Amy Selvaraj (DELWP)

From: Andrew Helps [redacted]
Sent: Wednesday, 10 February 2021 11:38 AM
To: Amy Selvaraj (DELWP)
Cc: [redacted]
Subject: Significant changes to the KALBAR operational equipment list
Attachments: 8344.pdf; 8319Rev4.pdf; 8330 Rev 33.pdf; 10022021110145.pdf

[redacted] [redacted]

EXTERNAL SENDER: Links and attachments may be unsafe.

Amy and Anthony.

Please find attached my comments re the proposed use of centrifuges by Kalbar at the Lindenow mine site.

I would like the opportunity to talk to both of you face to face on this critical issue.

Please inform me of a suitable time and place and I will come into the City for this meeting.

Kindest Regards

Andrew Helps
[redacted]
Mobile [redacted]
UNEP Global Mercury Partnership
Waste Management Partnership - designated expert
Mercury added products and alternatives – designated expert
Mercury Fate and Transport Group

Good morning Amy and Anthony,

I hold grave concerns with the KALBAR proposal to use centrifuges in their processing operation.
The KALBAR ore body has a number of Radionuclides (RADNUC's) of concern in the ore body.

As the Chinese miners (who were early adopters of the uses of centrifuges in Rare Earth mines have discovered) unless you know on a minute by minute basis the actual metals content (speciation) of the ore being fed into the centrifuges you are heading towards a limited and very brief life span along with a large number of nearby residents and workers.

The real problem is the presence of Zirconium in the ore stream and hence the processing plant dust stream.

Zirconium in the dust stream from a crusher plant will ignite at 20 degrees C.
My Colleagues in the Chinese Environment Bureau tell me that 4kg of dust from a centrifuge is the equivalent of a kg of prilled ammonium nitrate mixed with AVTUR..

The US EPA (EPA.Gov) has extensive data on this subject and it is of grave concern that KALBAR's consultants have not referenced this data base for the benefit of the Lindenow community.
This was probably because it was an awkward truth!

I suggest that you inform you self by loading down from the US EPA website a copy of the following document:
Evaluation of Guidelines to Technologically Enhanced Naturally Occurring Radioactive Materials
http://nap.edu/catalog/6360.html

Because of this failure by KALBAR's consultants to provide their advice on RADNUC issues (probably because they are not experienced in this area) the Lindenow the Gippsland Lakes RAMSAR and indeed the entire East Gippsland community will be put at risk if the KALBAR mine is permitted by your Department.

I have further concerns with the fact that the KALBAR consultants have not mentioned in their reports the explosive characteristics of the dust that will be emitted by the operational KALBAR Mine.

There was a very serious accident in China at a large REE mine in central west China in the Northern hemisphere Summer of 2010.

When I was at the UNEP Minamata Conference in Kumamoto Japan in 2013 (Which I chaired for the UNEP Secretary General) the Chinese representatives showed us footage of the explosion site – 57 site workers killed. Tracked excavators and Bulldozers were overturned by the blast, burned out and had all their aluminium and brass components melted!

The plant was destroyed and 20 children at a nearby primary school critically injured – 7 later died.
The Chinese have never re-activated this mine – they now prefer to buy their REE's from overseas.

After a team of experts from Beijing had conducted what we would call a coronial enquiry, the mine manager and the mine engineer were publicly executed in front of a crowd of nearly 1,000 people.

This is a level of mine managerial responsibility we do not have in Australia unfortunately (GBM mining Bendigo comes to mind here with at least two reported mine related arsenic cancer deaths each year for a mine that the Government holds a $ 6 million rehabilitation bond for).

If I was performing due diligence on the KALBAR proposal for one of the Global Investment NGO's (a task that I have often carried out over the last 40 years), the first document that I would look for would be the projects Radionuclide Carcinogenicity Slope Factor Table.

KALBAR would not even understand what this table is let alone have the skills or be able to buy the skills in Australia to compile such a document. To save time I have compiled this table (my file#8319 xlsx dated 15/01/2021.

It is interesting to note that KALBAR never refer to Carcinogens in any discussion of the metals in their ore body.
This leads to 2 critical, as yet unanswered questions:

Question 1. Does any senior executive in KALBAR understand the issues with carcinogenic metals in ore bodies?

Question 2. If the honest answer to question #1 (and I doubt that we will get anything approaching an honest answer from KALBAR) is NO then where is the roadmap from KALBAR to bring their senior managers skill set up to the required level from what is clearly a zero base.

The Lindenow Community do not have the time to wait for this answer.

This situation leads to an interesting situation with two options:

1. KALBAR have hired the consultants that they wanted to hire not the consultants that they needed to hire.

2. That KALBAR have been given data on prospective consultants in the mining sector by other mining companies that have no understanding of the complex issues involved in setting up a highly toxic and carcinogenic metal mine in a RAMSAR catchment.

My view is that KALBAR probably adopted option 1 because they were "new entrants" in this mining sector and were unsure if others in the mining encampment were being honest with them - this was a reasonable assumption.

Kalbar and their consultants are clearly new entrants to the REE mining sector and this lack of experience has detracted from the quality and veracity of the data that supports their EES.

This failure by KALBAR if it was presented to a competent tribunal would result in the project proposal being denied.

The Non-KALBAR independent surface ore body data.

My first involvement with the rapidly emerging KALBAR issues was when a number of the Lindenow farmers asked me to chair and speak at a public information session that they had organised at the Lindenow public hall in 2019.

I have compiled the attached table (File 8319.xlsx) which shows the Radionuclide Carcinogenicity Slope Factors. This data comes from the US EPA Federal Guidance Report No.13 Morbidity Risk Coefficients.

I respectfully suggest that you would be very wise not to ignore the data in this spreadsheet as it will be critical in future coronial enquiries into premature deaths in the Lindenow community with particular emphasis on infants and still births.

Kalbar are obviously unaware of this issue which will become of critical importance when as the development of the mine progresses and these toxic dusts particles impact the Lindenow community and the wider east Gippsland community.

I have put the relevant data from ENVIROLAB Analysis #22941 dated 16/10/2021 into this table. I took these samples at the Lindenow mine site on the 13th of October 2020.

THE SITE Fire Risk.

I have seen no information from KALBAR that informs me that they (KALBAR) understand the fire risks with the excavated ore body.

I would think that there are possibly two explanations for this failure:

1. KALBAR's consultants desire to please their client KALBAR under any circumstance.

2. That the KABAR consultants do not have the funds to buy a copy of the key reference Marks Standard Handbook For Engineers ISBN0-07-004997-1

   If KALBARS consultants did have access to this handbook, they could have informed their advice by looking at Sections 7-24 and 7-25 (copy attached) which deal with the Explosive Characteristics of Various Dusts (Table 7.1.24).

If the KALBAR consultants had looked at the Metals section on page 7-24 (and I am presuming here that the consultants have access to this sort of critical reference) then some form of alarm should have been raised by the data on Metals.

The KALBAR consultants have not raised this issue as far as I can see. I can only conclude that the KALBAR consultants were either incompetent or under instructions not to raise this issue.

3. Synopsis.

As you will see when you look at page 7-25 of the above referenced document you will notice the following alarming data:

3.1 Zirconium dust cloud Ignition temperature at 20 degrees Centigrade.
3.2 Uranium dust cloud Ignition temperature at 20 degrees Centigrade.
3.3 Vanadium dust cloud ignition temperature at 500 degrees centigrade.
3.4 Aluminium – dust cloud ignition temperature at 650 degrees centigrade, my last tests at 12,000 ug/L and 43,000 ug/L .
3.5 Thorium – my last test at 5 ug/l dust cloud ignition temperature 270 degrees centigrade.

A moderately slow grass fire in a medium fuel load (as was demonstrated in the 1983 Ash Wednesday fire) is capable of generating enough radiant heat to melt a steel motor car body (880 degrees C).

FINAL Comments.

I am fully aware that ERR will approve this mine in order to please the Minister and The Premier.
The simple logic of this approval is that it will create about 250 jobs in east Gippsland for CFMEU members.

My time to put this letter to you today is that I can at least say at the inevitable Coronial Inquiry following deaths from the inhalation of radioactive dust at in the perimeter of the Lindenow mine that I had warned the ERR Department via this letter that this would happen.

I realise that you will not respond in any meaningful way to this letter so I will just wait to provide evidence at the eventual Coronial enquiry.

Sincerely

Andrew Helps
UNEP Delegated toxic metal expert to the Minamata Convention on Mercury.

Signed Hard Copy by registered mail.

Radionuclide Table: Radionuclide Carcinogenicity - Slope Factors

Data Source US EPA Federal Guidance Report No. 13 Morbidity Risk Coefficients, in Units of Picocuries

Revision #2

The curie (Ci) is the customary unit of activity and is equal to 3.7 x 10^{10} nuclear transformations per second.

File: 8319.xlsx

20/08/2020

HBTOM Handbook of the Toxicology of Metals (Nordberg ET AL) 4th Edition

Slope Factor Morbidity Risk Coefficient
Lifetime excess Total Cancer Risk

NOTE:
US EPA Regulates radium in drinking water to no more than 5 pCi of combined radium-226 and radium 228 per litre of water.

Element	Kalbar Analysis	Element (Atomic Number)	HBTOM * Reference Pagess	Isotope	Radioactive Half Life (Years)	ICRP Lung Type	Gi Absorption Factor (f_1)[9]	Water Ingestion (Risk/pCi)	Food Ingestion (Risk/pCi)	Soil Ingestion (Risk/pCi)	Inhalation Risk (Risk/pCi)	External Exposure (Risk/y per pCi/g)
Aluminium	260-4500 mg/kg	13	549-560	Al-26	716000	M	0.0100	0.001730	2490	0.47000	0.000000000069	0.0000133
				Al-28	2.240							0.0000092
Antimony	<0.5 mg/kg		565-572	Sb 115	31.80	M	0.1000	0.000000000000051	0.0000000000001	0.11600	0.00000000000002	0.0000039
	Carcinogen			Sb 116	15.80	M	0.1000	0.000000000000051	0.0000000000001	0.11600	0.00000000000002	0.0000105
		51		Sb-126	12.40	M	0.10000	0.00000000001	0.00000000002	0.29	0.0000000000115	0.00000649
				Sb 127	3.85	M	0.1000	0.00000000001	0.0000000000147	0.00000000003	0.000000000008	0.00000307
Arsenic	61-491 mg/kg	33	582-610	As-69	15.20	M	0.50	0.000000000000105	0.00000000000015	0.2390	0.00000000000004	0.00000443
	Carcinogen			As-70	52.60	M	0.50	0.000000000000320	0.00000000000045	0.000000000001	0.00000000000014	0.0000196
				As-71	64.80	M	0.50	0.000000000000320	0.000000000003	0.00000000001	0.00000000000152	0.00000237
				As-72	26.00	M	0.50	0.10	0.00000000001	0.00000000003	0.00000000004	0.0000082
				As-73	80.30	M	0.50	0.000000000002	0.000000000002	0.000000000004	0.000000000004	0.000000006
				As-74	17.80	M	0.50	0.000000000007	0.000000000010	0.00000000002	0.00000000001	0.0000034
				As-76	26.30	M	0.50	0.000000000010	0.00000000001	0.00000000003	0.0000000000	0.0000020
				As-77	38.80	M	0.50	0.000000000003	0.000000000004	0.00000000001	0.000000000002	0.000000036
				As-78	90.70	M	0.50	0.0000000000006	0.0000000000009	0.000000000001	0.0000000000003	0.0000061
Thorium	1.0 -120 mg/kg	90		Th-226	30.90	m S	0.001	0.000000000001	0.000000000000923	0.0000000000016	0.00000000016	0.00000002
	Carcinogen			Th-227	18.70	d S	0.0005	0.00000000005	0.00000000005	0.00000000007	0.00000000014	0.0000004
				Th-228	1.91	y S	0.001	0.0000000001	0.0000000001	0.00000000029	0.00000013	0.00000001
				Th-228+D	1.91	y S	0.001	0.0000000003	0.0000000004	0.00000000081	0.00000014	0.00000776
	In Kalbar ore body			Th-229	7340.00	y S	0.001	0.0000000002	0.0000000003	0.00000000050	0.00000018	0.00000023
				Th-229+D	7340.00	y S	0.001	0.0000000005	0.0000000007	0.00000000129	0.00000023	0.00000117
	See pages 38-40 of TENORM	Handbook		Th-230	77000.00	y S	0.001	0.0000000001	0.000000000119	0.00000000020	0.00000003	0.00000000
				Th-231	25.50	h S	0.001	0.0000000000	0.000000000003	0.00000000001	0.000000000002	0.00000002
	Decays to Radium 228	Unstable		Th-232	14 Billion Years	y S	7340.00	0.0000000001	0.000000000133	0.00000000023	0.00000004	0.0000000003
				Th-234	24.10	d S	0.001	0.0000000000	0.000000000034	0.00000000007	0.00000000003	0.00000002
Tin	1.7 mg/kg	50	1242-1276	Sn-110	4.00	h M	0.020	0.0000000000019	0.000000000003	0.000000000005	0.00000000000067	0.000001130
				Sn-111	35.30	m M	0.020	0.0000000000019	0.00000000000008	0.000000000000	0.00000000000003	0.000002290
				Sn-113	115.00	d M	0.020	0.0000000000019	0.000000000006	0.000000000012	0.00000000001000	0.000000020
				Sn-117m	13.60	d M	0.020	0.0000000000019	0.00000000001	0.000000000013	0.00000000000884	0.000000469
				Sn-119m	293.00	d M	0.020	0.0000000000019	0.000000000003	0.000000000006	0.00000000000781	0.000000001
				Sn-121	27.10	h M	0.020	0.0000000000019	0.0000000000015	0.000000000004	0.00000000000102	0.000000000
				Sn-121m	55.00	y M	0.020	0.0000000000019	0.0000000000023	0.000000000007	0.00000000001540	0.000000001
				Sn-123	129.00	d M	0.020	0.0000000000019	0.0000000000140	0.000000000040	0.00000000003030	0.000000039
				Sn-123m	40.10	m M	0.020	0.0000000000019	0.0000000000001	0.000000000000	0.00000000000006	0.000000462
				Sn-125	9.64	d M	0.020	0.0000000000019	0.0000000000201	0.000000000058	0.00000000001410	0.000001530
				Sn-126	100000.00	y M	0.020	0.0000000000019	0.0000000000256	0.000000000071	0.00000000009950	0.000000100
				Sn-127	2.10	h M	0.020	0.0000000000019	0.0000000000008	0.000000000002	0.00000000000044	0.000009250
				Sn-128	59.10	m M	0.020	0.0000000000019	0.0000000000004	0.000000000001	0.00000000000023	0.000002620
Titanium	44-154 mg/kg	22		Ti-44	47.30	S	0.01000	0.000000000026	0.00000000004	0.0000000001	0.0000000003	0.0000002
	Carcinogen			Ti-45	3.08	S	0.0100	0.0000000000006	0.0000000000009	0.0000000000018	0.0000000000003	0.00000379
Tungsten	<1 mg/Kg	74		W-176	2.30	h F	0.3000	0.0000000000004	0.000000000001	0.0000000000011	0.0000000000001	0.00000032

			W-177	135.00	m F	0.3000	0.0000000000002	0.000000000000	0.0000000000005	0.0000000000001	0.00000363
			W-178	21.70	d	0.3000	0.0000000000012	0.300000000000	0.0000000000033	0.0000000000004	0.00000002
			W-179	37.50	m F	0.3000	0.0000000000000	0.000000000000	0.0000000000000	0.0000000000000	0.00000006
			W-181	121.00	d F	0.3000	0.0000000000004	0.000000000001	0.0000000000011	0.0000000000001	0.00000005
			W-185	75.10	d F	0.3000	0.0000000000029	0.000000000004	0.0000000000084	0.0000000000009	0.00000000
			W-187	23.90	h F	0.3000	0.0000000000037	0.000000000005	0.0000000000103	0.0000000000011	0.00000204
			W-188	69.40	d F	0.3000	0.0000000000140	0.000000000021	0.0000000000400	0.000000000005	0.00000001
Uranium	3-9 mg/kg	234	U-230	20.80	d M	0.0200	0.0000000002090	0.0000000002980	0.0000000005660	0.0000000455000	0.000000003
	Carcinogen		U-231	4.20	d M	0.0200	0.0000000000018	0.0000000000026	0.0000000000050	0.0000000000018	0.00000016
			U-232	72.00	y M	0.0200	0.0000000002920	0.0000000003850	0.0000000005740	0.0000000195000	0.000000001
			U-233	159000	y M	0.0200	0.0000000000718	0.0000000000969	0.0000000001600	0.0000000116000	0.00000000
			U-234	245000.00	y M	0.0200	0.0000000000707	0.0000000000955	0.0000000001580	0.0000000114000	0.00000000
			U-235	704000000	y M	0.0200	0.0000000000696	0.0000000000944	0.0000000001570	0.0000000101000	0.00000052
			U-235+D	704000000	y M	0.0200	0.0000000000718	0.0000000000976	0.0000000001630	0.0000000101000	0.00000054
			U-236	23400000	Y M	0.0200	0.0000000000670	0.0000000000903	0.0000000001490	0.0000000105000	0.00000000
			U-237	6.75	d M	0.0200	0.0000000000049	0.0000000000071	0.0000000000139	0.0000000000064	0.00000038
			U-238	4470000000	y M	0.0200	0.0000000000640	0.0000000000866	0.0000000001430	0.0000000093200	0.00000000
			U-238+D	4470000000	y M	0.0200	0.0000000000871	0.0000000001210	0.0000000002100	0.0000000093500	0.00000011
			U-239	23.50	m M	0.0200	0.0000000000001	0.0000000000001	0.0000000000002	0.0000000000001	0.00000012
			U-240	14.10	h M	0.0200	0.0000000000070	0.0000000000103	0.0000000000202	0.0000000000030	0.00000000
Vanadium	17-130 mg/kg		V-47	32.60	m M	0.0100	0.0000000000001	0.0000000000002	0.0000000000003	0.0000000000001	0.00000436
	Carcinogen		V48	16.20	d M	0.0100	0.0000000000081	0.0000000000117	0.0000000000213	0.0000000000093	0.00001400
			V49	330.00	d M	0.0100	0.0000000000001	0.0000000000002	0.0000000000004	0.0000000000001	0.00000000
Zirconium	6,250-42,750 mg/kg	40	Zr-97	16.90	m	0.0100	0.0000000000125	0.0000000000183	0.0000000000375	0.000000000005	0.0000008620
	Carcinogen										
		70kg Male	Inhalation of	50.4 M^3	Per Day						

UNEP Global Mercury Partnership

Partnership Areas: Mercury in Gold Mining, Mercury Supply and Storage, Mercury Air Transport and Fate, Mercury in Products.

DATA From Envirolab Analysis #22941 dated 16/10/2020

HI = +QTY Chemical / TDD

Author: Andrew Helps [redacted]

Conversion Factors

To Convert concentrations in air(at 25°C) from PPM to mg/m^3 = **6/12/2020**

(ppm) x (molecular weight of the compound) / (24.45) e.g for Antimony 1 ppm = 4.97 mg/m^3.)

KALBAR Resources Lindenow (Vic) Project

Note*
A Hazard Index in excess of 10 requires investigation and or remediation

PDRV - Prioritised Dose Response Value

Rare Earth/Toxic Element/Compound Calculation Template

Lindenow Testing on 13/10/2020

Revision 33
6th February 2021

Rare Earths in Italics

No.	CHEMICAL ELEMENTS/COMPOUNDS: mg/kg - ug/kg	Specific Gravity	Metal Group	Formula Weight (Molecular Weight)	California Rated as Carcinogen	ATSDR Rank	HBTOM* Ref Pages	Ignition Temperature (Dust °C)	Solubility in 100 parts Cold Water Formular Dependent D= Dissolves	ATSDR MRL's Chronic mg/kg/day	Australia Residential Soil mg/kg (HIL A)	ATSDR & USEPA Resident Air Carcinogenic Target Risk ug/m^3	ATSDR & USEPA Resident Tapwater mg/L	Australia Resident Tapwater ug/L	ATSDR SPL THEORETICAL Daily Dose TDD (mg/day) (Fit 70kg male)	USEPA PDRV* Non Cancer	CHRONIC INHALATION Data Source	USEPA PDRV* Cancer	USEPA PDRV* Cancer micrograms	13/10/2020 Water L-25 ug/L	Exceedence USEPA Tapwater	13/10/2020 Water L-28 ug/L	Exceedence USEPA Tapwater	13/10/2020 Sand L26 mg/kg	13/10/2020 Sand L27 mg/kg	13/10/2020 Sand L29 mg/kg	13/10/2020 Sand L30 mg/kg
1	Aluminium (Al)	2.70 g/cm^3	Group 13	26.97	Carcinogen	183	549-560	650	i	1		0.52	2000		10.323	Neurological	ATSDR			12000	6	43000		13000	4700	28000	14000
2	Antimony (Sb)	6.69 g/cm^3	Group 15	121.76	Carcinogen	232	565-572	420	i	0.0003		0.021	0.78	3	0.103992	0.2ug/m^3	IRIS IARC 2B	0.2ug/m^3	0.2	<1		<1		<7	<7	<7	<7
3	Arsenic (see note 1)	5.73 g/cm^3	Group 15	299.64	Carcinogen	1	582-610	815	i	0.0003	100	0.00065	0.052	10	0.071278	0.015ug/m^3	Cal IARC 1	0.015ug/m^3	0.0043ug/m^3	3	57.69	4.00		5.00	<4	8.00	4.00
4	Boron	2.47 g/cm^3	Group 13									2.1	400							30	0.08	60.00		<3	<3	15.00	<3
5	Arsine (gaseous AsH3)	2.769 g/cm^3	Group 15	77.93	Carcinogen	1	615	285	20cc			0.005	0.007			0.05 ug/m^3	IARC 1	0.0043ug/m^3	0.0043					?	?	?	?
6	Barium	3.51 g/cm^3	Group 2	137.36		134	625-633	725	D	0.2		0.00108	0.51499		0.61652					37.00	71.85	150.00		18	15.0	58.0	22.0
7	Beryllium (glucinum)	1.85 g/cm^3	Group 4	9.02	Carcinogen	43	636-651	1278	i	0.002	60	0.00000	2.50	60.0	0.0078	0.01 ug/m^3	IRIS IARC 1	0.0024ug/m^3	0.0024	<0.5		3.00		<1	<1	<1	<1
8	Bismuth (Bi)	9.72 g/cm^3	Group 4	209.00			655-663	271.3	i											<1		<1		<1	<1	<1	<1
9	Cadmium (Cd)	8.65 g/cm^3	Group 12	112.41	Carcinogen	7	668-708	1040	i	0.0005	20	0.00001	0.92	2	0.045127	0.01 ug/m3	ATSDR	0.0018ug/m^3	0.0018	<0.2		<0.2		<0.4	<0.4	<0.8	<0.4
11	Ceric Oxide (Cerium)Ce0$_2$	6.71 g/cm^3	Group 3	172.13	Suspected	570	101-102	3500	i	1 mSv/yr		0.094								14.00		66.00					
14	Chromium compounds (Cr)	7.19 g/cm^3	Group 6	52.01	Carcinogen	66	717-739	580	i	0.0009		0.00001			0.00263					11		48					
15	Cobalt (Co)	8.85 g/cm^3	Group 9	58.94	Carcinogen	52	743-759	760	i	1 mSv/yr	100	0.000031	0.6		0.67523	0.1 ug/m^3	ATSDR			1.0	1.67	6.00		2.00	1.00	8.00	3
	Caesium																			<1		2.00		1.00	1.00	1.00	1.00
16	Copper (Cu)	8.94 g/m^3	Group 11	63.57		125	765-782	900	i	0.01	6000		80	2000	0.47242					<2		5.00		<1	<1	570	<1
17	*Dysprosium Dy20$_3$*	8.53 g/m^3	Group 3	162.5	Suspected			2567	i																		
18	*Erbium Er20$_3$*	9.04 g/m^3	Group 12	167.26	Suspected			1529	i																		
19	*Europium Eu0$_3$*	5.25 g/cm^3	Group 3	151.96	Suspected	575		1800	i																		
20	*Gadollinium Gd2p0$_3$*	7.87 g/cm^3	Group 3	157.25	Suspected			3545	i																		
21	*Gallium*	5.91 g/cm^3	Group 13	69.72	Carcinogen		787-797	29.78				0.00001			0.00011									4.00	2	13	6.00
22	*Germanium*	5.32 g/cm^3	Group 14	72.63			800-813		i																		
23	*Holmium Ho20$_3$*	8.80 g/m^3	Group 12	164.93	Suspected			1474	i																		
24	Iron	7.87 g/cm^3	Group 8	55.85			878-902	420	i			0.01626	11.29		18.07					8100.00	717.45	30000.00		30000	12000	37000	26000
25	*Lanthanum -138*	6.17 g/m^3	Group 3	138.92	Suspected	711	903-908	920	i			0.00018	0.00268		0.02188					9.00	3358.21	43.00	**16044.78**	16	9	27	15
26	Lead - not 210 (Pb)	11.34 g/cm^3	Group 14	430.42	Carcinogen	2	129-131	710	i		300		15	10	0.330938	0.15 ug/m^3	OAQPS			6	0.40	30.0		10	4	29	11
27	*Lithium Oxide Li$_2$O*	0.53 g/cm^3	Group 1	29.88	Suspected	335	969-974	2600	to Li0H	0.404424			0.3835		0.404424		ATSDR			3.00	7.82	15.00		4	1	11	5
28	*Lutetium -176*	9.84 g/cm^3	Group 3	174.99	Suspected			1936	i																		
29	Magnesium	3.58 g/cm^3	Group 2	24.32				520	i			0.0907	33.3369		35.96134												
30	Manganese	7.47 g/cm^3	Group 6	54.93		140	975-1005	1246	D	0.3 ug/m3	3800	0.05	43	500	1.61855	0.03 ug/m^3	ATSDR			120	2.79	93		33	10	190	31
31	Mercury	13.55 g/cm^3	Group 12	200.61	Suspected	3	1014-1064	to gas @10°C	i	0.0002 mg/m3	40		0.063	1	0.051981	0.3ug/m^3	IRIS			<0.05		<0.05		<0.1	<0.1	<0.1	<0.1
32	Methyl Mercury	215.63g/mol	Group 12	417.22	Suspected	120	448-450	within organics	i	0.0003			0.2			0.1 ug/m^3	IRIS	0.1 ug/m^3	0.1		0.00						
33	Molybdenum	10.22 g/cm^3	Group 6	95.95		326	1077-1107	720	i	0.00004 mg/m^3			10	50	0.2412	0.2ug/m^3	IARC 2B			<1		<1		<1	<1	<1	<1
34	Nickel	8.90 g/cm^3	Group 10	58.69	Carcinogen	57	1091-1107	950+	i	0.00009 mg/m^3	400		20	20	0.38969	0.09 ug/m^3	ATSDR/CAL	0.00024 ug/m^3	0.00024	4	0.20	12.0		4.0	1	15	4
35	*Neodymium 144*	7.00 g/cm^3	Group 3	144.27	Suspected			1021	D											2.70		2.40					
36	*Palladium*	12.99 g/cm^3	Group 10	106.7	Suspected	173	1113-1121	2963	i			0.012000			0.00018												
37	*Platinum*	21.45 g/cm^3	Group 10	195.23			1125-1138		i																		
38	*Praseodymium Pro$_6$*	6.78 g/cm^3	Group 3	140.92	Suspected			3512	D																		
40	*Radium 222 , 226 or 228*	5.5 g/cm^3	Group 2	226.05	Carcinogen			1500	i			5pCi total combined per litre of water															
41	*Radium Bromide*	5.79 g/cm^3	Group 2	385.88																							
42	*Rhodium*	8.85 g/cm^3	Group 9	102.91			1143-1171		i																		
43	*Rubidium*	1.63 g/cm^3	Group1	85.48	Suspected	711			D			0.00001			0.000091					8.00		31.00					
44	*Samarium 147 (Chloride)*	7.54 g/cm^3	Group 3	150.43	Suspected				NK	EPA Doc EPA/690/R-09/050F																	
45	*Scandium Sc2O$_3$*	2.99 g/cm^3	Group 3	45.1	Suspected	584			NK											<1		8.00					
46	Selenium	4.50 g/cm^3	Group 16	631.68	Suspected	146	1176-1203	950+	i	0.005 mh/kg/day	200	0.00002	0.03657	10	0.03778	20 ug/m^3	CAL			<1		5.00		<2	<2	<2	<2
47	Silica PM$_{2.5}$ Faction)	2.33 g/cm^3	Group 14	60.06	Carcinogen		102	780	i				0.31000		Annual av												
48	Sulphur (%)	2.067 g/cm^3	Group 16	32.06				392	i			0.00122			0.01829												
49	Strontium SrO (Stable)	2.64 g/cm^3	Group 2	87.63	Carcinogen		455	768.85	D	2 mg/kg/day										28		69		5	2	31	4
50	*Tellurium*	6.24 g/cm^3	Group 16	127.61	Carcinogen		1218-1226	449.51	i			0.00003			0.00039					<0.5		<0.5		<1	<1	<1	<1
51	*Terbium Tb40$_7$*	8.27 g/cm^3	Group 3	159.2	Suspected			1356	NK																		
52	*Thallium*	11.86 g/cm^3	Group 13	204.39	Suspected	279	1229-1238	303	i			0.00007	0.01355		0.01579					<1		<1		<2	<2	<2	<2
54	*Thorium 229*	11.73 g/cm^3	Group 3	232.12	Carcinogen	227		270	i								IARC I	0.000185 pCi/m^3		1.0		5.0		6	3	5	6
55	*Thulium Tm2O$_3$*	9.33 g/cm^3	Group 12	169.4	Suspected			1950	i																		
56	Titanium	4.54 g/cm^3	Group 4	47.9	Carcinogen	310	1287-1294	460	i	0.0001 mg/m3			0.021		2.271688	0.01 ug/m^3	ATSDR	Respiratory		110		76					
57	Tin	7.29 g/cm^3	Group 14	118.7		307	1242-1276	630	i	0.3 mg/kg/day			1200	1200	0.09981					2.0		<1					
58	Tungsten	19.25 g/cm^3	Group 6	183.92			1297-1305	950	i											<1		<1					
59	Uranium 234	19.05 g/cm^3	Group 7	238.07	Carcinogen	97	1308-1338	20	i	0.00004 mg/m3										0.6		3.5		<1	<1	2	1
60	Vanadium (86%)	6.10 g/cm^3	Group 5	50.95	Carcinogen	200	1348-1364	500	i	0.0001 mg/m3			8.6		0.123043		CAL		0.00034	13		53		50	28	62	54
61	*Ytterbium Yb2O$_3$*	6.95 g/cm^3	Group 3	173.04	Suspected	581			NK																		
62	*Yttrium Y2O$_3$*	4.47 g/cm^3	Group 3	88.92	Suspected	711			D			0.0000006			0.000118					6.70		33.00		7.60	4.8	15	7.8
63	Zinc	7.14 g/cm^3	Group 12	65.38		75	1369-1382	600	i	0.3 mg/kg/day	7400		600		1.96084					9		25.0		4	1	280	3
64	Zirconium	6.51 g/cm^3	Group 4	91.22	Carcinogen	701		20	i				0.16	0.000022	0.00032												
65	Hydrogen Cyanide	0.69g/cm^3		179.16	Reproductive	35			NK		250		0.15	80	1.3058												
66	PM10								Particle	ICPMS Analysis					24 hour av												
67	PM2.5				Carcinogen				Particle	ICPMS Analysis					24 hour av	Annual Average											
	Radionuclides (Uranium)	18.7 g/cm^3	Group 3	238.03	Carcinogen	102	1307-1345		i									0.000185 pCi/m^3									

Note 1 **USEPA Residential level Average fit healthy 70 kg male inhales 50.4 m3 a day**

HBTOM - Handbook of the toxicology of Metals - Nordberg et al Fourth Edition
ATSDR Minimum Risk Levels (MRLs December 2019

Explosive Characteristics of Various Dusts* *(Continued)*

Type of dust	Ignition temperature of dust cloud, °C	Minimum igniting energy, J	Minimum explosive concentration, oz/ft³	Maximum explosion pressure, lb/in² gage	Maximum rate of pressure rise, lb/(m²)(s)	Terminal oxygen concentration, %†
›ounds (*Continued*):						
$C_6H_4(CO)_2NH$	630	0.050	0.030	79	4,500	
tartrate, $KHC_4H_4O_6$	520					
ɛ, o-$HOC_6H_4CONHC_6H_5$	610	0.020	0.040	61	4,400	
ɪulfate, anhydrous, $Na_2S_2O_3$	510					
	470	0.015	0.020	88	10,000+	
H)$_2$ COOH						
$H_{22}O_{11}$	420	0.040	0.045	82	4,200	14
0% finer than 44 μm	210	0.020	0.045	56	3,100	
⁄g particle size 4 μm	190	0.015	0.035	78	4,700	12
ylsalicylic acid), C_6H_4COOH, fine	660	0.025	0.050	83	10,000+	
xahydric alcohol), :OH)$_4CH_2OH$	460	0.040	0.065	82	2,800	
ɜodium, ,Na	520	0.960	0.100	54	500	
ɪcorbic acid,	460	0.060	0.070	88	4,800	15
related compounds:						
nide	500	0.045	0.040	94	6,500	
c acid	460	0.045	0.040	92	4,300	
liphenyl-urea nilide)	550	0.060	0.095	87	2,500	
ide (3,5-dinitro-ortho-	500	0.015	0.050	106	10,000−	13
	650	0.015	0.045	100	10,000+	2
	420	1.920	0.420	8	100	16
	470	0.060	0.100	90	2,400	
	570	4.000				
	580	0.140	0.230	56	5,000	14
	760					
	900					
	420	0.020	0.100	46	6,000	10
	710					
	520	0.020	0.020	94	10,000+	0
	720					
	950+					
	950+					
	780	0.080	0.100	106	10,000+	12
	630	0.120	0.200	51	3,700	
	550					
	270	0.005	0.075	48	3,300	0
	630	0.080	0.190	37	1,300	15
	460	0.010	0.045	80	10,000+	0
	950+					
	20	0.045	0.060	53	3,400	0
%	500	0.060	0.220	48	600	13
	600	0.640	0.480	48	1,800	9
	20	0.005	0.045	65	9,000	0
›unds:						
alt	950	0.100	0.180	78	8,500	
per	930	1.920	0.280	27	500	
	550	0.720	0.500	21	100	
;nesium	430	0.020	0.020	90	10,000	0
:el	940	0.080	0.190	79	10,000	14
·on, 12% Si	670	0.060	0.040	74	7,500	
ɜ	540	0.130	0.060	73	10,000+	8
, high-carbon	790		2.000			19
ɜ, medium-carbon	450	0.080	0.130	47	4,200	
% Si	860	0.400	0.420	87	3,600	16
ow-carbon	370	0.080	0.140	53	9,500	13

Table 7.1.24 Explosive Characteristics of Various Dusts* ***(Continued)***

Type of dust	Ignition temperature of dust cloud, °C	Minimum igniting energy, J	Minimum explosive concentration, oz/ft³	Maximum explosion pressure, lb/in² gage	Maximum rate of pressure rise, lb/(m²)(s)	Terminal oxygen concentration, %†
Alloys and compounds (*Continued*):						
Ferrovanadium	440	0.400	1.300			17
Thorium hydride	260	0.003	0.080	60	6,500	6
Titanium hydride	440	0.060	0.070	96	10,000+	13
Uranium hydride	20	0.005	0.060	43	6,500	0
Zirconium hydride	350	0.060	0.085	69	9,000	8
Plastics:						
Acetal resin (polyformaldehyde)	440	0.020	0.035	89	4,100	11
Acrylic polymer resin Methyl methacrylate-ethyl acrylate	480	0.010	0.030	85	6,000	11
Alkyd resin Alkyd molding compound	500	0.120	0.155	15	150	15
Allyl resin, allyl alcohol derivative, CR-39	500	0.020	0.035	106	10,000+	13
Amino resin, urea-formaldehyde molding compound	450	0.080	0.075	89	3,600	17
Cellulosic fillers, wood flour	430	0.020	0.035	110	5,500	17
Cellulosic resin, ethyl cellulose molding compound	320	0.010	0.025	102	6,000	11
Chlorinated polyether resin, chlorinated polyether alcohol	460	0.160	0.045	66	1,000	
Cold-molded resin, petroleum resin	510	0.030	0.025	94	4,600	
Coumarone-indene resin	520	0.010	0.015	93	10,000+	14
Epoxy resin	530	0.020	0.020	86	6,000	12
Fluorocarbon resin, fluorethylene polymer	600					
Furane resin, phenol furfural	520	0.010	0.025	90	8,500	14
Ingredients, hexamethylenetetramine	410	0.010	0.015	98	10,000+	14
Miscellaneous resins, petrin acrylate monomer	220	0.020	0.045	104	10,000+	
Natural resin, rosin, DK	390	0.010	0.015	87	10,000+	14
Nylon polymer resin	500	0.020	0.030	89	7,000	13
Phenolic resin, phenol-formaldehyde molding compound	500	0.020	0.030	92	10,000+	14
Polycarbonate resin	710	0.020	0.025	78	4,700	15
Polyester resin, polyethylene terephthalate	500	0.040	0.040	91	5,500	13
Polyethylene resin	410	0.010	0.020	83	5,000	12
Polymethylene resin, carboxypolymethylene	520	0.640	0.115	70	5,500	
Polypropylene resin	420	0.030	0.020	76	5,000	
Polyurethane resin, polyurethane foam	510	0.020	0.025	88	3,700	
Rayon (viscose) flock	520	0.240	0.055	88	1,700	
Rubber, synthetic	320	0.030	0.030	93	3,100	15
Styrene polymer resin, polystyrene latex	500	0.020	0.020	91	7,000	13
Vinyl polymer resin, polyvinyl butyral	390	0.010	0.020	84	2,000	14

* Data taken from the following *Bureau of Mines Reports of Investigations:* RI 5753, ''Explosibility of Agricultural Dusts''; RI 5971, ''Explosibility of Dusts Used in the Plastics Industry''; RI 6516, ''Explosibility of Metal Powders''; RI 7132, ''Dust Explosibility of Chemicals, Drugs, Dyes and Pesticides''; RI 7208, ''Explosibility of Miscellaneous Dusts.'' The data were obtained using the equipment described in RI 5624, ''Laboratory Equipment and Test Procedures for Evaluating Explosibility of Dusts.''

† The terminal oxygen concentration is the limiting oxygen concentration in air-CO_2 atmosphere required to prevent ignition of dust clouds by electric spark.

Experiments show the maximum rate of pressure rise in a highly turbulent dust-air mixture can be as much as 8 times higher than in a nonturbulent mixture (*BuMines Repts. Inv.* 5815 and 7507 and Nagy and Verakis).

Moisture and Other Inerts Moisture in a dust absorbs heat and tends to reduce the explosibility of a dust. A high concentration of moisture in the dust also tends to reduce the dispersibility of a dust. An increase in moisture content causes an increase in ignition temperature and a reduction in maximum pressure and rates of pressure rise. However, the amount of moisture required to produce a marked lowering of the explosibility parameters is higher than can ordinarily be tolerated in industrial processes. Most mineral inert dusts admixed with a combustible absorb heat during the combustion reaction and reduce explosibility similar to the action of water. Some chemical compounds, such as sodium and potassium carbonates, act as inhibitors and are more effective than mineral inerts; the limiting inert dust concentration required to prevent ignition and explosion depends on the strength of the igniting source.

Atmospheric Oxygen Concentration The pressure and rate of pressure development decrease as the oxygen concentration in the atmosphere decreases. The ignition sensitivity of dusts decreases with decrease in oxygen concentration and for most dusts, ignition and explosion can be prevented by reducing the oxygen concentration to a safe value. Carbon dioxide, nitrogen, argon, helium, and water vapor are effective diluents. For highly reactive metal powders, only argon and helium are chemically inert. Limiting oxygen concentrations using carbon dioxide as a diluent are given in Table 7.1.24 for many dusts. With carbon dioxide as a diluent, a reduction of oxygen in the atmosphere to 11 percent is sufficient to prevent ignition by sparks for all dusts tested except the metallic powders. With nitrogen as the diluent, ignition of nonmetallic dusts is prevented by diluting the atmosphere to 8 percent oxygen. Some metal dusts, such as magnesium, titanium, and zirconium, ignite by spark in a pure carbon dioxide atmosphere. Freon and halons are sometimes used as diluent gases, but if metal dusts are involved, they can intensify rather than suppress ignition. The limiting oxygen concentration decreases as the dust becomes finer in particle