Evaluation of selected aspects of the environmental assessment report for the Langer Heinrich Uranium Mining Project in Namibia

Darmstadt (DE), August 29, 2005

On behalf of

Earthlife Africa Namibia Branch, Windhoek/Namibia

With Financial Support of Grünen/Bündnis'90, Germany

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Content

1 Introduction, Task, Limitations and Structure

The company Langer Heinrich Uranium (Pty) Ltd. has, in 2004, proposed to establish and operate a uranium mine in the Namib desert, about 80 km East of the City of Swakopmund in Namibia and within the Namib-Naukluft National Park. Uranium mining and milling as well as the associated wastes from these processes cause several environmental impacts. As part of the permitting process, Langer Heinrich Uranium (Pty) Ltd. has commissioned the company Softchem of South Africa to prepare an environmental assessment report for the planned project. The draft report was issued, written comments were received and the public participation meetings were held in October 2004. The final environmental assessment report was then issued in April 2005 [Softchem 2005]. According to the owner company Paladin Resources Ltd.[1], in July 2005 the mining license for the Langer Heinrich Uranium Mine was granted by the Ministry of Mines and Energy (http://www.mme.gov.na).

In June 2005, Öko-Institut was asked by Earthlife Africa, Namibia Branch, to provide assistance by screening and evaluating the environmental assessment report. Financial support for this work was contributed by Bündnis’90/Die Grünen in Germany, and the following aspects of the environmental assessment report were selected for screening and evaluation:

- radiological consequences of the project for the general public,
- radiological consequences for employees,
- water resources use and water use by the mining and milling facilities,
- consequences of uranium mining and milling and of the disposal of associated wastes for the groundwater,
- management and disposal of waste from the leaching of ores and their long-term enclosure.

Due to the limited resources available, other than the listed environmental aspects in the report were not screened and evaluated. Especially the environmental consequences of the mining and milling operations for the natural vegetation and plant life as well as for animal life at the site was not included here.

Within the permitting process for facilities, the responsible Ministry usually evaluates the environmental consequences and, within the permit for such a project, issues additional conditions to limit these consequences, where appropriate and necessary. When evaluating environmental impacts, such additional conditions in the permit can be of a significant importance. We have tried to get a copy of the permit to include this in our evaluation, but neither the websites of the Ministry of Mines and Energy and of Paladin Resources Ltd. gives such information nor was Earthlife

[1] See the company’s letter to the Australian Stock Exchange Ltd. as available at its website http://www.paladinresources.com.au

Africa handed out a copy of the permit. We therefore can only evaluate the content of the final environmental assessment report, dated April 2005.

Our report predominantly lists shortcomings of the environmental assessment report. In order to give the reader a chance to better understand the environmental consequences of those shortcomings, we add additional hints on these consequences on the basis, that the facilities are build and operated as described in the report.

As readers of this paper, we had in mind persons who are aware of the basic principles of the project and have already read resp. have access to the environmental assessment report. We therefore only reproduce the report's content, as long it is necessary to understand our critical point. We also do not in detail explain the basic technical and scientific background. We therefore do think that this text is not recommendable for a wider distribution, but for members of Earthlife Africa that are well familiar with the Langer Heinrich Uranium project. Readers without this background are recommended to refer to the original report at Paladin Resource's website[2].

The structure of this report is as follows:

- Chapter 2 discusses the aspects of the report that deal with environmental consequences for the general public from radioactive doses.
- The radiological consequences for employees and the respective chapters of the report are discussed in chapter 3.
- Chapter 4 discusses water resources use and water use aspects.
- The consequences of the poor water management and disposal concept for the groundwater are discussed in chapter 5.
- The management and disposal of wastes from the leaching process and their long-term enclosure is focus in chapter 6.

The main findings, with some recommendations, are listet in short form in the summary chapter.

[2] See http://www.paladinresources.com.au/public_panel/documents.php?id=36

2 Radioactive Doses to the general public

To determine the risk for the public and for workers resulting from their exposure to radioactive pollutants, doses to the public and to workers have to be calculated. These calculations have to be based on specific parameters, for which some evidence must be given, and on computer model software, that has to be quality proofed. We looked at those two inputs, the following remarks have to be made.

Input data: Wrong Radium content of the ore and of the tailings

The most relevant input data, when calculating doses for the public and for workers, is the Radium content in the handled material. The Radium content is a central input for doses resulting from the inhalation of Radon, a radioactive daughter product of Radium. And it also determines doses from the inhalation of dust.

The EA assumes a specific activity of radium-226 in the tailings as 5 Bq/g (p.9-8) and states that this is a conservative value. This value is chosen as a "typical" value for mill tailings. However, the Ra-226 concentration in the tailings actually must be expected to be 21.5 Bq/g, given the uranium concentration in the ore used for leaching of 0.173% U[3]. This is by a factor of more than four higher than the value used for the calculation. No reason is given in the EA, why this selection was made instead using well-known site-specific data as input. Due to this selection of a generic value instead of site-specific values for Langer Heinrich Uranium Mine, all following dose calculations underestimate the doses by at least a factor of four. Consequences are discussed below.

Radiological assumptions: Low breathing rate assumed

In the dose calculations, a breathing rate of 0.4 m^3/h resp. 3,504 m^3/a was assumed (p.9-15, table 9.3). No reference is given for that chosen value. The assumed breathing rate has a linear effect on the dose: the higher the breathing rate, the higher the dose. This is true for Radon inhalation as well as for dust inhalation.

The assumed breathing rate is by a factor of more than two below internationally accepted rates. The US-NRC uses 0.91 m^3/h resp. 8,000 m^3/a. The German radiation protection ordinance uses a rate of 0.92 m^3/h resp. 8,100 m^3/a for persons over 17 years old. This is by a factor of 2.3 higher than the rate used in the anvironmental assessment.

3 With the following additional assumptions: a) All Radium content in the ore goes to the tailings, none to the product (which is realistic), b) Radium is in secular equilibrium with Uranium-238 (which is also realistic), and c) Uranium-238 has a specific activity of 12.4 kBq/g (resulting from its half-life time of 4.468 billion years).

Dose calculation: Incomplete nuclide spectrum

In the dose calculation for dust, only Radium-226 and Thorium-230 has been calculated. Calculations of that type have to include the whole Uranium decay series in equilibrium. If the source of the dust are the tailings only the Uranium activity in the decay chain might be reduced. The calculated dose must then sum up all doses from all radio-nuclides of the decay chain. The difference between selecting only Ra-226 and Th-230 and by calculating the whole decay chain are slighly higher dose values.

Consequences of the two unappropriate values chosen

The two values chosen (specific Radium activity, breathing rate) lead to an underestimation of doses by a factor of approximately 10. Assumed that the other assumptions and the calculations would be correct, all concentrations for Radium and Radon are by a factor of four higher and doses to be expected can be up to a factor of ten higher.

The calculated dose from inhalation of dust at Bloedkoppie, approximately 1.5 to 2.5 km away from the mine, has to be corrected in the above named way.

On the location at Bloedkoppie, chosen in the EA as the relevant location for dose modelling, Radon from tailings exhalation was modelled to be between 1 and 6 Bq/m³. Multiplication by four and unlimited (8760 h/a) stay at this location has a dose consequence of roughly an additional 1 mSv/a, adding to a similar dose from dust inhalation at that location.

It should be noted that Bloedkoppie is an area with public access and a site with some touristic attraction within the National Naukluft Park (camp site, etc.).

Missing: A clear concept for dose limitation

Radon gas and radioactive dust present the major hazards from uranium mill tailings via the aerial pathway. While the dust has a more local impact, radon is unique in that it can be carried over large distances. It was mainly the hazard from radon release that led U.S. Congress to adopt the Uranium Mill Tailings Radiation Control Act in 1978, setting for the first time standards for the management of uranium mill tailings. Interestingly, the ore grades of the uranium ores processed in the U.S. at that time (0.1 - 0.2% U) were comparable to those of the ore fraction to be used for leaching at the Langer Heinrich mill (0.173% U), the nature of the hazard therefore being similar.

Other than for some of the U.S. uranium mills, there are currently no permanent residents living near the proposed Langer Heinrich mill – but, land use in the surrounding area may be subject to change, while the hazards persist for millenia. The hazard from radon and dust emission should therefore be carefully assessed, anyway. In the U.S., the same standards for tailings management have been applied for tailings located in remote areas as for those located in densely populated areas, therefore.

Defining and assessing dose limits for the public makes sense, if it is clear, where those limits have to be applied. Usually, and the USA or Germany are examples for that, this is the, usually fenced, areal around a nuclear facility. Inside the fence, the operator has the duty to control doses, and he also has the power to control this. So inside the facility's enclosure usually an exposure time over 2,000 h/a has to be assumed, which is a reasonable assumption for workers at the facility. Outside the fence, the operator has no administrational power to control or limit exposure times and no control over habits, neither actually nor in the future. In this area an exposure time over 8760 h/a has to be assumed, and a standardised set of usual habits, land- and water-use, foot growing, etc., is defined, that can lead to exposures on the different pathways. The applicant for a permit has to show that under all these circumstances, be they actually real or not, that the sum of the doses over all pathways remains below the dose limit.

The EA neither clearly defines in which places or over which areal the dose limits for the public are applicable nor is the dose as sum over all different pathways calculated. It is clear from the values provided in the EA, that the dose limit is clearly exceeded outside of Langer Heinrich Uranium Mine's facility areal. But it remains unclear, how far reaching this is the case. As has been shown above, the area of Bloedkoppie is surely included. This uncertainty over the areal extend, where the dose limits are exceeded, is unacceptable. It is not state-of-the-art and not in line with commonly accepted radiation protection principles and standards to leave this extend unclear.

On this basis of an unclear areal extend of emission spreading and of exceeding radiation protection limits for the public in places where unlimited access is possible, a permit cannot be issued.

Additional aspects in the dose calculations for the public

Not conservative: Using Radon average concentrations

The Radon dispersion model calculates average Radon concentrations, averaged over the whole year. It is well known that this can cause large error margins for the resulting doses:

- Radon exhalation rates from the mine and from tailings are to a large extend depending on a number of additional conditions. They fluctuate over the year in a very wide range. Times with high peak concentrations of Radon contribute much more to the total integrated dose than average or below-average doses. Using average values does cut those peak concentrations, underestimating the resulting doses. This effect has to be carefully assessed when exposures over shorter times than a year are estimated.

- Extreme peak concentrations of Radon are reached in times of the year, where the wind speed is low or totally calm. This is especially relevant for areas in valleys, surrounded by mountains or rises in one or more directions. The times, where the wind is calm, are short, but they contribute much more than the average to the total dose. Wind measurements for Radon modelling therefore have to carefully register days with very small or no wind at all. The data base, as described in the EA (p.6-8), does neither register smaller wind speeds nor does it register the time over which the wind speed is too low to measure. Radon concentration modelling and dose calculations, that do not take this effect into account are therefore systematically underestimating doses.
- The Gauss plume model, that was used in the EA to model Radon and calculate its concentration, is systematically not able to model low wind speeds. So the effect of these times over the year is simply not included in the dose calculation. The dose calculation is not conservative, average Radon concentrations could be higher than those in the EA.

The extend of these effects cannot be estimated due to site-specific data. It could well reach another factor of ten, if certain conditions are given. The monitoring of the facility should be designed to later evaluate the models used for prediction. The monitoring is subject to a respective plan, to be enacted later on.

Unclear basis of model calculations

The calculation of Radon spreading and the calculation for dust dispersal use similar models and, presumably, use the same site-specific wind data as input. When comparing the output for Radon concentrations (p.9-11, figure 9.2) and for dust dispersion (p.9-13, figure 9.3), the result is very different. The directions, where the pollutants are spreading, are different and the concentration profiles on the main plume directions.

This difference is not plausible. No mention is given in the report, where this difference stems from. The description of the two models is not detailed enough to be able to identify these reasons.

3 Radioactive doses for mine workers

The worker's doses are not really assessed in the EA. The EA only refers to the appropriate rules, that will be applied, and points to the radiation protection management plan (RMP) and the respective monitoring programme RPMP, to be designed and enacted later on.

The EA cites measured and reported doses from Olympic Dam Mine, but does not undertake to compare the operations there with the ones planned at Langer Heinrich Uranium Mine. Mean individual doses for plant and oxide operators are cited. Mean individual doses are a less meaningful number in that case, the expected collective dose for the operations would be much more meaningful. Usually, the estimate on the expected collective dose is the basis for the permitting process and for the planning of the operations, because these figures allow a much more effective radiation management (ALARA, optimisation, etc.).

In an environmental assessment, the collective dose also is much more meaningful, because it allows to evaluate the total effects for the workforce, expected to be caused by the operation of the plant. No estimates are given on the collective dose for workers.

4 Water use and water resources

According to its water balance (p.4-23), Langer Heinrich Uranium Mine will use 1,306,024 tons of water per year. Considering that

- these amounts of water are not available at the site and cannot be produced in a sustainable way,
- the water has to be transported from Swakopmund to the site via pipeline,
- the water has to be produced at Swakopmund, by requiring additional 1.3 Mio. m³ to the presently used 10.4 Mio. m³ in the region, where 12.6 Mio. m³ are sustainably available,
- water is generally a valuable natural resource in Namibia, and
- reductions of water use and water conservation measures are a serious issue in many branches in Namibia,

the water requirements of the proposed facility are a significant factor for its environmental impact. It must be further added, that this water use will last for a very long time.

Of the above amount, the main portion of roughly two thirds are used in the counter current decanter (CCD), another one quarter is used for dust suppression. Other purposes contribute minor parts.

Water use for the CCD circuit

The EA states that it was hoped that the annual consumption of water might drop significantly by recovering water from tailings disposal. It was found that “elevated viscosities make this highly unlikely”.

The EA does neither give more details on the reasons for elevated viscosities nor does it debate the technical alternatives that were tested to recover water from the tailings. The descriptions do not allow an evaluation of the optimization of the production process towards a more effective water use.

Water use for dust suppression

The EA states that dust suppression water is required on the dirt roads in and around the Langer Heinrich process and mining area. No mention is made, if this includes any methods to optimize dust control or if these were checked for their applicability.

The simple use of water for dust suppression in the case of a climate, where evaporation is high and the effect of dust suppression so does not last very long, is not favorable. Alternatives that are better suited to these conditions have to be evaluated.

Modern methods of dust control include the use of different agents that coagulate grains of smaller size and so reduce airborne dust particles. A large variety of agents is available, each with preferred application characteristics. The agents usually are largely diluted, mixed or emulgated with water and applied with a usual or specially constructed spray system. The water evaporates, but the dust suppression effect lasts very much longer. A thorough evaluation of the applicability of such methods at the Langer Heinrich Uranium Mine would be recommendable, also the environmental assessment should include any detrimental effects by the use of such agents, and a careful selection should be made.

5 Tailings management and disposal

General poor quality of the description of the plan for tailings disposal

The draft Environmental Assessment (EA) of October 2004 covered a dry tailings disposal scheme. The tailings should have been filtered and the filter cake arising from the first years of operation should have been disposed of in a purpose-built dam in a side valley, and, once sufficient open pit space would have been available, further filter cake would have been disposed of in mined-out open pits. The tailings dam in the side valley would have been a permanent structure, not to be removed after the end of the mine life.

The final EA of April 2005 introduced two major changes compared to the draft EA: the tailings will now be disposed of as a slurry, rather than as a filter cake, and there will be no tailings dam in the side valley.

Regarding any further detail of the proposed tailings management scheme, the final EA is highly inconsistent, full of omissions and self-contradictions, and it is hardly possible to find out what the proposal actually is, not to speak about its environmental impacts.

While the change of the tailings management scheme alone already would have warranted a reopening of the public participation process, the inconsistencies, omissions, and errors in the final EA actually make this inevitable.

General environmental impacts of the disposal of mill tailings

Uranium mill tailings contain a variety of contaminants that have to be safely contained, to avoid environmental hazards. Since the milling process only extracts the uranium from the ore, all radioactive decay products that were associated with the uranium remain in the tailings. Among these are long-lived radionuclides such as thorium-230 (80,000 year half life) and radium-226 (1600 year half life). The latter is of specific concern, since it continuously decays to radon-222, which has a quite short half life of 3.8 days, but, as a gas, can easily escape from the tailings deposit. In the surroundings, radon presents a lung-cancer hazard when inhaled.

Moreover, the extraction process cannot remove all of the uranium, so some residual uranium remains in the tailings, too. Other non-radioactive - but nevertheless hazardous - ore constituents, such as heavy metals and arsenic also remain in the tailings.

In addition, reagents added during the milling process also end up in the tailings.

Due to the mechanical and chemical treatment in the milling process, the conditions for a mobilization of the contaminants contained – and thus for environmental hazards – are different for tailings compared to the ore. Due to the mechanical milling, the material is no longer rock-like, but sand-like, thus loosing its mechanical integrity, and becoming susceptible for dispersion into the environment, for example by wind. The larger surface area of the finely ground material enhances release of the radon gas continuously formed inside the particles.

The chemical processing in the mill changes the mobilization potential for the contaminants contained in the tailings, once they come into contact with water. And, lots of water are present initially, since the tailings are to be pumped and disposed of in the form of a slurry. Other sources of water include groundwater and precipitation – the latter occuring in rare events only at this site, but which nevertheless have to be dealt with.

Geotechnical stability of the mill tailings

Geotechnical stability is crucial for safe containment of the uranium mill tailings. It is of particular concern, if tailings are disposed above ground in impoundments, as is the case here for the tailings arising during the first years of operation, before sufficient mined-out open pit space is available for in-pit disposal.

In case of an embankment failure, tailings can liquefy and form a slurry wave travelling downstream, devastating large areas, and spreading the tailings in the environment. Typical causes of embankment failures are seismic loads, improper water management within the impoundment, heavy rainfall, floods, decant system problems, among others.

According to the EA, the tailings are to be sun-dryed in thin layers. This would enhance tailings stability, compared to simple wet disposal of the tailings slurry.

After tailings disposal ceases, the top of the tailings has to be sufficiently stable to support a cover (preferably of earthen material) and the heavy equipment required for its placement.

Particularly challenging is the task of assuring the stability of the tailings deposit in the long term. While liquefaction is becoming less of a concern with time, erosion becomes a major problem to be dealt with. Preferably, the stability of the deposit should be assured by design, so no active maintenance would be required. This implies siting at a location not subject to hazards from earthquakes, landslides, flooding, etc., adequate grading of the slopes, application of a multi-layer earthen cover, among others.

Nevertheless, regular monitoring of the site will be required in the long term, to be able to recognize any unforeseen problems and to timely initiate adequate remedial action. No such monitoring is currently foreseen in the plan.

Serious flaws

1) Contradictions in the descriptions

The EA does nearly not at all discuss the geotechnical stability of the "Stage 1 Tailings Deposit" (which is obviously meant to receive the tailings arising during the first years of operation), neither during operation, nor in the long term. This omission is particularly serious, since this deposit appears to be meant as a permanent rather than temporary structure (contrary to what is said on p.5-3 and p.12-2), comprises artificially constructed embankment dams and is not located in a pit, but on the ground (contrary to what is said on p.D-14).

The view that this tailings deposit is meant as a permanent structure, is supported by the fact that it is located on a free area between the ore deposits labeled "Detail 1" and "Detail 2", and not (contrary to what is said on p.12-2) on top of an area still to be mined. There is, furthermore, no mention of any later tailings relocation into a disposal pit, not to speak of how this would be accomplished.

2) Flood hazards not adequately addressed

For the discussion of the flood hazard, only a 100-year recurrence interval flood is being taken into account: this is totally inadequate for the periods of time to be considered and means that the deposit will nearly certainly be affected by flood – with the potential for large releases of tailings material with major environmental impacts.

If, for example, a 10% risk of destruction of the tailings deposit by flood would be conceded in a 1000 year period, a 10000-year recurrence interval flood would have to be considered. Since no sufficient experience on such long recurrence intervals can exist, recurrence events are not reasonable for the design of tailings facilities; rather the probable maximum flood (PMF) should be considered.

Other Problems

Unresolved questions concerning the tailings disposal process

Checking the EA for its completeness in respect to environmental consequences of the tailings disposal show the following missing informations:

- The EA does not describe the tailings disposal process with the detail necessary to assess its viability. Without this information, it is not possible to assess the possible environmental impacts of the tailings disposal.
- The initial water contents of the tailings is unclear: do they contain 40% solids (p.13-5), or 40% moisture (p.4-21)? This makes a big difference in the short

(tailings dry process) and longer term (total amount of contaminated water, and its contaminant load, seeping into the groundwater).

- There is no mention, how the tailings slurry is to be disposed in thin layers of 100 mm on an area of 0.25 km^2. According to TRS-335 [IAEA 1992] p.76, this method (called "Semi-dry tailings management") involves disposition of a thickened tailings slurry onto a gradually sloping beach of tailings. Has this procedure ever been tested with a tailings arising such as the one to be expected at Langer Heinrich? What slope angle is required, how will it be prepared initially? Are the tailings sufficiently thickened to minimize separation of the sand fraction and the slimes fraction? No mention in the EA.
- How is solar drying of tailings to work in the lower parts of mined-out open pits, where groundwater is present (p.4-3)?
- How is solar drying to work during fog days?
- How is dust suppression to be assured while the top layer is drying?
- What are the mechanical properties of the dryed tailings, and how is a new layer to be tested to assure that it is sufficiently dry?
- The whole tailings disposal process is unclear. There is no mention of any temporary storage for the tailings arising while one layer of tailings is drying, nor any scheme of alternating disposal on multiple tailings areas. The latter scheme would require large tailings areas to be open for long periods of time - as opposed to the goal of having them sequentially covered as soon as possible to minimize dust and radon releases.
- Fig. 4.5 and 4.6 show three stationary decant systems in the “Stage 1 Tailings Deposit”. Why is no floating decant system to be used, given that decant system problems are a common cause of tailings dam failures?
- The Ministry of Trade and Industry mentions that the Langer Heinrich processing plant could be used for processing of ore from other uranium deposits in the area (Klein Trekkopje and Klein Spitzkoppe) [MTI 2005]. Where would the tailings from any such processing be disposed? As the amount of additional material would be enormeous (365 million t!) and would cause additional environmental effects, the current environmental assessment would be obsolete in such a case.

Unresolved questions concerning long-term stability of the tailings deposits

The EA does not assess the aspect of long-term stability of the tailings deposits. Such an assessment is mandatory to assure that the tailings disposal method chosen is appropriate and minimizes the hazards for future generations.

One of the events that can uncover disposed tailings is rain- and stormwater. There is no mention, how the stormwater control dam (and any other features required for long-term safety of the tailings, such as safety berms and drainage trenches) will be maintained in the long term. Such structures can only function in the long term, if they are regularly maintained. In the past, in many cases these long-term obligations fell into public responsibility, with no resources left from the active phase of the mines and mills, and placed a long-term burden left for society and future generations to resolve these hazards.

There is no mention, how any intrusion into the tailings (by any future residents, by burrowing animals, through plant roots) is to be prevented, though this might affect performance of the deposit enclosure in the long term. Intrusion prevention is state-of-the-art in tailings disposal coverage.

There is no mention of taking into account the impacts of any climatic changes which may arise, on tailings disposal enclosure performance.

TheEA gives nearly no information on the properties of the cover to be placed on the tailings. What is the cover material and thickness, and what is the layer structure of the cover, if any? How will it be placed? What are the cover properties in terms of infiltration, evaporation, radon reduction, protection against erosion, behaviour upon settlement of underlying tailings, etc.? Without this information, it is impossible to assess the long-term health hazards presented by the tailings deposits.

There is no mention of any land use and/or access restrictions envisaged for the affected area (in particular for the tailings disposal areas), after termination of the mining operation, and how any such restrictions are to be enforced – in the short term and in the long term. Land use has major impacts on the radiation doses received by any future users of the land.

Waste rock disposal

Waste rock arises from the following sources: overburden removed from open pits, low grade material removed during mining, and the 60% of ROM ore removed before leaching.

This material is not necessarily free of hazards, since it may contain certain amounts of radionuclides and other contaminants. Depending on the contaminant concentrations, such material can be released for restricted or unrestricted use, or must be disposed of in a controlled way. In the latter case, the hazards presented by radon and dust are similar to those found with the tailings, though usually at a lower level.

The EA gives no data on the concentrations of radionuclides and other contaminants found in the waste rock. This information is essential for an assessment of the environmental impacts of waste rock disposal.

The EA gives no information on the measures to be taken to minimize the hazard from the waste rock deposits, such as covers for dust mitigation, radiation protection, erosion protection, flood protection, etc.

It is unclear, whether the two designated dump areas shown in Fig. 4-3 are meant to be permanent or temporary dumps.

If the waste rock dumps will be covered, what cover material and what cover layout is to be used?

6 Groundwater protection

Affected ground- and surface-water

In a desert area without any perennial streams, groundwater is a scarce resource. Groundwater is of importance for two reasons: as a water resource, and as a transport medium for the dispersal of contaminants. Groundwater can be affected in several ways (by spillages, stormwater overflow, etc.). These effects can be limited by the respective mitigation measures (accident prevention, stormwater catchment, etc.). In the following we concentrate on the most serious and most long-term effects. These result from the disposal of mill tailings. The relevant effects are:

- by any seepage leaking from the tailings disposal, and
- by direct contact with tailings (in cases where tailings are disposed below or in short distance above the water table).

In both cases radioactive as well as non-radioactive contaminants can dissolve and are transported with the groundwater stream. Depending on the prevailing chemical conditions, certain contaminants can be mobilized, contaminate the groundwater in near vicinity to the site, and migrate with groundwater over larger areas, thus spreading the contamination. Depending on the groundwater's chemistry and on the contaminants and from the time, over which these processes continue, this spreading area can reach many square-kilometers. The groundwater contamination plume then enters surface water streams, where the contaminants are further transported.

Requirements for an environmental assessment

Groundwater contaminations, and later the affected surface waters, have to be protected. The level of protection must be defined, which is usually done by setting permissable limits for the contaminant's concentration in ground- and surface-water. Any environmental assessment for a facility affecting ground- and surface-water must show, that these limits are respected and, furthermore, the reasonable protection measures are used to minimize the contamination of the water, even if this influence remains well below the permitted limits. In some countries, where groundwater is a scarce resource, an even more rigorous groundwater protection approach is in place: a regular release of contaminants into the groundwater is generally illegal, a permit allowing its contamination cannot be issued at all.

In an environmental assessment at least the following aspects have to be checked and proofed:

- The concentration of contaminants in groundwater over time must not exceed the limits.
- The internationally and nationally accepted dose limits for persons of the general public by the use of ground- and surface-water must not be exceeded.

- The contamination of the groundwater and the doses to the public must be kept as low as reasonably achievable.

Usually this takes two stages: in a first approch the maximum extend of the influence and extend is estimated on a conservative basis and it is determined, if there is a significant influence on the environment, that requires a more detailed analysis. If this is the case, the detailed analysis is made in stage 2, e.g. by determination of the relevant parameters and computer modelling the environmental impact. Measures to reduce this influence have then to be discussed, e.g.

- the use of underlying clay or other liners to reduce contaminant flow out of tailings,
- the use of cover materials and layers to reduce seepage through the tailings,
- the use of hydraulic walls to redirect and reduce groundwater flow,
- the use of reactive walls to catch contaminants and demobilize them,
- “pump and treat” measures,
- etc.

As the use and extend of these protection measures must be in balance with the environmental impact to be avoided, a quantification of the effects on one side and of the costs for these measures on the other side is necessary.

Ground- and surface-water protection in the environmental assessment

The Environmental Assessment, in its short chapter “8.3 Hydrology” does only implicitly define ground- and surface-waters as a constituent of the environment, that require protection, and does not define its protection level, neither qualitatively nor quantitatively. The sentence “Groundwater pollution is not an issue” (p.8-6) doesn’t define first, what is understood as “pollution” (what sorts of contaminants are meant and what concentrations of these are meant when using the word “issue”). An evaluation without a clearly defined target level is, in this case, simply not possible.

Another basic requirement for an EA remains also undefined: what is the areal extent of the environment one’s looking at. In that case: is it the groundwater that collects within the filled pits, is it the groundwater underneath the pits, is it the groundwater underneath the mine’s premises, is it the groundwater on the first, second or third water floor (if applicable), etc.

In the EA, ground- and surface water influences from the tailings disposal in the disposal areas and in open pits isn’t really analysed. It is only stated, that due to the alkaline leaching process groundwater pollution is not an issue. No data is given that supports such a general conclusion.

The main factors, that determine the influence and its quantitative extent and so allows to determine, if this influence is of environmental significance, like

- the radioactive and non-radioactive contaminant content of the tailings,
- the leaching characteristics and the mobility of these contaminants in the operational and post-operational phase of the disposal-areas and –pits,
- the rest-content of leaching chemicals in the tailings and their leaching characteristics over time,
- the extent of rain- and seepage-water in the operational and post-operational phase,
- the amount, direction and chemical characteristics of groundwater at the site and downstream,
- the surface water stream, that the groundwater flows to, and its characteristics, and
- the current and expected future use of ground- and surface-water downstream,

are not given.

The following arguments show that the environmental consequences of the tailings disposal for the groundwater must be evaluated with much more care:

- The remaining leaching chemicals in the tailings will in any case be leached and will reach the groundwater in a relatively short time. The resulting alkaline groundwater plume, its chemical content, the duration and consequences of the abnormally high pH in the groundwater, and its leaching characteristics, e.g. for Uranium, on the flowpath of the plume requires thorough evaluation.
- Alkaline conditions in the tailings do not generally mean, that contaminants are immobile. The opposite is true for Uranium and several other contaminants (e.g. Arsenic). Without a thorough analysis of representative ore samples from Lager Heinrich, this general conclusion is unreliable.
- Tailings, which are disposed in the lower parts of the open pits, are in direct contact with the groundwater. The alkaline chemicals are mobile and will be leached and removed relatively fast. The pH then drops and approximates the pH of the inflowing groundwater. Its pH is then the influencing factor for the leaching of the contaminants from the fine-grained tails material. Depending on the ore and its milling process, this might be totally different from the leaching under alkaline conditions.
- Uranium, which was not leached off completely in the milling process, and which at least in part will get mobile later on, will in any case reach the groundwater. The further spreading of the Uranium and the extent of its plume over time cannot just be ignored, as it is done in the environmental assessment. Its chemical toxicity and the radioactive doses imposed, when the Uranium leaves the premises of Langer Heinrich Uranium Mine with the groundwater flow and could be used by persons of the general public, has to be assessed.

Interestingly, these problems are recognized in the EA when discussing in-situ leaching (ISL) as an Alternative Mining Method: "... the nature of the ore plus surrounding and underlying geo-physical properties are not conducive to the control of reagent and uranium bearing solutions." (p.5-3), while any such problems with in-pit tailings disposal are categorically denied (p.4-18, p.8-6).

Estimate of the extent of groundwater contamination

Given an average run-of-mine (ROM) ore grade of 0.0815% U_3O_8 (=0.0691% U), and taking into account that 60% of the ROM feed is removed prior to leaching, the uranium concentration in the ore used for leaching must be 0.173% U (assuming no uranium is contained in the removed fraction).

The uranium extraction rate of the leaching process is mentioned as 90% (p.9-10). Assuming that this extraction rate is meant based on the ore used for leaching, this results in a residual concentration of 0.0173% U in the tailings. This is still 25% of the uranium concentration originally present in the ROM-ore and not negligible.

The pre-mining uranium concentrations in groundwater at Langer Heinrich (<20 - 428 µg U_3O_8/L, Table 6-4) exceed WHO's current provisional guideline value for uranium [WHO2004] in drinking water of 15 µg U/L (=17.7 µg U_3O_8/L) for all sample points with values above the lower limit of detection. With a lower limit of detection of apparently 20 µg U_3O_8/L, it thus was not even possible to identify any samples meeting the WHO guideline value. And, this guideline being based on chemical toxicity of uranium, the discussion of radiation doses posed from uranium in groundwater (p.6-69 and Table 6-16) is quite irrelevant.

Groundwater sampling

Additionally, there is no groundwater sample point at the location of the "Stage 1 Tailings Deposit". An assessment of the possible impact of tailings seepage is not possible here, therefore.

Moreover, for the sample points given, the sampling depth is not shown. It is therefore unclear, whether the samples were taken within or below the deposits. Any groundwater impact of the planned tailings disposal in the pits to be mined at these locations cannot be assessed, therefore, either.

Evaluation concerning ground- and surface-water protection

The environmental assessment of the consequences of the tailings disposal, e.g. in open pits for ground- and surface-water,

- is incomplete, because it does neither define protection levels nor the areal extent nor the indicators, that allow an environmental impact on groundwater to be assessed as insignifant or significant, low or high, legal or illegal,
- is not comprehensable, because no data or arguments are given to support the general assessment,

- is unclear, because it is not clearly stated, on which contaminants and on which expected levels of contaminants in which area of the water body the assessmernt has been based on,
- does not compare the impacts with rules and regulations,
- does not discuss and propose methods of reduction of impacts.

If the project is put into practice on the basis of this environmental assessment, the possible consequences will be:

- It is unclear, if internationally accepted protection levels (e.g. dose constraints for persons of the general public, WHO guidelines for the maximum permissible Uranium concentration in drinking water) will be exceeded and in which areas of groundwater downstream the facility this will be the case.
- The groundwater in a large area downstream the Langer Heinrich Uranium Mine will, after some years of practice, show a large plume of alkali, moving approximately with the groundwater flow-speed towards the next discharge into surface-waters. Due to missing data in the environmental assessment cannot be predicted, if, in which area and over which time downstream the groundwater will be unusable for drinking water or other purposes (e.g. for irrigation).
- The groundwater near pits, that were filled with tailings, will show elevated Uranium concentrations, moving in a plume. It is unclear which concentrations of Uranium will move fast and in which distance from the premises of the mine the Uranium plume will reduce its mobility.
- It cannot be excluded, that other contaminants will show similar mobility and concentrations with significant levels downstream the disposal pits.
- The groundwater sampling, as planned, is inadequate and does not allow for a realistic monitoring of the impacts.

7 Summary of the findings

Summary of the radiation exposure calculations for the public

Due to an inappropriate selection of input data (Radium in ore and tailings) and to a too small breathing rate, the dose calculations in the EA understimates the doses for the public. Together with a higher contribution of Radon to the total dose, a person at Bloedkoppie, a publicly accessable place and a tourist attraction in 1.5 to 2.5 km distance to the mine, can exceed internationally accepted dose limits. The EA does not clearly define the areal extend, where the doses are below the dose limits and where doses exceed the limits. The areal extend, where the dose limits are exceeded, clearly reach beyond the facility's operational area, probably reaching a distance of some kilometers. The missing definition of a clear boundary is a general short-coming of the EA and should be corrected.

Additional contradictions and problems in the EA's calculation of doses from Radon are discussed and can give rise to an additional underestimation of doses.

Radiation exposure for workers

No estimate has been made on the collective dose for the proposed operations, allowing a realistic view of the effects on the workforce.

Water use and reduction potential

The Langer Heinrich Uranium mine is planned with a water consumption of roughly 1.3 Mio. m³ per year and will be one of the largest single consumer of water in Namibia. In the EA, the water requirements of the plant are not discussed in enough detail. Measures that allow for a significant reduction of water use and optimise its use are either not discussed or are only discussed on a level of detail that does not allow an evaluation, if reduction potentials were sufficiently followed.

Evaluation of the environmental assessment of tailings disposal

Our review of the environmental assessment concerning the disposal of tailings resulting from the mine and mill operation has shown a large number of serious short-comings, flaws and unresolved problems. The following are only the main weaknesses with the most serious consequences:

- The tailings disposal plan is unclear, several contradictions in the text of the assessment do not allow to just describe clearly what is actually planned. On such a basis, an assessment of the plan and of the impact on the environment is not possible.
- The plan and the description miss major basic design characteristics, that will result in an inadequate protection of the environment, especially in the future.

Especially missing is any reliable description of the cover of the tailings to protect future generations from the remaining hazards of the tailings, their long-term care, their layout against probable conditions (erosion, natural impacts such as burrowing or floods, etc.).

- Basic data used in the environmental assessment, like the concentration of radioactive daughter products or the amount of tailings, is unclear.

On such a basis an environmental impact assessment does not yield enough quality information to really evaluate the impacts from the tailings disposal.

Serious flaws in the assessment of impacts on groundwater

The EA contains no discussion of the impact of the disposal of the highly alkaline (pH 10) tailings on groundwater. Any such discussion is blocked with the statement that the alkaline leaching scheme would avoid any such problems. There is no mention that some contaminants, in particular residual uranium, can be mobile also under alkaline conditions.

Those parts of the (highly alkaline) tailings that are to be disposed of in the deeper parts of mined-out pits, will be in direct contact with (near-neutral) groundwater. There is no discussion of the effects this will have on groundwater quality and on contaminant migration.

There is no information given on the flow conditions in the groundwater, neither for the present situation, nor for the conditions expected for the time after termination of the mining operation. This information is essential for an assessment of contaminant transport.

The impact of the proposed in-pit-disposal of tailings on groundwater has not been adequately addressed in the environmental assessment.

References

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