LISAD

Lisa 1

Andmed viitest: http://www.eneabba.net/tenorm/index.htm.

The data below are the 'raw' extracts from the documents and/or papers. Please refer to the last column for the reference and obtain the full text if required.

No	Data	Ref
1	Brazil, niobium mining and processing Effluent treatment was generally efficient to reduce radionuclide releases to the environment, with the exception of one niobium industry that had to include an additional step (precipitation with sulphate) to remove Ra-228 (in concentrations up to 5 Bq/l) from seepage water in its tailings dam. The predicted effective doses to the hypothetical critical groups are below 0.3 mSv/year.	**F-01**
2	Brazil, niobium mining and processing Open pit processing, Activity Median Aerodynamic Diameter (AMAD) + 1 micron, bioassay results were typically below minimum detection level but uranium was detected for some occupations (processing). Dose: open pit - 1.3 mSv/yr, leaching - 1.2 mSv/yr, other areas - 0.2-0.8 mSv/yr.	**L-01**
3	European Union, niobium processing Ferro-niobium production, raw material - pyrochlore or columbite ~ 50 Bq/g Th	**J-02**
4	European Union, niobium production Niobium is found in tantalite (Ta2O6)(Fe,Mn), columbite (Nb2O6Fe), fergusonite (Nb,Ta)O4(Y,Er,Ce)Nb2O7Ca2, samarskite, pyrochlore (Na,Ca,Ce)2Nb2O6F, koppite and loparite. The ore is processed by melting with sodium or potassium hydroxide, dissolving in hydrochloric acid, and processing with chlorine at 750-800°C. The resulting metallic niobium is then further purified. Ferro-niobium may be also produced using a process involving a high temperature exotermic reaction between pyrochlore and aluminium powder. General ranges of activity in ferro-niobium industry (Bq/g): Th-232 7-80; U-238 6-10; Ra-226 6-10, Pb-210 6-500 *Doses* Normal conditions, min. act. conc 0.05 mSv/y; Normal conditions, max act conc 320.0 mSv/yr Unlikely conditions, min act conc 0.19 mSv/y; Unlikely conditions, max act conc 640.0 mSv/yr	**D-02**
5	Brazil, niobium processing Brazilian pyrochlore - RNb2O6.R(Ti,Th)O2 operations in Araxá produce solid wastes with Ra-226 in the range 0.2-100.0 Bq/g, Ra-228 in range 0.5-300.0 Bq/g.	**P-04**
9	Russia, niobium and tantalum production <also relevant for tantalum, tin and beryllium> To manufacture ore concentrates of tantalum, niobium and tin the spodumen beryllium ores are used in a milling factory. After the preparation of the ore (fragmentation and rubbing) the final separation of each mineral is done by the specific techniques. Cassiterite (tin concentrate) is extracted using electromagnetic separation and niobium concentrate is manufactured using chemical extraction. Specific activities (Bq/g): *Raw material* Spodumen beryllium ore LiAlSi2O6?: U-nat 0.59, Ra-226 0.19, Th-232 0.022, Pa-231 0.0014 *Products* Ta-Nb concentrate: U-nat 960, Ra-226 240, Th-232 12 Deprived Ta-Nb concentrate: U-nat 55, Ra-226 3.7, Th-232 5.2 Ta concentrate: U-nat 0.67, Ra-226 0.004, Th-232 n/d Nb concentrate: U-nat 1.5, Ra-226 0.09, Th-232 n/d Tin concentrate: U-nat 670, Ra-226 110, Th-232 6.7 Tin concentrate of final purification: U-nat 370, Ra-226 89, Th-232 4.4, Pa-231 27.0 *Wastes* Natural iron: U-nat 110, Ra-226 11, Th-232 2.9 Pomergranate sand: U-nat 120, Ra-226 6.3, Th-232 0.3 Cake: U-nat 370, Ra-226 1.3, Th-232 0.2 Eticke: U-nat 28, Ra-226 48, Th-232 0.7 Smear of the equipment: U-nat 16, Ra-226 3.3, Th-232 0.07 *Metal tantalum production* Processing of Ta concentrates and wastes from Sn production. Producing potassium fluorotantalate, which is recovered to metal tantalum. >90% of activity transferred to wastes. Specific activities (Bq/g) *Raw materials* Russian: U-nat 77-152, Ra-226 20-36, Th-232 1.3-8.1, Pa-231 1-18.5, Ac-227 0.5-152 Imported (unspecified): U-nat 22-151, Ra-226 3-23, Th-232 3.1-100, Pa-231 5.2-5.9, Ac-227 89-100 German: U-nat 159, Ra-226 4.8, Th-232 7.4, Pa-231 n/d, Ac-227 137 Australian: U-nat 311, Ra-226 23, Th-232 4.4, Pa-231 12.2, Ac-227 n/d	**S-13**

	Products Potassium fluorotantalate: U-nat 0.04-0.22, Ra-226 0.02, Th-232 0.02, Pa-231 0.02, Ac-227 0.2-0.3 Niobium hydroxide: U-nat n/d, Ra-226 0.06, Th-232 0.03, Pa-231 0.06, Ac-227 0.04 *Wastes* Pulp: U-nat 14.1, Ra-226 2.1, Th-232 0.6, Pa-231 0.8, Ac-227 1.3 Ash: U-nat 0.8, Ra-226 0.3, Th-232 0.1, Pa-231 n/d, Ac-227 n/d	
10	<u>EU</u> Very high radionuclide concentrations occur in pyrochlore, the source of niobium, and this is reflected in the products and the wastes. Assessments of the radiological impact of operations associated with metal smelting generally indicate that worker doses are low, with the exception of those from pyrochlore where values of up to a few mSv/yr are possible. Exposure of the public owing to releases from these processes is generally assessed to be low. However, the potential doses from landfill disposal of waste could be more significant, where values up to 10 mSv/yr could occur as a result of intrusion and site redevelopment.	**E-08**

No	Data	Ref
1	<u>Brazil, monazite sands</u> Along the Atlantic coast of South and Southeastern Brazil there are several beaches where heavy minerals form placer deposits (black sand) with high concentrations of natural radioactivity. In Brazil the exposure to natural radiation is considered to be therapeutic, since a physician introduced a treatment for arthritis and rheumatism based on the exposure to natural radiation. As a result thousands of tourists visit the beaches throughout the year, preferably around the city of Guarapari, where deposits of radioactive black sand frequently occur. The main source of gamma radiation is the frequently found mineral monazite ([Ce,La,Th]PO4) which may contain considerable amounts of U and Th. The measured absorbed dose rates on areas with black sand are up to a few hundred times higher than the background values. A comparison of activity concentrations with data of tailings from a Czech uranium processing plant shows that the radium content of the monazite sand is higher than in these tailings, which are generally considered to be radiologically and environmentally harmful.	C-01
2	<u>Brazil, monazite processing</u> Bioassays for Th of background population (Rio de Janeiro), workers and local population. Th concentrations in faeces of workers is 3.6 times higher than the average for inhabitants and 10 times higher than for background areas.	J-01
3	<u>Brazil. monazite sands</u> Area of high natural radiation background in the North of Rio de Janeiro (large deposits of monazite sands), inhabitants of Buena are exposed to thorium through ingestion. The foodstuffs consumed by the population are basically composed of local products. A study that included the analysis of complete prepared meals has shown average concentrations of Th-232, Th-228, Ra-226 and Ra-228 of 12 mBq/kg fresh, 126 mBq/kg fresh, 167 Bq/kg fresh and 481 mBq/kg fresh, respectively. The results of the analyses of the urine and feces samples from volunteers have shown, in average, urine to feces excretion ratios for thorium higher than the predicted by ICRP models. The absorption of an element incorporated into food is higher than its ingestion in inorganic form. The use of standard parameters may lead to an underestimation of the internal radiation dose of the population.	M-04
4	<u>European Union, thorium minerals and compounds</u> *Minerals: monazite - (Ce,La,Nd,Th)PO4; bastnaesite (Ce,La,...)(CO3)F.* Monazite concentrate is obtained by gravimetric & electromagnetic separation from other heavy mineral sands. Strong acids or alkaline solutions are then used and lanthanides are precipitated. Bastnaesite ore concentrate is obtained by a wet process in which it is washed and separated in water. This concentrate is washed with hydrochloric acid and calcined in order to produce a crude oxide containing 90% of lanthanide oxides. Monazite concentrate, Th-232 chain: 8-3000 Bq/g, U-238 chain: 6-40 Bq/g. During the extraction process isotopes of radium are co-precipitated with barium sulphate to form a radium-bearing by-product (Ra-228 ~3000 Bq/g, Ra-226 ~450 Bq/g) Doses: Normal conditions, min act conc 0.002 mSv/y, Normal conditions, max act conc 3500.0 mSv/yr Unlikely conditions, min act conc 0.01 mSv/y, Unlikely conditions, max act conc 9800.0 mSv/yr *Thorium compounds* Decomposing concentrate with acids to produce thorium salts, these are raw materials for the metallic thorium. Use - thoriated tungsten welding electrodes, magnesium-thorium alloys for aerospace industry. Thorium nitrate - manufacture of gas mantles. Activity concentration of thoriated tungsten welding electrodes ~100 Bq/g of Th-232 &Th-228. Gas mantled contain ~ 1000 Bq of Th-232 and Th-228 each. Special alloys for jet engines may have an activity ~ 70 Bq/g Doses Normal conditions, min act conc 0.09 mSv/y, Normal conditions, max act conc 14.0 mSv/yr Unlikely conditions, min act conc 1.2 mSv/y, Unlikely conditions, max act conc 28.0 mSv/yr	D-02

5	<u>UK</u> *Rare earths in catalysts* Catalyst for the oil industry - incorporating a rare earth mixture into a zeolyte, deposit of isotopes of radium in tanks and pipes. *Thoriated tungsten welding electrodes* The addition of thoria improves the striking performance of tungsten welding electrodes. Pure thoria used in their manufacture, use: electrodes need to be occasionally ground to restore a conical tip - possibility of dust generation. *Thorium magnesium alloys for aero engine components* Hardened light alloy. Typical concentrations (Bq/g): Thoria: Th-232 3600, Ra-228 1800; Thorium magnesium alloy: Th-232 160.0, Ra-228 80.0; Thoriated tungsten: Th-232 160.0, Ra-228 80.0. Estimated typical dose for working with Th/Mg alloys: 9.1 mSv/year.	H-01
6	<u>Germany, thoriated electrodes</u> Specific activity of Th-232 ranges from less than MDL (~0) for WT-10 to 149 Bq/g for WT-40 electrodes. Possible exposure would be in range 5 - 20 mSv/y.	L-03
7	<u>Australia, monazite separation</u> *External gamma radiation* Principal source Tl-208 from Th chain. Significant only when monazite is in relatively concentrated form. Separation plant 0.5-5.0 microGy/hr, monazite separation section up to 20-30 microGy/hr, centre of full bag store ~250 microGy/hr *Internal exposure to dust (alpha)* Typical numbers 0.1 Bq/m3, some above 1.0 Bq/m3 *Surface contamination* Settled dust or loose mineral. Potential contribution to external gamma exposure plus dust re-suspension. *Radon/thoron + daughters* Th in monazite is chemically bound within the grain. There is little opportunity for emanation. Thoron is particularly unlikely to escape due to its half life of 55 sec. Measurements made under worst case scenarios have indicated a thoron emanation rate of <1%. Routine monitoring results are consistently low, <0.005WL thoron daughters, <0.0005WL radon daughters - around natural background. *Water contamination* Levels are less than ones applicable for members of the public	W-03
8	<u>Australia, monazite separation</u> Radiation exposure associated with monazite, external radiation 1-10 microGy/hr in plants, >150 microGy/hr in storage areas. Dust 0.05 - 5.0 Bq/m3 in 1989 ~15% of workers were receiving doses above 15 mSv/yr, small percent either approaching or exceeding 50 mSv/year.	H-05
9	<u>Australia, monazite separation</u> Some workers may have been exposed over their employment to a mean committed effective dose from inhalation in excess of 50 mSv/yr (since mid-1970's)	H-08
10	<u>Australia, monazite separation</u> Study of historical radiation exposure measuring thoron in breath of 62 workers. 8 workers (13%) >20 mSv/yr for many years; 2 workers (3%) >50 mSv/yr for many years.	T-02
11	<u>Australia, monazite separation</u> Ra-226 concentration strongly depends on grain diameter and decreases when the size of the grain is increased. Surface type of distribution. Radon emanation coefficient for a surface type of distribution and for the size range of monazite grains (70-130 microns) is about 0.5. A comparatively high emanation rate of radon from monazite was detected.	M-06
12	<u>Australia, monazite separation</u> In the past, occupational exposure to level of 50 mSv/yr were not uncommon.	U-01
13	<u>Australia, monazite separation</u> Monazite, being softer and finer than the zirconium and titanium minerals, may fragment during the numerous sizing and physical separation processes, becoming preferentially concentrated in airborne dust. Bioassay measurements of thorium in the urine and blood serum of mineral sands workers and unexposed persons were carried out. Levels of Th are much lower than predicted by ICRP-30. Discrepancy between measured & expected bioassay values up to an order of magnitude or higher. No correlation was found between the bioassay results and cumulative thorium concentration.	H-09
14	<u>Australia, monazite separation</u> An attempt to correlate thorium excreted in the faeces of two male workers in the monazite section of mineral sands dry separation plant over a 10-day period with personal air sampling measurements (inspirable dust filter, integrated personal dosimeter, personal cascade impactor). Th faecal analyses are able to detect acute and chronic exposures to the inhalation of Th-bearing dusts and to confirm the amount of inhaled thorium predicted from air sampling and metabolic models.	T-03
15	<u>Australia, monazite separation</u> In 1987 - positional samples - particle size characterisation, Activity Median aerodynamic Diameter	M-08 K-03

	(AMAD) average = 4 microns In 1988 personal cascade impactor was used to determine the actual AMAD size = 14 microns Another study returned the following AMAD data: personal 15.7 microns, positional indoors 4.6, positional outdoors 2.7 Further information on personal cascade impactors is available from [R-02]	
16	Radiobiological studies of workers involved in the extraction and milling of monazite (Brazil. 300 workers, ~14 mSv/year external dose) showed a significant difference in the proportion of chromosome aberrations between the control group and employees working in the physical/chemical treatment section of the plant. Epidemiological survey of >2,000 dust-inhaling Chinese miners was unable to establish a relationship between the relatively low thorium lung burden and lung cancer. However, an association was found between pneumoconiosis (stage 1) and an estimated Th lung burden of about 5.5 Bq. Mortality studies among US workers engaged in the production of thorium and rare-earth chemicals from monazite sand showed a statistically significantly elevated standardised mortality rate for pancreatic cancer.	S-08
17	<u>Australia, monazite separation</u> Airborne concentrations of Rn-222 and Rn-220 and their short-lived decay products are of no radiological concern. Typical gamma (microGy/hr): primary separation tails 0.2; heavy mineral concentrate stockpiles 1-2; secondary separation tails 2-7; stockpiled monazite >200 1987-1993 - external exposure decreased by 25-35%, an overall 4-fold decrease in the internal exposure, mostly due to the effect of the implemented engineering control measures of dust control.	K-02
18	<u>Australia, monazite processing</u> Monazite treatment waste can contain up to 1,100 Bq/g radium Monazite processing. Monazite contains up to 10% Th and 0.3% U. Concentration factor for waste can be up to 2, thus waste could contain 20%Th and 0.6%U	H-11
19	Monazite ore - exposure pathways: (1) Gamma - external, (2) Dust re-suspension - internal, (3) External beta risk to skin because of the energetic beta emitters in Th ore (beta particles with energy >1 MeV emitted by Ac-228, Bi-212, Tl-208). It can be shown that a contamination of skin of 1 Bq/cm2 (gross beta) of Th ore can give rise to a beta dose rate of 5 microGy/hr to the basal cells of the skin. *Monazite processing* Finely ground monazite (50% <10 microns) is generally treated by alkaline digestion. The caustic process involves cracking of the phosphate matrix with a hot 70% NaOH solution to dissolve the phospahte and convert the rare earths, Th and U to insoluble hydroxides. Crystallisation is used to recover the original hydroxide solution as a trisodium phosphate by-product. The filter cake from cracking (intermediate product) is subjected to an acid leach to selectively dissolve the rare earths leaving a crude residue containing hydrous U/Th oxides. Common leachants include HCl, in which case a RE chloride results, and HNO3, which results in RE nitrate product. After the acid leach, soluble radioactive isotopes such as Ra can be directed to the insoluble Th waste stream by the addition of BaCl2/H2SO4. Alternatively, the Ra stream can be allowed to enter the solvent extraction circuit where it will be rejected into the raffinate. The main solid waste is the sludge from the RE dissolution. It contains the same quantities f Th and U as the monazite but in a smaller mass. The rare earths are finally separated and purified by solvent extraction or ion exchange. *Radiological problems:* Potential of liberation of Rn-220 and Rn-222 is significantly enhanced in grinding and cracking stages. Practically all Th and most of U remain as insoluble hydroxides. The specific activity of Th/U solid residues - 2-3 times higher than for monazite. Gamma- levels from fresh gangue will depend upon the Ra amount reporting to the gangue. If less than 5% of Ra is present in gangue then initially the waste will contain 20-30% of the total radioactivity in monazite. With time due to ingrowth of Ra228, gamma will increase to ~300 microGy/hr. Without Ra removal, a very concentrated Ra waste stream (100-150 kBq/l Ra-226 and 1500-2000 kBq/l Ra-228) could be produced during the latter stages of processing (ie. Reporting to raffinate from solvent extraction). Highly active Ra residues in radium removal circuits. 30-2000 microGy/hr (2000 - in close proximity) *Doses - external:* India. Two workers > 2mSv/week, some 0.5-1.5 mSv/week. Annual >100 mSv. France. 5-10 mSv/yr, no workers exceed 30 mSv/yr USA. Doses for workers 10-20 mSv/yr Malaysia. 10-12.5 mSv/yr, job rotation. Brazil. 8-35 mSv/yr *Doses - internal:* India ~7.2 mSv/yr Brazil. 78-300 mSv/yr Estimated doses 10-1200 mSv/yr	H-12
20	<u>Australia, monazite processing</u> 1987-1992 dose assessment in minerals sands processing plant - all doses below 50 mSv/yr limit, and all below 15 mSv/yr.	A-06

	Tailings - 2 microGy/hr, small areas - 20 microGy/hr	
21	<u>Australia, monazite processing</u> Surveys in New South Wales. 1965, gamma up to 150 microGy/hr, alpha dust up to 5 Bq/m3 1971 gamma up to 150 microGy/hr (monazite bags), alpha dust 0.02 - 4 Bq/m3 1973, alpha dust <1 Bq/m3, but close to magnetic separator 7 Bq/m3, dose ~32 mSv/yr 1984, gamma 2-60 microGy/hr (monazite stockpiles), alpha dust 0.8-20 Bq/m3 Available data suggest that annual doses >100 mSv/yr have occurred.	C-06
22	<u>Russia, rare earth metals production</u> Specific activities (Bq/g) *Raw materials* Loparite: Th-232 1.3, Ra-228 1.4, U-nat 1.9, Ra-226 0.14, Ac-227 0.11 REM Chloride alloy: Th-232 2.3, Ra-228 3.2, U-nat 1.4, Ra-226 0.42, Ac-227 0.26 *Products* REM carbonates: Th-232 0.6, Ra-228 0.08, U-nat 1.5, Ra-226 0.05, Ac-227 0.18 REM carbonates from monazite: Th-232 0.32, Ra-228 0.47, U-nat 6.4, Ra-226 0.09, Ac-227 0.25 "Ftoropol": Th-232 0.21, Ra-228 0.03, U-nat 1.7, Ra-226 0.04, Ac-227 0.25 REM oxides: Th-232 0.07, Ra-228 0.01, U-nat 1.6, Ra-226 0.01, Ac-227 0.06 *Wastes* Fabric of the filtration (1 filter): Th-232 45,000, Ra-228 60,000, U-nat 100, Ra-226 4,900, Ac-227 1,200 Fabric of the filtration (filter 2): Th-232 0.7, Ra-228 1.6, U-nat 1,6, Ra-226 0.16, Ac-227 0.22 Sediments: Th-232 1.8, Ra-228 3.0, U-nat 1.6, Ra-226 0.07, Ac-227 0.17	S-13
25	<u>Malaysia</u> Rare earth industry operated in Malaysia in the period 1982-1992 and there is a substantial amount of waste left: xenotime sludge (190 Bq/g of Ra-226, 250 Bq/g of Ra-228), thoria (0.45%U, 15%Th), lead cake (26 Bq/g of Ra-226, 350 Bq/g of Ra-228), tri-calcium phosphates (0.1 Bq/g of Ra-226, 0.6 Bq/g of Ra-228). Regulation - if the dose to the public < 1 mSv/y - disposal exempted from control. In practice, however, a dose constraint of 0.3 mSv/y is used.	O-04

No	Data	Ref
1	<u>Russia, tantalum and niobium production</u> <also relevant for niobium, tin and beryllium> To manufacture ore concentrates of tantalum, niobium and tin the spodumen beryllium ores are used in a milling factory. After the preparation of the ore (fragmentation and rubbing) the final separation of each mineral is done by the specific techniques. Cassiterite (tin concentrate) is extracted using electromagnetic separation and niobium concentrate is manufactured using chemical extraction. Specific activities (Bq/g): *Raw material* Spodumen beryllium ore: U-nat 0.59, Ra-226 0.19, Th-232 0.022, Pa-231 0.0014 *Products* Ta-Nb concentrate: U-nat 960, Ra-226 240, Th-232 12 Deprived Ta-Nb concentrate: U-nat 55, Ra-226 3.7, Th-232 5.2 Ta concentrate: U-nat 0.67, Ra-226 0.004, Th-232 n/d Nb concentrate: U-nat 1.5, Ra-226 0.09, Th-232 n/d Tin concentrate: U-nat 670, Ra-226 110, Th-232 6.7 Tin concentrate of final purification: U-nat 370, Ra-226 89, Th-232 4.4, Pa-231 27.0 *Wastes* Natural iron: U-nat 110, Ra-226 11, Th-232 2.9 Pomergranate sand: U-nat 120, Ra-226 6.3, Th-232 0.3 Cake: U-nat 370, Ra-226 1.3, Th-232 0.2 Eticke: U-nat 28, Ra-226 48, Th-232 0.7 Smear of the equipment: U-nat 16, Ra-226 3.3, Th-232 0.07 *Metal tantalum production* Processing of Ta concentrates and wastes from Sn production. Producing potassium fluorotantalate, which is recovered to metal tantalum. >90% of activity transferred to wastes. Specific activities (Bq/g) *Raw materials* Russian: U-nat 77-152, Ra-226 20-36, Th-232 1.3-8.1, Pa-231 1-18.5, Ac-227 0.5-152 Imported (unspecified): U-nat 22-151, Ra-226 3-23, Th-232 3.1-100, Pa-231 5.2-5.9, Ac-227 89-100 German: U-nat 159, Ra-226 4.8, Th-232 7.4, Pa-231 n/d, Ac-227 137 Australian: U-nat 311, Ra-226 23, Th-232 4.4, Pa-231 12.2, Ac-227 n/d *Products* Potassium fluorotantalate: U-nat 0.04-0.22, Ra-226 0.02, Th-232 0.02, Pa-231 0.02, Ac-227 0.2-0.3 Niobium hydroxide: U-nat n/d, Ra-226 0.06, Th-232 0.03, Pa-231 0.06, Ac-227 0.04 *Wastes* Pulp: U-nat 14.1, Ra-226 2.1, Th-232 0.6, Pa-231 0.8, Ac-227 1.3 Ash: U-nat 0.8, Ra-226 0.3, Th-232 0.1, Pa-231 n/d, Ac-227 n/d	S-13

A-06 E.G. Alexander, N.D. Stewart, B.J. Wallace The Radiological Impact of Past and Presnt Practices of the Mineals Sands Industry in Queensland Radiation Protection in Australia, 1993, Vol.11, No.3, pp.80-84
C-01 J. Costa de Moura, P. Bossew, C.M. Wallfass, C.M. Wiedemann Enhanced Radiation Levels in Heavy Mineral Beach Deposits of the Guarapari Region, State of Espirito Santo, Brazil II International Symposium on Technologically Enhanced Natural Radiation, September 1999, Rio de Janeiro, Brazil
C-06 M.W. Carter, A.N. Coundouris Radiation Protection in the Mineral Sands Industry in New South Wales Radiation Protection in Australia, 1993, Vol.11, No.3, pp.90-96
C-12 K. Coy Incorporation of Radionuclides by Workers in Thorium Processing Industries - Monitoring and Minimising Internal Doses 2nd European ALARA Network Workshop, Good Radiation Practices in Industry and Research, England, Nov.1998, paper 18
D-02 J-P. Degrange, JSS Penfold, SF Mobbs Development of a Methodology for Assessing Occupational Exposure at Workplaces Where Materials are Processed which contain Enhanced Levels of Natural Radionuclides International Symposium on Radiological Problems in the Non-nuclear Industry, Amsterdam, September 1997
E-08 European Commission Fourth Report from the Commission on the Present Situation and Prospects for Radioactive Waste Management in the European Union European Commission COM (98) 799 final, pp.70-72
F-01 H.M. Fernandes, M. Pires do Rio, R. Rosa, Lene H.S. Veiga, E.C.S. Amaral Overview of the Technological Enhancement of Natural Radiation in the Brazilian Non-Uranium Industry II International Symposium on Technologically Enhanced Natural Radiation, September 1999, Rio de Janeiro, Brazil
H-01 J. Hipkin, P.V. Shaw Workplace Exposure to Ionising Radiation in The United Kingdom from the Use of Naturally Occurring Radioactive Materials International Symposium on Radiological Problems in the Non-nuclear Industry, Amsterdam, September 1997
H-05 G.S. Hewson, B.M. Hartley Radiation Research Priorities in the Mineral Sands Industry Journal of Radiological Protection, 1990, Vol.10, No.3, pp.221-229
H-08 G.S. Hewson, K.W. Terry Retrospective Assessment of Radioactivity Inhaled by Mineral Sands Workers Radiation Protection Dosimetry, 1995, Vol.59, No.4, pp.291-298
H-09 G.S. Hewson, K.W. Terry Thorium Metabolism and Bioassay of Mineral Sands Workers Health Physics, February 1993, Vol.64, No.2, pp.147-156
H-11 B. Hartley Disposal of Radioactive Waste from Mining and Milling of Mineral Sands Radiation Protection in Australia, 1993, Vol.11, No.2, pp.53-59
H-12 G. Hewson Occupational Radiological Aspects of the Downstream Processing of Minerals Sands Radiation Protection in Australia, 1993, Vol.11, No.2, pp.60-66
J-01 L.M.Q.C. Julião, J.L. Lipsztein, D.R. Melo Monazite Exposure in Brazil II International Symposium on Technologically Enhanced Natural Radiation, September 1999, Rio de Janeiro, Brazil
J-02 A. Janssens, M. Markkanen Provision on Natural radiation in the New Basic Safety Standards Directive International Symposium on Radiological Problems in the Non-nuclear Industry, Amsterdam, September 1997
K-02 J. Koperski Radiation Protection in The Mining and Milling of Mineral Sands Radiation Protection in Australia, 1993, Vol.11, No.2, pp.46-52
K-03 J. Koperski Particle Size Analyses In and Around Mineral Sands Operations Radiation Protection in Australia, 1993, Vol.11, No.3, pp.126-132
L-01 J.L. Lipsztein, D.R. Melo, K.M. Dias da Cunha, L.M.Q.C. Julião, F.F.L. Simões Filho, M.S. Santos, M.C. Lourenço Exposure of Workers in Mineral Processing Industries in Brazil II International Symposium on Technologically Enhanced Natural Radiation, September 1999, Rio de Janeiro, Brazil
L-02 J. Loy, A.J. Melbourne, G.C. Mason, M. Pegg The Formation and Role of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) 24th Annual Conference of the Australasian Radiation Protection Society, Margaret River, August 1999
L-11 T Ludwig, D. Schwass, G. Seitz, H. Siekmann Intakes of Thorium While Using Thoriated Tungsten Electrodes for TIG Welding Health Physics, Vol.77, No.4, October 1999, pp.462-469
M-04 D.R. Melo, J.L.Lipsztein, L.M.Q.C. Julião, M.C. Lourenço, D. Lauria Study on Thorium Absorption in the Gastrointestinal Tract II International Symposium on Technologically Enhanced Natural Radiation, September 1999, Rio de Janeiro, Brazil
M-06 L. Morawska, C. Jeffries Dirstibution of Radium in Mineral Sand Grains and Its Potential Effect on Radon Emanation Radiation Protection Dosimetry, 1994, Vol.56, pp.199-200
M-08 G. Meunier Use Of a Personal Cascade Impactor in The Mineral Sands Industry Proceedings of Minesafe International, 1990, Perth, WA, pp.733-738
O-04 M. Omar NORM Waste Management in Malaysia IAEA Waste Management Conference, Seville, Spain, 2000, paper IAEA-CN-78/22
P-04 A. Paschoa NORM and the Brazilian Non-nuclear Industries International Symposium on Radiological Problems in the Non-nuclear Industry, Amsterdam, September 1997
S-08 F. Steinhausler History of Occupational Exposure to Natural Radioisotopes Radiation Protection in Australia, 1993, Vol.11, No.2, pp.38-45
S-13 S.V. Stepanov, A.V. Simakov, S.V. Petrov, J.V. Abramov, O.V. Isaev
Methodological Problems of the Personnel Protection Supply in Case of Operations with Natural Radionuclide Materials IRPA-10 Congress, Hiroshima, Japan, May 2000 , Paper no P-6a-286.
T-02 K.W. Terry, G.S. Hewson
Thorium Lung Burdens of Mineral Sands Workers Health Physics, August 1995, Vol.69, No.2, pp.233-242
T-03 K.W. Terry, G.S. Hewson, G. Meunier. Thorium Excretion in Faeces of Mineral Sands Workers Health Physics, January 1995, Vol.68, No.1, pp.105-109
U-01 Uranium Information Centre
Mineral Sands Nuclear Issues briefing paper 25, January 1998
W-03 I.D. Watson, R.K. Taylor. The Development of Separate Radiation Protection Regulations for Monazite Production in Western Australia Radiation Protection in Australia, 1984, Vol.2, p.17

Lisa 2

Rn-222 Emanation Fraction U-tailings (http://www.antenna.nl/~wise/uranium/ctbh.html#INPTAIL)

Rn-222 Emanation Fraction in slimes, U-tailings
fraction of the total amount of radon-222 produced by radium decay that escapes from the slimes fraction of the tailings particles and gets into the pores of the material. It depends on the tailings material and the moisture content. It varies over a range of 0.1 - 0.4 or more; typical values are in the range of 0.2 - 0.3.
Rn-222 Emanation Fraction in sand
fraction of the total amount of radon-222 produced by radium decay that escapes from the sand fraction of the tailings particles and gets into the pores of the material. It depends on the tailings material and the moisture content. It varies over a range of 0.1 - 0.4 or more; typical values are in the range of 0.2 - 0.3.

Lisa 3

```
** RESRAD-BUILD Program Output, Version 3.21 08/13/03 17:07:59  Page:   1 **
 Title : Ladu toormega, 27 t ,1x4.5x1.5 m väliski
 Input File : C:\Program Files\RESRAD_Family\BUILD\Ladu_27ttoore1.bld
```

```
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒ                                          ƒƒƒ
ƒƒƒ       RESRAD-BUILD Table of Contents     ƒƒƒ
ƒƒƒ                                          ƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
```


```
RESRAD-BUILD Input Parameters...........  2
Building Information....................  3
Source Information......................  4
For time = 0.00E+00 yr
   Time Specific Parameters.............  7
   Receptor-Source Dose Summary......... 10
   Dose by Pathway Detail............... 11
   Dose by Nuclide Detail............... 12
For time = 1.00E+00 yr
   Time Specific Parameters............. 15
   Receptor-Source Dose Summary......... 18
   Dose by Pathway Detail............... 19
   Dose by Nuclide Detail............... 20
Full Summary............................ 22
```


```
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒ                                          ƒƒƒ
ƒƒƒ       RESRAD-BUILD Input Parameters      ƒƒƒ
ƒƒƒ                                          ƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
```

```
Number of Sources   :  3
Number of Receptors:   1
Total Time          :  3.650000E+02 days
Fraction Inside     :  2.000000E-01
```

ƒƒƒƒƒƒƒƒƒƒ Receptor Information ƒƒƒƒƒƒƒƒƒ

Receptor	Room	x [m]	y [m]	z [m]	FracTime	Inhalation [m3/day]	Ingestion(Dust) [m2/hr]
1	1	2.250	1.000	1.000	1.000	1.80E+01	1.00E-04

ƒƒƒ Receptor-Source Shielding Relationship ƒƒƒ

Receptor	Source	Density [g/cm3]	Thickness [cm]	Material
1	1	2.40E+00	0.00E+00	Concrete
1	2	2.40E+00	0.00E+00	Concrete
1	3	2.40E+00	0.00E+00	Concrete

ííííííí Building Information ííííííí

Building Air Exchange Rate: 8.00E-01 1/hr

```
 Height[m]           Air Exchanges [m3/hr]
 Area [m2]
                    ******************************
                    *                            *
                    *                            *
                    *                          <=Q01: 7.20E+01
 H1:    2.500       *         Room  1            *       Q10 :  7.20E+01
                    *   LAMBDA: 8.00E-01         *
Area  36.000        *                            *
                    *                            *
                    ******************************
```

Deposition velocity: 1.00E-02 [m/s]   Resuspension Rate: 5.00E-07 [1/s]

ííííííí Source Information ííííííí

```
Source:  1
       Location::  Room :  1  x:   0.75 y:   2.00  z:   0.75[m]
       Geometry::  Type: Volume       Area:2.25E+00 [m2]  Direction: y
       Pathway ::
            Direct Ingestion Rate:     0.000E+00 [gm/hr]
            Fraction released to air: 1.000E-01


     Containment ::   Number of Regions:  1 Contaminated Region:  1
  Region                  :    1
  Thickness [cm]          :1.00E+02
  Density [g/cm3]         :4.00E+00
  Material                :Concrete
  Erosion Rate [cm/day]   :2.40E-08
  Porosity                :1.00E-01
  Eff. Diffusion [m2/s]   :2.00E-05
  Emanation Fractions(1)  :2.00E-01
                     (2)  :2.00E-01
```

Contamination::

Nuclide	Concentration [Bq /g]	Dose Conversion Factor (Library: Ingestion [Sv /Bq]	Inhalation [Sv /Bq]	Submersion [Sv /yr/ (Bq /m3)]
U-238	2.000E+01	7.270E-08	3.189E-05	4.324E-08
U-234	2.000E+01	7.649E-08	3.568E-05	2.414E-10
TH-232	7.500E+01	7.378E-07	4.432E-04	2.757E-10
TH-230	2.000E+01	1.481E-07	8.811E-05	5.514E-10
TH-228	7.500E+01	2.184E-07	9.324E-05	2.543E-06
RA-228	7.500E+01	3.892E-07	1.373E-06	1.511E-06
RA-226	1.000E+01	3.595E-07	2.324E-06	2.811E-06
PB-210	0.000E+00	1.965E-06	6.270E-06	2.838E-09

```
Source:  2
       Location::  Room :  1  x:    2.25 y:    2.00   z:    0.75[m]
       Geometry::  Type: Volume      Area:2.25E+00 [m2]  Direction: y
       Pathway ::
            Direct Ingestion Rate:     0.000E+00 [gm/hr]
            Fraction released to air: 1.000E-01


       Containment ::   Number of Regions:  1 Contaminated Region:  1
   Region                 :    1
   Thickness [cm]         :1.00E+02
   Density [g/cm3]        :4.00E+00
   Material               :Concrete
   Erosion Rate [cm/day] :2.40E-08
   Porosity               :1.00E-01
   Eff. Diffusion [m2/s] :2.00E-05
   Emanation Fractions(1):2.00E-01
                      (2):2.00E-01


  Contamination::
   Nuclide Concentration       Dose Conversion Factor (Library:
```

ÄÄÄÄÄÄÄ	ÄÄÄÄÄÄÄÄÄÄÄÄÄ	ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ		
		Ingestion	Inhalation	Submersion
	[Bq /g]	[Sv /Bq]	[Sv /Bq]	[Sv /yr/ (Bq /m3)]
U-238	2.000E+01	7.270E-08	3.189E-05	4.324E-08
U-234	2.000E+01	7.649E-08	3.568E-05	2.414E-10
TH-232	7.500E+01	7.378E-07	4.432E-04	2.757E-10
TH-230	2.000E+01	1.481E-07	8.811E-05	5.514E-10
TH-228	7.500E+01	2.184E-07	9.324E-05	2.543E-06
RA-228	7.500E+01	3.892E-07	1.373E-06	1.511E-06
RA-226	1.000E+01	3.595E-07	2.324E-06	2.811E-06
PB-210	0.000E+00	1.965E-06	6.270E-06	2.838E-09

```
Source:  3
       Location::  Room :  1  x:    3.75 y:    2.00   z:    0.75[m]
       Geometry::  Type: Volume      Area:2.25E+00 [m2]  Direction: y
       Pathway ::
            Direct Ingestion Rate:     0.000E+00 [gm/hr]
            Fraction released to air: 1.000E-01


       Containment ::   Number of Regions:  1 Contaminated Region:  1
   Region                 :    1
   Thickness [cm]         :1.00E+02
   Density [g/cm3]        :4.00E+00
   Material               :Concrete
   Erosion Rate [cm/day] :2.40E-08
   Porosity               :1.00E-01
   Eff. Diffusion [m2/s] :2.00E-05
   Emanation Fractions(1):2.00E-01
                      (2):2.00E-01


  Contamination::
   Nuclide Concentration       Dose Conversion Factor (Library:
```

ÄÄÄÄÄÄÄ	ÄÄÄÄÄÄÄÄÄÄÄÄÄ	ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ		
		Ingestion	Inhalation	Submersion
	[Bq /g]	[Sv /Bq]	[Sv /Bq]	[Sv /yr/ (Bq /m3)]
U-238	2.000E+01	7.270E-08	3.189E-05	4.324E-08

U-234	2.000E+01	7.649E-08	3.568E-05	2.414E-10
TH-232	7.500E+01	7.378E-07	4.432E-04	2.757E-10
TH-230	2.000E+01	1.481E-07	8.811E-05	5.514E-10
TH-228	7.500E+01	2.184E-07	9.324E-05	2.543E-06
RA-228	7.500E+01	3.892E-07	1.373E-06	1.511E-06
RA-226	1.000E+01	3.595E-07	2.324E-06	2.811E-06
PB-210	0.000E+00	1.965E-06	6.270E-06	2.838E-09

```
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒ       Assessment for Time:  1               ƒƒƒ
ƒƒƒ              Time =0.00E+00 yr              ƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ


ƒƒƒƒƒƒƒƒ  Source Information  ƒƒƒƒƒƒƒƒ

Source:  1
       Location::  Room :  1  x:   0.75 y:   2.00  z:   0.75 [m]
       Geometry::  Type: Volume      Area:2.25E+00 [m2]  Direction: y
       Pathway ::
            Direct Ingestion Rate     : 0.000E+00 [gm/hr]
            Fraction released to air: 1.000E-01

       Containment ::   Number of Regions:  1 Contaminated Region:  1
    Region                 :    1
    Thickness [cm]         :1.00E+02
    Fraction Contaminated  :1.00E+00
    Density [g/cm3]        :4.00E+00

       Contamination::       Nuclide     Concentration
                                           [Bq /g]
                             U-238        2.000E+01
                             U-234        2.000E+01
                             TH-232       7.500E+01
                             TH-230       2.000E+01
                             TH-228       7.500E+01
                             RA-228       7.500E+01
                             RA-226       1.000E+01
                             PB-210       0.000E+00

Source:  2
       Location::  Room :  1  x:   2.25 y:   2.00  z:   0.75 [m]
       Geometry::  Type: Volume      Area:2.25E+00 [m2]  Direction: y
       Pathway ::
            Direct Ingestion Rate     : 0.000E+00 [gm/hr]
            Fraction released to air: 1.000E-01

       Containment ::   Number of Regions:  1 Contaminated Region:  1
    Region                 :    1
    Thickness [cm]         :1.00E+02
    Fraction Contaminated  :1.00E+00
    Density [g/cm3]        :4.00E+00

       Contamination::       Nuclide     Concentration
                                           [Bq /g]
                             U-238        2.000E+01
                             U-234        2.000E+01
                             TH-232       7.500E+01
```

TH-230	2.000E+01
TH-228	7.500E+01
RA-228	7.500E+01
RA-226	1.000E+01
PB-210	0.000E+00

Source: 3

Location:: Room : 1 x: 3.75 y: 2.00 z: 0.75 [m]
Geometry:: Type: Volume Area:2.25E+00 [m2] Direction: y
Pathway ::
Direct Ingestion Rate : 0.000E+00 [gm/hr]
Fraction released to air: 1.000E-01

Containment :: Number of Regions: 1 Contaminated Region: 1

Region	: 1
Thickness [cm]	:1.00E+02
Fraction Contaminated	:1.00E+00
Density [g/cm3]	:4.00E+00

Contamination::

Nuclide	Concentration [Bq /g]
U-238	2.000E+01
U-234	2.000E+01
TH-232	7.500E+01
TH-230	2.000E+01
TH-228	7.500E+01
RA-228	7.500E+01
RA-226	1.000E+01
PB-210	0.000E+00

ƒƒ
ƒƒ
ƒƒƒ ƒƒƒ
ƒƒƒ RESRAD-BUILDDose Tables ƒƒƒ
ƒƒƒ ƒƒƒ
ƒƒ
ƒƒ

Source Contributions to Receptor Doses
ƒƒ
[Sv]

	Source 1	Source 2	Source 3	Total
Receptor 1	2.09E-02	3.04E-02	2.09E-02	7.22E-02
Total	2.09E-02	3.04E-02	2.09E-02	7.22E-02

Pathway Detail of Doses
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
[Sv]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	4.40E-03	5.69E-10	6.62E-12	6.81E-06	1.65E-02	4.47E-08
Total	4.40E-03	5.69E-10	6.62E-12	6.81E-06	1.65E-02	4.47E-08

Source: 2

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	1.39E-02	5.69E-10	6.62E-12	6.81E-06	1.65E-02	4.47E-08
Total	1.39E-02	5.69E-10	6.62E-12	6.81E-06	1.65E-02	4.47E-08

Source: 3

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	4.40E-03	5.69E-10	6.62E-12	6.81E-06	1.65E-02	4.47E-08
Total	4.40E-03	5.69E-10	6.62E-12	6.81E-06	1.65E-02	4.47E-08

Nuclide Detail of Doses
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
[Sv]

Source: 1

Nuclide	Receptor 1	Total
U-238		
U-238	1.01E-05	1.01E-05
U-234	2.00E-13	2.00E-13
TH-230	2.32E-18	2.32E-18
RA-226	8.08E-17	8.08E-17
PB-210	2.20E-20	2.20E-20
U-234		
U-234	1.41E-07	1.41E-07
TH-230	1.62E-12	1.62E-12
RA-226	4.01E-12	4.01E-12
PB-210	3.40E-18	3.40E-18
TH-232		
TH-232	5.59E-06	5.59E-06
TH-228	1.61E-04	1.61E-04
RA-228	8.61E-05	8.61E-05
TH-230		
TH-230	3.60E-07	3.60E-07
RA-226	8.93E-07	8.93E-07
PB-210	1.20E-12	1.20E-12
TH-228		
TH-228	1.47E-02	1.47E-02
RA-228		
TH-228	2.47E-03	2.47E-03
RA-228	1.43E-03	1.43E-03
RA-226		
RA-226	2.06E-03	2.06E-03
PB-210	2.76E-09	2.76E-09

Source: 2

Nuclide	Receptor 1	Total
U-238		
U-238	3.22E-05	3.22E-05
U-234	2.80E-13	2.80E-13
TH-230	3.38E-18	3.38E-18
RA-226	1.13E-16	1.13E-16
PB-210	7.05E-20	7.05E-20
U-234		
U-234	1.98E-07	1.98E-07
TH-230	2.36E-12	2.36E-12
RA-226	5.60E-12	5.60E-12
PB-210	1.09E-17	1.09E-17
TH-232		
TH-232	5.86E-06	5.86E-06
TH-228	2.11E-04	2.11E-04
RA-228	2.75E-04	2.75E-04
TH-230		
TH-230	5.26E-07	5.26E-07
RA-226	1.25E-06	1.25E-06
PB-210	3.85E-12	3.85E-12

TH-228		
TH-228	1.92E-02	1.92E-02
RA-228		
TH-228	3.23E-03	3.23E-03
RA-228	4.57E-03	4.57E-03
RA-226		
RA-226	2.88E-03	2.88E-03
PB-210	8.84E-09	8.84E-09

Source: 3

Nuclide	Receptor 1	Total
U-238		
U-238	1.01E-05	1.01E-05
U-234	2.00E-13	2.00E-13
TH-230	2.32E-18	2.32E-18
RA-226	8.08E-17	8.08E-17
PB-210	2.20E-20	2.20E-20
U-234		
U-234	1.41E-07	1.41E-07
TH-230	1.62E-12	1.62E-12
RA-226	4.01E-12	4.01E-12
PB-210	3.40E-18	3.40E-18
TH-232		
TH-232	5.59E-06	5.59E-06
TH-228	1.61E-04	1.61E-04
RA-228	8.61E-05	8.61E-05
TH-230		
TH-230	3.60E-07	3.60E-07
RA-226	8.93E-07	8.93E-07
PB-210	1.20E-12	1.20E-12
TH-228		
TH-228	1.47E-02	1.47E-02
RA-228		
TH-228	2.47E-03	2.47E-03
RA-228	1.43E-03	1.43E-03
RA-226		
RA-226	2.06E-03	2.06E-03
PB-210	2.76E-09	2.76E-09

```
ííííííííííííííííííííííííííííííííííííííííííííííííí
ííííííííííííííííííííííííííííííííííííííííííííííííí
ííí                                            ííí
ííí     RESRAD-BUILD Dose (Time) Tables        ííí
ííí                                            ííí
ííííííííííííííííííííííííííííííííííííííííííííííííí
ííííííííííííííííííííííííííííííííííííííííííííííííí
```

Receptor Dose Received for the Exposure Duration
ííí
(Sv)

	Evaluation Time [yr]	
	0.00E+00	1.00E+00
	ÄÄÄÄÄÄÄÄ	ÄÄÄÄÄÄÄÄ
1	7.22E-02	7.22E-02

Receptor Dose/Yr Averaged Over Exposure Duration
ííí
(Sv/yr)

	Evaluation Time [yr]	
	0.00E+00	1.00E+00
	ÄÄÄÄÄÄÄÄ	ÄÄÄÄÄÄÄÄ
1	7.23E-02	7.23E-02

Lisa 4

```
** RESRAD-BUILD Program Output, Version 3.21 08/14/03 10:35:53  Page:    1 **
 Title : Pakendamine, 2 hor+2 vert, 2 lahti, 2 re
 Input File : C:\Program Files\RESRAD_Family\BUILD\Too2_2h_2v.bld
```

```
ffffffffffffffffffffffffffffffffffffffffffffffff
ffffffffffffffffffffffffffffffffffffffffffffffff
fff                                          fff
fff       RESRAD-BUILD Table of Contents     fff
fff                                          fff
ffffffffffffffffffffffffffffffffffffffffffffffff
ffffffffffffffffffffffffffffffffffffffffffffffff
```


```
RESRAD-BUILD Input Parameters...........    2
Building Information....................    3
Source Information......................    4
For time = 0.00E+00 yr
   Time Specific Parameters.............    8
   Receptor-Source Dose Summary.........   12
   Dose by Pathway Detail...............   13
   Dose by Nuclide Detail...............   14
     Full Summary...........................   25
```


```
ffffffffffffffffffffffffffffffffffffffffffffffff
ffffffffffffffffffffffffffffffffffffffffffffffff
fff                                          fff
fff       RESRAD-BUILD Input Parameters      fff
fff                                          fff
ffffffffffffffffffffffffffffffffffffffffffffffff
ffffffffffffffffffffffffffffffffffffffffffffffff
```

```
Number of Sources   :  4
Number of Receptors:   2
Total Time          :  3.650000E+02 days
Fraction Inside     :  2.000000E-01
```

ffffffffff Receptor Information ffffffffff

Receptor	Room	x [m]	y [m]	z [m]	FracTime	Inhalation [m3/day]	Ingestion(Dust) [m2/hr]
1	1	1.000	1.000	1.000	1.000	2.20E+01	1.00E-03
2	1	0.000	0.000	1.000	1.000	2.20E+01	1.00E-03

fff Receptor-Source Shielding Relationship fff

Receptor	Source	Density [g/cm3]	Thickness [cm]	Material
1	1	7.80E+00	2.00E-01	Fe
2	1	7.80E+00	2.00E-01	Fe
1	2	7.80E+00	2.00E-01	Fe
2	2	7.80E+00	2.00E-01	Fe
1	3	7.80E+00	2.00E-01	Fe
2	3	7.80E+00	2.00E-01	Fe
1	4	7.80E+00	2.00E-01	Fe
2	4	7.80E+00	2.00E-01	Fe

ffffffff Building Information ffffffff

Building Air Exchange Rate: 3.00E+00 1/hr

```
Height[m]          Air Exchanges [m3/hr]
Area [m2]
                ******************************
                *                            *
                *                            *
                *                            <=Q01: 1.08E+03
H1:  10.000     *          Room  1           *      Q10 :  1.08E+03
```

```
Area  36.000         *   LAMBDA: 3.00E+00           *
                     *                              *
                     *                              *
                     ********************************

    Deposition velocity: 3.00E-03 [m/s]   Resuspension Rate: 5.00E-06 [1/s]

           ffffffff  Source Information  ffffffff

 Source:  1
        Location::  Room :  1  x:    1.00 y:    1.75  z:    0.35[m]
        Geometry::  Type: Volume        Area:6.70E-01 [m2]  Direction: y
        Pathway ::
             Direct Ingestion Rate:     1.000E-02 [gm/hr]
             Fraction released to air: 2.000E-01


        Containment ::    Number of Regions:  1 Contaminated Region:  1
    Region                 :    1
    Thickness [cm]         :6.30E+01
    Density [g/cm3]        :1.00E+00
    Material               :Concrete
    Erosion Rate [cm/day]  :5.00E-04
    Porosity               :3.00E-01
    Eff. Diffusion [m2/s]  :4.00E-05
    Emanation Fractions(1) :2.50E-01
                       (2) :2.50E-01

   Contamination::
    Nuclide Concentration        Dose Conversion Factor (Library:
-----------------------------------------------------------------------------
   ÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
                            Ingestion    Inhalation   Submersion
                [Bq /g]     [Sv  /Bq]    [Sv  /Bq]    [Sv  /yr/
                                                       (Bq /m3)]
    U-238      2.500E+01    7.270E-08    3.189E-05    4.324E-08
    U-234      2.500E+01    7.649E-08    3.568E-05    2.414E-10
    TH-232     1.000E+02    7.378E-07    4.432E-04    2.757E-10
    TH-230     2.500E+01    1.481E-07    8.811E-05    5.514E-10
    TH-228     1.000E+02    2.184E-07    9.324E-05    2.543E-06
    RA-228     1.000E+02    3.892E-07    1.373E-06    1.511E-06
    RA-226     2.500E+01    3.595E-07    2.324E-06    2.811E-06
    PB-210     0.000E+00    1.965E-06    6.270E-06    2.838E-09
 Source:  2
        Location::  Room :  1  x:    1.75 y:    1.00  z:    0.35[m]
        Geometry::  Type: Volume        Area:6.70E-01 [m2]  Direction: x
        Pathway ::
             Direct Ingestion Rate:     1.000E-02 [gm/hr]
             Fraction released to air: 2.000E-01

        Containment ::    Number of Regions:  1 Contaminated Region:  1
    Region                 :    1
    Thickness [cm]         :6.30E+01
    Density [g/cm3]        :1.00E+00
    Material               :Concrete
    Erosion Rate [cm/day]  :5.00E-04
    Porosity               :3.00E-01
    Eff. Diffusion [m2/s]  :4.00E-05
    Emanation Fractions(1) :2.50E-01
                       (2) :2.50E-01

   Contamination::
    Nuclide Concentration        Dose Conversion Factor (Library:
-----------------------------------------------------------------------------
   ÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
                            Ingestion    Inhalation   Submersion
                [Bq /g]     [Sv  /Bq]    [Sv  /Bq]    [Sv  /yr/
                                                       (Bq /m3)]
    U-238      2.500E+01    7.270E-08    3.189E-05    4.324E-08
    U-234      2.500E+01    7.649E-08    3.568E-05    2.414E-10
    TH-232     1.000E+02    7.378E-07    4.432E-04    2.757E-10
    TH-230     2.500E+01    1.481E-07    8.811E-05    5.514E-10
    TH-228     1.000E+02    2.184E-07    9.324E-05    2.543E-06
    RA-228     1.000E+02    3.892E-07    1.373E-06    1.511E-06
    RA-226     2.500E+01    3.595E-07    2.324E-06    2.811E-06
    PB-210     0.000E+00    1.965E-06    6.270E-06    2.838E-09
```

```
Source:  3
        Location::  Room :  1  x:    1.75 y:    0.30  z:    0.35[m]
        Geometry::  Type: Volume       Area:6.70E-01 [m2]  Direction: x
        Pathway ::
             Direct Ingestion Rate:     1.000E-04 [gm/hr]
             Fraction released to air: 2.000E-02

        Containment ::   Number of Regions:  1 Contaminated Region:  1
    Region                   :    1
    Thickness [cm]           :6.30E+01
    Density [g/cm3]          :1.00E+00
    Material                 :Concrete
    Erosion Rate [cm/day]    :2.40E-09
    Porosity                 :1.00E-02
    Eff. Diffusion [m2/s]    :2.00E-05
    Emanation Fractions(1)   :2.00E-03
                       (2)   :2.00E-03

  Contamination::
   Nuclide Concentration        Dose Conversion Factor (Library:
  ÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
                         Ingestion     Inhalation    Submersion
            [Bq /g]     [Sv  /Bq]     [Sv  /Bq]     [Sv  /yr/
                                                     (Bq /m3)]
   U-238     2.500E+01  7.270E-08   3.189E-05   4.324E-08
   U-234     2.500E+01  7.649E-08   3.568E-05   2.414E-10
   TH-232    1.000E+02  7.378E-07   4.432E-04   2.757E-10
   TH-230    2.500E+01  1.481E-07   8.811E-05   5.514E-10
   TH-228    1.000E+02  2.184E-07   9.324E-05   2.543E-06
   RA-228    1.000E+02  3.892E-07   1.373E-06   1.511E-06
   RA-226    2.500E+01  3.595E-07   2.324E-06   2.811E-06
   PB-210    0.000E+00  1.965E-06   6.270E-06   2.838E-09
Source:  4
        Location::  Room :  1  x:    1.00 y:    1.75  z:    1.10[m]
        Geometry::  Type: Volume       Area:6.70E-01 [m2]  Direction: y
        Pathway ::
             Direct Ingestion Rate:     1.000E-04 [gm/hr]
             Fraction released to air: 2.000E-02

        Containment ::   Number of Regions:  1 Contaminated Region:  1
    Region                   :    1
    Thickness [cm]           :6.30E+01
    Density [g/cm3]          :1.00E+00
    Material                 :Concrete
    Erosion Rate [cm/day]    :2.40E-09
    Porosity                 :2.00E-02
    Eff. Diffusion [m2/s]    :2.00E-05
    Emanation Fractions(1)   :2.00E-03
                       (2)   :2.00E-03

  Contamination::
   Nuclide Concentration        Dose Conversion Factor (Library:
  ÄÄÄÄÄÄÄ ÄÄÄÄÄÄÄÄÄÄÄÄÄ  ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
                         Ingestion     Inhalation    Submersion
            [Bq /g]     [Sv  /Bq]     [Sv  /Bq]     [Sv  /yr/
                                                     (Bq /m3)]
   U-238     2.500E+01  7.270E-08   3.189E-05   4.324E-08
   U-234     2.500E+01  7.649E-08   3.568E-05   2.414E-10
   TH-232    1.000E+02  7.378E-07   4.432E-04   2.757E-10
   TH-230    2.500E+01  1.481E-07   8.811E-05   5.514E-10
   TH-228    1.000E+02  2.184E-07   9.324E-05   2.543E-06
   RA-228    1.000E+02  3.892E-07   1.373E-06   1.511E-06
   RA-226    2.500E+01  3.595E-07   2.324E-06   2.811E-06
   PB-210    0.000E+00  1.965E-06   6.270E-06   2.838E-09
          ffffffffffffffffffffffffffffffffffffffffffffffff
          ffffffffffffffffffffffffffffffffffffffffffffffff
          fff        Assessment for Time:  1             fff
          fff              Time =0.00E+00 yr             fff
          ffffffffffffffffffffffffffffffffffffffffffffffff
          ffffffffffffffffffffffffffffffffffffffffffffffff

          ffffffff  Source Information  ffffffff
```

```
Source:  1
        Location::  Room :  1  x:    1.00 y:   1.75   z:    0.35 [m]
        Geometry::  Type: Volume       Area:6.70E-01 [m2]  Direction: y
        Pathway ::
             Direct Ingestion Rate    : 1.000E-02 [gm/hr]
             Fraction released to air: 2.000E-01


        Containment ::   Number of Regions:  1 Contaminated Region:  1
    Region                  :    1
    Thickness [cm]          :6.30E+01
    Fraction Contaminated :1.00E+00
    Density [g/cm3]         :1.00E+00


        Contamination::          Nuclide     Concentration
                                              [Bq /g]
                                 U-238        2.500E+01
                                 U-234        2.500E+01
                                 TH-232       1.000E+02
                                 TH-230       2.500E+01
                                 TH-228       1.000E+02
                                 RA-228       1.000E+02
                                 RA-226       2.500E+01
                                 PB-210       0.000E+00

Source:  2
        Location::  Room :  1  x:    1.75 y:   1.00   z:    0.35 [m]
        Geometry::  Type: Volume       Area:6.70E-01 [m2]  Direction: x
        Pathway ::
             Direct Ingestion Rate    : 1.000E-02 [gm/hr]
             Fraction released to air: 2.000E-01


        Containment ::   Number of Regions:  1 Contaminated Region:  1
    Region                  :    1
    Thickness [cm]          :6.30E+01
    Fraction Contaminated :1.00E+00
    Density [g/cm3]         :1.00E+00


        Contamination::          Nuclide     Concentration
                                              [Bq /g]
                                 U-238        2.500E+01
                                 U-234        2.500E+01
                                 TH-232       1.000E+02
                                 TH-230       2.500E+01
                                 TH-228       1.000E+02
                                 RA-228       1.000E+02
                                 RA-226       2.500E+01
                                 PB-210       0.000E+00

Source:  3
        Location::  Room :  1  x:    1.75 y:   0.30   z:    0.35 [m]
        Geometry::  Type: Volume       Area:6.70E-01 [m2]  Direction: x
        Pathway ::
             Direct Ingestion Rate    : 1.000E-04 [gm/hr]
             Fraction released to air: 2.000E-02


        Containment ::   Number of Regions:  1 Contaminated Region:  1
    Region                  :    1
    Thickness [cm]          :6.30E+01
    Fraction Contaminated :1.00E+00
    Density [g/cm3]         :1.00E+00


        Contamination::          Nuclide     Concentration
                                              [Bq /g]
                                 U-238        2.500E+01
                                 U-234        2.500E+01
                                 TH-232       1.000E+02
                                 TH-230       2.500E+01
                                 TH-228       1.000E+02
                                 RA-228       1.000E+02
                                 RA-226       2.500E+01
```

PB-210 0.000E+00

Source: 4

Location:: Room : 1 x: 1.00 y: 1.75 z: 1.10 [m]
Geometry:: Type: Volume Area:6.70E-01 [m2] Direction: y
Pathway ::
Direct Ingestion Rate : 1.000E-04 [gm/hr]
Fraction released to air: 2.000E-02

Containment :: Number of Regions: 1 Contaminated Region: 1
Region : 1
Thickness [cm] :6.30E+01
Fraction Contaminated :1.00E+00
Density [g/cm3] :1.00E+00

Contamination::

Nuclide	Concentration [Bq /g]
U-238	2.500E+01
U-234	2.500E+01
TH-232	1.000E+02
TH-230	2.500E+01
TH-228	1.000E+02
RA-228	1.000E+02
RA-226	2.500E+01
PB-210	0.000E+00

ƒƒ

RESRAD-BUILDDose Tables

ƒƒ

Source Contributions to Receptor Doses

ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ

[Sv]

	Source 1	Source 2	Source 3	Source 4	Total
Receptor 1	1.36E-02	1.36E-02	4.28E-03	9.59E-03	4.10E-02
Receptor 2	8.86E-03	8.86E-03	2.13E-03	1.86E-03	2.17E-02
Total	2.24E-02	2.24E-02	6.41E-03	1.14E-02	6.27E-02

Pathway Detail of Doses

ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ

[Sv]

Source: 1

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	6.34E-03	6.41E-09	2.47E-09	2.40E-03	2.18E-03	2.65E-03
2	1.63E-03	6.41E-09	2.47E-09	2.40E-03	2.18E-03	2.65E-03
Total	7.97E-03	1.28E-08	4.93E-09	4.79E-03	4.37E-03	5.30E-03

Source: 2

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	6.34E-03	6.41E-09	2.47E-09	2.40E-03	2.18E-03	2.65E-03
2	1.63E-03	6.41E-09	2.47E-09	2.40E-03	2.18E-03	2.65E-03
Total	7.97E-03	1.28E-08	4.93E-09	4.79E-03	4.37E-03	5.30E-03

Source: 3

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion
1	4.24E-03	3.07E-15	1.18E-15	1.15E-09	1.25E-05	2.64E-05
2	2.09E-03	3.07E-15	1.18E-15	1.15E-09	1.25E-05	2.64E-05
Total	6.33E-03	6.15E-15	2.37E-15	2.30E-09	2.49E-05	5.29E-05

Source: 4

Receptor	External	Deposition	Immersion	Inhalation	Radon	Ingestion

1	9.55E-03	3.07E-15	1.18E-15	1.15E-09	1.25E-05	2.64E-05
2	1.82E-03	3.07E-15	1.18E-15	1.15E-09	1.25E-05	2.64E-05
Total	1.14E-02	6.15E-15	2.37E-15	2.30E-09	2.49E-05	5.29E-05

Nuclide Detail of Doses
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
[Sv]

Source: 1

Nuclide	Receptor 1	Receptor 2	Total
U-238			
U-238	7.66E-05	6.80E-05	1.45E-04
U-234			
U-234	7.06E-05	7.06E-05	1.41E-04
TH-232			
TH-232	3.13E-03	3.13E-03	6.27E-03
TH-230			
TH-230	1.56E-04	1.56E-04	3.13E-04
TH-228			
TH-228	6.23E-03	3.77E-03	1.00E-02
RA-228			
RA-228	2.75E-03	1.22E-03	3.97E-03
RA-226			
RA-226	1.15E-03	4.46E-04	1.60E-03

Source: 2

Nuclide	Receptor 1	Receptor 2	Total
U-238			
U-238	7.66E-05	6.80E-05	1.45E-04
U-234			
U-234	7.06E-05	7.06E-05	1.41E-04
TH-232			
TH-232	3.13E-03	3.13E-03	6.27E-03
TH-230			
TH-230	1.56E-04	1.56E-04	3.13E-04
TH-228			
TH-228	6.23E-03	3.77E-03	1.00E-02
RA-228			
RA-228	2.75E-03	1.22E-03	3.97E-03
RA-226			
RA-226	1.15E-03	4.46E-04	1.60E-03

Source: 3

Nuclide	Receptor 1	Receptor 2	Total
U-238			
U-238	7.81E-06	4.20E-06	1.20E-05
U-234			
U-234	3.40E-07	3.39E-07	6.79E-07
TH-232			
TH-232	1.30E-05	1.30E-05	2.59E-05
TH-230			
TH-230	6.78E-07	6.69E-07	1.35E-06
TH-228			
TH-228	2.25E-03	1.11E-03	3.36E-03
RA-228			
RA-228	1.37E-03	6.89E-04	2.06E-03
RA-226			
RA-226	6.34E-04	3.16E-04	9.50E-04

Source: 4

Nuclide	Receptor 1	Receptor 2	Total
U-238			
U-238	1.85E-05	3.66E-06	2.21E-05
U-234			
U-234	3.56E-07	3.38E-07	6.95E-07

TH-232			
TH-232	1.31E-05	1.29E-05	2.60E-05
TH-230			
TH-230	7.53E-07	6.65E-07	1.42E-06
TH-228			
TH-228	4.98E-03	9.69E-04	5.94E-03
RA-228			
RA-228	3.14E-03	5.98E-04	3.74E-03
RA-226			
RA-226	1.44E-03	2.74E-04	1.71E-03

ffffffffffffffffffffffffffffffffffffffffffffffffffffff

RESRAD-BUILD Dose (Time) Tables

ffffffffffffffffffffffffffffffffffffffffffffffffffffff

Receptor Dose Received for the Exposure Duration

(Sv)

Evaluation Time [yr]

	0.00E+00	1.00E+00
1	4.10E-02	4.10E-02
2	2.17E-02	2.18E-02

Receptor Dose/Yr Averaged Over Exposure Duration

(Sv/yr)

Evaluation Time [yr]

	0.00E+00	1.00E+00
1	4.10E-02	4.11E-02
2	2.17E-02	2.18E-02