Disease Reduction Programme: Cancer Project

The nature and extent of use of, and occupational exposure to, chemical carcinogens in current UK workplaces

ANNEX 2 - DETAILED SUMMARIES OF THE RESULTS FROM THE PHASE 2 REVIEWS

CONTENTS

1.0 CARCINOGENS OF CONCERN

These are the carcinogens for which the phase 1 review considered there to be sufficient evidence, based on potential for cancer causation, large numbers of workers exposed and significant occupational exposures to indicate a cause for concern.

1.1 Polycyclic aromatic hydrocarbons (PAHs)

PAHs are a collective term for hydrocarbons with 2 or more aromatic rings fused together. They can either occur naturally or can be process generated and are considered a human carcinogen. They are ubiquitous in the environment as a result of partial combustion of organic matter.

PAHs have not been assigned a WEL although an 8hr TWA guidance value of 1400 $\mu g/m^3$ was included in EH40 from 1989 to 1993. More recently, a proposal to assign a WEL of 500 $\mu g/m^3$ was withdrawn in 2003. A biological monitoring guidance value (BMGV) of 4 µmol 1-hydroxy pyrene/mol creatinine was agreed by WATCH however as extensive research had shown this substance to be a suitable marker for total PAH exposure. The BMGV represents the 90th percentile of sites where good exposure control is applied.

Several industries where workers are potentially exposed to PAHs have been in decline in recent years, notably the coke production industry, chimney sweeping and coal tar users (in favour of petroleum based alternatives, which contain lower concentrations, by orders of magnitude, of typical PAHs). The numbers of workers currently exposed to PAHs at coke ovens (about 5 sites with 5 workers/site potentially exposed) and aluminium production (2 sites with about 100 workers/site potentially exposed) is likely to be low but much larger numbers can be exposed in the rubber, foundry and oil/bitumen industries.

The most recently (2006) published exposure surveys carried out by HSE (219 personal samples collected from 25 sites) measured PAH exposures ranging from 0.08 to 1912.6 $\mu g/m^3$ 8hr TWA (mean 93.62 $\mu g/m^3$, median 15.24 $\mu g/m^3$).

The highest exposures are shown in table 1.1.1 and were found at timber impregnation, tar distillation and pipeline coating work activities. There were also significant exposures amongst coke oven workers and foundry workers.

Some further information gathering visits were carried out by HSE to the tar distillation and timber impregnation industries as a part of the phase 2 reviews. Contact was also established with the chimney sweeping industry as HSE hold little information on risks to health for this group.

Table 1.1.1: summary table of significant PAH personal 8hr TWA exposures

Industry	No. of samples	Total PAH personal exposure 8hr TWA	
		Mean (µg/m^3)	Range (µg/m^3)
Timber impregnation	11	835.06	29.93 to 1912.6
Tar distillation (high temp)	12	278.82	51.9 to 1130.21
Pipeline coating	11	263.64	73.34 to 758.22
Coke oven workers, site 1 of 3	11	79.17	8.80 to 184.55
Coke oven workers, site 2 of 3	13	70.66	9.93 to 294.63
Petroleum tar distillation	8	68.94	15.21 to 280.03
Foundry, site 1 of 2	11	65.75	26.97 to 120.13
Aluminium production	9	60.88	10.45 to 138.38
Coke oven workers, site 3 of 3	13	49.87	5.88 to 131.64
Foundry, site 2 of 2	7	21.12	8.88 to 47.38

There is only one UK business engaged in coal tar and petroleum tar distillation. They have two UK sites and import all coke oven crude tar direct from the UK steel industry and import petroleum tar from France.

The larger of the two sites handles 120,000 tonnes/yr of crude tar and produces 120,000 tonnes of distillate. The smaller site handles 36,000 tonnes/yr of crude tar and produces 36,000 tonnes of distillate. The small amount of waste material produced is recycled within the plants or returned to the steelworks for burning in the coke ovens. Worker profiles (including exposure) for the distillation business are shown in table 1.1.2.

Table 1.1.2: worker/exposure profiles for supply and distribution of tar and petroleum distillate

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events	
		M	F	<5	5 – 15	>15	Duration/day (hrs)	Data (Y/N)
Distillation (site 1)	60	100	Nil			60	7	Y[1]
Distillation (site 2)	20	100	Nil			20	8	Y[1]

[1] Biological monitoring data may become available and will be added.

The process is totally enclosed. Breaches in the closed system occur however when the crude tars are transferred from the road tankers and when the distilled product is transferred for distribution into road tanker or ship. A breach in the closed system also occurs when samples are collected for analysis. Breaches in the closed system also occur when the solid pencil pitch and anthracene are bagged.

The distillate (or pitch) contains PAHs and is sold for use by several markets. The most significant markets are: manufacture of electrodes for aluminium ore smelting (80,000 tonnes of pitch/yr); creosote manufacture (internal business for the UK distillation company, 20,000 tonnes/yr) for timber preservation (professional market only); and, manufacture of ‘clay pigeons’ (1000 tonnes of pitch/yr) for clay pigeon shooting.

Significant improvements have been made within the aluminium smelting industry to reduce PAH emissions during the making of anodes used in the electrolytic process and exhaust ventilation of fumes is also now well established. No visits were made to this sector and exposure data at table 1.1.1 refers.

The UK distillation company also manufacture and distribute creosote. Worker profiles (including exposure) for this activity are shown at table 1.1.3

Table 1.1.3: worker/exposure profiles for manufacture and supply of creosote

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events	
		M	F	<5	5 – 15	> >15	Duration/day (mins)	Data (Y/N)
Delivery	1	100	Nil			1	40	Y[1]
Blending	2	100	Nil			2	180	Y[1]
Packing	1	100	Nil			1	60	Y[1]
Cleaning / Maintenance	1	100	Nil			1	Varies	Y[1]
Quality Control	1	100	Nil			1	480	Y[1]

[1] Biological monitoring data may become available and will be added.

The majority of the process is totally enclosed. Breaches in the closed system occur: during tanker delivery of creosote to central storage tanks; when tank liquid level checks (using an ultrasonic probe) are carried out; when samples are collected for analysis; and, when the product is manually decanted into 25 and 250 litre drums.

The recently (2006) published HSE PAH exposure surveys already referred to, also included a clay pigeon manufacturing site. HSE measured 8 personal samples at 1 site and measured PAH exposures ranging from 13.39 to 38.69 $\mu g/m^3$ 8hr TWA (mean 24.67 $\mu g/m^3$). There is now only one UK manufacturer and they were visited as part of the phase 2 surveys as they are a significant user of pitch. Worker profiles (including exposure) for this activity are shown at table 1.1.4

Table 1.1.4: worker/exposure profiles for manufacture of clay pigeons

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events	
		M	F	<5	5 – 15	> >15	Duration/day (hrs)	Data (Y/N)
Pitch moulding	3	100	Nil	2		1	12	Y[1]
Cleaning /maintenance	5	100	Nil	3		2	12	Y[1]
Disposal	1	100	Nil	1			12	Y[1]

[1] Biological monitoring data may become available and will be added.

The majority of the process is totally enclosed. Breaches in the closed system occur during tanker delivery of molten pitch for offloading to bulk storage tanks; when the mixture of pitch and chalk is being tested for fluidity; and, when the mixture is fed into the mould.

Impregnation of timber with creosote is carried out at four UK sites. One site was visited as part of the phase 2 surveys as they are a significant user of pitch. Estimated worker profiles (including exposure) for this activity across all four sites are shown at table 1.1.5

Table 1.1.5: estimated worker/exposure profiles for timber treatment industry

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events	
		M	F	<5	5 – 15	> >15	Duration/day (hrs)	Data (Y/N)
Delivery	2	100	Nil		2		1	Y[1]
Pressure treatment	4	100	Nil		4		7.5	Y[1]
Cleaning / Maintenance	4	100	Nil		4		Variable	Y[1]
Quality Control	1	100	Nil		1		1	Y[1]
Disposal	1	100	Nil		1		1	Y[1]

[1] Biological monitoring data may become available and will be added.

Exposures occur at tanker delivery of creosote during offloading to bulk storage. The pressure treatment process is partially enclosed. The main exposure risk occurs when opening the pressure doors after timber treatment. PPE is worn for this task.

HSE hold little information on health risks to peripatetic workers from exposure to chemical carcinogens. Chimney sweeps are potentially exposed to PAHs and probably form the largest group of peripatetic workers potentially exposed to a carcinogen of concern. The chimney sweeps trade association were engaged as part of the phase 2 surveys in order to plug this apparent knowledge gap.

Industry estimate there to be currently a total of some 2500 chimney sweeps in the UK with 250 affiliated to a representative trade association. Trade association members are regularly informed of health risks by the association and work to a high standard of cleanliness. Non-members however have no direct access to such support and HSE have no knowledge of their working practices.

The trade association have recruited 10% of their members to participate in a one-week biological monitoring exercise (2 samples per day for 5 days). HSE have recruited 22 non-members to participate in the same exercise.

It is hoped that comparison of the results will help HSE establish the standard of cleanliness to which non-members work as compared to members and thus establish the current level of health risk for non-members. No results are yet available but will be added to this paper as soon as available.

1.2 Ferrous Foundry Particulate (FFP)

Atmospheric contamination in foundries is a complex mixture of dust, fume, gases and vapours produced as a consequence of the foundry process. The particulate fraction of the atmospheric contamination is described as FFP. The composition of FFP will vary according to the process producing it and the materials used. Processes include mould making, pouring, knockout, fettling and finishing.

Some of the individual components of the FFP are known to be carcinogenic and some have been assigned WELs. Carcinogens such as PAHs, nickel, chrome, refractory ceramic fibres (RCFs) and silica could be present.

Exposure surveys from 1960-90 indicate average exposures to FFP at 10 mg/m^3, however, significant proportion of samples for all processes were in excess of 10 $mg.m^{-3}$. FFP carry a UK workplace exposure limit (WEL) total inhalable dust 10 $mg.m^{-3}$ 8hr TWA and respirable dust 4 $mg.m^{-3}$ 8 hr TWA.

Industry data made available to HSE identifies that in 2004 there were estimated to be a total of 540 foundries employing 31,500 workers. The foundry types and likely employee profiles are given at table 1.2.1.

Table 1.2.1: Types of foundry and employee profiles

Type of Foundry	Estimated number of Foundries	Estimated total potentially exposed population	Gender (%)		Estimated length of service (Years)		
			M	F	<5	5 – 15	> >15
Iron	200	11,670	90	10[1]	1000	670	10,000
Non-ferrous (aluminium)	200	11,670	100	nil	1000	670	10,000
Steel	55	3205	100	nil	300	105	2800
Lost wax investment castings	45	2625	90	10[1]	260	65	2300
Copper	20	1165	100	nil	115	50	1000
Zinc	20	1165	100	nil	115	50	1000

[1] Iron and Lost wax investment foundries employ female workers to carry out the fettling and finishing of small parts.

The likely carcinogenic FFP components for each foundry type are given at table 1.2.2

Table 1.2.2: Types of foundry and likely carcinogenic FFP components

Type of Foundry	**Likely carcinogenic FFP components**
Iron	PAHs, nickel (high), chrome, RCFs and silica
Non-ferrous (aluminium)	PAHs, RCFs and silica
Steel	PAHs, nickel, chrome, RCFs and silica
Lost wax investment castings	PAHs, nickel, RCFs and silica
Copper	PAHs, nickel, RCFs and silica
Zinc	PAHs, RCFs and silica

The interrelationship between the individual components of FFP is complex and it may be inappropriate to rely on the individual WELs in assessing overall exposure to airborne contaminants in the foundry atmosphere. A number of sampling visits will therefore be carried out to sample for individual carcinogens likely to be present in FFPs.

1.3 Wood Dust

Both hardwood and softwood dust carry UK workplace exposure limits (WELs) of 5.0 mg/m^3 8 hour TWA. This is not however a 'safe' limit. SCOEL has reported that workers exposed to dust from hard or soft wood at concentrations greater than 0.5 mg/m^3 have exhibited significant health impairment. As carcinogens, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

In 1999/2000 some 16,000 registered work units employing about 219,000 workers manufactured wooden products or were engaged in sawmilling in the United Kingdom (Office for National Statistics, 2000). Seventy nine percent employed fewer than ten workers and 96 % less than 50. The inclusion of construction industry woodworkers to the number potentially exposed brings the total to 384,000.

Exposure to wood dust and compliance with the Control of Substances Hazardous to Health Regulations was assessed by HSE in 2000 at a representative cross-section of the British woodworking industry. The median exposure was 2.4 mg/m^3 and overall, 27% of values exceeded the WEL. Although these results were unsatisfactory they showed an improvement over the previous ten years.

The WEL for wood dust has been identified as requiring review. Some EU countries work to a limit of 2.0 mg/m^3. Only 42% of values measured in 2000 complied with this figure.

1.4 Rubber fume/Rubber process dust

Rubber fume and rubber process dust carry UK workplace exposure limits (WELs) of 0.6 mg/m^3 8 hour TWA and 6.0 mg/m^3 8 hour TWA respectively (limits relate to cyclohexane soluble material). As carcinogens, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

Rubber process dust and fume are complex process-generated materials. Rubber dust occurs when compounds are weighed, mixed, milled and handled during the process of rubber manufacture. Rubber fume occurs where rubber or synthetic polymers are heated e.g. tyre manufacture, retreading and in the manufacture of moulded rubber goods. The rubber industry is well established, has strong links with HSE and employs approximately 10,000 people at about 250 UK sites.

Much work has already been done by HSE and Industry in this area. Good guidance on the control of exposure is already available and there is a clear will amongst stakeholders to continue to improve control.

An exposure survey in 1984; NEDB exposure data up to 1997; a further exposure survey in 1995; and, the IOM report on trends in inhalation exposure all indicate a steady improvement in exposure control. However, significant potential for exposures above the current occupational exposure limits still exists. Results from the most recent 1995 survey indicate:

- 19% of sampling results for rubber fume were greater than or equal to the WEL;
- 5% of sampling results for rubber fume were at least two times greater than the WEL;
- 5% of sampling results for rubber dust were greater than or equal to the WEL;
- 2% of sampling results for rubber dust were at least two times greater the WEL.

In 2006, HSE carried out a qualitative survey at a random selection of the poorer performers from the 1995 survey but were unable to identify a clear indication of any significant improvement in exposure control at the sites visited.

1.5 Sulphuric acid mist

Sulphuric acid is claimed to be the highest volume commodity chemical supplied in the world. The majority of applications do not provide for aerosol generation and subsequent potential for exposure to sulphuric acid mist. The total amount of sulphuric acid supplied to the market therefore has not been assessed for the phase 2 surveys.

HSE issued a Chemical Hazard Alert Notice (CHAN) in 2001 recommending that exposure levels should be reduced to 0.3 mg/m^3 to protect against inflammation in the larynx.

There are two UK manufacturers of sulphuric acid and both confirm there is no potential for acid mist exposure during normal manufacturing operations.

Although the use of sulphuric acid in the chemical industry may lead to mist formation in certain processes, the enclosed chemical plant used in this industry removes the risk of worker exposure.

Applications that do provide for aerosol generation and subsequent potential for exposure to sulphuric acid mist are: manufacture of lead acid batteries; metal finishing; and, the use of sulphuric acid as an agricultural crop desiccant.

Sulphuric acid is used as an electrolyte in lead acid batteries. These are used in automotive, and aerospace applications, industrial electrical vehicles (fork lift trucks, etc.) and in uninterruptible power supplies used in burglar and fire alarm systems and power back up systems.

Historically, a large number of UK sites manufactured lead acid batteries. However, in recent years much of this work has moved abroad and it is estimated that this process is run at only five UK sites. Two sites were visited as part of the phase 2 reviews. Site A employed 350 workers with a potentially exposed population of 15 whilst site B employed 650 workers with a potentially exposed population of 30. Estimated worker profiles (including exposure) for this activity across all five sites are shown at table 1.5.1.

Table 1.5.1: estimated worker/exposure profiles for initial charging of batteries

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
		M	F	<5	5 – 15	>15	Frequency (events/wk)	Number / event	Event duration (hrs)	Data (Y/N)
Initial charge	75 to 150	>95	< 5	No data			5	75 to 150	8	Y

The stage of the process with the greatest potential for acid mist exposure is the initial charging of the battery plates. This takes place in a large charging hall, several thousand cubic metres in capacity. Typically, 8,000 to 10,000 batteries will be charged at any one time. The acid reservoirs are loosely capped during charging to reduce acid mist emissions from each battery. Forced dilution ventilation is used in the charging hall to prevent hydrogen build up but will also reduce airborne acid mist concentrations.

Table 1.5.2: summarised quantitative personal exposure data for battery manufacture from NEDB

Site ref	Survey date	Number of samples	Results mg/m^3			
			Min	Max	Median	>0.3mg/m^3
1	August 1997	4	0.3	0.4	0.35	4
2	March 2002	8	<0.04	1.4	0.36	4
2	October 2002	1	0.24	0.24	0.24	0
2	April 2004	5	<0.04	<0.04	<0.04	0
3	May 2002	2	0.023	0.056	0.04	0
3	August 2003	3	<0.04	<0.04	<0.04	0
3	November 2004	2	<0.04	<0.04	<0.04	0
4	Summer 2006	10	0.005	0.012	0.007	0

There are 35 data points in NEDB for sulphuric acid mist exposure in battery manufacture. Of these, 31 are non-validated industry data, and less reliable than HSE data. Eight data points (22.9%) are 0.3 mg/m^3 or higher and two exceed 1 mg/m^3. This is a limited data set but indicates there is potential for significant exposures in this industry. Exposure potential during battery breaking is anticipated to be low as the batteries are drained of acid before breaking.

Sulphuric acid is used in a variety of processes in the metal finishing industry. These include anodising, copper micro etching, electrolytic nickel plating, electroless nickel plating, jig tin plating, barrel tin plating, stainless steel electropolishing and stainless steel etching. No site visits were made to metal finishers as part of the carcinogens baseline project. Information was obtained from contact with trade associations and from NEDB.

There are 33 data points in NEDB for sulphuric acid mist exposure in metal finishing businesses and only one measured exposure exceeds 0.3 mg/m^3.

The single result in excess for 0.3mg/m^3 (see table 1.5.3) was obtained from a worker involved in the anodising process. HSE and industry concluded this limited data set indicated that, for the various processes studied, anodising had the highest exposure potential. However, given that data were obtained from 10 sites, from an estimated 200 sites performing anodising (see table 1.5.4), there are uncertainties associated with this conclusion.

Table 1.5.3: summarised quantitative personal exposure data for metal finishing businesses from NEDB

Site ID	Survey date	Number of samples	Results (mg/m^3)			
			Min	Max	Median	>0.3
1	January 1986	1	<0.08	<0.08	<0.08	0
2	July 1986	2	0.02	0.03	0.03	0
3	September 2004	3	0.1	0.58	0.12	1
4	July 2004	4	<0.05	<0.05	<0.05	0
5	June 2002	1	<0.1	<0.1	<0.1	0
6	September 2004	5	<0.05	0.07	<0.05	0
7	October 2004	2	<0.05	0.05	0.05	0
8	September 2004	6	<0.05	0.05	<0.05	0
8	June 1991	4	0.01	0.1	0.02	0
10	September 2004	5	<0.05	<0.05	<0.05	0

Table 1.5.4: estimated number of UK metal finishing businesses

Business type	**Number of premises**
Electroplaters	300 to 400
Anodisers	200
In-house electroplating facility	100

Table 1.5.5: estimated worker/exposure profiles for metal finishing businesses

Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
	M	F	<5	5 – 15	>15	Frequency (events/wk)	Number / event	Event duration (hrs)	Data (Y/N)
3150	>75	<25	800	1150	1200	5	1	8	Y

Industry estimate an average of 18 employees per site, with 25% of these potentially exposed. This would equate to a maximum of 3,150 potentially exposed workers ((400 + 200 + 100) x 18 x 0.25).

However, if only anodising has the potential for exposures to exceed 0.3 mg/m^3 then the estimated number of workers potentially exposed above 0.3 mg/m^3 falls to 900. The proportion of these workers exposed above 0.3 mg/m^3 is dependant upon the quality of exposure controls actually employed. This cannot be estimated accurately from the limited data currently held by HSE.

Sulphuric acid is used as an agricultural desiccant in crop treatment. HSE engaged with industry in 2002 to carry out a national survey of this work activity and thus have good quality, recent, quantitative exposure data for this activity. Estimated worker profiles (including exposure) for this activity are shown at table 1.5.6.

Table 1.5.6: estimated worker/exposure profiles for crop spraying

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
		M	F	<5	5 – 15	>15	Frequency (events/wk)	Number / event	Event duration (hrs)	Data (Y/N)
Crop spraying	50 to 100	>90	<10	No data			7[1]	1	8	Y[2]

[1]This work is seasonal for about six weeks per year per worker
[2] Inhalation exposure measurements

Sulphuric acid is applied using dedicated spraying equipment. Operators sit in the closed cab of the sprayer and acid is sprayed from numerous heads attached to booms extending several metres from each side of the cab. Typically the cabs are fitted with filtration on the air inlets to remove acid mist, and other particulate material, from the air entering the cab.

Approximately 12,500 tonnes of 77% sulphuric acid are applied to 80,000 hectares of potatoes annually. Work is seasonal and carried out by an estimated 50 to 100 contractors. Spraying activity in a particular geographical area may spread over 6 weeks and it is assumed that this is the maximum period for which any individual sprayer would be exposed. During this period operators may work for 10 to 12 hours per day, six or seven days per week.

There are 11 data points on NEDB for sulphuric acid mist exposure for crop spraying. These were all obtained during a national HSE industry survey in 2002. Statistical analysis of the data from this work indicates that 95% of all exposures would be 0.3 mg/m^3 or less for this application.

1.6 Aromatic amines (4,4-methylene bis(2-chlroraniline) [MbOCA], Methylene dianiline [MDA])

MbOCA carries a UK workplace exposure limit (WEL) of 0.005 mg/m^3, 8 hour TWA, and a biological monitoring guidance value (BMGV) of 15µmol/mol creatinine, urine post-shift sample. As a carcinogen there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP. MbOCA carries ‘Sk’ notation, indicating that exposure by the dermal route can add to the systemic dose. Absorption through the skin is the main route of exposure.

MbOCA is an elastomer (curing agent) and is mixed with isocyanate (mainly TDI) based pre-polymer resins in the manufacture of polyurethane products. There is no UK manufacture of MbOCA but three suppliers import for supply to the UK

Some 25 UK companies used over 200 tonnes of MbOCA (and 2000 tonnes of resin) in 2005. This represents a growth in use compared to 1984 when about 36 UK companies used 100 tonnes. Almost half of the user companies employ less than 10 workers and it is estimated that about 300 workers (almost all male) may be directly exposed to MbOCA during handling and over 1000 workers indirectly.

Table 1.6.1: estimated worker/exposure profiles for MbOCA

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
		M	F	<5	5 – 15	>15	Frequency (events/wk)	Number / event	Event duration (hrs)	Data (Y/N)
Handling	300	>95	<5	75	90	195	5	300	8	Y[1]

[1]Inhalation exposure measurements, biological monitoring data, surface samples and glove samples

The handling of MbOCA is by manual and/or automatic (e.g. heating and mixing in a reactor vessel and automatic dispensing) means. Manual casting consists of seven stages – scooping, weighing, melting, and mixing with pre-polymer resin, casting, curing and finishing. Inhalation and skin exposure to the substance can occur during all stages of polyurethane production. Weighing, melting, mixing and casting are generally carried out under extraction. There is the potential for surface contamination with MbOCA during all process stages in particular during scooping, weighing and pouring into moulds.

HSE carried out a national occupational hygiene survey of MbOCA users in 2005. Over 80 personal exposure samples were collected. Thirteen (16%) personal exposures had detectable MbOCA and 2 exposures exceeded the WEL (the highest 0.0111mg/m^3 8-hour TWA). The high exposures occurred when pouring into moulds without extraction.

A total of 78 urine samples were also collected to measure the concentrations of urinary MbOCA. Forty (51%) of the urine samples had detectable urinary MbOCA levels. Three (4%) of these samples (from workers pouring moulds) were above the BMGV of 15umol/mol creatinine and 21% of those indirectly exposed to MbOCA had detectable urinary MbOCA levels.

A total of 334 surface samples were taken from MbOCA user sites. The majority of samples (71%) had measurable concentrations of MbOCA indicating poor handling and poor cleaning of spillages. Concentrations were particularly high around hoppers and weighing scales. There was also evidence that external surfaces of imported MbOCA drums were contaminated with the chemical.

A total of 147 glove samples (inner and outer gloves) were taken. The concentrations of MbOCA on the outer gloves were higher than those of the inner gloves. Thirteen types of outer gloves/gauntlets (e.g. mainly leather, Terry towelling) and 5 types of inner gloves (e.g. mainly cotton, disposable latex) are worn in the industry; there is no standardisation.

Fume cupboards are mainly used to control MbOCA exposure but partial booths and canopies are also used. The survey revealed that 14 (70%) of the

MbOCA users had not carried out a thorough examination and test of their LEV systems as required by COSHH. Most of the LEV systems tested during the survey performed poorly with capture and/or face velocities well below 0.5 m/s and were poorly maintained

There is widespread evidence of unsuitable and insufficient risk assessments, poor maintenance of PPE/RPE, a lack of awareness of respirator fit tests, inadequate storage and welfare facilities, insufficient training, instruction and information etc. The provision of health surveillance was poor as only 12 companies carried out urinary MbOCA testing every 6 months as recommended and 2 companies never test urine samples.

MDA carries a UK workplace exposure limit (WEL) of 0.08 mg/m^3 8 hour TWA and a biological monitoring guidance value (BMGV) of 50 µmol/mol creatinine. As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP. MDA carries 'Sk' notation, indicating that exposure by the dermal route can add to the systemic dose.

MDA is not manufactured in the UK but HSE estimate that approximately 2,550 tonnes/yr are imported. Data available (circa 1991) to HSE identifies that MDA is used as a curing agent in multi-pack epoxy resin products, designed for specialist applications and more than 1000 workers are potentially exposed during epoxy formulation, predominantly by the dermal route. There was evidence of high exposures for some activities (handling MDA flakes and spraying MDA-based coatings) and reliance on PPE for control.

The largest known importer was approached during the phase 2 reviews, but to date has supplied very little information to HSE.

Two formulators were visited as part of the phase 2 surveys and they explained that there are now six formulators in the UK. Typically, the two companies visited import 40 tonnes/yr for blending into final product containing free unreacted monomeric MDA. Thirteen operators at the two sites may be exposed to MDA during 1 hour weekly or 2 day monthly campaigns.

Two users were also visited as part of the phase 2 surveys. One user encapsulates electronic components for protection against aggressive environments. This site handle only small amounts, typically around 20 kg per year. However, MDA is used daily in a process with a good deal of manual operator input. The second user visited manufactures epoxy based foams. Typically, they use between 50 and 100 tonnes of MDA/yr. In total, sixteen operators at the two sites may be exposed to MDA on a daily basis. There may be up to 100 user companies but in the absence of information from the key importer this data cannot be confirmed.

1.7 TRIGLYCIDYL ISOCYANURATE (TGIC)

TGIC carries a UK workplace exposure limit (WEL) of 0.1 mg/m^3 8 hour TWA. As a carcinogen, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

HSE reviewed exposure control standards to TGIC in 1992. Exposure measurements were recorded during the formulation and use of powder coatings. A total of 28 personal exposure measurements were made for formulation. Exposures (8 hr TWA) ranged from 0.01 to 0.44 mg/m^3 with a mean of 0.1mg/m^3 and 35% exceeded the mean. A total of 53 personal exposure measurements were made for application of powder coatings. Exposures ranged from 0.001 to 1.5 mg/m^3, with a mean of 0.24 mg/m^3 and 52% exceeded 0.1 mg/m^3.

The use of RPE was fairly common and so actual exposures are potentially somewhat lower in this situation. Anecdotal evidence indicates that powder coatings containing TGIC continue to be used with less than adequate exposure control.

There is no UK manufacture of TGIC. The 1992 review clearly demonstrated evidence of poor exposure control standards in the powder coating industry. No further reviews have been carried out since then. Approximately 400 tonnes/yr were imported in 1992 and this peaked in 1997 at about 500 tonnes/yr. Since then however, usage has declined steadily and only 17.5 tonnes were imported in 2005. Further reductions are anticipated, as the surface coating industry prefer now to apply primid based polyester products. Use of TGIC is now believed to be intermittent in nature by an estimated 100 workers at an estimated 10 user sites.

1.8 Beryllium and compounds

Beryllium and compounds carry a UK workplace exposure limit (WEL) of 0.002 mg/m^3 8 hour TWA. As a carcinogen with R49 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

There is no extraction of beryllium or manufacture of any of its compounds in the UK. The uses are as the pure metal, its alloys or its oxide. Only one company in the UK machines pure beryllium and exposure is well controlled. Only one company in the UK uses beryllium oxide and here too exposure is well controlled and the numbers potentially exposed are low (maximum of about 22 in each company). Approximately 51 companies employing approximately 700 employees (assuming an average of 14 workers per company) in the UK manufacture/machine products containing beryllium as an alloy. Any excess pure metal or alloy from UK manufacturing industry is returned abroad to the original supplier.

Recycling of electronics, computers and scrap alloy to recover copper could result in the potential for beryllium exposure however, Enquiries to a number of metal recyclers indicate that smelting of scrap metal containing beryllium does not occur in the UK and that such material is largely exported.

Table 1.8.1: exposure to beryllium and compounds

Work activity	Potentially exposed population	Gender (%)		Length of service (Years)			Exposure events		
		M	F	<5	5 – 15	> >15	Duration	Days worked	Data (Y/N)
Handling beryllium oxide powder	22	90	10			22	< 0.5 hrs/day	5	N
Machining/cutting beryllium metal	700	90[2]	10[2]		190[2]	510[2]	8.5 hrs/day	4.5	Y[1]
Aluminium production	120	100	nil			120	12 hrs/day	4	Y[1]

[1]Inhalation exposure measurements and biological monitoring data may become available and will be added.
[2] Estimates based on information provided by six companies visited.

The evidence from visits indicates that engineering companies tend to use a variety of metals for their manufacturing activities and generally process beryllium/copper parts infrequently and not all actually machine the alloy. In cases where the alloy is drilled this takes place for a short time and exposure is to small amounts of swarf rather than dust. Where grinding takes place this is more problematic although in the one firm where this activity was undertaken this was only for a short time and the beryllium/copper alloy was only one of a number of metals being used.

There are five records dating from 1987-1990 on NEDB concerning beryllium. Four of these relate to beryllium/copper and one to beryllium oxide use in ceramics. Of these 5 companies, one is no longer in business and three of the others were visited as part of the 2006 survey. Occupational exposure data for a variety of tasks was submitted as part of an October 1991 WATCH paper on beryllium exposure and identified all exposures as below the WEL.

A biological monitoring programme has been initiated at the three sites where beryllium metal or beryllium/copper is used and at one site where aluminium ore (which contains beryllium as an impurity) is crushed.

1.9 Nickel and compounds

Nickel and its inorganic compounds (with some exceptions) carry a UK workplace exposure limit (WEL) of 0.1 mg/m^3, 8 hour TWA. Insoluble nickel compounds are assigned a WEL of 0.5 mg/m^3 and are not classified as carcinogens.

As carcinogens, nickel oxide, nickel sulphate and nickel chloride also carry an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

There is no mining or smelting of nickel ores in the UK but refining of nickel oxide is carried out at only one UK site using the carbonyl process. The main use is in the production of alloys (including stainless steel) and to a lesser extent in nickel plating and the production of batteries, catalysts, coinage welding rods and magnets.

HSE have agreed with industry to carry out sampling and monitoring visits to a small number of foundries that manufacture alloys containing nickel, as there are no available exposure data for this work activity. The types of foundry likely to incur nickel exposures are given at table 1.9.1.

Table 1.9.1: Types of foundry likely to incur nickel exposures

Type of Foundry	**Likely carcinogens evolved**
Iron	PAHs, nickel (high), chrome, RCFs and silica
Steel	PAHs, nickel, chrome, RCFs and silica
Lost wax investment castings	PAHs, nickel, RCFs and silica
Copper	PAHs, nickel, RCFs and silica

Industry data made available to HSE identifies that in 2004 there were estimated to be a total of 320 foundries employing 18,665 workers likely to incur nickel exposures. The foundry types and likely employee profiles are given at table 1.9.2.

Table 1.9.2: Types of foundry and estimated employee profiles

Type of Foundry	Estimated number of Foundries	Estimated total potentially exposed population	Gender (%)		Estimated length of service (Years)		
			M	F	<5	5 – 15	> >15
Iron	200	11,670	90	10[1]	1000	670	10,000
Steel	55	3205	100	nil	300	105	2800
Lost wax investment castings	45	2625	90	10[1]	260	65	2300
Copper	20	1165	100	nil	115	50	1000

[1] Iron and Lost wax investment foundries employ female workers to carry out the fettling and finishing of small parts.

Industry estimate there are up to 500 nickel electroplating businesses in the UK (table 1.9.2 refers) employing an average of 18 employees per site, with 25% of these potentially exposed. This would equate to a maximum of 2,250 potentially exposed workers ((400 + 100) x 18 x 0.25).

Table 1.9.2: estimated number of UK nickel electroplating businesses

Business type	**Number of premises**
Electroplaters	300 to 400
In-house electroplating facility	100

Table 1.9.3: estimated worker/exposure profiles for UK nickel electroplating businesses

Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
	M	F	<5	5 – 15	>15	Frequency (events/wk)	Number / event	Event duration (hrs)	Data (Y/N)
2250	>75	<25	570	820	860	5	1	8	Y

HSE have agreed with industry to carry out sampling and monitoring visits to a small number of nickel electroplating businesses, as there are no available exposure data for this work activity.

In general, exposure will vary from the short and infrequent (eg welding or grinding stainless steel) to regular and significant (e.g. nickel chemicals production). Exposures in smelting and refining are generally well below 1 mg/m^3 but higher exposures may occur in furnace charging, tapping and cleaning and in powder plants where RPE is necessary. Exposures are generally low in welding, hot cutting and machining of alloys. Levels are well controlled in catalyst production but in dusty jobs (e.g. metal spraying, nickel-compound making and packing) elevated exposures have occurred.

1.10 Hexavalent chromium and compounds

Hexavalent chromium compounds cover a wide range of compounds (chromium trioxide, chromic acid, lead chromate, chromyl chloride, potassium chromate, potassium dichromate, zinc chromates). They carry a UK workplace exposure limit (WEL) of 0.05 mg/m^3, 8 hour TWA. They are also assigned a BMGV of 10 µmol/mol creatinine). As carcinogens, they also carry an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

Chromium (VI) compounds are the primary source of all other chromium chemicals and pure metallic chromium. They are used in plating and anodising solutions, in the production and use of stainless steel and other alloys, pigments and dyestuffs, catalysts and in certain refractory materials. They are no longer used in wood preservatives following legislative restrictions and the extent of use in electroplating has declined through substitution by other materials and by the introduction of chromium (III) processes for some decorative applications.

Chromium (VI) compounds can also arise as fume from welding stainless steel. The number of welders exposed to chromium (VI) is not known, however, there are estimated to be more than 60,000 welders employed in maunufacturing businesses where welding of stainless steels could be undertaken. Short-term exposures in stainless steel welding vary widely and are controlled by the use of LEV and RPE. Personal exposures substantially above 0.5 mg/m^3 have been recorded and anecdotal evidence suggests poor standards of control to be widespread.

Industry data made available to HSE identifies that in 2004 there were estimated to be a total of 255 foundries employing 14,875 workers likely to incur chrome exposures. The types of foundry likely to incur chrome exposures are given at table 1.10.1 and the their likely employee profiles are given at table 1.10.2.

Table 1.10.1: Types of foundry likely to incur chrome exposures

Type of Foundry	**Likely carcinogens evolved**
Iron	PAHs, nickel (high), chrome, RCFs and silica
Steel	PAHs, nickel, chrome, RCFs and silica

HSE have not to date, considered there to be a significant risk to foundry workers from chrome exposures but will re-examine the possibility.

Table 1.10.2: Types of foundry and estimated employee profiles

Type of Foundry	Estimated number of Foundries	Estimated total potentially exposed population	Gender (%)		Estimated length of service (Years)		
			M	F	<5	5 – 15	> >15
Iron	200	11,670	90	10[1]	1000	670	10,000
Steel	55	3205	100	nil	300	105	2800

[1] Iron foundries employ female workers to carry out the fettling and finishing of small parts.

Industry estimate there are up to 500 chrome-electroplating businesses in the UK (table 1.10.3 refers) employing an average of 18 employees per site, with 25% of these potentially exposed. This would equate to a maximum of 2,250 potentially exposed workers ((400 + 100) x 18 x 0.25).

Table 1.10.3: estimated number of UK chrome electroplating businesses

Business type	**Number of premises**
Electroplaters	300 to 400
In-house electroplating facility	100

Table 1.10.4: estimated worker/exposure profiles for UK chrome electroplating businesses

Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
	M	F	<5	5 – 15	>15	Frequency (events/wk)	Number / event	Event duration (hrs)	Data (Y/N)
2250	>75	<25	570	820	860	5	1	8	Y

In electroplating, sprays or aerosols may be released from the plating baths while in active use and LEV and PPE is needed to control inhalation and dermal exposure. Exposures are generally well below 0.05 mg/m^3 with most (90%) being below 0.01 mg/m^3

Exposures in chromate pigment manufacture (mainly powder handling) averaged 0.06 mg/m^3 but ranged up to 0.3 mg/m^3. Exposures in pigment use were much lower, averaging 0.01 mg/m^3. RPE is needed in some powder handling, stainless steel welding and spray painting operations (specific issue in relation to chromate primers in the shipbuilding industry). Exposures from the use of wood preservatives and from cement dust, which contains traces of chromium, are low. Data recently aquired to support the assigning of a BMGV will be added to this review in due course.

2.0 CARCINOGENS OF POSSIBLE CONCERN

These are the carcinogens the phase 1 review considered might be of concern but further background information would be required. The basis of their inclusion is either high potency or evidence to suggest widespread use and potential for significant exposure.

2.1 Refractory Ceramic Fibres (RCFs) and special purpose fibres

RCFs are high temperature insulation wools produced at two UK sites by electric fusion from a mixture made up essentially of silica and alumina. RCFs were developed in the 1950s and have been manufactured on an industrial basis for some 50 years.

RCFs carry a UK workplace exposure limit (WEL) of 5 $mg.m^{-3}$, 1 fibre/ml, 8hr TWA. As a carcinogen with R49 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

They are used most commonly to line furnaces, kilns and heaters but can be found as insulants in: domestic boilers (floor standing only); ladles and casts in foundries; and, in the automotive industry for catalytic converters. Their use is now in decline however as a result of the increased use of low bio-persistent wools. Production peaked at 8,000 tonnes in 1994 and the latest industry data estimates production for 2006 will be approximately 4,800 tonnes. The total exposed population in manufacture, use and removal is estimated at 3,500 workers.

There is a well-established industry responsible care programme. Personal exposure data measured by industry over the last seven years identifies 87% of measured exposures as below the WEL. Exposures in excess of the WEL tend to occur during maintenance operations, most notably furnace relining, and require the use of RPE to attenuate exposures.

2.2 Leather dust in shoe manufacture

The chemical nature of the hazards present in boot and shoe manufacture and repair is not well defined. The available literature indicates the following substances may have been present in this industry: silicones and waxes; vinyl chloride monomer; isocyanides; benzene; formaldehyde; and other solvents. Hexavalent chromium was used in the past for tanning leather and residual chromium may have been present in leather dust.

The COSHH Approved Code of Practice indicates that exposures to “leather dust in boot and shoe manufacture, arising during preparation and finishing.” should be reduced as far as reasonably practicable, well below the limits for dusty particles i.e., total inhalable dust 10 $mg.m^{-3}$ 8hr TWA and respirable dust 4 $mg.m^{-3}$ 8 hr TWA.

Ten major companies in the UK, manufacture traditional leather boots and shoes. These companies each employ between 40 and 100 workers. About 10% (100 max) of the workers are potentially exposed to leather dust during finishing of the boots and shoes. The remaining 90% are employed in the general assembly of boots and shoes and are not at risk of exposure to the leather dust. The workers are skilled and experienced, many having 20 to 30 years experience.

Table 2.2.1: leather dust exposure in shoe manufacture.

Work activity	Potentially exposed population	Gender (%)		Length of service (Years)			Exposure events		
		M	F	<5	5 – 15	> >15	Duration	Days worked	Data (Y/N)
General boot and shoe assembly	nil	60	40		15	150	nil	4.5	N
Boot and Shoe finishing	100 max	100	0			30	8.5 hrs/day	4.5	N

Industry recognizes exposure to leather dust as an area of concern and has sought to significantly reduce worker exposure. Control measures at the sites visited were all effective in controlling workers exposure to leather dust and needed no further improvement. Dust extraction was fitted to all the machines that generate leather dust and all surfaces appeared free of dust.

2.2 Plastic process fume

ABS (acrylonitrile butadiene styrene) plastics are used in a wide variety of applications as they offer good surface quality, colourfastness, luster, high heat resistance and will tolerate high impact.

Studies have shown however that when ABS plastics are heated at temperatures in excess of 350^{o}c, the carcinogens acylonitrile and butadiene will evolve. Industry were questioned whether hot cutting could generate a surface temperature greater than 350^{o}c at the point of cut. Their response however was to assure HSE that process temperatures would not normally exceed 250^{o}c, otherwise the product would begin to decompose and suffer irreversible damage.

Research has also shown that a number of carcinogens, principally PAHs, are liberated from thermal decomposition of many common plastics. These include polycarbonate, polyethyleneterephthalate (PET) and PVC. Thermal decomposition can occur wherever laser cutting is performed. The prevalence of this technique is unknown, but this was increasing in use in the early 1990s. Further investigation will be required to establish the true risk associated with this practice.

2.4 Dyestuffs - Auramine manufacture, Magenta manufacture, CI direct dyes (black, blue, red, disperse blue, violet), 3,3-dichlorobenzidine

Auramine and magenta manufacture are both carcinogens as defined in COSHH Regulation 2(1). Industry confirms however that there are no remaining manufacturers of either of these dyestuffs in the UK.

They advise also that the only remaining carcinogen used in the manufacture of dyes or pigments is 3,3-dichlorobenzidine. This is used to manufacture yellow/orange pigment and is manufactured at two UK sites. They estimate that no more than ten workers at each site are potentially exposed. Some developmental work will also be undertaken involving approximately 20 laboratory workers. Typically, such activities are carried out under controlled conditions in a fume cupboard and exposure risk will be low. Standard industry health surveillance is also provided.

The yellow/orange pigment remains in widespread use in the manufacture of printing inks, plastics and paints. Very low levels of active carcinogen remain in these products, typically no more than 500ppm. The products are not classified as carcinogenic and their use is not considered to present an exposure risk.

2.5 Nitrosamines

N-Nitrosamines are a group of organic substances which have the general chemical formula $R_1(R_2)$-N-N=O. R_1 and R_2 can be virtually any organic group, although they are usually either alkyl or aromatic in nature. They are generated adventitiously from a number of industrial processes as result of nitrosation of amines and many are genotoxic carcinogens.

Main occupational exposures occur in rubber industry, foundries and chemical industry. In the late 1980's, a number of laryngeal cancers occurred in workers in the German rubber industry and were linked to nitrosamine exposure.

There are no UK workplace exposure limits for nitrosamines. The German government however has set a general industry limit of 1 $\mu g/m^3$ with a special dispensatory limit of 2.5 $\mu g/m^3$ for the rubber vulcanisation process.

Task specific exposure measurements recorded in a HSL Survey in the late 1990s, on usage and exposures indicate that exposure control could possibly be improved in the rubber industry by substitution and or better engineering controls. Unfortunately, this survey did not record rubber fume exposures at the general rubber goods manufacturing sites visited so a number of revisits will be carried out to sample for both nitrosamines and rubber fume at general rubber goods manufacturing sites. The task specific survey exposure data for nitrosamines is shown at table 2.5.1.

Table 2.5.1: task specific nitrosamine exposures from HSL survey

Site ID	Industry	No samples	Results µg/m^3	Main nitrosamines detected
1	Tyre manufacture	18	ND – 0.27	NMOR, NDMA, NDEA
2	General rubber goods manufacture	15	0.06 – 8.85	NDMA, NDEA, NPIP, NDBA
3	Fish smoking	1	ND	
4	Fish smoking	2	ND	
5	Ferrous foundry	12	ND – 0.2	NMEA,NDMA,
6	General rubber goods manufacture	7	1.84 – 3.43	NDMA, NMOR
7	Tyre manufacture	12	ND	
8	Aluminium foundry	9	ND	
9	Metal working	10	ND	
10	General rubber goods	14	ND – 3.37	NMOR, NDMA
11	Metal working	12	ND	
12	Rubber curing accelerator manufacture	3	0.25 – 0.51	NPIP, NDBA, NDMA
13	General rubber goods	5	1.33 – 4.35	NMOR, NDMA
14 - 19	Food manufacture	18 static samples	ND	
20 - 25	Food cooking	12 static samples	ND	

Note: ND indicates no measurable detection of nitrosamine

2.6 Hydrazine, 1,2-dimethyl hydrazine, salts of hydrazine (sulphate, nitrate, perchlorate)

Hydrazine carries a UK workplace exposure limit (WEL) of 0.02 ppm, 8 hour TWA, with a STEL of 0.1 ppm. As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP. Hydrazine carries ‘Sk’ notation, indicating that exposure by the dermal route can add to the systemic dose.

There is no UK manufacture or use of pure hydrazine. For all applications requiring hydrazine in the UK, hydrazine hydrate is preferred. There is no UK manufacture of hydrazine hydrate and 500 to 1,000 tonnes per year are imported. The majority of this material (in excess of 90%) is supplied via a single UK agent, operating from a single site. There are 2 main industrial uses of hydrazine hydrate in the UK. It is used as an oxygen scavenger in boiler feed water in power stations, and also as a raw material for synthesis in the chemical industry.

Worker profiles (including exposure) for the supply, distribution and use of hydrazine hydrate are shown at Tables 2.6.1 to 2.6.3.

Table 2.6.1: supply and distribution of hydrazine hydrate

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
		M	F	<5	5 – 15	>15	Frequency (events/wk)	Number/ event	Event duration (mins)	Data (Y/N)
Bulk transfer (site 1)	3	100	Nil		3		3	1	180	Y[1]
Bulk transfer (site 2)	3	100	Nil			3	1	1	30	Y[1]
QC sample (site 1)	3	100	Nil		3		3	1	<5	Y[1]

[1] Biological monitoring data may become available and will be added.

Table 2.6.2: use of hydrazine hydrate in the chemical synthesis sector

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
		M	F	< 5	5 – 15	>15	Frequency (events/wk)	Number/ event	Event duration (mins)	Data
Bulk transfer (large user, site 3)	14	100	Nil		14		6	1	15	Y[1]
QC sampling (large user, site 3)	14	100	Nil		14		6	1	2	Y[1]
Bulk transfer (10 small users)	100	100	Nil		No data		6		30	N
QC sampling (10 small users)	100	100	Nil		No data		No data	No data	No data	N

[1] Biological monitoring data may become available and will be added.

Table 2.6.3: use of hydrazine hydrate in power stations (estimated 90 sites)

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
		M	F	<5	5 – 15	>1>15	Frequency (events /week)	Number/ event	Event duration (mins)	Data
Bulk transfer	1800	100	Nil	No data	No data	No data	90	1	15	Y[1]

[1] Biological monitoring data may become available and will be added.

An estimated 2,000 workers may be occupationally exposed in the UK. Exposures are all task specific, and away from distribution (less than 10 workers at 2 workplaces) no workers would typically be exposed for more than 30 minutes at a time, with a maximum of three exposure events per week. The majority of exposed individuals would be exposed for shorter periods, and less frequently than this.

A high proportion of user sites have effective control measures utilising contained systems. Limited exposure data held on NEDB indicates industry can comply with the WEL. There have been significant improvements in control in recent years. There is a clear will amongst stakeholders to continue to seek improvement in control.

Table 2.6.4: summarised quantitative exposure data from NEDB

Site ID	Transfer system	Exposure duration (minutes)	Measured exposure (ppm)	Equivalent 8 hour TWA (ppm)
Site 1 – visit 1	Open, manual	45 (approx)	0.0034	0.00032
Site 1 – visit 2	Open manual	60 (approx)	0.0073	0.00091
Site 1 – visit 3	Open, manual	41	0.01	0.00085
Site 2 – task 1	Closed, manual	15	0.0015	0.000047
Site 2 – task 2	Closed, manual	15	0.0023	0.000072

2.7 Epichlorohydrin

Epichlorohydrin (1-chloro-2-3-epoxypropane) carries a UK workplace exposure limit (WEL) of 0.5 ppm, 8 hour TWA, with a STEL of 1.5 ppm. As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible, to reduce exposure to ALARP.

Epichlorohydrin is not manufactured in the UK but approximately 4,000 tonnes/yr are imported. It is used in water treatment systems, as a flame retardent and in the pharmaceutical industry. There are seven principal purchasers who use almost all of the imported epichlorohydrin. A small amount (no more than 50 tonnes/yr) however is used by a large number of small users.

The seven principal users take delivery by tanker for transfer to bulk storage. Dry break couplings are used at the tanker delivery point so exposures at this point will generally well controlled as delivery is carried out under near full containment. Transfer from bulk storage to the process is performed under total containment thus eliminating exposure risk.

One supplier decants epichlorohydrin and repackages for smaller users. There will be potential for exposure at delivery, repackaging and final application. HSE have no available exposure data and further contact with this small users group will be necessary.

2.8 Dimethylsulphamoyl chloride

There is evidence of high potency for this chemical. Enquiries made of the UK chemical manufacturers and importers however do not identify there to be any UK manufacture or supply of this chemical.

2.9 1-methyl-3-nitro-1-nitrosoguanadine

There is evidence of high potency for this chemical. Enquiries made of the UK chemical manufacturers and importers however do not identify there to be any UK manufacture or supply of this chemical.

2.10 Dimethylcarbamoyl chloride

There is evidence of high potency for this chemical. Enquiries made of the UK chemical manufacturers and importers however do not identify there to be any UK manufacture or supply of this chemical.

2.11 1,3-propane sultone

There is evidence of high potency for this chemical. Enquiries made of the UK chemical manufacturers and importers however do not identify there to be any UK manufacture or supply of this chemical.

2.12 1,4-dichlorobut-2-ene

There is evidence of high potency for this chemical. Enquiries made of the UK chemical manufacturers and importers however do not identify there to be any UK manufacture or supply of this chemical.

2.13 Ethyleneimine

There is evidence of high potency for this chemical. Enquiries made of the UK chemical manufacturers and importers however do not identify there to be any UK manufacture or supply of this chemical.

2.14 Dimethyl sulphate

Dimethyl sulphate carries a UK workplace exposure limit (WEL) of 0.05 ppm, 8 hour TWA (ref 2). As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP. Dimethyl sulphate carries ‘Sk’ notation, indicating that exposure by the dermal route can add to the systemic dose.

Dimethyl sulphate is not manufactured in the UK but approximately 2,750 tonnes/yr are imported for internal use in chemical synthesis. Exposures will be generally well controlled as most operations are carried out under near full containment.

2.15 Chlorodimethyl ether (CDME) and Bis(chloromethyl)ether (BCME)

There is evidence of high potency for these chemicals. Enquiries made of the UK chemical manufacturers and importers however do not identify there to be any UK manufacture or supply of either chemical.

2.16 Styrene oxide

The CAREX database identifies that almost 18,000 workers were exposed to this agent in 1993. No evidence however of UK manufacture, import or commercial application has been identified in this review. No further action on this subject is anticipated.

3.0 PHASE 2 REVIEW - CARCINOGENS OF LOW CONCERN

These are the carcinogens for which the phase 1 review considered there to be sufficient evidence on use and control to conclude that they are of low concern in the order of priorities and would require no further investigation unless other evidence came to light.

3.1 Diesel Engine Exhaust Emissions (DEEEs)

DEEEs are a complex mix of particulates, gases and vapours, which occur whenever diesel fuelled engines operate. Hundreds of thousands of UK workers are occupationally exposed to DEEE with garages, motor vehicle repair, roll-on roll-off (RoRo) ferries, railway depots, forklift trucks (FLTs) and tollbooths as locations where significant exposures could occur. HSE survey in 1994/5 found that individual DEEE constituents with an OEL were well below that OEL and this exposure risk could be considered as one of low priority.

The best marker of exposure was identified as elemental carbon and highest exposures were in warehouses where FLTs operate and in mines.

A further small survey of ten sites was carried out in 2006 to bus garages, RoRo ferries and tollbooths. Personal exposures to respirable dust, total and elemental carbon, aldehydes, CO, CO_2 and PAHs were measured. Exposures were significantly below the appropriate WELs.

3.2 Benzene

Benzene carries a UK workplace exposure limit (WEL) of 1 ppm, 8 hour TWA. As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

Benzene is a highly flammable liquid, which occurs naturally in crude oil, natural gas and in some underground waters. It is manufactured from crude oil and it’s main use as a starting material for the manufacture of chemicals such as cyclohexane, ethyl benzene, and phenol and maelic anhydride. It was formerly used as a solvent but in most cases safer alternatives have now replaced this use. In the UK, petrol contains about 2-3% benzene and small amounts of it are produced when some organic substances burn incompletely e.g. cigarette smoke, vehicle exhaust and manufacture of coke from coal.

Several thousand workers are potentially exposed to benzene in the petrochemical industry (oil/gas exploration, refining, distribution and use in chemical synthesis). Several hundred workers will be exposed during coke oven operations and coal tar distillation. About a 1000 trading standards officers are exposed during inspection of petrol pumps and hundreds of thousands maybe exposed in motor vehicle repair shops and petrol stations. Exposure will occur via inhalation of vapour and dermal exposure to the liquid.

Manufacture of benzene takes place within enclosed plant, as do most of the processes using benzene as a raw material. Exposure will therefore only occur when this containment is breached for certain types of sampling, during maintenance and during tanker loading and unloading. Extensive data from industry is available and indicates that most exposures in the petrochemical industry are below 1 ppm. The highest exposures were observed for workers involved in distribution, particularly amongst loaders carrying out top loading operations (range <0.05 – 80 ppm), however, most exposures (>70% were below 1 ppm). Exposures for trading standards officers, petrol station attendants and laboratory staff were well below 1 ppm.

3.3 Vinyl chloride monomer

Vinyl chloride monomer (VCM) carries a UK workplace exposure limit (WEL) of 3 ppm, 8 hour TWA. As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

There is one UK manufacturer who produces 250,000 tonnes/yr. In addition, 150,000-230,000 tonnes/yr are imported into the UK. VCM is used to manufacture PVC at 4 UK sites. About 120 workers are employed at each manufacturing site. Very high standards of controls are employed during manufacture, transportation and conversion to PVC with exposures below the MEL and typically below 1 ppm.

3.4 Trichloroethylene

Trichloroethylene carries a UK workplace exposure limit (WEL) of 100 ppm, 8 hour TWA, with a STEL of 150 ppm. As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP. Trichloroethylene carries ‘Sk’ notation, indicating that exposure by the dermal route can add to the systemic dose.

There is one UK manufacturer who produces 70,000 tonnes/yr. There are no known available data on import/export/distribution. Trichloroethylene has widespread use as a degreasing agent, production of adhesives and refrigerants and in consumer products. There is evidence to suggest poor control within the degreasing operations.

3.5 Arsenic

Arsenic and arsenic compounds (except arsine) carry a UK workplace exposure limit (WEL) of 0.1 mg/m^3, 8 hour TWA. Arsenic trioxide has a carcinogen classification R45 and carries an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

There is no extraction of arsenic or any of its compounds in the UK. The only compound imported in significant quantities is the trioxide. One company import approximately 3 tonnes per year of the trioxide for use in the manufacture of specialist glass for the nuclear industry.

Table 3.5.1: use of arsenic trioxide in specialist glass manufacture

Work activity	Potentially exposed population	Gender (%)		Length of service (years)			Exposure events			
		M	F	<5	5 – 15	15 -20	Frequency (events /day)	Number/ event per week	Event duration (mins)	Data
Bulk transfer	9	100	Nil	0	1	8	10	70	40	Y[1]

[1] Biological monitoring data may become available and will be added

Exposures occur to 9 workers during bulk transfer operations that typically take 40 minutes with a maximum of seventy exposure events per week. The majority of the process is fully enclosed and exposures will be low.

A biological monitoring programme to investigate arsenic trioxide exposures has been initiated at the glass manufacturing site visited.

Small amounts of various arsenic compounds are imported for use in research. Additionally, gallium arsenide is imported for use in semi-conductor manufacture however this industry is well controlled and regulated.

3.6 Cadmium

Cadmium and cadmium compounds (except oxide fume, sulphide and sulphide pigments) carry a UK workplace exposure limit (WEL) of 0.025 mg/m^3, 8 hour TWA (ref 2). Cadmium oxide fume carries a UK workplace exposure limit (WEL) of 0.025 mg/m^3, 8 hour TWA and a STEL of 0.05 mg/m^3.

As carcinogens, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP for cadmium metal, chloride, fluoride, sulphate and oxide fume (carries R45 classification).

Evidence from the 2003 ESR review indicates that Cadmium is extracted and used in the UK but gives no details of UK production or use. Cadmium sulphate/chloride solutions occur as intermediates during the production of cadmium metal, in electroplating and pigment production.

The main uses of cadmium are in battery manufacture, pigment production, PVC stabilisers, plating and coating of metals and production of alloys. There is no Cd battery or Cd alloy manufacturing in the UK. Regulatory action restricts the use of Cd in PVC stabilisers, plating and coating of metals and pigment production. Historically the alloys used for silver solder contained up to 25% Cd, however, this use has declined in the last 10 years and there are very few places soldering Cd or soldering with Cd containing materials. The number of workers potentially exposed will be in the hundreds. Exposures during manufacture are generally below 0.01 mg/m^3. Exposures at brazing are generally low with mean concentrations ranging from <0.002 to 0.028 mg/m^3 (CF MEL 0.025 mg/m^3). Mean exposures for the cadmium pigment manufacture were in the range of 0.01 – 0.09 mg/m^3, however, most of this will be to the various cadmium pigments and not the starting material (CdO or Cd metal) or cadmium sulphate.

3.7 Ethylene oxide

Ethylene oxide carries a UK workplace exposure limit (WEL) of 5 ppm, 8 hour TWA. As a carcinogen with R45 classification, there is an additional, explicit requirement under COSHH to either prevent exposure or, where this is not possible to reduce exposure to ALARP.

There is one UK manufacturer who produces about 300,000 tonnes/yr and about 30 workers are potentially exposed during manufacture. Ethylene oxide is used as a chemical intermediate at about 8 UK sites in enclosed systems and is also used as a sterilising agent in hospitals. This is a minor use (1,000 tonnes/yr) and the available evidence indicates that exposure controls within hospitals are to a very high standard and, where possible, hospitals contract out sterilisation work requiring the use of ethylene oxide to dedicated sterilisation companies.

4.0 DISCUSSION

Currently, the chemical carcinogens considered to pose the greatest problems are those with either greatest inherent potency, those for which exposure is least well controlled and/or those with large exposed populations.

The risks to health posed by exposure to chemical carcinogens other than asbestos are not well understood. Quantification of the risks such chemicals pose can be especially difficult given the complex nature of occupational exposure and cancer development itself. There may well be more than one causative agent involved in the workplace exposure and more than one factor involved in the development of cancer. The long latency period of cancer development and the associated difficulty of attribution to work further make current risk levels unclear.

Ideally, real Occupational Hygiene data should be used to assess exposures but frequently this is not available. If data is available, one needs to estimate or determine the number of workers exposed at different exposure levels. Often however, there is no indication of intensity of exposure beyond ‘ever’ and ‘never’ or ‘high’ and ‘low’. Some assessors apply an arbitrary assumption 10% “high” and 90% “low”. Others use 50%. The selection is particularly important for chemical carcinogens which do not act with a genotoxic mechanism, for which there may be a threshold of response.

Table 4.1 summarises the data collected from the phase 2 reviews of those processes and/or chemical carcinogens observed as posing the greatest problems of:

- inherent potency;
- difficulty to control occupational exposure; or,
- involving potentially high numbers of exposed workers.

Many of the substances considered in the phase 2 reviews are currently assigned WELs. When these limits were set, the chronic irreversible health effects associated with these substances, principally carcinogenicity in most cases, lead to a maximum exposure limt (MEL) being assigned. MELs were not health-based limits. Most were set on the grounds of what industry could achieve with reasonably practicable controls, although socio-economic factors were also considered. Often, the exposure data considered when MELs were set was industry’s own data. Hence, it is to be expected that, for most substances considered the majority of exposures will be below the current WEL.

The most numerous occupational group (>200,000 workers) found to be at risk were those involved in woodworking. The primary health concern for these workers however is non-cancer respiratory disease, and as such the respiratory disease strand of the DRP will focus on this group. Stonemasons and welders of stainless steels are also large occupational groups potentially exposed to carcinogens (silica and chrome respectively). The primary health concern for these workers also is non-cancer respiratory disease and are also dealt with by the respiratory disease strand of the DRP. Interventions introduced by the respiratory disease strand will aim to reduce exposures and should therefore also result in a reduced cancer risk for these industries.

The iron and steel and rubber goods manufacturing industries combine relatively large numbers of potentially exposed workers (up to 40,000 workers) with both inherent potency and difficulty to control exposures.

There could be up to 3,000 workers in the metal finishing industry exposed to multiple agents with carcinogenic potential throughout their working day. Whilst exposures in the industry are generally less than the WELs for the constituent carcinogens, the high number of workers potentially at risk demonstrates widespread use and potential for prolonged multiple exposures.

A similarly high number of workers are potentially exposed to RCFs, however the industry responsible CARE programme continues to monitor potentially exposed workers and numbers exposed are in decline.

A relatively high though scattered population may be exposed to hydrazine on an intermittent basis but available data indicates exposures are below the

WEL. Up to 700 workers may be exposed to beryllium but exposures are again below the WEL. The primary health concern for workers exposed to beryllium is non-cancer respiratory disease. No more than 100 workers are now probably exposed to TGIC (and then only intermittently) but exposures remain poorly controlled.

Exposures to MbOCA are better controlled now than in the recent past but the observed increase in usage may require further review by HSE. To date, little information has been collected on MDA and further work will be required in this area.

The only known peripatetic workers potentially exposed to chemical carcinogens of concern are chimney sweeps. Neither industry nor HSE, as yet, have any exposure data for this group of workers. HSE are working with the industry to establish data to quantify the standard of cleanliness to which sweeps work and establish the level of health risk. No results are yet available but will be added to this paper as soon as available.

Exposure to carcinogens in the chemical manufacturing and supply industry are generally well controlled as most operations are carried out under near full containment. This was identified in a recent HSE project established to review exposure control at specific tasks carried out at chemical carcinogen manufacture.

This study identifies five chemical carcinogens as manufactured in the UK. The remainder are imported. Further work is currently underway with the chemical distribution industry to review a further thirty chemicals to check on UK manufacture and supply.

It is likely that there could be a large number of SMEs engaged in the contract import, processing and repackaging of chemical carcinogens for use in the UK. Such contract processors and repackers comprise a group of workers who combine a number of the risk factors. They work closely, often in potentially dusty or contaminating activities of opening, milling, sieving and reweighing, with materials which, for one reason or another, the contracting company does not want to handle in-house.

In the past, HSE has found such contractors processing carcinogens (e.g. hydrazine sulphate), dye intermediates with structures suggesting high toxicity (e.g. chloronitroanilines), and similar risk chemicals. Typically, contract processors are hard to identify, to engage and to re-educate. Information accompanying the materials to be processed is often in short supply. When the contracting company is also the maker or importer (or employs the importer), it has a good deal of the responsibility for discovering safety information and advising and educating the contract processor and then needs to apply and use the information.

The phase 2 reviews did not identify dyestuffs as a potential risk. The phase 2 reviews did however identify a potential risk associated with plastic process fume. Some further review may also be necessary here.

The phase 2 reviews also identified the gender and age groups of the exposed workers. With few exceptions (some specialised foundry work) workers were predominantly male. The only known large group of potentially exposed female workers is in the microelectronics and semiconductor industry. Exposure controls in this sector are well established and effective and this sector requires no further attention within the DRP. The phase 2 reviews have not identified any significant female groups at risk bar those carrying out specialised foundry work.

Table 4.1: summary of processes and/or chemical carcinogens identified in phase 2 reviews as posing the greatest problems of inherent potency, difficulty to control or involving potentially high numbers of exposed workers.

Process and/or Chemical Carcinogen	Key Points
Wood Dust	• exposed population estimated at 219,000; • 27% of personal 8hr TWA measured exposures were greater than the WEL (5.0 mg/m^3); • primary health hazard non-cancer respiratory disease.
PAHs	• exposed population estimated at 34,300; • measured personal exposures range from 0.08 to 1912.6 µg/m^3 8hr TWA (mean 93.62 µg/m^3, median 15.24 µg/m^3); • occur in a wide variety of workplaces – timber treatment, coal and petroleum tar distillation, iron/steel production, pipeline coating and chimney sweeps; • HSE carrying out a programme of biological monitoring to investigate trends in exposure.
Ferrous foundry particulate	• atmospheric contamination in foundries can be a complex mixture of carcinogens such as PAHs, nickel, chrome, RCFs and silica; • primary health hazard for silica is respiratory disease; • total exposed population estimated at 31,500.
Rubber goods manufacture – potential exposure to rubber fume, rubber process dust and nitrosamines	• exposed population estimated at 10,000; • 19% of personal 8hr TWA measured exposures to rubber fume were greater than the WEL (0.6 mg/m^3); • 5% of personal 8hr TWA measured exposures to rubber process dust were greater than the WEL (6.0 mg/m^3); • measured personal (task specific) exposures to nitrosamines of up to 4.35 µg/m^3 at rubber goods manufacture indicate possibility of poor exposure control - HSE to carry out some sampling and monitoring visits to investigate.
Refractory ceramic fibres	• exposed population estimated at 3,500; • 13% of personal 8hr TWA measured exposures were greater than the WEL (1 fibre/ml); • well established industry CARE programme but high exposures can occur at furnace relining operations.
Metal finishing industry – potential exposure to nickel, chromium and/or sulphuric acid mist at electroplating and/or anodising.	• exposed population estimated at 3,150; • sulphuric acid mist exposure data measured from 2002 to 2004 range from <0.05 to 0.12 mg/m^3; • no available exposure data for nickel in electroplating - HSE to carry out some sampling and monitoring visits to investigate; • chrome exposures are generally less than the WEL (0.05 mg/m^3).
Hydrazine	• exposed population estimated at 2,000; • limited available exposure data indicates industry comply with the WEL (0.02 ppm); • HSE carrying out a programme of biological monitoring to investigate trends in exposure.

Beryllium	• exposed population estimated at 700; • limited available exposure data indicates industry comply with the WEL (0.002 mg/m^3); • HSE carrying out a programme of biological monitoring to investigate trends in exposure; • primary health hazard non-cancer respiratory disease.
MbOCA	• exposed population estimated at 300; • 16% of personal 8hr TWA measured exposures were detectable MbOCA; • <3% of personal 8hr TWA measured exposures were greater than the WEL (0.005 mg/m^3); • use of chemical likely to increase.
MDA	• exposed population estimated at 1,000; • at least 50 to 100 Te/yr imported; • incomplete data to draw conclusions yet.
TGIC	• exposed population (intermittent only) estimated at <100; • 35% of personal 8hr TWA measured exposures at formulators were greater than the WEL (0.1 mg/m^3); • 52% of personal 8hr TWA measured exposures at applicators were greater than the WEL (0.1 mg/m^3); • only 17.5 tonnes imported for use in 2005 compared to 500 tonnes in 1997 and further reductions are anticipated.
Pastics process fume	• research provides evidence of hazard which requires further investigation.

5.0 CONCLUSIONS

Occupational exposure to chemical carcinogens in current UK workplaces is in overall terms in decline. This is due to a number of factors:

- elimination or reduction in size of the process and the number of workers employed;
- substitution by a non carcinogenic alternative; and,
- improvements in exposure control.

The only carcinogens found to have increased in use over the last 10 to 15 years were MbOCA and Beryllium. The chemical manufacturing industry produce very few chemical carcinogens in the UK and contract processing and repackaging of imported chemical carcinogens by SMEs is suspected to be increasing.

The traditional areas of exposure risks to chemical carcinogens such as iron and steel production, rubber manufacture and metal finishing still exist as large UK employers despite the general shrinkage of the UK manufacturing industry.

J J McALINDEN
CHSD3

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