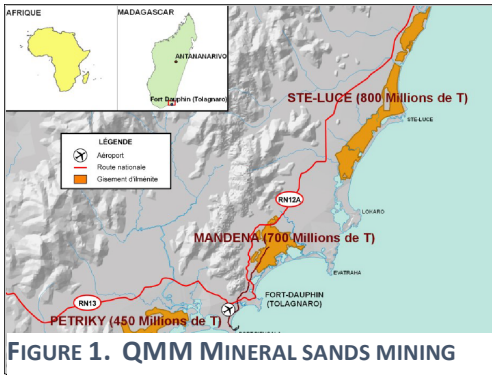


FIGURE 1. QMM MINERAL SANDS MINING AREAS IN THE ANOSY REGION. CURRENT MINE IS AT THE MANDENA SITE.

Rio Tinto's QMM mine is located in the Anosy region near Fort Dauphin on the southeastern tip of Madagascar. Rio Tinto owns 80% of QMM, with the remaining 20% owned by the Government of Madagascar. Current mine operations are at the Mandena site. Planned later phases of mining will be at the Ste-Luce and Petriky sites.

The mineral sands mined by QMM contain multiple minerals, but the minerals of interest are ilmenite and zirsill. QMM extracts ilmenite (which contains 60% titanium dioxide) and zirsill (which contains zircon).

The ilmenite and zirsill are transported about 15 km to Port d'Ehoala. Ilmenite is shipped to Canada where it is processed and prepared for sale as a pigment agent for whitening of paints, plastics and paper. The smaller quantity of zirsill export is used in the production of ceramic tiles, television screens and computer monitors (Hoagland 2013). **Monazite** is shipped to China for extraction of rare earth oxides (see below).

The Extraction Process

QMM uses dredging and a plant that floats on a constructed pond as the first step in separating out the minerals of interest (the wet circuit) (Figure 2). Dredged mineral sand is passed through a floating separation plant to remove heavy minerals such as **ilmenite** and **zirsill**. Lighter materials such as silica are returned to the dredging pond. Ilmenite is removed using electrostatic processing. More separation is then required to remove residual minerals so that the zirsill remains. The separation processes remove magnetic minerals such as **monazite** ("magnetic rejects").

"Mineral sands" contain a number of minerals including ilmenite (which can be processed to yield titanium dioxide) and 'zirsill' (which is a mix of zircon and sillimanite). When ilmenite and zirsill have been extracted from the mineral sands, the residual material contains various minerals including monazite. Monazite is of interest because it's the mineral that contains the rare earths.

The volume of fresh water required for processing of the mineral sands is reduced through recycling. About 9.4 million litres per year of process effluent is produced. Process effluent is treated in settling basins prior to discharge to a wetland on the mine site that drains to the Mandromondromotra River.

According to Rio Tinto, approximately 5% of all the mined mineral sand is sent to the dry plant. After the removal of valuable commodities (1% of the initial mined volume), the reject sand is returned to the wet plant for disposal at depth of about 15 m below sea level. The wet plant reject sand is discharged on top of the dry plant reject sand.

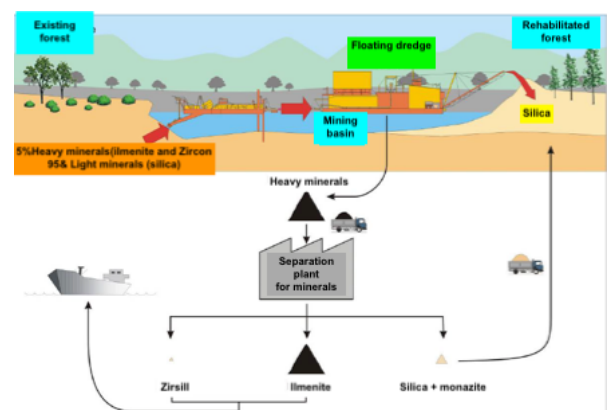


FIGURE 2. QMM EXTRACTION PROCESS (PROVIDED BY QMM)

Rio Tinto explains that, adjacent to the dry plant, is a stockpile area. The area is approximately 7.5 ha in size and contains a range of materials such as HMC 86 (Heavy Mineral Concentrate from the wet plant). It is also used as a temporary storage area for magnetic rejects (monazite) material; this is a small area approximately 30 metres across and is not a permanent storage area for this material. Access to the magnetic rejects stockpiles, which contain monazite, is restricted and members of the public are not be allowed near these areas.

Mineral Sands in Anosy and Dose Limit

The International Atomic Energy Agency (IAEA) dose limit for the general public is 1 millisievert (mSv) in a year (IAEA 2018). A millisievert is a unit of ionizing radiation dose. It is used to represent the biological effects of different forms of radiation on human tissue.

Dose limits are restrictions related to an individual person and apply to the total dose received by that individual from all relevant sources (IAEA 2018).

Mineral sands areas, and specifically monazite sands within the Anosy region, have high natural background levels of radiation.

People in the region have always been exposed to these natural levels of radiation in air, soil, water and food. It should be noted that the natural background radiation in the Mandena region is not as elevated as some other high natural background areas in the world; see Figure 3 below. Such areas, including areas in the Anosy region, can exceed the dose limit without consideration of any other sources.

Therefore, the dose limit for **incremental exposure**, over and above the natural background present in the Anosy region, is 1 mSv/yr.

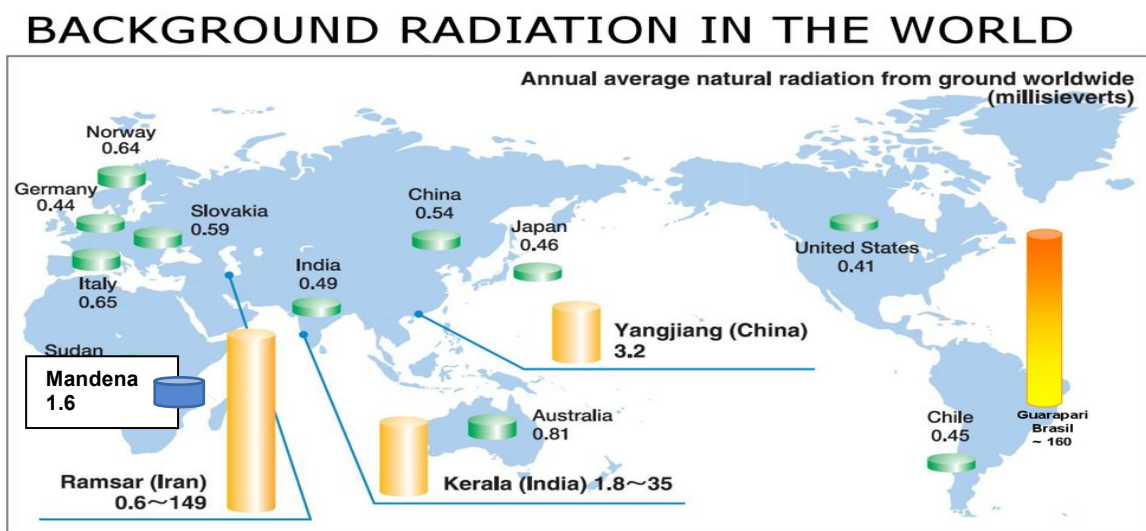


Figure 3. Comparison of yearly average natural radiation emitted from the ground worldwide

In Figure 3, high natural background areas are shown in yellow/orange. The Mandena region average radiation level is **shown in blue**. Radiation levels in areas without naturally elevated background are shown in green. [Figure adapted from <https://en.ppt-online.org/303224>].

There are two ways that people can be exposed to radiation: (1) they can be exposed externally to a near-by source of radiation; or, (2) they can be exposed internally by radioactive material that has entered the body through inhalation or ingestion.

People living in the vicinity of the QMM mine can be **exposed to radiation via several pathways**: external gamma radiation; radon inhalation; dust inhalation; and, ingestion of water, food and soil. **See Exposure Pathways diagram, page 6.**



Gamma Radiation Exposure

The potential for the QMM mining activities to increase exposure to gamma radiation was investigated.

Mineral sands areas in the Anosy region emit gamma radiation because of the presence of radionuclides such as uranium and thorium. QMM mining activities disturb, redistribute, and in some cases, concentrate, these naturally-occurring radionuclides.

Any QMM contribution to gamma exposure would be restricted to the immediate vicinity of the project and the adjacent areas (of the order of one hundred metres). This is because gamma exposure rapidly decreases with distance from the source.

Three potential scenarios were considered for gamma exposure: post-mining exposure, wood collection at QMM, and transport of material off site

The dose from gamma exposure to people living on rehabilitated land may be slightly less than that from the natural pre-mining levels because of the placement at depth of monazite sands containing higher levels of radioactivity. However, this is only true if a large area is considered because of the nature of the mining and subsequent reposition of monazite sands, and there will be a high variability on a location by location basis.

Much more sampling is required to obtain a more confident indication of the site-wide gamma dose rate post mining, and whether there may be specific areas where post-mine exposure has increased.

For wood collection, a hypothetical dose of 0.2 mSv/y was estimated based on the assumption that a wood collector would be on the site in unmined areas for 6 hours per day, 3 days a week, every week of the year. The incremental risk of health effects of any dose which is less than 1 mSv/y is very small. However, the estimated 0.2 mSv/y from gamma exposure during wood collection would not be the only exposure pathway for a wood collector.

It is important that people are aware that small incremental gamma exposures can occur if they enter the site. Furthermore, additional incremental doses to a wood collector could result from other exposure pathways such as inhaling dust from the QMM site.

Monazite Shipments



In 2018, QMM started shipping monazite for extraction of rare earth oxides. Rare earth oxides are used in many important products such as batteries and electric cars. Monazite also contains uranium and thorium and their radioactive decay products, so shipment can potentially expose the public to radiation. Classified as radioactive material, monazite shipments are subject to international safety standards. The material is placed in bulk bags (see standard bulk bag image, left) and then sealed in shipping containers.

A very conservative model was used for the transport of monazite to Port d'Ehoala using assumptions of people being in very close proximity to large transport trucks for relatively long periods of time. A hypothetical roadside seller, who is at a stop sign location, was assumed to come within one metre of a container for one minute; often enough to be exposed to half of the trucks with containers that pass by. Therefore, for an entire shipment of 400 containers of monazite, he or she would spend 200 minutes 1 metre away from the containers. Based on the above assumptions, the potential exposure would be 0.07 mSv per shipment of 400 containers.

Assuming 4 shipments per year then the potential dose to this hypothetical person would be 0.27mSv/yr. This estimate is highly uncertain and far higher than worst-case estimated doses calculated for shipments of similar material in Australia. Specific monitoring of rare earth oxide shipments is required to reduce the uncertainty in these estimates.

Radon Exposure

Radon is an inert gas produced by both the uranium and the thorium decay series. The uranium-238 series produces radon-222 with a half-life of 3.8 days. Radon-222 decays to a series of short-lived radionuclide progeny with a maximum half-life of 27 minutes. The thorium-232 series produces radon-220, commonly called thoron, which has a half-life of 55 seconds. Radon-220 decays to a series of short-lived radionuclide progeny with a maximum half-life of 11 hours. The short-lived progeny are the primary issue because, unlike radon-222 and radon-220, which are inert gases that don't interact with tissues in the body, the progeny may attach to the lung or upper respiratory tract. Radon-222 is the most significant for public exposure because of its 3.8-day half-life compared to the 55-second half-life of radon-220, which is so short that there is insufficient time for it to diffuse out of the mineral sands, let alone be transported offsite.

The inhalation of radon gas and its short-lived progeny is not expected to be a significant source of exposure to the public from the QMM operation. This is primarily due to the local weather conditions that provide ample dispersal of the radon gas and prevent its build-up in inhabited areas. QMM-related doses of the order of a few thousandths of a milli-Sievert per year would be the maximum expected in any community.

After mining is completed, the rehabilitated land may become a site of either permanent or temporary residence for local communities; therefore, the potential for exposure to radon should be considered. It is expected that the post-mining burial of the more radioactive material at depth would cause the post-mining radon exposure to be less than that which would have occurred in the natural pre-mining situation. This is because both forms of radon have relatively short half-lives (3.8 days and 55 seconds for Rn-222 and Rn-220, respectively) and any increase in depth will decrease the amount of radon which can escape to the surface environment.

Consistent placement of minerals containing radioactivity at sufficient depth is required to produce conditions where post-mining radon exposure is not distinguishable from background.

Inhalation of Long-Lived Radionuclides in Dust

QMM activities generate dust, which may contain enhanced quantities of radionuclides. This dust may be carried via the prevailing wind to the local communities where it can be inhaled. Not all dust in the air can be taken into the lungs. It is the smaller particles (called PM₁₀ dust or dust particles that are smaller than 10 µm in diameter) that are important for this pathway.

The longer-lived radionuclides dominate the dose from inhaled dust particles. The potential exposure from shorter-lived radionuclides is far less and may be incorporated into the dose from the parent radionuclides. The longer-lived radionuclides important to the consideration of dust inhalation emit gamma, alpha and beta radiation. Inhalation, together with ingestion, is the mechanism for exposure to alpha and beta radiation.

The incremental contribution of QMM operations to dust in nearby communities was estimated using air monitoring data. A conservative approach was used whereby the lowest dust concentration measured at any of the sites was used as the background dust level. The operational component was then calculated based on taking the dust concentrations at the two community sites in the downwind wind direction (Ampasy Nahampoana and Maroamalona and then subtracting this regional background dust concentration (thereby maximising the operational component).

Estimated yearly doses from dust inhalation were highest for the 1-2-year-old age group. This result reflects breathing rates for this age group as well as higher dose conversion factors for some of the radionuclides. Estimated doses were consistently higher for Maroamalona than for Ampasy Nahampoana across all age groups.

Dose conversion factors convert measured quantities of radiation (e.g. Bq/m³ uranium-238 in a cubic metre of air) to radiation dose to tissues within the body (expressed as mSv/yr.). The conversion factors account for the fact that different radionuclides produce different proportions of radiation types (gamma, alpha, beta), which, in turn, deposit different amounts of energy in tissues. Dose conversion factors account for the solubility of individual radionuclides in body tissues. Dose conversion factors also vary with age (e.g. young children versus adults).

The results should be considered an overestimation of the potential dust-related dose due to the conservative nature of the assumptions used. However, the results do provide a useful indication of the potential significance of the dust pathway. Estimated doses from inhalation of dust generated by QMM operations are from about 20-40% of the yearly 1 mSv dose limit for the general public. This is a substantial proportion of the allowable *incremental dose*.

The application of best practices for effective dust management at the QMM operations is important in order to keep the incremental dose to the public well below the limit. It is equally important to reduce the uncertainty associated with the dose due to dust inhalation by obtaining more monitoring data (see Recommendations section, main technical review).

Exposure via Ingestion

Exposure via ingestion occurs via drinking water, eating food, or accidentally eating soil that is on food or on people's hands. The people who have the highest potential for receiving QMM-related radiation doses via ingestion would live nearby and obtain a substantial amount of their drinking water and food from adjacent rivers, lakes, fields, and pastures. It is assumed that this applies to all of the settlements in the immediate vicinity of QMM mining operations.

Over 75% (or more) of households in the Mandena area rely on surface water bodies for drinking water, including the Mandromondromotra River, which receives mine effluent via a wetland immediately adjacent to the river. Groundwater seepage may release radionuclides to Lake Ambavarano and Lake Besaroy. The Méandre River may receive radionuclides via dust deposition.

All radionuclide levels in river and lake water samples were well below World Health Organization drinking water guidelines for radiation exposure. However, these measurements were from one sampling event only. Therefore, there is no way of knowing whether these results represent typical conditions. Furthermore, there were several anomalies in the data, which indicate that there may be significant problems with the laboratory analysis results.

Because the radionuclide data for water were so limited (and questionable), results of analysis of uranium and thorium as heavy metals were evaluated. With one exception, thorium was not detectable in river water at stations adjacent to QMM effluent discharges.

Uranium was detectable at all Mandromondromotra River stations and all concentrations were above the WHO drinking water quality guideline for chemical toxicity, often by substantial margins (e.g., 50x the guideline near the weir).

Uranium concentrations that are above drinking water quality guidelines are a concern because of the chemical hazard of uranium rather than its radioactivity (which is very low). The contribution to uranium concentrations from QMM operations versus natural background uranium is unknown. However, no matter what the source of uranium in water is, the results should trigger early action to confirm the degree of exceedances (frequency and location) and the degree of difference between upstream (reference) versus downstream (mine-affected) sampling stations on the Mandromondromotra River.

Radionuclides that enter the Mandromondromotra River, Lake Ambavarano or Lake Besaroy may not stay in the water column; instead, they may attach to particles in the water and settle on to river or lake sediments. People could then be exposed via direct skin contact or accidental ingestion of sediments (e.g., children playing in shallow water). Radionuclides in sediments can be re-emitted into the water, causing a gradual increase in radioactivity levels (PARC 2013).

There are no data for radionuclide concentrations in sediments in the river; nor are there any data for lake sediments. Data are required in order to evaluate the potential exposure to radiation via contact with sediments.

The direction of groundwater flow from the QMM site is to the south. Therefore, uranium and thorium series radionuclides can be expected to migrate via shallow groundwater south to Lake Ambavarano. QMM groundwater monitoring data for wells located down-gradient from the site are limited, but elevated uranium concentrations were observed. A well located adjacent to the northern shoreline of Lake Ambavarano had uranium concentrations substantially above the WHO drinking water guideline. Water in this well was also very saline, indicating a connection with seawater entering the lake. The salinity level was so high that the water would be unsuitable for drinking.

The results indicate a definite need for increased monitoring of groundwater in the area likely to receive shallow groundwater seepage from the QMM site.

Accidental soil ingestion is of most concern for children because children typically ingest more soil via play and are more likely to place their hands in their mouths. QMM did not provide soil monitoring data for off-site areas. Therefore, the dose associated with accidental soil ingestion could not be calculated.

It can be assumed that much of the food consumed by people in the area is obtained locally. There are no data on radionuclide concentrations in any food items in the Mandena region. Past estimates of radiation dose from ingestion approached the 1 mSv/y dose limit (PARC 2013); however, these estimates are highly uncertain.

Total Public Radiation Dose

Notwithstanding the uncertainty associated with past estimates of total public dose, they are high enough to ***trigger additional investigation***.

This review confirmed the potentially significant contribution of the dust inhalation pathway.

The contribution of the ingestion pathway requires particular attention in the near future.

Conclusions

Monitoring Methods and Approach Used in Monitoring and Management of Radioactive Materials by QMM

As far as can be determined by the information provided by QMM, the methods and approach used in the monitoring and management of radioactive materials by QMM are not sufficient. There are large gaps in the monitoring program, especially regarding the ingestion pathway. In some cases, the quality of the monitoring data is questionable. The quantity of data is often insufficient for understanding spatial or temporal trends.

To the knowledge of the author, there is no over-arching monitoring plan and no explicit connection between the results of environmental monitoring and management of radiation dose to the public. It is recommended that a standard process be used to develop the QMM environmental radiation monitoring plan such as that provided in US EPA (2006).

There were no formal Data Quality Objectives (DQOs) for the monitoring program provided to the author. Data Quality Objectives are highly recommended when monitoring data are relied upon to make decisions about the management of risks. For example, regulatory or industry decisions regarding whether current QMM mitigation measures are effective in maintaining acceptable radionuclide concentrations in the receiving environment must be made with a known degree of confidence in the monitoring information.

There can be no general conclusions drawn regarding total QMM-related incremental radiation dose to the general public because it is unknown whether current dose estimates are, indeed, very conservative or whether in some cases they are not.

Are Levels of Naturally Occurring Radioactive Materials Resulting from the QMM Mine Operation within International Exposure Limits?

Based upon available information, conservatively estimated incremental doses due to gamma radiation and exposure via dust inhalation due to QMM operations are less than 1 mSv/yr and incremental doses from radon exposure are negligible.

However, the data supporting these preliminary conclusions are limited. Furthermore, exposure of specific individuals with a combined exposure to gamma radiation on-site (e.g., for wood collection) plus dust inhalation exposure, plus exposure via ingestion may approach or exceed 1 mSv/yr.

No conclusions are possible with respect to incremental doses from ingestion pathways (water, food, accidental ingestion of soil). There is an almost complete lack of information for this pathway. Given the reliance of local people on surface water for drinking water and the use of locally produced foods, the complete lack of relevant monitoring data is unacceptable.

The general conclusion drawn by Madagascar Institute for Nuclear Science and Technology (INSTN) that the risk of exposure is “minimal” for members of the public is not consistent with the conservative findings of this report, particularly with respect to the lack of any information on the ingestion pathway.

Furthermore, the complete lack of any data for the food ingestion pathway prevents general conclusions.

In summary, while the expectation is that incremental doses to the public due to QMM operations will meet international limits, there are insufficient data to come to any confident conclusions in this regard, particularly with respect to ingestion. The dust inhalation pathway may also contribute an important portion of total incremental dose.

Are Pathways of Radionuclide Exposure Managed to Internationally Recognised Standards for the Protection of Local Citizens?

It is expected that QMM use “good practices” that have been demonstrated to be effective in reducing radiation exposure at other, relevant mining operations. The author did not receive information that would indicate that QMM is consistently using good practice with respect to control of gamma, dust, or ingestion pathways. It is impossible to draw any conclusions with respect to the degree to which QMM applies good practice because of the absence of comprehensive monitoring data, particularly with respect to the ingestion exposure pathway. Additional monitoring data are essential in order to inform QMM about where additional mitigation measures are required.

It is imperative that QMM demonstrates that it is managing risk using good practice and in accordance with the 1 mSv/yr limit.

QMM-related risks from exposure to the chemical hazard of uranium in drinking water must be managed.

The uranium concentrations in the Mandromondromotra River are much higher than WHO drinking water guidelines. These elevated concentrations may be due to a combination of natural sources and QMM operations. However, no matter what the source of the uranium, this issue must be addressed in order that the risk associated with uranium toxicity is confirmed and managed.

Recommendations

A series of recommendations for monitoring are presented at the end of the main technical report.

Effective communication and community engagement are vital. It doesn't matter how good a monitoring program is if nobody believes the results.

Characteristics of effective communication are: Trust, Understanding, Credibility, Satisfaction, Cooperation, Agreement. The following recommendations apply to QMM's communication and engagement with community members in the Anosy region:

- A communication and engagement plan that aims to achieve the above six characteristics;
- Retention of risk communication experts with specific experience in communication of radiation risks;
- Emphasis on clear and accessible communication that is readily available in a variety of forms;
- Training of front-line QMM staff in communication regarding radiation risk, with particular focus on transparency, empathy, and the building of trust;
- Public release of relevant documents such as the Madagascar Institute National des Sciences et Techniques Nucléaires (INSTN) reports (local monitoring for QMM).

Rio Tinto Response to Swanson's findings

In acknowledgement of Rio Tinto's provision of data for this study, a framework agreement allowed for the company to add comments to the radioactivity review if it did not agree with Swanson's analysis of the available data or her conclusions. Rio Tinto's Chief Advisor, Radiation Governance and Product Stewardship, reviewed all of Swanson's analysis in 2018 and 2019. After a further internal review in 2019, Rio Tinto/QMM expressed two areas of disagreement:

1. Ingestion pathway monitoring – deemed 'unacceptable' by Swanson

Rio Tinto says: "Current environmental monitoring has focused on the exposure pathways where the incremental contribution from QMM can quantitatively be measured. QMM acknowledges that there is historically missing information for the ingestion pathway. Given that this approach is approved by the national regulator and the expectation is that the ingestion pathway is unlikely to exceed the dose limit, QMM does not agree with the term "unacceptable". Rather QMM believes that a more constructive and appropriate finding would be: *Given the reliance of local people on surface water for drinking water and the use of locally produced foods, it is recommended that QMM assess the need to gather more data with regards to community exposure.*"

2. Management of uranium levels found in surface water

Rio Tinto says: "As was determined before the commencement of mining (web link baseline study) the area surrounding QMM has naturally elevated levels of radiation. This is a result of the surrounding geological conditions and this leads to naturally enhanced levels of uranium in drinking water. This is not a QMM related impact and is an aspect of the water used by local communities before the commencement of construction or operations at QMM. Due to the vital need for access to water for local communities, care must be taken when comparing to conservative guidelines such as the WHO Drinking Water Guidelines. In fact, in the WHO Drinking Water Guidelines, it specifically states: *Where supplies exceed 30 µg/l, it is important that precipitate action be avoided. Consideration should first be given to exposure from all sources and the availability of alternative safe sources.*"

The complete response from Rio Tinto can be accessed in the full technical report.
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