Dose scenario in Zircon industry

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- Zircon and Zirconia
- Use in Ceramic Tiles and Refractory's
- Scenarios in these industries
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Zircon

- Zircon (zirconium silicate) occurs in nature as part of a heavy mineral sands
- Has a wide range of industrial applications
- Consumption over a million tonnes / year.
- Feedstock for the manufacture of zirconia (zirconium dioxide), zirconium chemicals and zirconium metal
- Micronized zircon is a common opacifying constituent of glazes

Properties of Zircon

- Premium grade zircon sand: 66% ZrO_2, 32% SiO_2, 0.5% Al_2O_3, 0.1% TiO_2 and 0.05% Fe_2O_3.
- Density range: 4200–4800 kg/m3
- melting point: > 2000ºC
- Refractive index: 1.80–1.98 (very high)
- Hardness: 7–7.5 Mohs
- Particles:110-130 µm

Radiological Properties of Zircon

- The geological processes that formed zircon led to the incorporation of radionuclides uranium and thorium into the crystal structure.
- Activity concentrations of the U-238 decay series (2-4 Bq/g) and of Th-232 decay series (0.4-1 Bq/g)
- Within definition of NORM (only minor deviations from decay chain equilibrium)

Properties of Zirconia

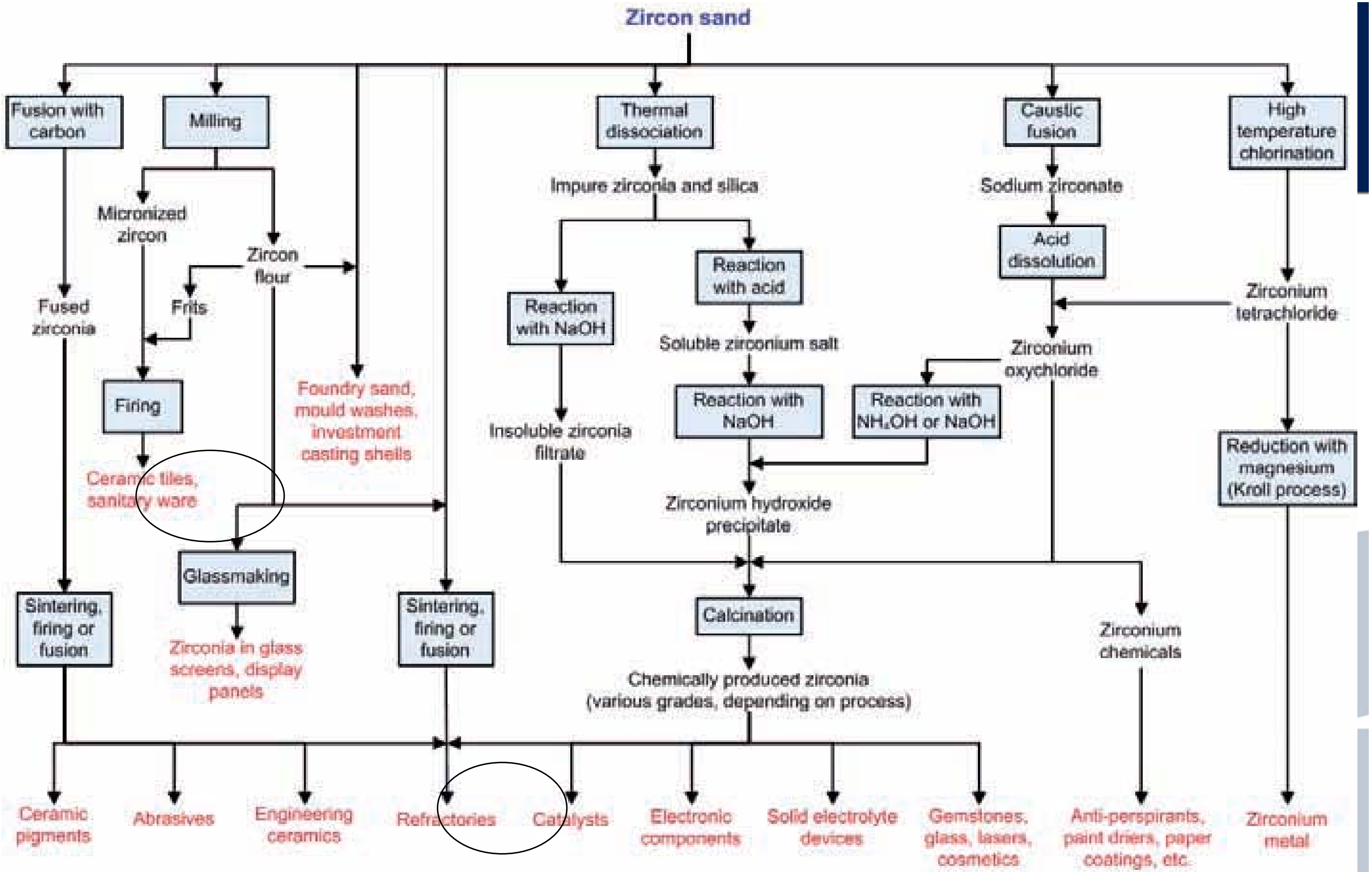
- The geological processes that formed Baddelyite, the only significant natural form of zirconia is currently produced only in the Kovdor region of Russia
- Special grade for refractories: 99% ZrO_2, 0.05% SiO_2, 0.15% TiO_2, 0.01% Fe_2O_3 and 0.02% SO_3

Properties of Zirconia

- $2ZrSiO_4 + 3Al_2O_3 \rightarrow 2ZrO_2 + 3\,Al_2O_3 \cdot 2SiO_2$
- Zirconia exhibits three well defined crystal structures: the monoclinic, tetragonal and cubic phases
- Melting points: 1200, 2300 and 2680 ºC

Radiological Properties of Zirconia

- Activity concentrations of the U-238 decay series (2 – 5 Bq/g) and of Th-232 decay series (0.1- 1 Bq/g)
- for Baddeleyite there is greater disruption of decay chain equilibrium.
- Radon emanation coefficient will be very low because 238U is bound within the crystal lattic
- AMAD of 5 µm >Lung absorption class “S”


Zircon sand
Fusion with carbon
Milling
Thermal dissociation
Caustic fusion
High temperature chlorination
Micronized zircon
Zircon flour
Frits
Fused zirconia
Firing
Ceramic tiles, sanitary ware
Foundry sand, mould washes, investment casting shells
Glassmaking
Zirconia in glass screens, display panels
Sintering, firing or fusion
Sintering, firing or fusion
Impure zirconia and silica
Reaction with NaOH
Reaction with acid
Insoluble zirconia filtrate
Soluble zirconium salt
Reaction with NaOH
Reaction with NH_4OH or NaOH
Zirconium hydroxide precipitate
Calcination
Chemically produced zirconia (various grades, depending on process)
Sodium zirconate
Acid dissolution
Zirconium oxychloride
Zirconium tetrachloride
Reduction with magnesium (Kroll process)
Zirconium chemicals
Ceramic pigments
Abrasives
Engineering ceramics
Refractories
Catalysts
Electronic components
Solid electrolyte devices
Gemstones, glass, lasers, cosmetics
Anti-perspirants, paint driers, paper coatings, etc.
Zirconium metal

Tile industry (video)

Activity concentrations of raw materials (Tiles)

Site	Material	Mass [ton]	U238 [Bq/g]	Th232 [Bq/g]	SUM ACTIVITY
Wall tiles	Zircon Superfine	25	3.9	0.7	4.6
	K4200	2	4.1	0.5	4.6
	CK 10038	2	2.4	0.6	3.0
Floor tiles	Zetazircon	21	3.5	0.6	4.1
	Zircon silicate	4	3.2	0.7	3.9
	Ferro	1	2.4	0.6	3.0
	Yellow	6	2.4	0.6	3.0

Total activity used in the radiological model

nuclide chain	Floor tile plant	Wall tile plant
U 238 sec	300 MBq	300 MBq
Th 232 sec	150 MBq	150 MBq
sum	**450 MBq**	**450 MBq**

Scenarios in Tile Industry

- exposure of workers working in the plants and
- exposure of the general public outside the sites.

scenario “W1”
Operator

- The operator works 4 hours per day in storage area of which 1 hour in handling NORM in big bags
- The operator works another 3 hours per day in general storage area

scenario “W2”
general worker

- The general worker is working for 0.5 hour per day in general storage,
- the general worker is working 4 hours in a shielded area next to storage and
- the rest of the day is spend at the office

General public (P1)

- The most restrictive scenario for the general public is at the East fence of the site. The distance to the storage sites of the NORM materials are:
- 10 m (North) to 50 Mg of Zircon sand,
- 20 m (East) to 50 Mg of Zircon sand,
- 20 m of railway to 50 Mg of Zircon sand

DOSE CALCULATION

The dose rates calculated for the different dose points are shown in Table →

The dose points for external exposure have been calculated with the program MicroShield.

For work in the storage or near a big bag the anterior/posterior orientation is assumed.

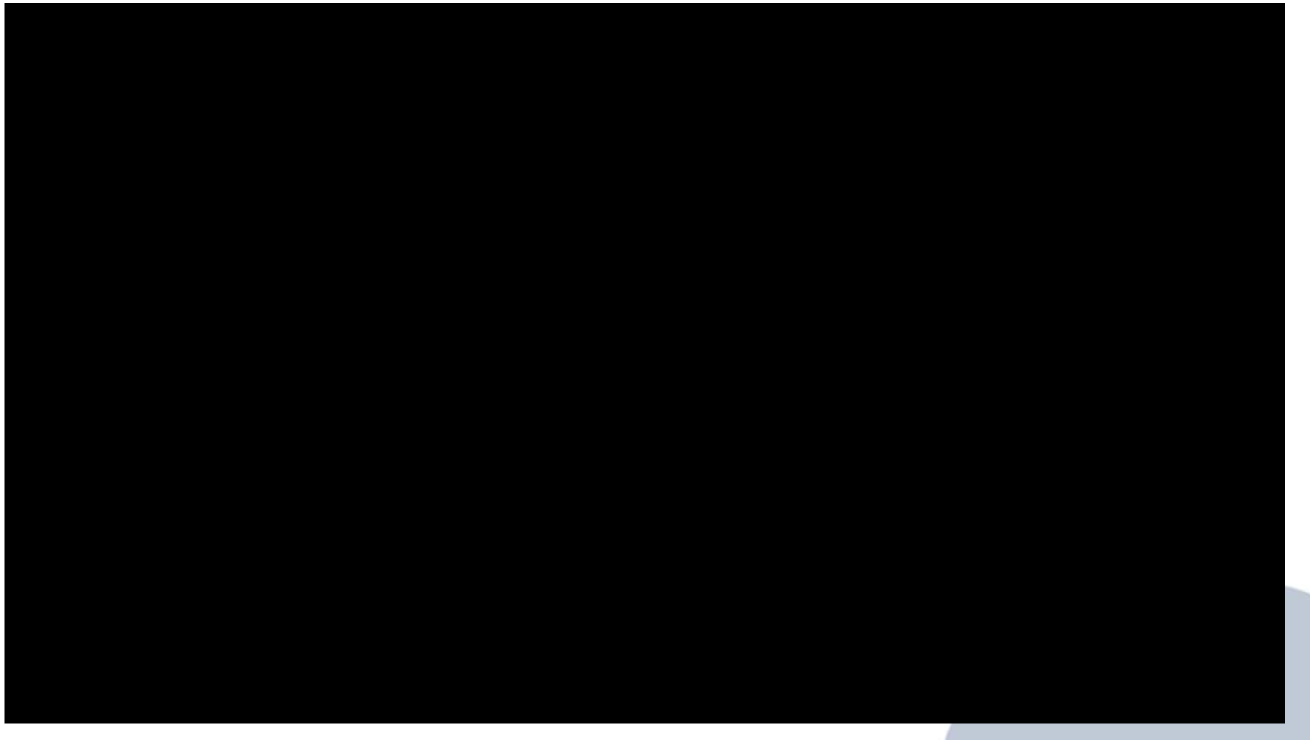
For work on the floor below the storage the orientation is isotropic

For all other dose points the exposure is equally distributed from all sides (rotational,rot).

Doses calculated caused by Tile industry

exposed group	dose point	dose rate [µSv/h]	exposure time [h/a]	dose [µSv/a]	dose [µSv/a]
W1 Operator Floor and Wall Tile plant	11	0.426	220	94	**552**
	1	1.426	55	78	
	7	1.140	55	63	
	2	0.290	220	64	
	9	0.078	440	34	
	6	0.058	880	51	
	inhalation	2.507	55	138	
W2 Generalworker in Floor/Wall Tile plant	2	0.290	55	16	**71**
	9	0.078	55	4	
	6	0.058	880	51	
General public dose point 3	Ind. dose	0.08	8760	700	**190**
	Multi Ind. dose	0.08	2380	190	
	Act. Ind. dose	0.08	88	7	

Refractory Industry (video)



Activity concentrations of raw materials

material	max. mass in Mg at site	U-238max [1)] in Bq/g	Th-232max [2)] in Bq/g	SF [3)]
Portalum	100	0,06	0,24	0,3
Zirconia	50	2,82	0,74	3,56
Microsilica	100	2,80	0,37	3,17
bauxite	200	0,43	0,42	0,85

1) maximum of the nuclides of the U-238 decay chain
2) maximum of the nuclides of the Th-232 decay chain
3) summation formula according to *Bijlage 3* of the *Besluit stralingsbescherming*

Activity concentrations of Portalum and Bauxite used in the radiological model

Radionuclides of the U-238 decay chain	Activity concentration in [Bq/g]	Radionuclides of the U-235 decay chain	Activity concentration in [Bq/g]	Radionuclides of the Th-232 decay chain	Activity concentration in [Bq/g]
U-238	0,5	U-235	0,02	Th-232	0,5
Th-234	0,5	Th-231	0,02	Ra-228	0,5
Pa-234m	0,5	Pa-231	0,02	Ac-228	0,5
U-234	0,5	Ac-227	0,02	Th-228	0,5
Th-230	0,5	Th-227	0,02	Ra-224	0,5
Ra-226	0,5	Ra-223	0,02	Rn-220	0,5
Rn-222	0,5	Rn-219	0,02	Po-216	0,5
Po-218	0,5	Po-215	0,02	Pb-212	0,5
Pb-214	0,5	Pb-211	0,02	Bi-212	0,5
Bi-214	0,5	Bi-211	0,02	Po-212	0,3
Po-214	0,5	Tl-207	0,02	Tl-208	0,2
Pb-210	0,5				
Bi-210	0,5				
Po-210	0,5				

Activity concentrations of Zirconia and Microsilica used in the radiological model

Radionuclides of the U 238 decay chain	Activity concentration in [Bq/g]	Radionuclides of the U 235 decay chain	Activity concentration in [Bq/g]	Radionuclides of the Th 232 decay chain	Activity concentration in [Bq/g]
U 238	3,0	U 235	0,14	Th 232	1,0
Th 234	3,0	Th 231	0,14	Ra 228	1,0
Pa 234m	3,0	Pa 231	0,14	Ac 228	1,0
U 234	3,0	Ac 227	0,14	Th 228	1,0
Th 230	3,0	Th 227	0,14	Ra 224	1,0
Ra 226	3,0	Ra 223	0,14	Rn 220	1,0
Rn 222	3,0	Rn 219	0,14	Po 216	1,0
Po 218	3,0	Po 215	0,14	Pb 212	1,0
Pb 214	3,0	Pb 211	0,14	Bi 212	1,0
Bi 214	3,0	Bi 211	0,14	Po 212	0,6
Po 214	3,0	Tl 207	0,14	Tl 208	0,4
Pb 210	3,0				
Bi 210	3,0				
Po 210	3,0				

Total activity used in the radiological model

nuclide chain	site
U 238 sec	600 MBq
Th 232 sec	300 MBq
sum	900 MBq

Scenarios in Refractory Industry

- exposure of workers working in the plants and
- exposure of the general public outside the sites.

scenario “W1” Worker “transport”

- The unloading of a truck (24 Mg, distance 1 m,) takes 20 minutes for Portalum, Zirconia and Microsilica and 5 minutes for bauxite. For these materials 4, 1, 5 and 21 deliveries respectively take place per year. Thus the worker is exposed for 1,3 h, 0,3 h, 1,7 h and 1,8 h per year respectively.

storage

continued…
Worker "transport"

- The storage holds 100 Mg Portalum, 50 Mg Zirconia, 100 Mg Microsilica and 200 Mg bauxite. The worker enters the storage 2.000 times per year. Each time is exposed by each of the 4 materials for 1 minute in a distance of 5 m
- In this scenario no inhalation is considered.

scenario “W2”
Worker “mixing”
(total work is distributed over eight persons)

- The workers transport Portalum, Zirconia and Microsilica (1 Mg per transport) from the storage to the mixing site.
- The workers are exposed by the interim storage of Portalum, Zirconia and Microsilica (1 Mg per material)
- The workers transport small quantities (0,2 Mg) of the 3 materials at the mixing site

mixing

Continued…
Worker "mixing"

- The workers transport bauxite (1,2 Mg per transport) from the milling site to the mixing site
- Inhalation is assumed for a time of 14 hours per year (Portalum), 2,7 hours per year (Zirconia), 18,9 hours per year (Microsilica) and 0,9 hours per year (Bauxite) respectively

scenario ”W3”
Worker “milling”

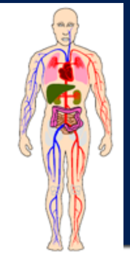
- The total work is distributed over five persons. Of the NORM material, for this scenario only Bauxite is relevant.
- Inhalation is assumed for a time of 36,9 hours per year. A dust concentration of the air of 1 mg/m^3 is assumed. The assumed volumetric respiratory flow is 1,2 m^3/h.

milling

Continued…
Worker “milling”

- The workers transport bauxite (1,5 Mg per transport) from the storage to milling site
- The workers supervise the milling of the Bauxite (1,5 Mg per batch)
- The workers supervise the sieving of the Bauxite (1,5 Mg per batch)
- The workers transport bauxite (1,5 Mg per transport) from the milling site to storage

Doses calculated for the worker scenarios of the radiological model



exposed group	material	dose point	dose rate [µSv/h]	exposure time [h/a]	dose [µSv/a]	dose [µSv/a]
W1	Portalum	DP B1	0,16	1,3	0,21	11
		DP B8	0,03	33,3	1,06	
	Zirconia	DP Z1	0,56	0,3	0,19	
		DP Z5	0,09	33,3	3,07	
	Microsilica	DP Z1	0,56	1,7	0,94	
		DP Z8	0,12	33,3	3,85	
	Bauxite	DP B1	0,16	1,8	1,27	
		DP B12	0,05	33,3	1,51	
W2	Portalum	DP B17	0,04	0,5	0,02	29
		DP B17	0,04	10,0	0,41	
		DP B18	0,05	3,9	0,19	
		inh B	0,24	14,4	3,52	
	Zirconia	DP Z17	0,15	0,1	0,01	
		DP Z17	0,15	2,0	0,30	
		DP Z18	0,17	0,6	0,10	
		inh Z	0,98	2,7	2,62	
	Microsilica	DP Z17	0,15	0,7	0,10	
		DP Z17	0,15	13,0	1,95	
		DP Z18	0,17	5,3	0,91	
		inh Z	0,98	18,9	18,46	
	Bauxite	DP B20	0,01	0,9	0,01	
		inh B	0,24	0,9	0,22	
W3	Bbauxite	DP B21	0,05	3,4	0,17	3
		DP B23	0,001	11,2	0,01	
		DP B23	0,001	11,2	0,01	
		DP B23	0,001	11,2	0,01	
		inh M	0,08	36,9	3,00	

General public

- The most restrictive scenario for the general public is a worker at the north-east border of the site. The distance to the storage sites of the NORM materials are:
- 50 m to 100 Mg of Portalum,
- 25 m to 50 Mg of Zirconia,
- 25 m to 100 Mg of Microsilica and
- 10 m to 200 Mg of Bauxite.

DOSE CALCULATION

The dose rates calculated for the different dose points are shown in Table →

The dose points for external exposure have been calculated with the program MicroShield. For all dose points it has been assumed that the exposure is equally distributed from all sides (rotational, rot).

Doses calculated for the general public scenarios of the radiological model

exposed group		material	dose point	dose rate in µSv/h	ABC factor	dose in mSv/a
P1	Multi functional individual Dose	Portalum	DP B11	0,0003	0.25	0.05
		Zirconia	DP Z6	0,004		
		Microsilica	DP Z10	0,005		
		Bauxite	DP B13	0,014		
	Actual individual Dose	Portalum	DP B11	0,0003	0,20	0.04
		Zirconia	DP Z6	0,004		
		Microsilica	DP Z10	0,005		
		Bauxite	DP B13	0,014		

Summary

- The Individual Dose (ID) in Tile industry for workers is at maximum 0.5 mSv per year and Multi Individual Dose (MID) for public is 0.190 mSv per year
- ID in Refractory industry for workers is at maximum 0.05 mSv per year and MID for public is at maximum 0.04 mSv per year
- Duration of work near NORM is in Tile industry 10 x more then in Refractories

Good practices

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use the Dust masks,

and wear them!

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Sweap the floor,

Or use the vacuum cleaner !

shield off,

or use bagging equipment !

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or make containment !!

and avoid draft

Do not forget maintenance

and finally;
do what mammie says!

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