EFFLUENT CONTROL FOR THE URANIUM MINE AREA AT POÇOS DE CALDAS, BRAZIL

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ABSTRACT

Derived levels for effluents control for the Industrial Complex of Poços de Caldas - CIPC, Brazil were set based on the IAEA recommendation for the dose assessment of critical groups. Although the industry has stopped the uranium extraction in 1988, the installation is kept under regulatory control, as it has not yet been decommissioned. A screening procedure was set to control the effluent releases from the three main areas, the open pit mine area, the tailings dam and the waste rock piles. To each one of these areas, the dose restriction of 0,3 mSv/a was adopted, since each effluent refers to a different critical group. Monthly-composed samples are collected weekly at each outflow and sent to IRD. The radionuclides analyzed are ^{238}U, ^{226}Ra, ^{210}Pb, ^{232}Th and ^{228}Ra. If the activity concentration for any of these nuclides surpasses the established reference level to that particular source, a complete dose assessment for the critical group is performed using the computer program, Monitor, built based on IAEA recommendations for dose assessment to critical groups. The results show that Brazilian regulations related to public exposure are being accomplished by the installation operation. It is pointed out the relevance of maintaining the current treatment to the acid drainages and effluents from the tailings dam, until the whole area is properly decommissioned.

INTRODUCTION

Occupational and environmental control programs performed by both the operator and by IRD/CNEN are maintained after the end of the operational phase of the Industrial Complex of Poços de Caldas - CIPC. The IRD program includes the auditing of documents and records; verification of occupational, effluent and environment control reports; inspections, including independent sampling and measurements; and a yearly campaign of environmental sampling. Since 1990 IRD develop a program of effluent monitoring based on weekly collected samples composed in a monthly basis. If the annual average concentration of a radionuclide surpasses the approved reference level, dose calculations are performed to critical groups based on actual measured data using the methodology suggested by the IAEA and ICRP (1,2). This paper describes the main results from this program.

1. HISTORICAL DESCRIPTION OF THE OPERATION OF CIPC

The Industrial Complex of Poços de Caldas (CIPC) was designed to operate the open pit Uranium mining, milling and processing of uranium ore for production of uranium concentrate in the form of ammonium diuranate (DUA). The first authorization for initial operation (AOI) for the installation was delivered in 1981. In 1988 the mining activities were interrupted and the activities of the chemical processing plant were interrupted in 1989.

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During the operational period, both the operator and the regulatory authority performed environmental monitoring programs on the surroundings of the mine-milling area. Values were routinely compared to pre-operational levels. During the operation of the Complex there were produced 1.200 tons, in equivalent U_3O_8, of DUA. For this production it was necessary the processing of 2.111.920 tons of ore, with the generation of 44.560.000 m^3 of waste rock disposed in the site around the mining area, the treatment of 13.360.000 m^3 of marginal waters and the generation of 2.452.560 tons of solid wastes disposed in the waste dam.

A new AOI was granted in 1990 to allow the processing in experimental basis of a mixture compose by the uranium ore previously extracted and a residue from a monazite processing industry containing U and Th, called "Pye II". For this new license, the environmental impact assessment procedures had already been developed by the Brazilian Instituto de Radioproteção e Dosimetria, IRD/CNEN, and derived levels for the effluent releases from the installation were determined. The experimental operation, however, was interrupted after 2 months due to problems related to overflow of the tailings dam and infiltration of waste material retained in the thorium retention dam.

CIPC presents a quite complex situation related to environmental liabilities. There is a need of continuous treatment of the acid drainage waters from the waste rock piles. This acid drainage is collected in a dam for chemical treatment before the release of the liquid fraction to the environment. The uranium containing solid fraction is deposited in a section of the mining area. However, these acid waters are also generated in the tailings dam and on the open pit mine area. The decommissioning of CIPC shall then mainly address the remediation of 3 main focuses of environment impact, which are the acid drainage from the waste piles, the tailings dam and the mining area.

2. EFFLUENTS

The dose criteria used for effluents discharges to the environment is 0,3 mSv/y for critical groups of members of the public and three critical groups are considered for this installation, each one related to an environmental source, as there are 3 main effluents release points, each one affecting a different population group. The controlled effluents correspond to the interfaces of the releases or drainages of CIPC with the adjacent environment:

P 014–exit of the Antas creek dam, which receives the treated water from both the drainage of the mining area and from the waste pile drainage dam;
P 025–exit of tailings dam, after treatment for radium precipitation with $BaCl_2$; and,
P 076–exit of the Consulta creek dam that receives the overflow from the main waste rock pile dam, when pumps systems to the treatment area are not enough to transfer all the drained flow rate.

The schematic location of these points is shown in Figure 1, centered at the mining area.

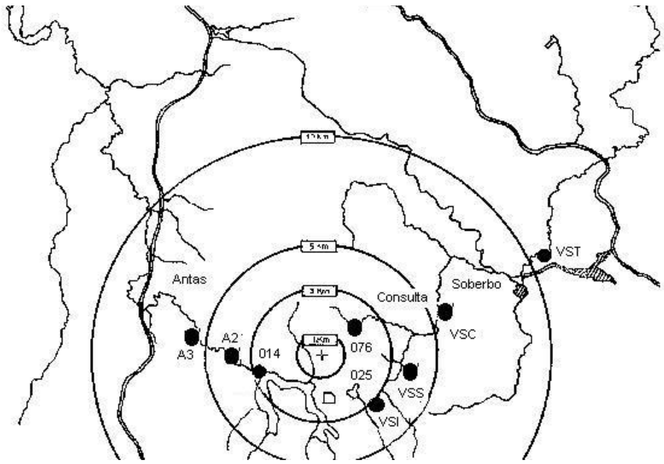

Figure 1 Layout of CIPC site with main effluents and possible critical groups

3. MODELING APPROACHES

The model used for dose assessments of critical groups is based on that recommended by IAEA(1). It is considered an operational period of 10 years. Critical groups are rural adult residents as at the time the program started there was no internationally accepted set of dose conversion factor adequate for children.

As cattle uses to be fed from fresh pasture the whole year, it is not considered pasture irrigation. Meat and milk contamination are due only to cattle watering. Crops irrigation is usual in the region and translocation from leaf deposited activity to edible part of the plant is considered according to the environmental mobility of the radionuclide. Ra and U were considered as mobile elements, and Th, Pb and Po as less mobile elements.

The determinations made by IRD on effluents samples include ^{238}U, ^{226}Ra, ^{210}Pb, ^{228}Ra and ^{232}Th. For the dose assessment, the radionuclides ^{234}U, ^{210}Po, ^{230}Th and ^{228}Th are also considered and the following approaches are used in the calculation (3):

i) The activity of ^{234}U is same as that of ^{238}U in all samples;
ii) The activity of ^{230}Th in the effluent is 1/10 of that of ^{238}U;
iii) The activity of ^{210}Po in the effluent is same of that of 210Pb; and
iv) The activity ^{228}Th is the same as that of ^{232}Th.

It was also assumed, conservatively, that values lower than detection limit are equal to detection limit values, what means that the doses are overestimated. In the first screening several reaches have been considered. Exposure pathways considered for each possible critical group are presented on Table 1.

Generic parameters used in the dose calculation are presented on table 2. Table 3 presents the dilution factors for each location considered in calculations, according to flow rates measured at each site. Table 4 presents the radioactive decay rates and dose conversion factor for the radionuclides included in the dose assessment. Table 5 presents the element dependent parameters (transfer factors).

Table 1: pathway considered for different possible critical groups related to each effluent

Effluent		_014		_025		_076		
Pathways		A2	A3	VSI	VSS	76	VSC	VST
Ingestion	Water	No	No	No	No	No	No	Yes
	Fish	Yes	Yes	No	No	No	No	Yes
	Vegetables	Yes	Yes	No	Yes	No	Yes	Yes
	Meat	No	Yes	Yes	Yes	Yes	Yes	Yes
	Milk	No	Yes	Yes	Yes	Yes	Yes	Yes
	Poultry	No	Yes	No	No	No	Yes	Yes
	Eggs	No	Yes	No	No	No	Yes	Yes
External	Water	No	No	No	No	No	No	Yes
	sediments	No	No	No	No	No	No	Yes

Table 2: generic parameters used in dose assessment (1,4,5)

Parameter	Unit	Value	Parameter	Unit	Value
weathering from root zone of soil	d^{-1}	3,0E-05	average anual irrigation rate	l/m^2d	1,0E+00
weathering from leaf deposition	d^{-1}	4,6E-02	pasture: R/Y	m2/kg	2,0E+00
soil surface density (root zone)	kg/m^2	2,0E+02	leafy vegetables: R/Y	m^2/kg	1,0E-01
vegetable intake for poultry	kg/d	1,2E-01	non leafy vegetables: R/Y	m2/kg	3,3E-01
vegetable intake for chicken (egg)poultry	kg/d	1,2E-01	translocation factor-mobile elements		3,0E-01
water intake by cows (milk)	l/d	6,0E+01	translocation factor-immobile elements		1,0E-01
water intake by cattle	l/d	5,0E+01	growing season for vegetables	d	6,0E+01
water intake by poultry	l/d	3,0E-01	growing season for pasture	d	3,0E+01

Table 3: Dilution factor for possible critical group sites

Effluent	_014		_025		_076		
Location	A2	A3	VSI	VSS	_076	VSC	VST
dilution	0,80	0,44	0,73	0,47	1	0,16	0,04

Table 4: nuclide dependent parameters – dose conversion factors and radioactive decay (6,7)

Nuclide	λ	Ingestion	Ext. soil	Ext.water
	(d-1)	(Sv/Bq)	$(Sv/a)/(Bq/m^2)$	$(Sv/a)/(Bq/m^3)$
^{238}U	4,25E-13	6,53E-08	1,86E-08	1,75E-07
^{234}U	7,77E-09	7,21E-08	3,21E-11	6,33E-10
^{226}Ra	1,19E-06	3,02E-07	6,30E-08	2,44E-08
^{210}Pb	8,52E-05	1,41E-06	6,50E-09	4,60E-08
^{210}Po	5,02E-03	4,40E-07	2,52E-13	2,80E-11
^{230}Th	2,47E-08	1,62E-07	3,29E-11	1,41E-09
^{232}Th	1,35E-13	8,61E-06	8,89E-08	7,23E-10
^{228}Ra	3,15E-04	3,25E-07	8,89E-08	3,09E-06
^{228}Th	9,34E-04	1,03E-07	5,61E-08	3,90E-08

Table 5: element dependent parameters: transfer factors (1,4)

Element	Kd	Bp	Poultry	Eggs	Meat	Milk	Vegetable
	L/kg	L/kg	d/kg	d/kg	d/kg	d/kg	Bv
U	1,0E+04	1,0E+01	1,2E+00	2,0E+00	3,0E-02	6,0E-04	2,0E-03
Ra	1,0E+04	5,0E+01	1,2E-01	2,0E-01	5,0E-04	6,0E-04	4,0E-02
Pb	1,0E+04	3,0E+02	3,0E-02	3,0E-01	8,0E-04	3,0E-04	1,0E-02
Po	1,0E+04	5,0E+01	1,2E+00	2,0E+00	3,0E-03	5,0E-04	2,0E-04
Th	1,0E+04	3,0E+01	4,0E-03	4,0E-02	1,0E-04	5,0E-06	5,0E-04

4. RESULTS

Average yearly activities per unit volume of measured effluents are presented on Figure 2. Dose coefficients per unit activity in 1L of river water at each location were calculated and are presented on Table 7. Dilution factors and water uses for each location were then applied to get dose coefficients related to unit activity per liter of effluent for each radionuclide.

From these screening results, critical groups have been selected and doses for these groups were estimated based on average yearly concentration measured in effluents. These results are shown in Figures 2 to critical group related to the effluent from the mining area (effluent 014), located at site A2, to the effluent from the tailings dam (effluent 025) located at site VSS, and for the outflow of the waste rock drainage dam (effluent 076), located at site VST.

Direct water ingestion by the population was considered at VST although it has not been verified at the region. For other locations, water quality is not adequate to human consumption and the region is very rich in water sources of better quality. Although VST location is more distant from the effluent 076, the more broad water usages may lead to higher doses to members of the public. The same occurs with effluent 025, as location VSI is closer to the discharge point but has more restricted uses than location VSS. For the effluent 014, from the mining area, the critical group was defined to be located at A2, which is more close to the installation and has similar uses as location A3.

From Figure 2, it can be observed that eventually some measured concentration values, mainly for uranium, surpass the established reference levels for the corresponding effluent, but generally, this occur due to acid drainage and values for other radionuclides stay enough below the established levels.

The dose restriction used is 0.3 mSv/a for each effluent, once they are related to different population groups. It can be verified that doses are kept below of the authorized levels since 1992 for all effluents, as required by CNEN since 1990. Higher values observed before 1992 were due to the acid drainage from waste pile rocks and tailings dam, observed by the IRD environmental monitoring program in 1988 (8). The construction of a dam and acid water treatments provided by the operator and was efficient to keep doses below authorized levels.

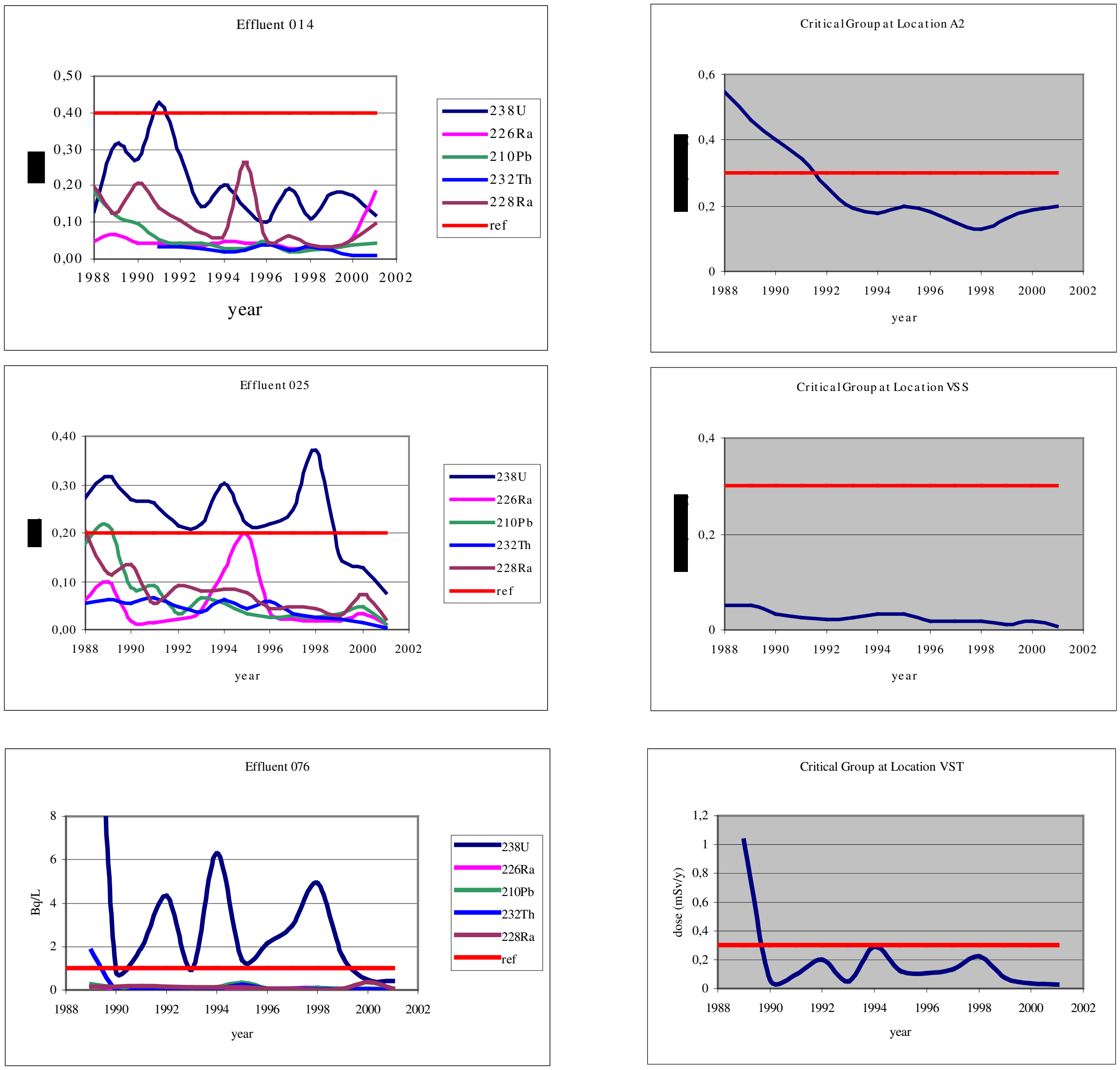

Figure 2: Results on radionuclides activity per liter of effluent and doses to critical groups

Table 7: Doses per unit concentration in surface water at point of use (Sv/a per Bq/L in river water)

pathway	*Doses per unit concentration in surface water at point of use*								
Ingestion	^{238}U	^{234}U	^{226}Ra	^{210}Pb	^{210}Po	^{230}Th	^{232}Th	^{228}Ra	^{228}Th
Water	3,0E-5	3,4E-5	1,3E-4	6,4E-4	3,1E-4	8,4E-3	3,4E-4	1,0E-4	4,1E-5
Fish	4,3E-6	4,9E-6	9,1E-6	2,7E-3	1,5E-4	3,6E-3	1,5E-4	7,4E-5	1,8E-5
vegetables	2,2E-5	2,5E-5	1,6E-4	1,3E-4	3,1E-5	9,6E-4	3,9E-5	2,1E-4	4,7E-6
Poultry	3,7E-7	4,3E-6	3,1E-9	2,1E-8	2,0E-8	3,5E-8	1,5E-9	3,0E-8	1,7E-6
Egg	1,9E-7	2,2E-7	9,3E-8	6,2E-8	6,1E-8	1,1E-7	4,3E-9	9,0E-8	5,2E-10
Meat	4,2E-6	4,7E-6	3,0E-07	2,4E-6	3,0E-6	3,9E-6	1,6E-7	2,9E-7	1,9E-8
Milk	1,5E-6	1,6E-6	1,4E-5	4,0E-5	1,6E-6	5,4E-6	1,2E-7	1,7E-5	5,5E-8
External	^{238}U	^{234}U	^{226}Ra	^{210}Pb	^{210}Po	230Th	^{232}Th	^{228}Ra	^{228}Th
Water	6,1E-9	2,2E-11	7,8E-10	1,8E-9	9,8E-10	4,9E-11	2,5E-11	1,1E-07	1,4E-9
Sediment	3,2E-4	5,5E-7	1,1E-3	1,1E-4	4,3E-10	5,6E-7	1,5E-3	1,5E-3	9,6E-4

5.CONCLUSIONS

Along the last years the corrective measures adopted by the operator was shown to be efficient for keeping the public exposure doses due to liquid effluents of CIPC below the authorized limits. However it is important to point out that the operator maintains a high cost operation for the effluent treatment of the acid drainage of the waste piles, of the marginal waters of mine area, and of the overflow of waste dam. The chemical treatment also generates solid waste disposed on the tailings dam or inside the mine area. For the authorization of new practices, the proper decommissioning of these degraded areas must be performed by the operator.

Also, for a new operational phase, it must be taken into account the changes in land use in the surroundings of CIPC. Large farms usual in the 80´s are now being divided into smaller farms. This restricts access to water sources and several small farms are now using river water for irrigation in places where it was not usual when this assessment was done. It is also under investigation the use of water of Antas dam for irrigation upstream the outflow from mining area, as the dam’s flux may suffer inversion due to this use at the dry season. Also, new activities such as fish farming have also been recently observed in the region (9). Finally, as the Brazilian standards for radiological protection are being revised, the new dose assessments must be performed using effective doses and dose conversion factors recommended by IAEA (10).

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