OCCUPATIONAL EXPOSURE IN A ZIRCONIA PRODUCTION FACILITY

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1 ABSTRACT

Zircon/Zirconia mineral is a sought-after material, especially in the refractories- and ceramics industries. However, with the publication of International Atomic Energy Agency Safety Series 115 and European Union Council Directive 96/29/EURATOM, the radiological risk of the mineral became an issue of concern. The Zirconia Minerals Committee, consisting of zircon- and zirconia producers internationally, pro-actively started a program to assess the extent of the radiological impact of the commodity. This presentation reports on one component of the program, that of the occupational exposure during the production of zirconia from the zircon sands.

2 AIM

This paper evaluates typical occupational doses incurred by workers in a Fused Zirconia Production Plant, suggests a frequency for monitoring in similar plants and concludes with some recommendations with regards to the radiation protection program.

3 INTRODUCTION

Foskor obtained a nuclear licence in terms of the South African Nuclear Energy Act, No 131/1993 in 1993. However, the assessment for the Foskor operations was only completed by 1995 with two areas, the Heavy Minerals Plant and the Fused Zirconia Plant, classified as radiological controlled areas. [1,2] Both these plants are managed by Foskor Zirconia, which produces electro-fused zirconium from zircon sand obtained from an external source.

The radiological protection program at the Foskor Zirconia Plant was implemented at the beginning 1997. This paper represents the personal monitoring program results over the four-year period 1997-2000. [3,4,5,6]

4 PROCESS DESCRIPTION

Figure 1 is a schematic flow diagram of the Zirconia manufacturing process.

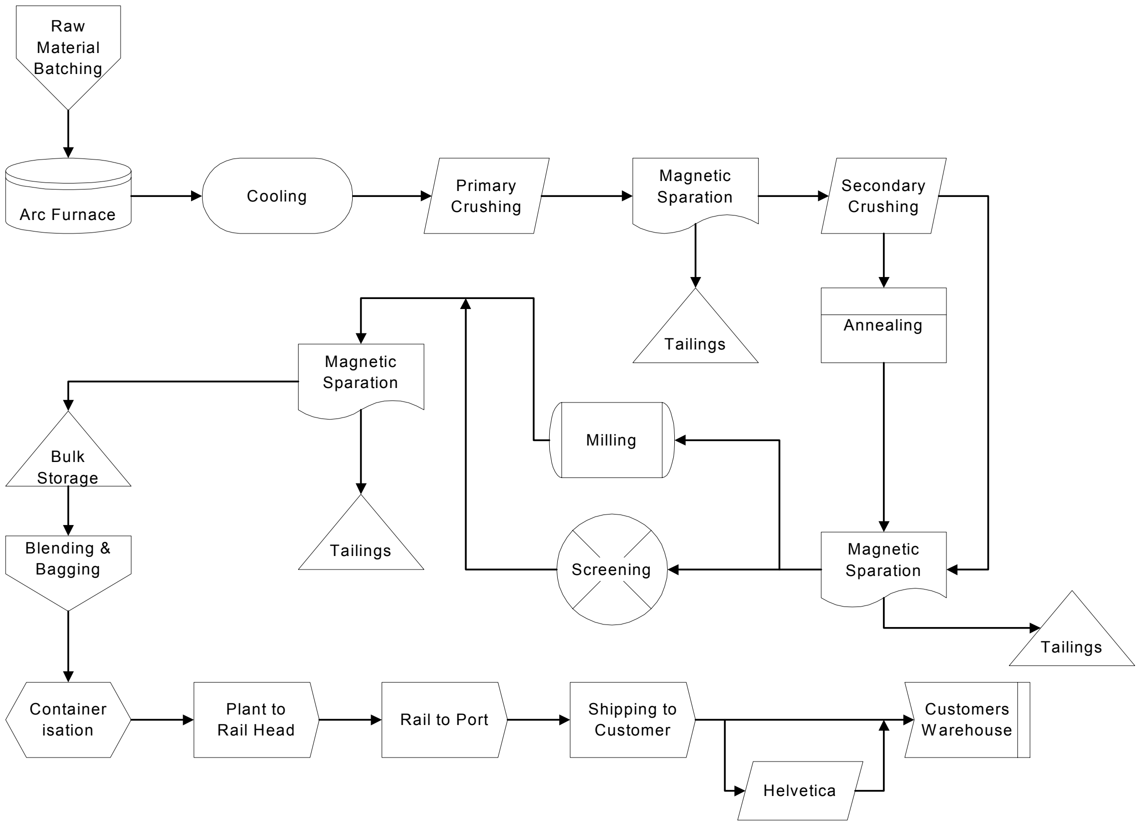

Figure 1: Manufacturing process of fused zirconium

Figure 2 presents a broad outline of the radiation protection program for the plant.

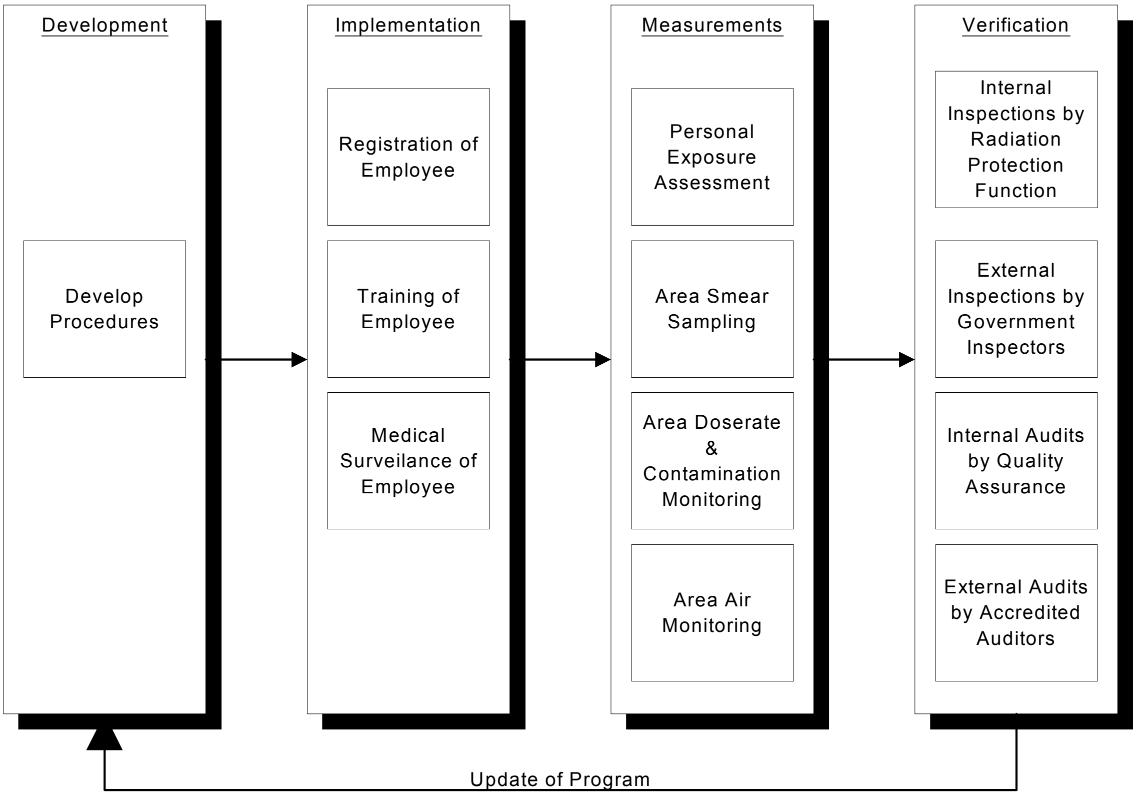

Figure 2: Management program for radiation protection.

5 TECHNICAL DATA

Table 1 lists the average activity concentrations when the various products were analysed for their radionuclide content.

Table 1: Nuclide specific activity of the process materials

Sample No.	Gross Alpha	Gross Beta	U-238	Th-232	Ra-226	Ra-228	Th-228	U-235	K-40
	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g
Zircon Sand	*	*	3.9	0.6	3.8	0.54	0.54	*	*
Product A	69.0	34.2	3.9	0.7	1.8	0.3	0.5	0.2	0.3
Product B	37.6	23.9	2.1	0.7	2.4	0.4	0.5	0.1	0.4
Product C	73.3	31.9	3.7	0.6	2.4	0.3	0.6	0.2	0.2
Fumed Silica	36.8	34.4	1.0	*	5.8	0.9	0.2	0.04	*

*Incomplete analysis results

A shortcoming in the analytical results is the absence of activity concentrations for Pb-210 and Po-210, which could not be analysed reliably in the past. By assuming that no activity from these nuclides is present in the material, conservative dose coefficients were calculated for assessing inhalation doses.

Other applicable parameters used for the assessments are listed below.

Table 2: Exposure calculation parameters

Parameter	Parameter Value
Particle Size	5 μm
Dose Coefficient (ICRP 68)	~8 μSv/Bq
Breathing rate or volume of air inhaled.	1.2 m^3/h
Protection Factor for use of dust mask*.	5
Protection Factor when no dust mask is used.	1
Exposure period	8 $h.shift^{-1}$
Number of shifts	250 $shifts.a^{-1}$

* Dust masks are compulsory in the Smelter, Powder and Logistics Section as part of the normal Occupation Hygiene Program.

6 MEASUREMENT METHODOLOGY

The personal monitoring program is one of random sampling within a specific worker category. The categories were identified taking cognisance of location, physical parameters such as the building layout, job specifications, periods of exposure etc. The major worker categories identified are:

Classification	Area	Group 1	Group 2
Production	Smelter Section	Operator	Supervisor
	Powder Section	Operator	Supervisor
	Annealing Section	Operator	
	Logistics	Operator	
Non-Production	Workshop	Artisan/Worker	
	Laboratory	Sampler	Analyst

Because all workers wear gloves, the ingestion pathway is not considered in the dose assessment. Radon measurements also indicated this pathway not to be of concern. A worker is issued with an electronic dosimeter, for measurement of the external gamma radiation dose, and a personal dust pump for the estimation of the inhalation dose. Based on the activity of the collected dust, the inhalation dose, excluding radon, is calculated as

$$E = \frac{V * h_{inh} * M * \overline{C}}{100 * PF}$$

Where:			
	E	Effective dose	mSv over M shifts
	V	Volume of air inhaled per shift	m^3/shift
	h_{inh}	Effective dose coefficient	μSv/Bq
	M	Average number of shifts between monitoring	
	$\overline{C}$	ALLAAC over the sampling period	Bq/m^3
	PF	Protection factor for dust mask	

7 DATA EVALUATION

Figure 3 presents the personal dose data for the various worker categories for 1997-2000.

7.1 Occupational Exposure.

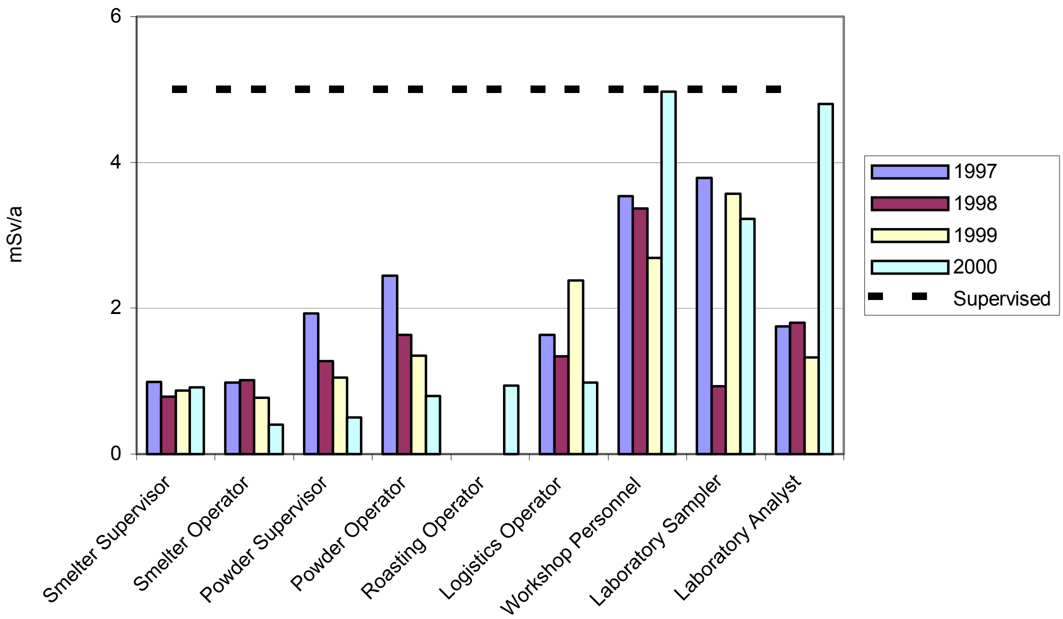

Figure 3: Occupational exposure measured since 1997.

7.2 Dose Distribution

Figure 4 shows the typical lognormal shape of the dose distribution

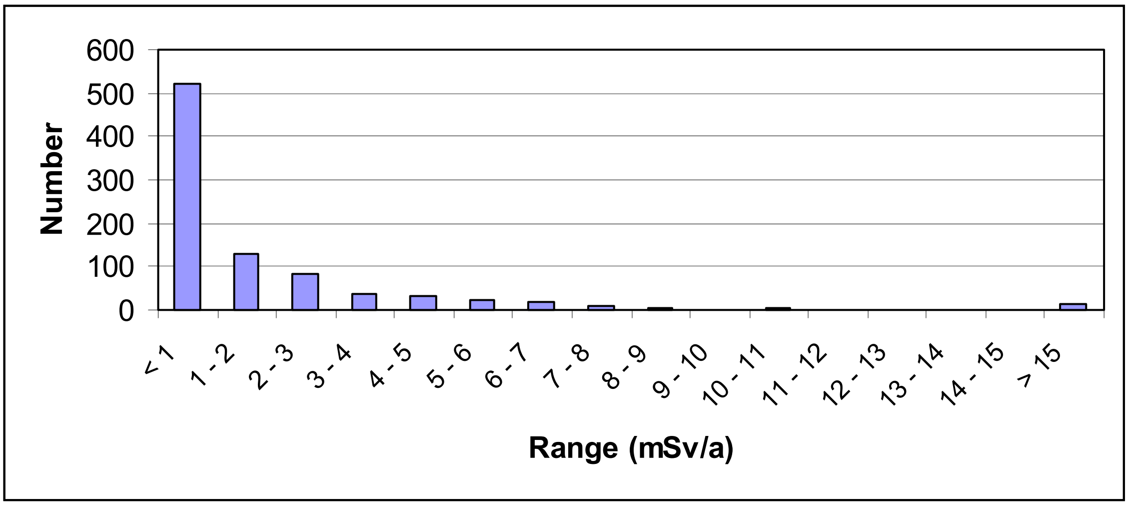

Figure 4: Distribution of measured exposures based on single measurements.

7.3 Radiation Protection 95 [7]

The European Union document RP 95 classifies various NORM industries in regulatory bands according to annual doses expected for these industries. Zircon sands industries are classified as within Band 3 (6-20 mSv/a) as indicated in Figure 5 below. The results reported here, seems to indicate, however, rather a classification in Band 2 (1-5 mSv/a) as also indicated in Figure 5.

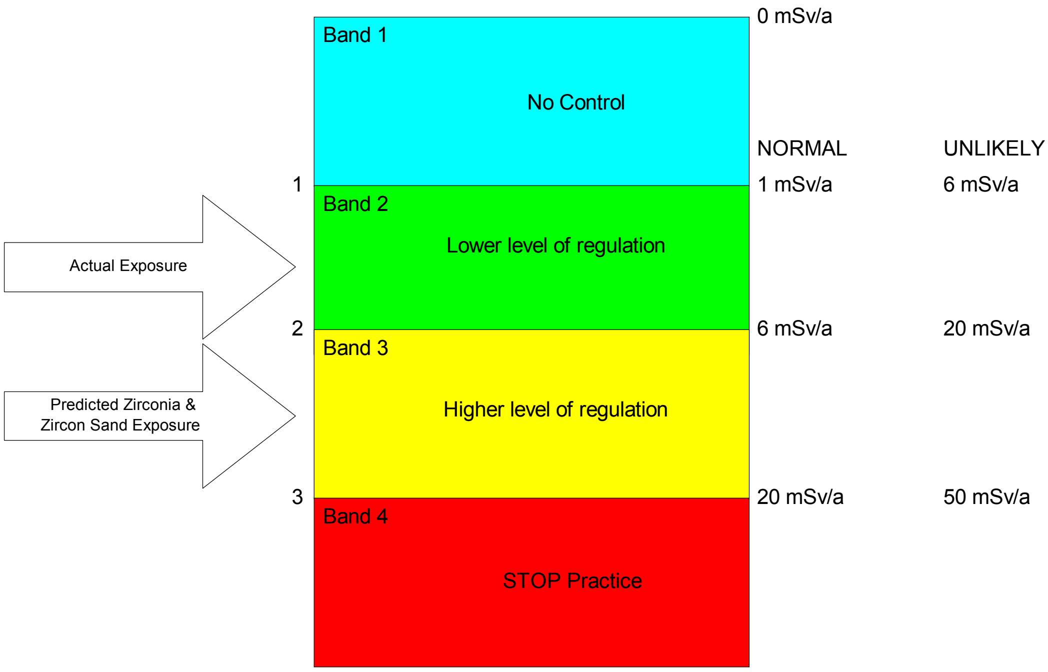

Figure 5: Comparison between measured results and exposure predicted by RP 95.

7.4 Statistically Representative Sampling

Because of cost constraints, all workers cannot be monitored continuously throughout the year. Workers are rather classified in specific worker categories and a random selection of workers within each category is monitored. Initially it was assumed that the dose distribution is normal. The number of random measurements required was therefor determined for various worker categories by performing a student-t test on the initial results.

This method was, however, reviewed as the dose distributions prove to be lognormal rather than normal (see Figure 4). A new approach is hence considered. This will still record the arithmetic mean of the results for each worker category. The number of samples will, however, be sufficient to ensure at the 90 % confidence level for the lognormal dose distribution of each worker category to comply with each of the following criteria:

- The dose is below 5 mSv/a for supervised areas
- The dose is below 20 mSv/a for controlled areas
- The relative error in the dose is less than 50 %

Table 4: The minimum frequency necessary at 90% confidence level using the results obtained during 2000.

Category	Minimum number of samples		
	< 20 mSv/a	< 5 mSv/a	50 % Error
PRODUCTION			
Smelter Supervisor	2	6	27
Smelter Operator	2	3	27
Powder Supervisor	2	3	23
Powder Operator	2	6	36
Annealing Operator	2	5	33
Logistics Operator	4	12	45
NON-PRODUCTION			
Workshop Personnel	18	82	38
Laboratory Sampler	10	3202	41
Laboratory Analyst	13	77	35

A new Operator may use the above to optimise his assessment and routine monitoring program. A limited number of samples are sufficient to determine the area classification of the various sections of typical plants.

Once the area classification has been determined, the number of samples necessary for the routine monitoring program for a controlled area may then be allocated, using the values represented by the 50% error at 90% confidence.

8 CONCLUSION

Doses remain well below 20 mSv/a, and should even be below 5 mSv/a if dust masks become compulsory in the areas with high airborne dust concentration e.g. typical occupational hygiene measures.

Increased awareness, regular clean-ups to minimise the source of airborne dust etc lead to the decrease in occupational exposure in the Production Areas. Nevertheless, the non-production workers, (Maintenance and Laboratory), showed varying exposures, most probably due to tasks that needs to be performed under varying conditions.

Workshop and Laboratory personnel exposure remains below 5 mSv/a even without a protection factor for the use of a dust mask. The present monitoring frequency, however, fails the statistical test required to reclassify the area as supervised. The use of Personal Protective Equipment remains compulsory for infrequent workers, but it was excluded, as it was difficult to proof continual compliance.

Higher doses are predicted when using RP 95. As seen from the results, actual values recorded are lower, especially for the Production Areas.

Less than 15 samples per annum in the various sections seem to be sufficient to determine the classification of an operational area, even as a supervised area, whereas 18 samples may be required to designate non-production areas as controlled. Thirty samples per section seem to be sufficient to determine the annual exposure of workers in production areas with a 50% error at 90% confidence. However, in non-production areas, expected variations in exposure conditions due to varying tasks may require no less than 45 samples.

9 REFERENCES

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