INVESTIGATION OF AERIAL DISPERSION OF RADIOACTIVE DUST FROM AN OPEN-PIT URANIUM MINE

H.B.L. Pettersson * and J. Koperski **
*) Dept. of Radiation Physics, University of Lund, Lund, Sweden.
**) Ranger Uranium Mines P/L, Jabiru, NT, Australia

ABSTRACT

Detailed investigation of aerial dispersion of radioactive dust from the biggest uranium mining and milling operations in Australia has been carried out. Spatial distributions of the long-lived uranium series radionuclides and their origin (mining and milling operations versus natural radiation background) have been studied.

Air concentration, horizontal flux and dry and wet deposition of the radionuclides were investigated along 45 km transect, in the direction of the prevailing monsoonal winds in the region.

INTRODUCTION

Ranger Uranium Mines operates an open-pit mine and treatment plant at a remote, subequatorial part of the Northern Territory. Characteristic for the region are two distinct seasons, dry and wet, with steady monsoonal winds. Ranger deposits are located c. 200 km east of Darwin, in the lowlands of the Alligator Rivers region.

About 6 mln tonnes of rock is mined annually from the only operating orebody no.1, resulting in an annual output of c. 3000 tonnes of uranium oxide (U_3O_8).

About 1500 people live permanently near Ranger, among them c. 1200 in Jabiru township, distant 8 km WNW of Ranger, and c. 300 in Jabiru East, 3 km NW of Ranger (Fig. 1).

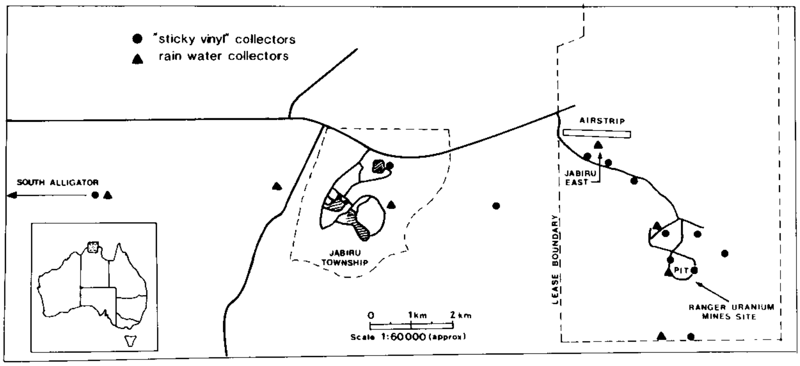


Fig. 1

The principal aim of the study was to investigate the spatial distribution of the longlived radionuclides of the ^{238}U series and their origin i.e. mining operations versus natural radiation background, along the path of the monsoonal winds in the region. Incidentally, the Ranger site and the townships are located along that path, with the prevailing dry season (April-October) winds blowing towards the townships.

The investigations were conducted from mid 1984 till the beginning of 1987. They included passive and active dry deposition collection, and were complemented by wet dust collection during the wet seasons of 1984/1985 and 1986/1987. The wind frequence for E+SE winds are on average 75 %, 20% and 50% in dry season, wet season and all seasons respectively.

MATERIALS AND METHODS

Passive "sticky vinyl" dust collectors were used as principal dust monitoring devices during the dry seasons. The collectors were made of a clear self-adhesive vinyl ("Contact" brand, Nylex Corp. Ltd, Victoria). Each collector consisted of a sheet of the vinyl streched on a plywood frame, with areas between 0.35 to 1 m^2. Horizontal frames were at 1 m height and the vertical frames were 1.5 m above the ground at their centre. The monitoring sites extended along up to 45 km long transect from the Ranger site, parallel to the path of the prevailing winds in the region (Fig. 1). The collectors were changed about once per month.

Periodically, in some of the above sites, simultaneous active dust sampling was conducted by means of high volume air filter sampling. In most sites, wet deposition of radionuclides in rainfalls was also carried out by means of 30 liter sealed plastic containers equipped with 0.20 m diameter collecting funnels.

RESULTS AND DISCUSSION

The investigation on horizontal transport of radionuclides in dust from the pit, was carried out during part of the dry seasons 1984-1986. Figure 2 displays the average load on vertically oriented "sticky vinyls", all facing the pit along a transect from approximate SE to NW direction. The observed decrease of activity load, J, with distance from the pit, x, in NW direction, is represented by expressions of the form;

$$J = k \cdot x^a$$

where J is expressed in $Bq \cdot m^{-2} \cdot d^{-1}$ and x in km, and k and a are constants for each radionuclide. The line of best fit using this expression is shown for each radionuclide in Figure 2, and the values for k and a are given in Table 1. The data for x=45 km are considered to represent natural background levels and were therefore omitted in the fitting exercise.

TABLE 1.

Vinyl orientation	Radionuclide	a	k ($Bq \cdot m^{-2} \cdot d^{-1}$)	r
Vertical	$^{238,234}U$	-3.18	0.234	0.97
"	^{232}Th	-1.51	0.0015	0.85
"	^{230}Th	-3.10	0.236	0.96
"	^{226}Ra	-2.92	0.367	0.99
"	^{210}Pb	-2.40	0.243	0.97
"	^{210}Po	-2.44	0.079	0.87
"	Average, except ^{232}Th	-3.0	0.25	0.94
Horizontal	$^{238,234}U$	-2.67	1.93	0.98

a and k are constants described in the text, r is the correlation coefficient.

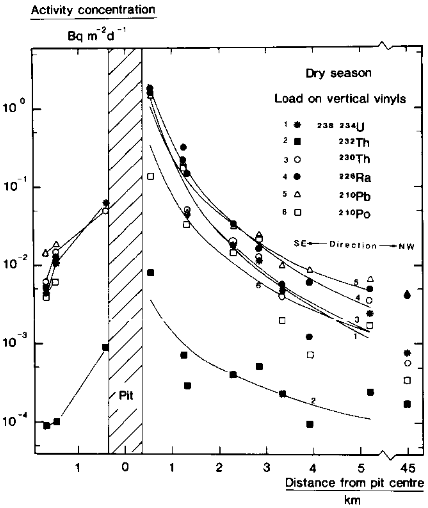


Fig.2

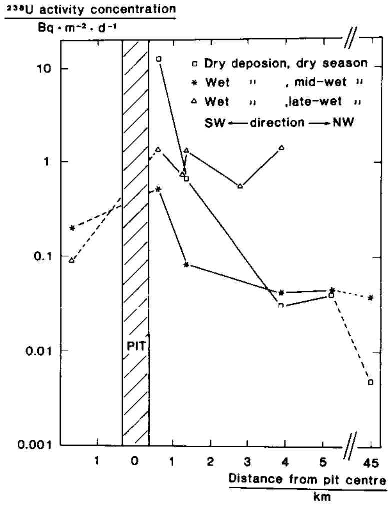


Fig.3

The data for the uranium series radionuclides, except ^{210}Pb and ^{210}Po, are well described by an inverse cubic dependence of activity load versus distance. The less rapid decrease of load for ^{210}Pb and ^{210}Po reflects a faster approach to the relatively higher natural background for these nuclides. For ^{210}Po is the load as well generally much lower, which is unexpected. We believe the reason might be evaporation of ^{210}Po from the vinyls. For ^{232}Th, where we have found that activity concentrations in soil are of the same order of magnitude in the pit as in the surroundings, is the activity load expectedly much lower and a faster approach to natural background levels is found.

Along with vertically oriented vinyls were horizontally oriented vinyls exposed at 5 joint sampling locations for the same time periods. The latter vinyls will act as dry deposition/ fall-out collectors, but will not distinguish between different source directions. Figure 3 shows the observed dry deposition activity concentrations for ^{238}U as a function of distance from the pit in the NW direction. A fit of the data, using the same expression as for vertical vinyls, gives a somewhat slower decrease rate (Table 1), which is expected because of contributions to dry deposition from sources with directions other than the pit area, i.e. natural background sources.

By gravimetric measurements on the mass load per unit area of horizontal vinyls, were the specific activities on the vinyls determined (Table 2). It is interesting to note the closeness between surface soil activity concentration in the pit, which corresponds to about 0.18 % uranium, and the dry deposition concentration close to the pit, although the former is only a grab sample and does not represent an average concentration in the pit surface soil. In the surroundings, more than a few km's away from the pit, will the dry deposition concentrations clearly exceed the surface soil concentrations, giving a activity contribution of uranium series radionuclides to the top soil, surfaces like plants and water of the order of 5-100 $Bq \cdot m^{-2} \cdot y^{-1}$.

The wet deposition of radionuclides was studied during the wet seasons by means of rain collectors, at sampling locations identical to the dry season study. The radionuclide load per unit area in rainfall was determined and Figure 3 shows the results for ^{238}U wet deposition rate during "mid-wet" season and "late-wet" season. The radionuclide load is overestimated because dry deposition was not prevented. The results for the "late-wet" period indicates an almost distance independence on load in the NW direction. This contrasts sharply with dry deposition data (Fig. 3), but if we assume a wash-out of the total air column and that transverse dispersion at distances comparable with the source diameter is not significant, and that the plume height is less than the cloud height, one could expect an almost constant radionuclide load with distance from the source.

TABLE 2.

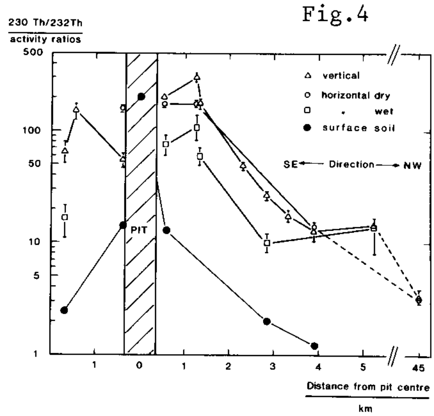
Specific activities (Bq·kg^{-1}) of radionuclides in dust from dry deposition and surface soil.

Distance from pit centre (km)	Horizontal vinyl ^{238,234}U	^{232}Th	^{230}Th	Surface soil ^{238,234}U	^{232}Th	^{230}Th
0	-	-	-	23000	115	23250
0.55	20250	130	22800	2120	235	3090
1.325	7605	45	7920	425	-	-
2.95	-	-	-	115	75	150
3.9	220	18	260	65	65	80
5.2	240	-	-	25	-	-
45	-	-	-	20	-	-

During the "mid-wet" period is the wind no longer pronounced in the E-SE direction. This would reduce the activity load in the NW direction. The results (Fig. 3) confirms that and also shows that for locations like Jabiru-East and Jabiru is the dry and wet deposition of radionuclides of the same strength.

Figure 4 shows the average ^{230}Th/ ^{232}Th activity ratios obtained for vertical and horizontal vinyls and surface soil. The ratios drop fast for the surface soil when leaving the pit area compared to the wet and dry load. This makes clear that the pit area is acting as a source of radioactive dust along the transect. If we use a ^{232}Th/ ^{232}Th activity ratio of 200 for the pit and between 1 and 2 for the surroundings we find that for Jabiru-East and Jabiru will the aerial dispersion from the pit area give a 4-9 times increase in dry and wet activity load , compared to natural background levels.

Fig.4



By comparing the load of radionuclides on vertical vinyls exposed simultaneously in 4 major wind directions at 4 sites along the transect with radionuclide concentrations in the air by air filter sampling, the load on vertical vinyls was transformed to "generated" air concentrations. For the locations Jabiru-East and Jabiru the obtained air concentrations would give rise to a committed effective dose equivalent of the order of 0.05-0.20 mSv for one year exposure.