MAXIMUM EXPOSURE LIMIT FOR MANGANESE AND ITS INORGANIC COMPOUNDS
REGULATORY IMPACT ASSESSMENT

PURPOSE AND INTENDED EFFECT

Issue and objective

1. Manganese is a hard, brittle metallic element with a melting point of 1244 ^{o}C. It is brilliant white in colour with a reddish tinge. The principal manganese ores are pyrolusite, hausmannite and psilomelane; pure manganese is obtained electrolytically. There are a number of inorganic forms of manganese. The most commonly used are manganese sulphate, manganese dioxide, manganese oxide and potassium permanganate.

2. The Advisory Committee on Toxic Substances (ACTS) Working Group for the Assessment of Toxic Chemicals (WATCH) considered the risk assessment on manganese and its inorganic compounds in January 2000. WATCH concluded that the criteria for setting an Occupational Exposure Standard (OES) could not be met, and that in view of the neurological effects of manganese it was appropriate to set a Maximum Exposure Limit (MEL) (8-hour TWA). WATCH also concluded that the toxicological characteristics of manganese were such that neither a Short Term Exposure Limit (STEL) nor an “Sk” or “Sen” notation were appropriate, and that it was not possible to derive a biological monitoring guidance value (BMGV). A Chemical Hazard Alert Notice (CHAN) on manganese and its inorganic compounds, providing interim advice, was issued in June 2000.

3. The objective of setting a MEL for manganese and its inorganic compounds is to reduce occupational exposure and thereby reduce the risks of adverse health effects. This RIA informed ACTS of the costs to industry and the possible health benefits resulting from setting a MEL. The costs quoted in the document are (unless otherwise stated) those that were current at the time this RIA was written (2000).

RISK ASSESSMENT

4. Between 65,000 and 90,000 employees in Great Britain are exposed to manganese as a result of their occupation. The current exposure levels and numbers exposed in the business sectors affected are shown in detail in the section dealing with compliance costs for industry. The highest exposures are found in steelmaking, casting manganese steel (steel containing greater than 10% manganese), finishing (i.e. fettling, cutting etc) manganese steel, animal feed premix manufacture, mineral supplement manufacture and trace element fertiliser manufacture. 8-hour TWA manganese exposures in these industries/operations are mostly below 5 $mg.m^{-3}$. However, even with current

good practice, 8-hour TWA manganese exposures of between 2 to 3 $mg.m^{-3}$ are not unusual.

5. There is an extensive toxicology database for inorganic compounds of manganese, both in terms of animal and human data (Reviewed IPCS 1981, DFG 1999). However, no toxicological studies have been identified for elemental manganese and there are also no reliable data with which to compare the toxicological effects of dust or fume arising from processes involving manganese.

6. From a large number of recent epidemiological studies (WHO IPCS 1981; DFG 1999; Luccini *et al*. 1995, 1997, 1999; Gibbs *et al*. 1999; Crump and Rousseau 1999; Roels *et al*. 1999) it can be seen that the key health hazard associated with occupational exposure to inorganic manganese compounds is a disturbance of motor function, leading to loss of fine control of intentional movements. Typically, the mean occupational exposure levels at which motor effects have been reported in relatively recent studies range from 0.25 to 1.6 $mg.m^{-3}$ (8-hour TWA) for manganese in inhalable dust. However, the precise exposure/response relationship for the effects of manganese on neurological function has not been clearly characterised and a clear threshold level of exposure for the development of neurological effects cannot be reliably identified.

7. Historically, effects on the lungs (a poorly characterised pneumonitis condition) have been a prominent feature of occupational exposure to manganese. However, there is no evidence for effects on pulmonary function or respiratory symptoms in contemporary epidemiological studies with total inhalable manganese exposures from manganese dioxide below about 1 $mg.m^{-3}$, although only two studies have investigated this aspect (DFG 1999). The exposure concentrations at which respiratory effects would begin to occur are not known, nor is anything known about possible differences in the pulmonary effects of different manganese compounds. Unfortunately, the animal database provides little additional useful information in this regard, although it does confirm that high (approximately 43 $mg.m^{-3}$) manganese exposures (as manganese dioxide) over two weeks, can cause marked pulmonary oedema (Shiotsuka 1984).

8. It is evident from early reports of workers suffering from manganism that effects on libido and male fertility were commonly reported. Only two recent epidemiological studies (Gennart *et al*. 1992, Lauwerys *et al*. 1985) have investigated male fertility in manganese-exposed workers and they provide no reliable information concerning the potential effects of manganese on male fertility, largely because no information was sought from the wives of either the manganese-exposed workers or the control groups, and hence the influence of medical and sexual history, including the use of contraception, could not be taken into account. The animal database relating to the potential effects of

manganese compounds on fertility provides a variable pattern of results (reviewed Barlow and Sullivan 1982). Results from the more reliable studies indicate no effects of manganese on either the male reproductive organs, or on male reproductive performance, even when administered at systemically toxic doses. In contrast, there are studies claiming testicular toxicity at doses of manganese which do not produce any other toxicological effects. These "positive" studies are all of poor quality in terms of study design and clarity of reporting. Overall, there is no reliable evidence from any well-conducted animal study for an effect of manganese on the male reproductive organs. It seems more likely that the effects on libido and male fertility historically associated with manganism in humans were secondary to more general CNS disturbances rather than indicative of a direct effect on the gonads.

9. The potential mutagenicity of elemental manganese and its inorganic compounds has not been adequately investigated. Under certain experimental conditions, manganese compounds are mutagenic in bacteria. In addition, positive results have been reported in a variety of mammalian cell assays conducted *in vitro* using the divalent manganese ion (Oberly *et al*. 1982, Miyaki *et al*. 1979). The positive *in vitro* results arise as a secondary consequence of the substitution of magnesium ions by divalent manganese ions in DNA polymerases, which reduces the fidelity of DNA replication. No reliable *in vivo* data are available. However, no treatment-related tumours were observed in a well-conducted carcinogenicity study, offering some evidence for an absence of genotoxic carcinogenicity (NTP 1992).

10. There are no studies of the potential mutagenic effects of elemental manganese or its compounds in humans. There is only one study which has investigated the potential carcinogenicity of manganese compounds in humans (Kjuus *et al*. 1986); this was a cancer incidence study in ferroalloy workers (n=3961) exposed to manganese compounds for at least 18 months in Norway with a follow-up time of a minimum of 12 years. The results showed no increase in cancer (total or site specific) incidence.

INFORMATION SOURCES AND BACKGROUND ASSUMPTIONS

11. Two separate consultations with industry were undertaken for this RIA. In the first round (July 2000) three options were consulted on; 5, 0.5 and 0.1 $mg.m^{-3}$ and in the second round (June 2001) information was requested regarding three more options; 0.2, 1 and 2 $mg.m^{-3}$. Not everyone who responded to the first consultation replied to the second questionnaire and therefore there are some instances where information is not available across the whole range of options.

12. A number of organizations were contacted for information (see Results of Consultation). Some trade associations and businesses provided

recent exposure data which was not used in the risk assessment presented to WATCH in January 2000.

13. Information on the costing of RPE was obtained from HSE guidance note HSG53 (The selection use and maintenance of RPE, 1998), HSE Specialist Inspector's Report number 50 (Costing a RPE programme, 1996) and a manufacturer of RPE. The extra cost for an experienced chemist determining the manganese content of air samples was confirmed by HSL. LEV system prices were obtained from equipment manufacturers and some of the affected business sectors. An industrial vacuum cleaner manufacturer also supplied some costs. All other costs in this report were obtained from industry in 2000.

14. All other assumptions used in the estimation of compliance costs are detailed in Annex 1 (Detailed Compliance Costs). In some cases industry figures differ from HSE's calculations. We do not know the basis on which industry derived these costs.

Technical assumptions

15. Costs and benefits of this regulation are calculated over the appraisal period 2001/2 - 2010/11 and are expressed in net present terms. In arriving at ten year cost figures two adjustments are made. Firstly, earnings are assumed to rise by 1.8% per year in real terms which is the observed increase for the whole economy over the past twenty-five years or so. Secondly, costs are discounted to present value using the Treasury recommended 6% discount rate.

OPTIONS

16. The costs and benefits of setting MELs for manganese and its inorganic compounds at 5, 2, 1, 0.5, 0.2 and 0.1 $mg.m^{-3}$ will be assessed. The mean occupational exposure levels at which neurological effects have been observed range from 0.25 to 1.6 $mg.m^{-3}$ (8-hour TWA) for manganese in total inhalable dust. The precise exposure-response relationship for the effects of manganese on neurological function has not been clearly characterised, and a clear threshold level of exposure below which there would be no risk of developing neurological effects cannot be reliably identified. Therefore, the level of risk to human health resulting from long term exposure to levels below 0.1 $mg.m^{-3}$ is uncertain. Although it is below the range in which neurological damage has been observed, concentrations greater than or equal to 0.5 $mg.m^{-3}$ are above the range in which neurological changes are known to occur.

BENEFITS

17. The key health hazard from occupational exposure to manganese and its inorganic compounds is a neurological syndrome "manganism", characterised by lack of motor co-ordination, gait disturbance, and psychological features such

as mania. Most of the available information is from cross-sectional studies, with very little information concerning long-term follow-up. The pattern of information suggests that the neurological disturbances are likely to be irreversible; they may not progress in severity if exposures have been well controlled to below about 1 mg $Mn.m^{-3}$ (8-hr TWA), but in workers with high exposures, even after exposure has ceased, the effects may progress in severity as the years go by.

18. In general, overt cases of manganism are no longer seen in developed countries. A few (6) very severe cases occurred in the early 1990's in Chinese workers in a plant where the ventilation system had broken down, and exposures were in the region of 30 mg $Mn.m^{-3}$ for a period of about 20 months. However, the durations of these high daily exposures were only for about 30 minutes, indicating that 8-hour TWA exposures would have been much lower. No reliable estimates of the 8-hour TWA exposures can be derived because these exposure measurements derive from static samplers, and personal exposures may have been higher still. Nonetheless, given that the overall duration of these high exposures was only 20 months, it might be considered prudent to ensure that long-term exposures to manganese do not exceed 2 mg $Mn.m^{-3}$ (8-hr TWA). These workers were followed up some years after they had received these high exposures, and their clinical conditions had notably progressed in severity

19. In workplaces where exposures to manganese are controlled to between 0.25 - 1.6 mg $Mn.m^{-3}$ (8-hour TWA), a large number of studies have consistently shown that manganese-exposed workers perform less well than control groups of the same age in tests of neurological function. Typically, manganese-exposed workers show a fine tremor when trying to undertake controlled hand-arm movements. There is also a suggestion that they perform less well in cognitive tests but the evidence for this is not consistent.

20. The practical consequence for these workers is that they would experience difficulty in undertaking tasks such as threading a needle, or in hobby activities such as model aeroplane building or painting, anything which required a fine controlled movement. It is uncertain from the data available whether they would experience impaired cognitive function (defects in mental reasoning and memory).

21. The information available suggests that occupational exposure to concentrations at and above 0.25 mg $Mn.m^{-3}$ (8-hour TWA) can cause neurological changes. However, the pattern of information also suggests that with exposures between 0.25 -1 mg $Mn.m^{-3}$, the changes would be sub-clinical, and would take place gradually, such that individual workers may remain unaware of their impaired motor co-ordination, or might even consider such changes a result of ageing, rather than of occupational causation. Therefore, it is unlikely that exposures over this range would directly lead to sickness absence or loss of income that could be attributed to manganese exposure. Furthermore,

there are no health surveillance data from UK industry directly relating to the effects of exposure to manganese. Nor are there any statistics concerning the numbers of manganese-exposed workers who have changed employment or retired early due to the irreversible neurotoxic effects of manganese. There is no information concerning whether or not manganese-exposed workers might seek medical treatment for health effects caused by exposure to manganese. Overall therefore, it is not possible to assign any monetary costs to the health benefits of a particular MEL value based on standard parameters such as loss of income or costs of medical treatment.

22. One possible approach might be to estimate costs based on the likely pain and suffering (mild functional disability) associated with the impaired motor coordination (hand-eye coordination and postural balance), and possible cognitive impairment caused by exposure to manganese. It needs to be borne in mind that the degree of disablement would depend on the level of exposure.

23. HSE (1999) details valuations of human costs of injuries and ill health following descriptions in Galasco et al (1986) of various states of disability caused by injury or illness. These are used below to assign monetary values to estimates of benefit from the introduction of a MEL.

MEL of 5 mg Mn.m^{-3} (8-hour TWA)

24. The pattern of evidence strongly suggests the possibility of developing clinically overt irreversible neurological changes, i.e. a readily detectable tremor and marked difficulty in controlling fine movement. Even after exposure has ceased, the effects may progress in severity as the years go by for those workers exposed to higher levels. If we assume that this health state is comparable to a moderate form of permanent incapacitating illness, we can assume this is roughly equivalent to 20% of the figure for a permanent incapacitating illness[1], that is £35,152.

MEL of 2 mg Mn.m^{-3} (8-hour TWA)

25. The evidence suggests a high probability of discernible neurological change, but this would be less severe than at 5 mg m^{-3} Mn. Hence, we might value it at approximately 10% of the figure for a permanent incapacitating illness, that is £17,576.

MEL of 1 mg Mn. m^{-3} (8-hour TWA)

26. Workers are likely to develop mild neurological changes. The effects may not be readily detectable, and would be subtle in their impact on daily

[1] The value used for a permanent incapacitating illness is taken from HSE (1999) £136,1000. Uprating to 2001 prices (using GDP per capita as recommended by DETR in the Highways Economics Notes No.1) gives a figure of £175,759.

activities. We therefore apply a value of 5% of the figure for a permanent incapacitating illness, that is £8,788.

MEL of 0.2- 0.5 mg $Mn.m^{-3}$ (8-hour TWA)

27. Workers are likely to develop mild neurological changes, which would be less severe and have less of a functional impact compared to 1 mg $Mn.m^{-3}$. The workers themselves may be unaware of any occupationally related changes in their motor skills and control of fine movement. In view of the uncertain possibility of mild effects we apply a value of just 1% of the figure for a permanent incapacitating illness, that is £1,758.

MEL of below 0.2 mg $Mn.m^{-3}$ (8-hour TWA)

28. There is little evidence to indicate what the likely health effect of exposure below 0.2 mg $Mn.m^{-3}$ (8-hour TWA) might be. Therefore we do not apply any value.

29. The benefits shown in Table 1 below are based on estimates of numbers of workers exposed to levels of manganese above each MEL value. These estimates are only partly derived from industry information and should be treated as indicative only. Furthermore, the benefit values could be underestimates as they are only the costs of pain, grief and suffering awarded to the effects of exposure. This is not an estimate of the value of pain and suffering each year. It is an estimate for pain and suffering in present value terms expressed by how much individuals are willing to pay today to avoid having poorer health due to exposure to manganese, the effects of which will last for many years.

30. It is also the case that these benefits could be overestimated. These estimates are only the costs of pain, grief and suffering if these workers develop the effects described above. Without any information about labour turnover, we do not know over what time period these workers are exposed. Also, it has not been possible to quantify the potential effects on manganese-exposed workers who may have changed employment or retired early due to the irreversible neurotoxic effects of manganese. Neither have we been able to quantify any medical treatment costs that may have been incurred by these exposed workers.

Table 1 Health benefits associated with proposed MEL values for manganese

	5 mg $Mn.m^{-3}$	2 mg $Mn. m^{-3}$	1 mg $Mn. m^{-3}$	0.5 mg $Mn.m^{-3}$	0.2 mg $Mn.m^{-3}$	0.1 mg $Mn.m^{-3}$
Number exposed workers	30	700	4,400	5953	40,410	55,511
Benefit (£m)	1	13	45	127	127	127

rounded						

COMPLIANCE COSTS FOR BUSINESS, CHARITIES AND VOLUNTARY ORGANISATIONS

Business sectors affected

31. The risk assessment document (RAD) identified numerous industries where people are exposed to manganese and/or its inorganic compounds. The number exposed is up to 90,000. It is not possible to clearly define some business sectors without a degree of overlap. For example, the casting/metal finishing sector and the welding sector, where, for example, some welders are exposed to manganese by grinding (i.e. finishing) a welded part of a work piece.

32. The business sectors potentially affected by implementing a MEL for manganese and its inorganic compounds are listed below. Other relevant information, such as the numbers exposed and exposure data, is also summarised. Exposure results are all expressed in $mg.m^{-3}$, sampled as the inhalable fraction. All results are less than 10 years old. Most results are for manganese exposure and we have not distinguished between dust or fume exposure. Manganese exposures for three business sectors have been calculated from inhalable dust results. Manganese exposures were modelled for four business sectors. The controls currently used and the controls required to comply with the MEL options are covered in the next section on the compliance costs to industry. Table 2 summarises the current capability of the different industry sectors to achieve control of exposure to the proposed levels.

Table 2 Summary of current ability of industry to achieve control exposure

Sector	**Proposed MEL ($mg.m^{-3}$, 8-hour TWA)**					
	5	**2**	**1**	**0.5**	**0.2**	**0.1**
Steel making	Y	N	N	N	N	N
Casting and metal finishing	Y	Y	N	N	N	N
Welding	Y	Y	N	N	N	N
Welding consumable manufacture	Y	Y	Y	N	N	N
Premix, trace element fertiliser manufacture	N	N	N	N	N	N
Animal feed manufacture	Y	Y	Y	Y	Y	Y
Animal feed use	Y	Y	Y	Y	Y	Y
Trace element fertiliser use	Y	Y	Y	Y	N	N
Cosmetics manufacture	Y	Y	Y	Y	Y	Y
Cleaning preparation, manufacture and use of potassium permanganate	Y	N	N	N	N	N
Manganese octoate and manganese acetate manufacture	Y	Y	Y	Y	Y	Y
Manganese octoate and	Y	Y	Y	Y	Y	Y

manganese acetate use						
Battery manufacture	Y	Y	Y	N	N	N

Y = currently able to achieve control   N = currently not able to achieve control

Steel making.

33. The total number employed in steelmaking is between 30,000 and 40,000. However, the total number of employees exposed to manganese is between 1,000 and 1,500. The occupations with greatest manganese exposure are alloy handlers and furnacemen. The number of furnacemen working in steelmaking is between 100 and 200 and the number of alloy handlers is between 50 and 100. There are now 3 Basic Oxygen Steelmaking (BOS) plants and 5 Electric Arc Furnace (EAF) plants in Great Britain.

34. 8-hour TWA personal exposure results for a variety of tasks during steelmaking are summarised in Table 3. The data were supplied by a large UK steel producer and they are assumed to reflect exposure in all BOS and EAF plants.

Table 3: Manganese sampling results from the steelmaking industry.

Type of plant	Job	Number of samples	% of samples above 5 $mg.m^{-3}$	% of samples above 2 $mg.m^{-3}$	% of samples above 1 $mg.m^{-3}$	% of samples above 0.5 $mg.m^{-3}$	% of samples above 0.2 $mg.m^{-3}$	% of samples above 0.1 $mg.m^{-3}$
Basic oxygen steel-making	Alloy handling	26	4	23	54	88	na	96
	Vessel oper-ators	110	2	6	23	56	na	99
Electric arc furnace	Alloy handling	14	14	28	57	79	na	100
	Furnace-men	189	0	0	16	28	na	72

na – no information available

35. The data in Table 2 clearly illustrate that alloy handling is associated with higher manganese exposure than vessel or furnace operation in BOS and EAF plants. However, since most of this data was obtained, the provider has reduced exposure by modifying the cabs of their shovel driver trucks. This modification, which consists of ventilating the cab with filtered air, has reduced the 8-hour TWA personal manganese exposure of alloy handlers to between 0.2 and 0.5 $mg.m^{-3}$.

36. A small amount of data has recently been made available from a stainless steel making plant, which uses an EAF. Of the four personal sampling results for furnacemen all were below 0.1 $mg.m^{-3}$ and, of the four personal sampling

results for alloy handlers, three were below 0.1 $mg.m^{-3}$ and the fourth was 0.12 $mg.m^{-3}$. Although this is a small data set, it would seem to indicate that, at this plant, exposures to manganese could be controlled to below 0.2 $mg.m^{-3}$.

Casting and metal finishing.

37. We estimate that there are approximately 40,000 people employed in foundries in Great Britain. This figure excludes those working in bulk steel production. Approximately 30,000 employees are exposed to manganese and the total number of foundries in Great Britain is around 300. Ten of these foundries are much bigger than the rest and they account for around 90% of the total production.

38. Between 6 and 10 foundries carry out casting and fettling of manganese steel. It is estimated that this type of work accounts for between 20 and 70% of their production. Between 20 and 40 furnacemen and 50 to 100 fettlers are exposed to manganese in this part of the sector.

39. Personal exposure data for this business sector are summarised in Table 4. The data were supplied by the Castings Development Centre (CDC).

Table 4: Personal manganese exposure results (8-hour TWAs) during foundry operations.

Number of samples	Metal melted	Range ($mg.m^{-3}$)	Number of samples above 5$mg.m^{-3}$	Number of samples above 2 $mg.m^{-3}$	Number of samples above 1 $mg.m^{-3}$	Number of samples above 0.5 $mg.m^{-3}$	Number of samples above 0.2 $mg.m^{-3}$	Number of samples above 0.1 $mg.m^{-3}$
4	Manganese steel	0.27 - 1.9	0	0	1	2	4	4
3	Mix of steel and manganese steel	0.14 - 0.40	0	0	0	0	1	3
10	Steel containing less than 1.5% manganese	0.04 - 0.29	0	0	0	0	2	4

40. The CDC estimates that furnacemen and fettlers working with manganese steels can have intermittent manganese exposure of up to 3 $mg.m^{-3}$ and 10 $mg.m^{-3}$ respectively.

Welding.

41. The number employed in this business sector is not accurately known, but it is estimated to be between 30,000 and 40,000. This is less than the range given in the RAD and is based on revised information from The Welding Institute

(TWI) and the Welding Manufacturers Association. The number exposed to manganese is also uncertain, but the consumables and base materials used in over 95% of the processes contain manganese as a minor component. Exposure to manganese fume is usually intermittent with the duration of exposure lasting from a few minutes to most of the shift. Some recent HSE exposure data is summarised in Table 5. The data were not available when the RAD was prepared. The exposure results (mean sampling time = 2.2 hours) were obtained from a recent survey of 12 workplaces carrying out stainless steel welding.

Table 5: Personal inhalable manganese fume exposure results obtained from an HSE survey of welding operations in Great Britain.

Welding Task	Number of samples	Range ($mg.m^{-3}$)	% of samples above 5 $mg.m^{-3}$	% of samples above 2 $mg.m^{-3}$	% of samples above 1 $mg.m^{-3}$	% of samples above 0.5 $mg.m^{-3}$	% of samples above 0.2 $mg.m^{-3}$	% of samples above 0.1 $mg.m^{-3}$	Control measures	% of samples to which control measures apply
MIG/ MAG	25	0.003 to 0.53	0	0	0	4	16	52	LEV + RPE LEV alone RPE alone None	0 48 16 36
TIG	5	<0.002 to 0.06	0	0	0	0	0	0	LEV + RPE LEV alone RPE alone None	20 20 40 20
MMA	18	<0.002 to 0.55	0	0	0	6	11	28	LEV + RPE LEV alone RPE alone None	39 11 50 0
FCW	12	0.03 to 2.45	0	8	25	25	42	67	LEV + RPE LEV alone RPE alone None	75 0 25 0
All tasks	60	<0.002 to 2.45	0	1	5	8	18	43	LEV + RPE LEV alone RPE alone None	28 25 30 17

MIG = metal inert gas, MAG = metal active gas, TIG = tungsten inert gas, MMA = manual metal arc, FCW = flux-cored wire.

42. Information gathered from TWI for the RAD indicated that the lowest manganese fume concentrations generally occur during submerged arc welding

(SAW) and TIG welding. Manganese fume concentrations during MIG/MAG and MMA welding are relatively higher. Recent information provided by TWI indicated that MIG/MAG welding is currently the most common process. The relative amounts of consumables used in the UK in 1997 for different types of welding is shown in Table 6.

Table 6: Welding consumable use in 1997.

Consumable use (%)				
MAG	TIG	MMA	FCW	SAW
51	2	29	12	7

Welding consumable manufacture.

43. Typically, welding consumables contains approximately 5% manganese. There are approximately 10 welding consumable manufacturers in Great Britain and we assume that the total number of employees exposed to manganese in this sector is between 200 to 300. Estimated manganese exposure results, based on inhalable dust measurements from this sector, suggest that eight hour TWA manganese exposure just above 0.5 $mg.m^{-3}$ is likely for dusty processes such as transferring and weighing powders containing manganese. The data also indicate that the manganese exposure associated with other processes is less than 0.1 $mg.m^{-3}$.

Premix manufacture mineral supplement manufacture, and trace element fertiliser manufacture.

44. The business sectors considered in this and the next section are defined as follows:

a) Animal feed manufacture (considered in the following section) is the process of manufacturing final feed based on ingredients such as cereals (wheat and barley) and protein sources (soya bean meal) to which a premix is added. Within compound feed mills the complete mixture is generally processed into pellets.

b) Premix manufacture involves the blending of individual minerals and vitamins into a final mixture, which is distributed to feed mills largely as bagged finished product. There are seven premix manufacturers in Great Britain and we assume that, at each site, a total of between six and eight people are exposed to manganese during rip-and-tip operations.

c) Mineral supplement manufacture is similar to premix manufacture. The differences are that the finished product goes direct to farmers and the businesses are smaller. There are between 15 and 20 mineral supplement manufacturers in Great Britain and we assume that between two and four people per site are exposed to manganese during rip-and-tip operations.

d) Trace element fertilisers are made commercially by either mixing different combinations of trace element compounds and complexes or dissolving the ingredients in water. Most trace element fertilisers go to farmers, who spray a diluted solution of the product directly onto crop leaves (foliar application). There are approximately 20 fertiliser companies in Great Britain, where it is estimated that between 50 and 100 are exposed to manganese, also during rip-and-tip operations.

45. The total number of people exposed in premix manufacture, mineral supplement manufacture and trace element fertiliser manufacture during rip-and-tip operations is between 124 and 236.

46. Premix manufacture, mineral supplement manufacture and trace element fertiliser manufacture are considered together because the patterns of exposure and current controls are similar. In addition, we have manganese exposure data for fertiliser manufacture but not for premix or mineral supplement manufacture. It is assumed that the levels of exposure are similar in all businesses. The data (average sampling time = four hours) are summarised in Table 7.

Table 7: Personal manganese exposure results during the formulation of trace element fertilisers.

Number of samples	Range ($mg.m^{-3}$)	% of samples above 5 $mg.m^{-3}$	% of samples above 2 $mg.m^{-3}$	% of samples above 1 $mg.m^{-3}$	% of samples above 0.5 $g.m^{-3}$	% of samples above 0.2 $g.m^{-3}$	% of samples above 0.1 $mg.m^{-3}$
18	<LOD – 3.6	11	16	39	56	61	67

LOD = limit of detection.

47. Dust exposure in these sectors is relatively poorly controlled. 45% of 8-hour TWA personal inhalable dust results measured at one premix manufacturer were above 10 $mg.m^{-3}$. The main source of exposure in all sectors is rip-and-tip operations, in which the contents of 25 kg bags of manganese compounds are transferred into mixing vessels, hoppers etc. The duration of exposure is no more than 1 hour per day.

Animal feed manufacture.

48. Industry reported that short-term inhalable dust concentrations of between 1 to 3 $mg.m^{-3}$ can occur when adding a premix to a feed. The maximum time spent adding premixes during an eight-hour shift is one hour. This equates to a maximum possible eight hour TWA manganese exposure of 0.07 $mg.m^{-3}$. Consequently, it is our opinion that there will be no cost to this business sector for any of the MEL options.

Animal feed use.

49. Animal feeds, which are supplied as non-dusty nuts, pellets or “pencils”, are used by farmers to feed cattle, sheep, pigs, turkey etc. The feeds can contain up to 0.03% manganese. They are typically manually tipped from a 25 kg bag onto animal feed such as silage or hay in an open trough, whilst walking the length of the trough. This activity is usually carried out in naturally ventilated area and is most prevalent on small farms during the winter months. It is usually a daily task which lasts for no more than 10 minutes. The exposure modelled in the risk assessment using the EASE (Estimation and Assessment of Substance Exposure) model for this activity was 0 to 0.001 $mg.m^{-3}$. We therefore believe that this business sector should not incur costs for any of the MEL options.

Trace element fertiliser use.

50. Farm workers can be exposed to manganese when preparing and spraying trace element fertiliser solutions. The duration of exposure is short during preparation and considerably longer during the foliar application of the diluted product. The exposure during spraying was modelled in the risk assessment using POEM (the Predictive Operator Exposure Model) because this model is more suited to predicting exposure than EASE in this instance. The predicted exposure for eight hours spraying a solution containing 1% manganese using hydraulic nozzles with segregation of the farmer in the tractor was 0.1 $mg.m^{-3}$.

51. The National Farmers Union (NFU) estimates that out of a total of 80,000 spray rig operators, around 20,000 carry out 80% of the work. To estimate the number of farm workers who were likely to be ever exposed to an eight hour TWA manganese exposure of around 0.1 $mg.m^{-3}$ or slightly greater, the NFU considered:

a. The proportion of the land in Great Britain which is not deficient in manganese; and

b. The proportion of workers who were likely to spend eight hours or more spraying.

Their estimate was between 3,000 and 7,000. They felt that most of these would be exposed once per year.

Cosmetics manufacture.

52. Manganese violet is used to colour cosmetics such as mascara and eye shadow. Exposure occurs from operations including charging blenders from 25 kg bags and bagging or weighing a formulation containing the pigment. Exposures are infrequent and short term. Personal 8-hour TWA inhalable dust data were considered in the risk assessment. The data were obtained from a company that blends two types of manganese violet. The formulation contains 250 kg of one type of the pigment and 50 kg of another type. The process is carried out approximately

once per month. The data were for two people monitored in 1999 and their 8-hour TWA inhalable dust results were 0.41 and 0.21 mg.m^{-3}. The lower result was for an employee charging a blender from 25 kg bags (10 to 15 minutes per shift) and subsequently discharging the blender (up to 1.5 hours per shift) into 25 kg, polythene lined plastic kegs. The higher result was for repacking the blended manganese violet from 25 kg kegs into 5 kg buckets. This process takes less than an hour to complete. LEV was used during the blending/discharge operations. The repacking operation was carried out in a ventilated booth. RPE was used in both operations.

53. The manganese content of manganese violet is 22%. Consequently, if the reported data were purely a consequence of manganese violet exposure, total dust results of 0.41 and 0.21 mg.m^{-3} would be equivalent to manganese dust concentrations of 0.09 and 0.05 mg.m^{-3} respectively. However, it is unlikely that the measured dust is exclusively manganese violet and so the actual manganese concentrations are likely to be even lower. Consequently, we assume that this business sector should not incur any costs for any of the MEL options.

Cleaning preparation manufacture and potassium permanganate use.

54. Numerous industrial operations associated with potential occupational exposure to potassium permanganate were found during the risk assessment. We were unable to find any information regarding the numbers exposed. We assume that the main uses of potassium permanganate are metal cleaning and printed circuit board production. Exposures were predicted for the risk assessment using the EASE model. These are shown in Table 8.

Table 8. Modeled exposure for some of the industrial applications of potassium permanganate.

Use of potassium permanganate	Task	Typical exposure duration (minutes per shift)	Predicted 8 hour TWA manganese exposure (mg.m^{-3})
Preparing a mixture of sodium hydroxide and potassium permanganate.	Tipping 25 kg drums into mixing vessels.	5	0.01 - 0.02
	Bagging the product.	20	0.01 -.0.02
	Drum disposal.	5	0.02 - 0.2
Metal cleaning.	Tipping 25 kg drums into vessels without LEV.	30	0.1 - 1
	Tipping 25 kg drums into vessels with LEV.	30	0.04 - 0.1
	Drum disposal.	5	0.02 - 0.2

55. As far as we have been able to determine, the number of businesses using potassium permanganate in metal cleaning applications is small in comparison to those using trichloroethylene for metal degreasing. Potassium

permanganate metal cleaning applications are relatively more specialised. It is used when oxidation is part of the cleaning process. We have assumed that between 20 and 100 businesses use potassium permanganate in this sector.

Manganese octoate and manganese acetate manufacture.

56. These business sectors are considered together because the pattern and duration of exposure and the controls are similar. We assume that there are a total of between five and eight companies manufacturing these compounds in Great Britain. The number of workers exposed is assumed to be between 30 and 50. The exposure sources during manufacture are ripping and tipping manganese from 25 kg bags and disposal of the bags. We assume that the total number of tipping points is between 10 and 15. The duration of exposure during the rip-and-tip operation and bag disposal is less than 15 minutes and less than five minutes respectively. LEV and RPE are used during ripping and tipping. RPE is used during bag disposal. The eight-hour TWA manganese exposures modelled in the risk assessment using the EASE model were 0.1 to 0.2 $mg.m^{-3}$ for ripping and tipping and 0.05 to 0.5 $mg.m^{-3}$ for bag disposal.

Manganese octoate and manganese acetate use.

57. Because manganese octoate and manganese acetate are used as relatively dilute solutions and because most handling of the solutions is in closed mixing vessels and filling lines, we assume that the use of manganese octoate and manganese acetate (for e.g. in inks, paint and catalysis) is only ever likely to produce eight hour TWA manganese exposures considerably below 0.1 $mg.m^{-3}$. No cost should be incurred by these sectors for adopting a MEL for manganese and its inorganic compounds.

Battery manufacture.

58. This industry has declined significantly in Great Britain and, to the best of our knowledge, there are only two manufacturers remaining. The total employed in this business sector is around 130 and the number exposed to manganese is approximately 11. Exposure data provided by one manufacturer (Company A) are summarised in Table 9. Inhalable dust data were supplied. The maximum proportion of manganese in the mixture (commercially sensitive information) which is used in the process was used to estimate the manganese exposure. A single personal manganese exposure result of 0.3 $mg.m^{-3}$ (sampling time around two hours) was supplied by the other manufacturer (Company B).

Table 9: Estimated eight-hour TWA personal inhalable manganese exposure results during battery manufacture.

Number of samples	Range ($mg.m^{-3}$)	% of samples above 5 $mg.m^{-3}$	% of samples above 2 $mg.m^{-3}$	% of samples above 1 $mg.m^{-3}$	% of samples above 0.5 $mg.m^{-3}$	% of samples above 0.2 $mg.m^{-3}$	% of samples above 0.1 $mg.m^{-3}$
9	0.2 - 0.9	0	0	0	33	89	100

CHARITIES AND VOLUNTARY ORGANISATIONS AFFECTED

59. As far as we are able to determine, charities and voluntary organisations will not be affected by adopting a MEL for manganese and its inorganic compounds.

COMPLIANCE COSTS TO INDUSTRY

60. The purpose of this section is to present a summary of the costs of implementing a MEL of either 5, 2,1, 0.5, 0.2 or 0.1 $mg.m^{-3}$ in the business sectors affected. Details of the actual costings are described below in Annex 1.

61. Some contributions from industry, trade associations and consultants have been incorporated into this section and the sections on the impact on small businesses and the results of consultations. Industry contributions are presented in *italicised* format. Information on the costing of RPE was obtained from HSE guidance note HSG53 (*The Selection, Use and Maintenance of RPE*, 1998), HSE Specialist Inspector's Report number 50 (*Costing a RPE Programme*, 1996) and a manufacturer of RPE. The extra cost for an experienced chemist determining the manganese content of air samples was confirmed by HSL. LEV system prices were obtained from equipment manufacturers and some of the affected business sectors. An industrial vacuum cleaner manufacturer also supplied some costs. All other costs in this report were obtained from industry in 2000.

62. Manganese monitoring costs were determined using the following information. The daily cost of employing a consultant occupational hygienist to carry out air monitoring is between £310 and £730. This was obtained from the 1996/97 directory of occupational hygiene consultants, published by the British Institute of Occupational Hygienists. It is assumed that each time consultants are hired, they charge for one and a half days (one day on site work and a half day report writing). The cost of determining manganese in an air sample is between £7 and £11. This was based on quotes from three representative laboratories. Some laboratories offer a discount for bulk sample analysis but we assume that all of the business sectors considered in this RIA are unlikely to generate sufficient samples to qualify. Professional judgment and the monitoring data in the previous section were used to decide at which MEL option businesses would need to carry out monitoring. It was assumed that individual businesses affected would monitor once

in the year after the MEL is set to establish the “baseline” exposure. Control measures would then be implemented and they would monitor again to determine the efficacy of the measures. We assume that individual businesses affected will monitor once a year after the controls are implemented, modified and checked.

Steel Making

63. It is assumed that all BOS plants and three or four out of five EAF plants carry out their own air monitoring. We believe that where this is the case, the frequency of monitoring is sufficient to check control strategies for all of the proposed MELs. It is assumed that a consultant occupational hygienist is employed to carry out air monitoring at two EAF plants and that five samples per visit are taken.

Control costs

64. We believe that the most effective capture of manganese fume generated by EAFs and BOS vessels would be achieved by totally enclosing the furnaces and vessels in “dog houses”. It is difficult to cost accurately. It is assumed that all plants will require new or upgraded dog houses and that some plants will already have suitable extraction systems. Some plants will require new extraction systems. We assume that the number of vessels or furnaces per plant is between one and three and that the average initial cost of a new/upgraded dog house plus new/upgraded extraction is between £1,500k and £5,000k. The total cost of enclosure and extraction is therefore between £1,500k x 1 x 7 = £10,500k and £5,000k x 3 x 7 = £105,000k. The annual recurring costs are assumed to be between £1,050k and £10,500k. This solution is prohibitively expensive and not considered to be reasonably practicable.

65. To estimate the costs incurred by this business sector it is assumed:

a. that the nature and cost of controlling manganese exposure at its various sources are similar for BOS and EAF processes;

b. that retrofitting controls will be possible at all vessels and furnaces; and

c. that manganese exposure is much less significant at one of the three BOS plants because this plants use much less ferromanganese.

66. For a MEL of 2 or 5 $mg.m^{-3}$, it is assumed that there will be no additional control costs.

67. Therefore for a MEL of 1, 0.5, 0.2 or 0.1 $mg.m^{-3}$, we assume that a range of control measures will be required. These include more effective capture of fume generated by EAFs and BOS vessels, modifying some shovel driver truck

cabs and engineering control measures for transport and additions of manganese alloys and the use of RPE for some high exposure tasks.

68. For a MEL of 1 $mg.m^{-3}$ it is assumed that at the 3 BOS plants enclosed and ventilated conveyor systems will be installed as well as improvements to the enclosure and extraction at argon stirring. It is assumed that there will be improvements to the LEV at 5 plants.

69. For a MEL of 0.5 $mg.m^{-3}$ it is assumed that at the 3 BOS plants enclosed and ventilated conveyor systems will be installed as well as improvements to the enclosure and extraction at argon stirring. It is assumed that there will need to be improvements to the LEV at 6 plants. It is assumed that RPE will also be necessary for furnacemen at all plants for high exposure tasks. It is assumed that at three EAF plants ventilation systems will need to be installed into the cabs of the alloy handlers.

70. For a MEL of 0.2 or 0.1 $mg.m^{-3}$ it is assumed that at the 3 BOS plants enclosed and ventilated conveyor systems will be installed as well as improvements to the enclosure and extraction at argon stirring. It is assumed that there will need to be improvements to the LEV at 7 plants. It is assumed that RPE will also be necessary for furnacemen at all plants for high exposure tasks. It is also assumed that at four EAF plants ventilation systems will need to be installed into the cabs of the alloy handlers. For a MEL set at either of these levels we have assumed that the cab ventilation will not be sufficient at three plant and disposable respirators will be have to be worn for high exposure tasks.

Overall costs

71. The overall costs associated with the casting and metal finishing business sector complying with the MEL options are summarised in Table 10.

Table 10: Costs for the steelmaking business sector to comply with a variety of MELs. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	**Cost(£k) for 5 $mg.m^{-3}$**	**Cost (£k) for 2 $mg.m^{-3}$**	**Cost (£k) for 1 $mg.m^{-3}$**	**Cost (£k) for 0.5 $mg.m^{-3}$**	**Cost (£k) for 0.2 $mg.m^{-3}$**	**Cost (£k) for 0.1 $mg.m^{-3}$**
Monitoring	0 *(0)*	2 - 5 *(1 – 2)*	2 - 5 *(1 – 2)*	2 - 5 *(1 – 2)*	2 - 5 *(1 – 2)*	2 - 5 *(1 – 2)*
Control	0 *(0)*	0 *(0)*	215 – 540 *(17 – 67)*	320 – 912 *(32 – 99)*	340 – 927 *(46 – 106)*	340 – 927 *(46 – 106)*
Total	0 *(0)*	2 –5 *(1 – 2)*	217 –545 *(18 – 69)*	322 – 917 *(33 – 101)*	342 – 932 *(47 – 108)*	342 – 932 *(47 – 108)*

Casting and Metal Finishing

72. Foundries do not monitor for manganese on a routine basis. Most foundries who carry out air monitoring use consultant occupational hygienists. It is assumed that where additional air monitoring is carried out, a consultant is employed and that three samples per visit are taken. For MELs of 2 and 5 $mg.m^{-3}$, the exposure data (Table 4) suggest that current control strategies are sufficient to comply. It is therefore assumed that no additional monitoring will be carried out in the year after the MEL is set. For MELs of 1, 0.5 and 2 $mg.m^{-3}$, the exposure data (Table 4) suggest that, for foundries working with manganese steels (six to ten foundries), additional monitoring will need to take place. For a MEL of 0.1 $mg.m^{-3}$, the exposure data (Table 4) show that, with current control strategies, most results (65%) are above 0.1 $mg.m^{-3}$. It is therefore assumed that monitoring will be carried out in the year after the MEL is set by all (approximately 300) foundries.

73. It is difficult to estimate the cost of appropriate control in this business sector without making a number of assumptions. Relevant information on control in this business sector was provided by CDC. The information, which assisted us in formulating our assumptions is detailed in Annex 1.

74. Using the information provided by the CDC, and the exposure data in Table 3, we have assumed that control costs will not be incurred by any of the foundries in this business sector by adopting a MEL of 2 or 5 $mg.m^{-3}$. For a MEL of 1 or 0.5 $mg.m^{-3}$, we have assumed that only the foundries working with manganese steels will be affected (six to ten foundries). For a MEL of 0.1 or 0.2 $mg.m^{-3}$, we estimate that additional control costs would be incurred by up to 80% of all foundries.

75. For a MEL of 1 or 0.5 $mg.m^{-3}$, we have assumed that for some of these foundries appropriate control would be achieved by installing new, dedicated LEV plant, ducting and close capture hoods/fettling benches at operations where exposure originates. For other foundries working with manganese steels, it is assumed that an upgrade of their existing LEV would be sufficient. We have also assumed that, even with new or upgraded LEV, it is possible that fettlers working manganese steels will require an upgrade in their RPE. We assume that powered respirators will be sufficient and practical for all fettlers.

Overall costs

76. The overall costs associated with the casting and metal finishing business sector complying with the MEL options are summarised in Table 11.

Table 11: Costs for the casting and metal finishing sector to comply with a variety of MELs. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	Cost (£k) for 5 mg.m^{-3}	Cost (£k) for 2 mg.m^{-3}	Cost (£k) for 1 mg.m^{-3}	Cost (£k) for 0.5 mg.m^{-3}	Cost (£k) for 0.2 mg.m^{-3}	Cost (£k) for 0.1 mg.m^{-3}
Monitoring	0 *(0)*	0 *(0)*	10 – 23 *(5 – 11)*	10 – 23 *(5 – 11)*	10 – 23 *(5 – 11)*	292 - 677 *(146 - 338)*
Control	0 *(0)*	0 (0)	43 - 181 *(27 - 163)*	43 - 181 *(27 - 163)*	1,575 - 4,073 *(911 - 1,493)*	1,575 - 4,073 *(911 - 1,493)*
Total	0 *(0)*	0 (0)	53 - 204 *(32 - 174)*	53 - 204 *(32 - 174)*	1,585 – 4,096 *(916 - ,1504)*	1,867 - 4,750 *(1,057 - 1,831)*

77. Using different assumptions the CDC estimated the costs of their foundries complying with the MEL options. These are set out in Table 12.

Table 12: Costs (provided by the CDC) for foundries to comply with a variety of MELs. Running costs are in brackets.

Cost for a MEL of 5 mg.m^{-3} (£k)	Cost for a MEL of 0.5 mg.m^{-3} (£k)	Cost for a MEL of 0.1 mg.m^{-3} (£k)
0 (0)	Around 1,000 (Around 100)	Around 4,000 (Around 400)

Welding

78. To estimate the number of workshops in Great Britain carrying out welding operations, we assume that each workshop employs between two and eight welders. The number of workshops is therefore between 40,000 ÷ 8 = 5,000 and 30,000 ÷ 2 = 15,000. In estimating the costs to this business sector it is assumed that there will be no additional costs associated with any of the MEL options for SAW and TIG welding because manganese exposure is controlled below 0.1 mg.m^{-3}. To take account of this assumption, we assume a smaller number of workshops will incur costs if a MEL is adopted. Using the information in Table 4 for the relative amounts of welding consumables used in the UK, we assume that the number of workshops affected will be between 4,500 and 13,500. It is assumed that this range represents workshops which spend a minimum of around 2 hours per day welding and excludes small garages where intermittent welding operations (up to three jobs per week) are carried out.

79. The majority of businesses in this sector who carry out air monitoring, employ consultant occupational hygienists to determine occupational exposure. In addition, most companies adopt the assessment approach outlined in the HSE publication EH54, Assessment of exposure to fume from welding and allied

processes. Using the suppliers' fume analysis data, this method is used to calculate the welding fume exposure result ($mg.m^{-3}$) at which each component of the fume reaches its OEL. Following discussions with TWI, it has been estimated that between 4,050 and 12,150 workshops could incur monitoring costs. It is assumed that the monitoring regimes at workshops currently carrying out monitoring would be suitable to check controls if any of the proposed MELs were adopted.

80. It is assumed that where additional monitoring is carried out, a consultant is employed and that that three samples per visit are taken. We have assumed that all workshops request manganese analysis. For a MEL of 2 or 5 $mg.m^{-3}$, the exposure data (Table 4) suggest that current control strategies are sufficient to comply for all welding tasks. It is therefore assumed that no additional monitoring will be carried out after the MEL is set.

Overall costs

81. The exposure data in Table 4 indicate that current control methods are suitable and sufficient for a MEL of 2 or 5 $mg.m^{-3}$. The data also indicate that extra costs will be incurred to control to a MEL of 1, 0.5, 0.2 and 0.1 $mg.m^{-3}$. We assume that LEV alone will be required in some workshops to control to a MEL of 1 or 0.5 $mg.m^{-3}$. The type of LEV required will vary considerably between workshops. Totally new LEV plant, ducting and booths/"elephant trunks" will required in some workshops, whilst others will only require modifications to existing systems. To control to a MEL of 0.2 or 0.1 $mg.m^{-3}$ we assume that engineering control will not be sufficient in some workshops and that RPE will also be required to control residual exposure.

82. The overall costs associated with the welding business sector complying with the MEL options are summarised in Table 13.

Table 13: Costs for the welding business sector to comply with a variety of MELs. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	Cost (£k) for 5 $mg.m^{-3}$	Cost (£k) for 2 $mg.m^{-3}$	Cost (£k) for 1 $mg.m^{-3}$	Cost (£k) for 0.5 $mg.m^{-3}$	Cost (£k) for 0.2 $mg.m^{-3}$	Cost (£k) for 0.1 $mg.m^{-3}$
Monitoring	0 *(0)*	0 *(0)*	194 - 1,354 *(97- 677)*	292 – 2,256 *(146–1,128)*	729 - 4964 *(365-,2482)*	1,750- 11,956 *(875- 5,978)*
Control	0 *(0)*	0 *(0)*	2,250- 6,750 *(225 –675)*	2,250- 6,750 *(225 –675)*	11,480- 45,274 *(1,491- 28071)*	11,480- 45,274 *(1491- 28071)*
Total	0 *(0)*	0 *(0)*	2,444- 8,104 *(322- 1,352)*	2,542- 9,006 *(371- 1,803)*	12,209- 50,238 *(1,856- 30,553)*	13,230- 57,230 *(2,366- 34,049)*

83. With the exception of the steelmaking industry, these costs are much greater than the costs incurred by other business sectors. There are two reasons. First, there are a large number of workshops in Great Britain. Second, this business sector traditionally carries out far less air monitoring than the current legislation requires. It is therefore likely that the actual monitoring costs incurred by this business sector will be considerably less than those summarised in Table 12. However, it is not possible to estimate the actual costs.

Welding consumable manufacture

84. The jobs associated with greatest manganese exposure include weighing, blending and transferring powders containing manganese. The duration of dust exposure lasts for most of a shift from a process, which is frequently totally or partially enclosed, and under LEV. RPE is often used during these tasks.

85. It is assumed that all consumable manufacturing companies who monitor hire consultant occupational hygienists to carry out their air monitoring. It is assumed that where additional monitoring is carried out, the consultant takes three samples per visit.

86. We have assumed that there will be no control costs associated with complying with a MEL of 5, 2 or 1 $mg.m^{-3}$. For a MEL of 0.5 $mg.m^{-3}$, we have assumed that increasing the level of enclosure of the processes generating exposure will be sufficient to adequately control exposure. For a MEL of 0.2 or 0.1 $mg.m^{-3}$, we have assumed that, in addition to increasing the level of enclosure, new dedicated LEV plant and ducting are installed to service the processes.

Overall costs

87. The estimated costs are summarised in Table 14.

Table 14: Costs for the welding consumable manufacture sector to comply with a variety of MELs. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	Cost (£k) for 5 $mg.m^{-3}$	Cost (£k) for 2 $mg.m^{-3}$	Cost (£k) for 1 $mg.m^{-3}$	Cost (£k) for 0.5 $mg.m^{-3}$	Cost (£k) for 0.2 $mg.m^{-3}$	Cost (£k) for 0.1 $mg.m^{-3}$
Monitoring	0 *(0)*	0 *(0)*	0 *(0)*	10 – 23 *(5 – 11)*	10 – 23 *(5 – 11)*	10 – 23 *(5 – 11)*
Control	0 *(0)*	0 *(0)*	0 *(0)*	20 – 40 *(2 – 4)*	120 – 170 *(18 – 33)*	120 – 170 *(18 – 33)*
Total	0 *(0)*	0 *(0)*	0 *(0)*	30 – 63 *(7 – 15)*	130 – 193 *(23 – 44)*	130 – 193 *(23 – 44)*

88. One of the large welding consumable manufacturers assessed the costs of the MEL options. They concluded that there would be no cost for a MEL of

5,2, 1 or 0.5 mg.m^{-3}. For a MEL of 0.2 or 0.1 mg.m^{-3}, they may need to invest in more efficient extraction systems, at a total initial cost of £54k.

89. This manufacturer currently operates good hygiene practice for this business sector and probably would incur either minimal or no control costs for a MEL of 0.5 mg.m^{-3}. However, they probably would incur some monitoring costs for this MEL option, for switching from monitoring inhalable dust to determining manganese in air samples.

Premix manufacture mineral supplement manufacture, and trace element fertiliser manufacture.

90. We have assumed that costs will be incurred for staff training, staff supervision, extra monitoring, vacuum cleaner purchase, vacuum cleaner servicing and engineering control. Exposure in these sectors can be reduced by training workers with increased supervision in the correct use of ventilated enclosures to ensure that the training is utilised. It is assumed that the training will be formulated and delivered by employees within the sectors.

91. It is assumed that, where monitoring is carried out, premix, mineral supplement and fertiliser manufacturers hire consultants to carry out their air monitoring. We assume that an average of four samples per visit are taken and that the total number of plants, which could potentially incur monitoring costs, is 25.

92. The use of LEV in these business sectors is widespread but dust exposure is still poorly controlled and 11% of the manganese results in Table 5 are above 5 mg.m^{-3}. The main form of control during rip-and-tip operations is a ventilated enclosure. We estimate that approximately 50% of these are fitted with waste bag collectors. RPE use is also widespread. We estimate that approximately 30% of employees use powered respirators and that the remainder use RPE with lower Assigned Protection Factors. Control costs include costs for cleaning of premises and for the purchase and use of vacuum cleaners.

Overall costs

93. The estimated costs are summarised in Table 15.

Table 15: Costs for the mineral supplement manufactures, premix manufactures and trace element fertiliser manufactures to comply with a variety of MELs. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	Cost (£k) for 5 mg.m^{-3}	Cost (£k) for 2 mg.m^{-3}	Cost (£k) for 1 mg.m^{-3}	Cost (£k) for 0.5 mg.m^{-3}	Cost (£k) for 0.2 mg.m^{-3}	Cost (£k) for 0.1 mg.m^{-3}
Training and supervision	42 - 77 *(11 - 21)*	42 - 77 *(11 - 21)*	42 - 77 *(11 - 21)*	42 - 77 *(11 - 21)*	42 - 77 *(11 - 21)*	42 - 77 *(11 - 21)*
Monitoring	3 – 7 *(1 – 3)*	4 – 9 *(2 –5)*	10 – 23 *(5 – 11)*	14 – 32 *(7 – 16)*	15 – 34 *(7 – 17)*	17 – 39 *(8 – 19)*
Control	27 – 34 *(85– 179)*	27 – 34 *(85– 179)*	221- 727 *(111- 259)*	248 – 761 *(122 - 273)*	988 – 2393 *(204 – 447)*	988 – 2393 *(204 – 447)*
Total	72 – 118 *(97 - 203)*	73 – 120 *(98 – 205)*	273 - 827 *(127 - 291)_*	304 - 870 *(140- 310)*	1,045- 2,504 *(222 - 485)*	1,047- 2,509 *(223 - 487)*

94. In our opinion, most mineral supplement manufactures, premix manufactures and trace element fertiliser manufactures will have great difficulty controlling to a MEL of 0.1 or 0.2 mg.m^{-3}. In addition, some (approx 30 –50%) manufacturers will struggle to comply with a MEL of 0.5 mg.m^{-3}.

Animal feed manufacture.

95. In our opinion, this business sector will not incur costs for any of the MEL options.

96. The United Kingdom Agricultural Supply Trade Association (UKASTA) distributed questionnaires on manganese exposure and costs to its members. One company responded, estimating their costs to be £497k for MELs of 0.1 and 0.5 mg.m^{-3}. The estimated cost for a MEL of 5 mg.m^{-3} was £60k. They did not distinguish between initial and recurring costs, although we assume the quoted figures to be initial costs.

97. We do not agree with this because, based on information supplied by industry, we are of the opinion that the maximum possible eight hour TWA manganese exposure during feed manufacture is 0.07 mg.m^{-3}.

Animal feed use.

98. It is our opinion that this business sector will not be affected by adopting any of the MEL options for manganese and its inorganic compounds.

99. Under our definition of feed manufacture and use, we assume that these companies are feed manufacturers and not users. We do not agree with their costs because we are of the opinion that manganese exposure is currently controlled sufficiently far below 0.1 mg.m^{-3} in this sector.

Trace element fertiliser use.

100. In our opinion, this business sector will not incur costs for the MEL options of 5, 2, 1 and 0.5 $mg.m^{-3}$. The most likely control method that will be selected by farm workers to control to a MEL of 0.2 or 0.1 $mg.m^{-3}$ is the disposable filtering facepiece respirator. We assume that all exposed farm workers will opt for RPE in order to mitigate their manganese exposure during spraying. We assume that single use filtering half masks (FF P3) will be suitable. However, it is our opinion that, if this MEL option is adopted, this control method is likely not to be used in practice.

101. We assume that, other than the protection offered by an enclosed tractor cab, all farm workers are unlikely to use any other controls during fertiliser spraying.

102. For a MEL of 0.2 or 0.1 $mg.m^{-3}$, the total of the annual recurring costs is between £33k and £76k.

Cleaning preparation manufacture and potassium permanganate use.

103. Estimating the costs to this business sector of adopting a MEL for manganese and its inorganic compounds was more difficult than any other business sector because we determined little regarding numbers exposed and their actual exposures. We were not able to identify a trade association representing any of the businesses handling potassium permanganate. In addition, we were unable to identify an individual who had any useful knowledge of either the business sector as a whole or the “subsections” of the sector, such as metal cleaning. For the purposes of this assessment we have assumed between 20 and 100 businesses handle potassium permanganate and that all are controlling to below 5 $mg.m^{-3}$.

104. It is assumed that all companies in this business sector who monitor, hire consultants to carry out their air monitoring. We assume that two samples per visit are taken.

105. It is assumed that new/upgraded enclosures plus new/ upgraded/existing LEV plant would be sufficient to control exposure for any of the proposed numbers. Consequently the range of costs at individual businesses will be large because there is a large difference in the cost of an upgraded enclosure plus existing LEV compared with a new enclosure plus new LEV plant. We also assume that even with improved engineering control, around 30% of the workers would still be exposed to manganese in excess of 0.1 $mg.m^{-3}$ (8-hour TWA). In these cases it is likely that additional RPE will be used to mitigate exposure. We assume that single use filtering half masks (FF P3) will be suitable.

Overall costs

106. The estimated costs associated with complying with different MELs for businesses handling potassium permanganate are summarised in Table 16.

Table 16: Estimated overall costs for industries where workers are exposed to potassium permanganate. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	Cost (£k) for 5 $mg.m^{-3}$	Cost (£k) for 2 $mg.m^{-3}$	Cost (£k) for 1 $mg.m^{-3}$	Cost (£k) for 0.5 $mg.m^{-3}$	Cost (£k) for 0.2 $mg.m^{-3}$	Cost (£k) for 0.1 $mg.m^{-3}$
Monitoring	0 *(0)*	5 - 11 *(2 – 6)*	10 – 22 *(5 – 11)*	19 – 45 *(10 – 22)*	38 – 90 *(19 – 45)*	48 – 112 *(24 – 56)*
Control	0 *(0)*	15 – 50 *(2 –5)*	30 –100 *(3 – 10)*	60 –200 *(6 – 20)*	120 – 400 *(12 – 40)*	150 – 500 *(16 – 51)*
Total	0 *(0)*	20 – 61 *(4 – 11)*	40 – 122 *(8 – 21)*	79 – 245 *(16 – 42)*	158 – 490 *(31 – 85)*	198 – 612 *(40 – 107)*

Manganese octoate and manganese acetate manufacture.

107. Even though the 8-hour TWA manganese exposures modelled in the risk assessment (using the EASE model) were 0.1 to 0.2 $mg.m^{-3}$ for ripping and tipping and 0.05 to 0.5 $mg.m^{-3}$ for bag disposal, we assume that actual exposure will always be below 0.5 $mg.m^{-3}$ and that these business sectors will only incur costs for a MEL option of 0.2 or 0.1 $mg.m^{-3}$.

Overall costs

108. The estimated costs associated with complying with different MELs for manufacturing manganese octoate and manganese acetate are summarised in Table 17.

Table 17: Costs for manganese octoate and manganese acetate manufacturers to comply with a variety of MELs. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	Cost (£k) for 5 $mg.m^{-3}$	Cost (£k) for 2 $mg.m^{-3}$	Cost (£k) for 1 $mg.m^{-3}$	Cost (£k) for 0.5 $mg.m^{-3}$	Cost (£k) for 0.2 $mg.m^{-3}$	Cost (£k) for 0.1 $mg.m^{-3}$
Monitoring	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	8 – 18 (4 – 9)	8 – 18 (4 – 9)
Control	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	40 - 105 *(4 - 11)*	40 - 105 *(4 - 11)*
Total	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	48 - 123 *(8 - 30)*	48 - 123 *(8 - 30)*

Battery manufacture.

109. There are only two battery manufacturers in the UK. Monitoring is carried out in-house at Company A. The pattern of monitoring they currently use we believe is sufficient to check their control strategy for all of the proposed MELs. However, the method of sampling and analysis will need to be changed. Costs are included for this. Company B uses consultants. As there is very little exposure data from Company B we have assumed that they have similar levels of control as Company A.

110. Both battery manufacturers already provide their employees with RPE for use during the initial stages of manufacture. Therefore, the provision of RPE will not contribute to any additional control costs. The exposure data in Table 7 suggest that there should be no additional control costs for a MEL of 5, 2 or 1mg.m^{-3}.

111. For a MEL of 0.5 mg.m^{-3} we have assumed that a ventilated enclosure would provide an appropriate level of control. Enclosing the bag opening/weighing parts of the process should be sufficient. We estimate that a total of two enclosures with waste bag collectors will be required.

112. For a MEL of 0.2 or 0.1 mg.m^{-3} we have also assumed that ventilated enclosures would also be suitable. They should be used at all points in the process where manganese dioxide is handled as a powder, prior to the addition of liquid which converts the powder into a paste. We estimate that at each manufacturer, three enclosures will be required; one with a waste bag collector.

Overall costs

113. The estimated costs associated with complying with different MELs for battery manufacture are summarised in Table 18.

Table 18: Costs for battery manufacturers to comply with a variety of MELs. Initial costs are given in Roman, running costs are italicised, in brackets.

Operation	Cost (£k) for 5 mg.m^{-3}	Cost (£k) for 2 mg.m^{-3}	Cost (£k) for 1 mg.m^{-3}	Cost (£k) for 0.5 mg.m^{-3}	Cost (£k) for 0.2 mg.m^{-3}	Cost (£k) for 0.1 mg.m^{-3}
Monitoring	3 - 5 *(1 - 2)*	3 - 5 *(1 - 2)*	3 - 5 *(1 - 2)*	5 – 7 *(2 – 3)*	5 – 7 *(2 – 3)*	5 – 7 *(2 – 3)*
Control	0 *(0)*	0 *(0)*	0 *(0)*	8 - 14 *(1)*	34 - 58 *(3 - 7)*	34 – 58 *(3 - 7)*
Total	3 - 5 *(1 - 2)*	3 - 5 *(1 – 2)*	3 - 5 *(1 – 2)*	13 – 21 *(3 – 4)*	39 – 65 *(5 – 10)*	39 – 65 *(5 – 10)*

114. Using different assumptions, the estimated costs calculated by combining the information provided by companies A and B are shown in Table 19.

Table 19: Costs (provided by industry) for battery manufacturers to comply with a variety of MELs. Initial costs are given first, running costs are in brackets.

Cost for a MEL of 5 $mg.m^{-3}$ (£k)	Cost for a MEL of 0.5 $mg.m^{-3}$ (£k)	Cost for a MEL of 0.1 $mg.m^{-3}$ (£k)
0 (0)	27 - 30 (2 - 3)	82 - 92 (5 - 8)

115. Given the large number of assumptions made in costing the proposed MELs, it is likely that estimates will vary.

All business sectors

116. The total costs for all of the business sectors potentially affected by adopting a MEL for manganese and its inorganic compounds are summarised in Table 20.

Table 20: Summary of costs associated with implementing different MEL options. Initial costs are given in Roman, running costs are italicised, in brackets.

Business sector	Cost (£k) for 5 $mg.m^{-3}$	Cost (£k) for 2 $mg.m^{-3}$	Cost (£k) for 1 $mg.m^{-3}$	Cost (£k) for 0.5 $mg.m^{-3}$	Cost (£k) for 0.2 $mg.m^{-3}$	Cost (£k) for 0.1 $mg.m^{-3}$
Steelmaking	0 (0)	2 – 5 *(1 –2)*	217 – 545 *(18 – 69)*	322 – 917 *(33 – 101)*	342 – 929 *(47 – 108)*	342 – 929 *(47 – 108)*
Casting and metal finishing	0 *(0)*	0 *(0)*	53 – 204 *(32 – 174)*	53 – 204 *(32 - 174)*	1,585 – 4,096 *(916 – 1,504)*	1,867 – 4,750 *(1,507 – 1,831*)
Welding	0 *(0)*	0 *(0)*	2,444 - 8,104 *(322 – 1,352*)	2,542 – 9,006 *(371 – 1,803)*	12,209 – 50,238 *(1,856 – 30,553)*	13,230 – 57,230 *(2,366 – 34,049)*
Welding consumable manufacture	0 *(0)*	0 *(0)*	0 *(0)*	30 –63 *(7 – 15)*	130 – 193 *(23 – 44)*	130 – 193 *(23 – 44)*
mineral supplement, premix and trace element fertiliser manufacture	72 –118 *(97 – 203)*	73 – 120 *(97 – 205)*	273 – 827 *(127 – 291)*	304 – 870 *(140 – 310)*	1,045 – 2,504 *(222 – 485)*	1,047 – 2,509 *(223 – 487)*
Animal feed manufacture	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
Animal feed use	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
Trace element fertiliser use	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(33 – 76)*	0 *(33 – 76)*
Cosmetics manufacture	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
Cleaning preparation manufacture and potassium permanganate use	0 *(0)*	20 – 61 *(4 – 11)*	40 – 122 *(8 – 21)*	79 – 245 *(16 – 42)*	158 – 490 *(31 – 85)*	198 – 612 *(40 – 107)*
Manganese octoate and manganese acetate manufacture	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
Manganese octoate and manganese acetate use	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*	0 *(0)*
Battery manufacture	0 *(0)*	0 *(0)*	0 *(0)*	12 – 21 *(3 – 4)*	39 – 65 *(5 – 10)*	39 – 65 *(5 – 10)*
Total cost (£k)	72 – 118 *(97 – 203)*	95 – 186 *(102 – 218)*	3,027 – 9,802 *(507 – 1,907)*	3,342- 11,326 *(602 – 2,449*)	15,508 – 58,515 *(3,133 – 32,865)*	16,853 – 66,288 *(4,244 – 36,712*)

Table 21: Annual (undiscounted) and ten year net present values associated with implementing different MEL options (including both policy and implementation costs).

MEL	Annual (£m) Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Yr7	Yr8	Yr9	Yr10	10 Yr NPV (£m)
5	0.08-0.1	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.8-1.7
2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.9-1.8
1	3-10	0.5-2	0.5-2	0.5-2	0.5-2	0.5-2	0.5-2	0.5-2	0.5-2	0.5-2	7-24
0.5	3-11	0.6-2	0.6-2	0.6-2	0.6-2	0.6-2	0.6-2	0.6-2	0.6-2	0.6-2	8-30
0.2	16-59	3-33	3-33	3-33	3-33	3-33	3-33	3-33	3-33	3-33	39-302
0.1	17-66	4-37	4-37	4-37	4-37	4-37	4-37	4-37	4-37	4-37	46-340

117. Total policy costs, over ten years in net present value terms are given in Table 22 below.

Table 22

	5 mg.m^{-3}	**2 mg.m^{-3}**	**1 mg.m^{-3}**	**0.5 mg.m^{-3}**	**0.2 mg.m^{-3}**	**0.1 mg.m^{-3}**
Cost (£m)	0.7-1.4	0.8-1.6	6.7-24	7.8-30	39-302	45-340

118. Total implementation costs, over ten years in net present value terms are given in Table 23 below.

Table 23

	5 mg.m^{-3}	**2 mg.m^{-3}**	**1 mg.m^{-3}**	**0.5 mg.m^{-3}**	**0.2 mg.m^{-3}**	**0.1 mg.m^{-3}**
Cost (£m)	0.1- 0.2	0.1-0.2	0.1-0.2	0.1-0.4	0.6-0.7	0.6-0.7

IMPACT ON SMALL BUSINESSES

119. Of the thirteen business sectors considered, nine incurred costs for some or all of the MEL options. Of these, we assume that five (steelmaking, welding consumable manufacture, animal feed supplement premix manufacture and trace element fertiliser manufacture, manganese octoate and manganese acetate manufacture and battery manufacture) would not be regarded as small businesses. Each of the other eight business sectors is comprised of individual operations which can be regarded as small businesses; i.e. they employ less than 50 people. We were able to obtain some information about the impact on small businesses in the casting and metal finishing sector and the welding sector.

120. We have considered the casting and metal finishing sector to be comprised of foundries. There are around 300 in Great Britain. The majority of foundries are SMEs and ten are much larger than the rest. Of the remaining 290,

between 60 to 90 can be considered as small businesses. One of these regularly melts manganese steel and therefore the costs to this business of adopting a MEL for manganese and its compounds will be greater than the costs incurred by the other small foundries. Their output is about 5 to 6% manganese steel, the rest being grey iron. They contributed to this part of the RIA via the Castings Development Centre. Their response was:

> "For a MEL of 0.1 $mg.m^{-3}$, in common with most other foundries, we would have great difficulty in complying except by the use of PPE. For a MEL of 0.5 $mg.m^{-3}$, we would have few problems. Because of the low percentage of manganese steel we would never have a day producing just manganese steel. Manganese steel would only be produced at all perhaps twice per month. For a MEL of 5 $mg.m^{-3}$ - no problems".

121 The welding sector contains many small businesses. We are uncertain of the actual proportion, but in formulating the costs for this sector, we assumed that each workshop employed between two and eight welders. We assume this to be a realistic average, but there will be exceptions, where more than 50 people are employed. Contributions from the Welding Institute, the Welding Manufacturers Association and a consultant gave a consistent view that a MEL of 0.1 or 0.2 $mg.m^{-3}$ would incur significant costs. For a MEL of 0.5 $mg.m^{-3}$, many small businesses would incur some costs but they would be significantly less than the costs associated with a MEL of 0.1 $mg.m^{-3}$. A MEL of 1 mg.m-3 could incur some costs. A MEL of 5 or 2$mg.m^{-3}$ would not incur any costs.

ENVIRONMENTAL IMPACTS

122. It is believed that there will be no environmental impact from the setting a MEL at either 5 $mg.m^{-3}$, 2 $mg.m^{-3}$, 1 $mg.m^{-3}$, 0.5 $mg.m^{-3}$. 0.2 $mg.m^{-3}$ or 0.1 $mg.m^{-3}$.

BALANCE OF COSTS AND BENEFITS

123. There will be a cost to industry associated with compliance to a MEL for manganese set at either 5 $mg.m^{-3}$, 2 $mg.m^{-3}$, 1 $mg.m^{-3}$, 0.5 $mg.m^{-3}$,0.2 $mg.m^{-3}$ or 0.1 $mg.m^{-3}$. The total cost of a MEL set at 5 $mg.m^{-3}$ is expected to be in the range of £ 0.8 million and £1.7 million in present values over a ten year appraisal period. The total cost of a MEL set at 2 $mg.m^{-3}$ is expected to be approximately £0.9 million to £1.8 million in present values over a ten year appraisal period. The total cost of a MEL set at 1 $mg.m^{-3}$ is expected to be approximately £7 million to £24 million in present values over a ten year appraisal period. The total cost of a MEL set at 0.5 $mg.m^{-3}$ is expected to be in the range of £8 million and £30 million in present values over a ten year appraisal period. The total cost of a MEL set at 0.2 $mg.m^{-3}$ is expected to be approximately £39 million to £302 million in present values over a ten year appraisal period. The total cost of a MEL set at 0.1 $mg.m^{-3}$ is

expected to be approximately £46 million to £340 million in present values over a ten-year appraisal period.

124. Total quantifiable benefits for a MEL of either 5 mg.m^{-3}, 2 mg.m^{-3} , 1 mg.m^{-3}, 0.5 mg.m^{-3} ,0.2 mg.m^{-3} or 0.1 mg.m^{-3} have been valued at £1 million, £13 million, £45 million, £127 million and £127 million respectively.

125. Below is an indication of what the costs per exposed worker are from setting a MEL for manganese and how these costs compare with past MELs. The RIA for phenol listed examples of costs of exposure per worker for some recent MELs in its Table 4. These were around £500 for alkyl sulphates, £400-£1,300 for hydrazine, and £14 for phenol; and for V_2O_5 are £550-£1,800 for an engineering control strategy and £1100-£2,700 for an RPE control strategy. Given the total compliance costs and the number of workers exposed, Table 24 sets out the cost per employee exposed with setting a MEL at 5, 2, 1, 0.5, 0.2 and 0.1 mg.m^{-3}. However, as there have been no previous RIAs addressing these specific health effects, comparison with other MELs is of limited value.

Table 24

MEL proposal mg Mn.m^{-3}	**Cost per exposed worker**
5	£27,000-£55,000
2	£1,300 - £2,600
1	£1,600 - £5,500
0.5	£1,300 - £5,000
0.2	£970 - £7,500
0.1	£820 - £6,100

UNCERTAINTIES

126. Uncertainties in the assumptions made on costs are reflected in the use of ranges rather than point estimates.

127. The benefits are subject to substantial uncertainties because of the limited information about the numbers of workers currently exposed above each limit option. There is also uncertainty about the duration of exposure for these workers.

SECURING COMPLIANCE

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128. If a MEL of 2 mg Mn.m^{-3} were adopted there would be compliance implications for the following industry sectors: steel making, premix, trace element fertiliser manufacture, cleaning and preparation, manufacture and use of potassium permanganate. If a MEL of 1 mg Mn.m^{-3} were adopted there would be compliance implications for the following additional industry sectors: casting and metal finishing and welding. If a MEL of 0.5 mg Mn.m^{-3} were adopted there would be compliance

implications for the following additional industry sectors: welding consumable manufacture and battery manufacture.

129. HSE considers that it would be possible to devise control strategies that would reduce exposures below any of the MEL options given above. However, there would be significant costs, particularly for the welding industry, in a MEL of 1 mg $Mn.m^{-3}$ or 0.5 mg $Mn.m^{-3}$, mainly due to the need to install better engineering controls such as LEV. The controls required to comply with a MEL at 0.5 mg $Mn.m^{-3}$ may include RPE (e.g. in steel making) and there may be practicability issues over the use of RPE in such an environment.

RESULTS OF CONSULTATIONS

130. Manganese is used in a number of processes, and so the consultation exercise was relatively extensive. Questionnaires designed to determine the costs associated with implementing a MEL for manganese and its inorganic compounds were sent to the following trade associations:

The British Association for Chemical Specialties
The British Association on Feed Supplement and Additive Manufacture
The British Battery Manufacturers Association
The British Chemical Distributors & Traders Association Limited
The British Coatings Federation
The British Foundry Association
The British Investment Casting Trade Association
The Castings Development Centre
The Chemical Industries Association
The Cosmetic, Toiletry and Perfumery Association Ltd
The Surface Engineering Association
The Welding Institute
The Welding Manufacturers Association
The United Kingdom Agricultural Supply Trade Association Ltd
The UK Steel Association

Some of the trade associations were visited.

131. A number of businesses were also consulted and visited. Some trade associations and businesses provided recent exposure data that was not used in the risk assessment presented to WATCH in January 2000.

132. Other organisations contacted were:

The Charity Commission for England and Wales
The International Manganese Institute
The National Farmers Union
The (US) Ferroalloy Association
A manufacturer of industrial vacuum cleaners

A manufacturer of conveyor systems
Suppliers of local exhaust ventilation equipment
Laboratories providing analytical services to consultant occupational hygienists

133. Of the trade associations and businesses consulted, those involved in casting, steel production and welding were most concerned about the financial implications of adopting a MEL for manganese and its inorganic compounds.

134. A further wide consultation was held between March and June 2002. All respondents supported the establishment of a MEL set at 0.5 $mg.m^{-3}$, although it was pointed out by one respondent that there were certain tasks in the steel industry for which respiratory protective equipment would be required in order to achieve the proposed limit.

SUMMARY AND RECOMMENDATIONS

135. There will be minimal costs to industry of a MEL set at 5 mg $Mn.m^{-3}$ or 2 mg $Mn.m^{-3}$ (£0.8 million – £1.7 million and £0.9 million – £1.8 million respectively). However, the occupational health benefits of a MEL set at either of these levels will also be minimal since both these levels are above the level where significant adverse neurotoxicological effects have been observed. The effects of manganese exposure are non-reversible and may be progressive, even after exposure has ceased or been reduced.

136. A MEL set at 1 mg $Mn.m^{-3}$ or 0.5 mg $Mn.m^{-3}$ will impart significant costs to industry (£7 million – £24 million and £8 million – £30 million respectively), Anticipated costs at both levels are comparable, however the anticipated occupational health benefits are likely to be significantly greater at 0.5 mg $Mn.m^{-3}$ since this is below the level at which adverse neurotoxicological effects are observed (although not below the level at which subtle neurotoxicological changes are observed).

137. A MEL set at 0.2 mg $Mn.m^{-3}$ or 0.1 mg $Mn.m^{-3}$ is likely to prove prohibitively expensive for large sections of British industry with costs estimated at £39 million – £302 million and £46 million – £340 million respectively. In addition, the occupational health benefits associated with a MEL at these levels are not considered to be significantly greater than benefits achieved by setting the MEL at 0.5 mg $Mn.m^{-3}$.

ENFORCEMENT, SANCTIONS, MONITORING AND REVIEW

138. The MEL will be enforced at workplaces by HSE. Assigning a MEL will require an increase in the emphasis inspectors attach to manganese exposure. This will result in a slightly increased workload during inspections and any resulting enforcement action. The MEL will be revised if significant new information becomes available, which places doubt on the current assessment of the health risks.

Contact point:

Richard Pedersen
Health and Safety Executive
Chemicals and Flammables Policy Division
International Chemicals Unit
7NW Rose Court, 2 Southwark Bridge
London SE1 9HS
Tel: 020 7717 6216
May 2004

References

Barlow SM and Sullivan FM (1982). Manganese and its compounds. In: *Reproductive hazards of Industrial chemicals.* Academic Press, New York. 370-385

Crump KS and Rousseau P. (1999). Results from eleven years of neurological health surveillance at a manganese oxide and salt producing plant. *NeuroToxicology* **20(2-3):** 273-286

DFG (1999). Occupational toxicants: Critical data evaluation for MAK values (references up to July 1994). **Vol 12.** ISBN 0944 - 4459

Gennart JP, Buchet JP, Roels H *et al*. (1992) Fertility of male workers exposed to cadmium, lead or manganese. *Am J Epidemiology* **135 (11):**1208-1219

Gibbs JP, Crump KS, Houck DP *et al*. (1999). Focused medical surveillance: A search for subclinical movement disorders in a cohort of U.S. workers exposed to low levels of manganese dust. *NeuroToxicology* **20(2-3):** 299-314

HSE (1999). The costs to Britain of workplace accidents and work related ill health in 1995/96.

Kjuus H, Andersen A, Langard S, Knudsen KE. (1986). Cancer incidence among workers in the Norwegian ferro-alloy industry. *Br J Ind Med* **43:** 227-236

Lauwerys R, Roels H, Genet P et al (1985) Fertility of male workers exposed to mercury vapour or to manganese dust: a questionnaire study. *Am J Ind Med* **7**:171-176

Lucchini R, Selis L, Folli D et al. (1995). Neurobehavioral effects of manganese in workers from a ferro-alloy plant after temporary cessation of exposure. *Scand J Work Environ Health* **21:** 143-149

Lucchini R, Bergamaschi E, Smargiassi A *et al*. (1997). Motor function, olfactory threshold and haematological indices in manganese-exposed ferroalloy workers. *Envir Research* **73:** 175-180

Lucchini R, Apostoli P, Perrone C *et al*. (1999). Long term exposure to "low levels" of manganese oxides and neurofunctional changes in ferroalloy workers. *NeuroToxicology* **20(2-3):** 287-298

Miyaki M, Akamatsu N, Ono T, Koyama H. (1979). Mutagenicity of metal cations in cultured cells from Chinese hamsters. *Mutat Res* **68:** 259-263

NTP. (1992). Toxicology and carcinogenesis studies of manganese (II) sulphate monohydrate in F344/N rats and B6C3F1 mice (feed studies). **TR-428.** NTP P.O. Box 12233, Research Triangle Park, NC 27709.

Oberly TJ, Piper CE, McDonald DS. (1982). Mutagenicity of metal salts in the L5178Y mouse lymphoma assay. *J Toxicol Environ Health* **9:** 367-376

Roels H, Ortega Eslava MI, Ceulemans E *et al*. (1999). Prospective study on the reversibility of neurobehavioural effects in workers exposed to manganese dioxide. *NeuroToxicology* **20(2-3):** 255-272

Shiotsuka RN (1984). Inhalation toxicity of manganese dioxide and a magnesium oxide-manganese dioxide mixture. *US Army Medical Research and Development Command, Govt.* Accession No. AD-A148868

University of Michigan Transportation Research Institute *Impact of recent and anticipated changes in airborne emission exposure limits on shipyard workers* National Shipbuilding Research Program Report 0463 1996

WHO (1981). IPCS Environmental Health Criteria. **17,** Manganese. ISBN 92 4 154077 X

Annex 1

Detailed Compliance Costs

1. The purpose of this section is to present the detailed costs of implementing a MEL of either 5, 2, 1, 0.5, 0.2 or 0.1 $mg.m^{-3}$ in the business sectors affected. Some contributions from industry, trade associations and consultants have been incorporated into this section and the sections on the impact on small businesses and the results of consultations. Industry contributions are presented *italicised in arial font*. Information on the costing of RPE was obtained from HSE guidance note HSG53 (The selection use and maintenance of RPE, 1998), HSE Specialist Inspector's Report number 50 (Costing a RPE programme, 1996) and a manufacturer of RPE. The extra cost for an experienced chemist determining the manganese content of air samples was confirmed by HSL. LEV system prices were obtained from equipment manufacturers and some of the affected business sectors. An industrial vacuum cleaner manufacturer and a conveyor manufacturer also supplied some costs. All other costs in this report were obtained from industry in 2000. Details of the actual costings are described below.

Monitoring costs

2. Manganese monitoring costs were determined using the following information. The daily cost of employing a consultant occupational hygienist to carry out air monitoring is between £310 and £730. This was obtained from the 1996/97 directory of occupational hygiene consultants, published by the British Institute of Occupational Hygienists. It is assumed that each time consultants are hired, they charge for one and a half days (one day on site work and a half day report writing). The cost of determining manganese in an air sample is between £7 and £11. This was based on quotes from three representative laboratories. Some laboratories offer a discount for bulk sample analysis but we assume that all of the business sectors considered in this RIA are unlikely to generate sufficient samples to qualify. Professional judgment and the monitoring data in the main report were used to decide at which MEL option, businesses would need to carry out monitoring. It was assumed that individual businesses affected would monitor once in the year after the MEL is set to establish the "baseline" exposure. Control measures would then be implemented and they would monitor again to determine the efficacy of the measures. We assume that individual businesses affected will monitor once a year after the controls are implemented, modified and checked.

3. Manganese monitoring costs were determined using the following equation.

(1.5 x consultant daily rate) + (No. of samples x analysis cost) x No. of businesses

The range of initial costs for monitoring was calculated using:

((1.5 x £310) + (No. of samples x £7)) x A x 2 = £Ck to

((1.5 x £730) + (No. of samples x £11)) x B x 2 = £Dk.

A and B are used when the actual number of businesses affected is unknown and a range is used. A is the lowest number in the range. B is the highest number in the range. When the number of businesses affected is known; A = B = No. of businesses affected.

The range of annual recurring costs for monitoring was calculated using:

((1.5 x £310) + (No. of samples x £7)) x A x 1 = £Ek to
((1.5 x £730) + (No. of samples x £11)) x B x 1 = £Fk.

Steelmaking.

4. To estimate the costs incurred by this business sector it is assumed that:
a) The nature and cost of controlling manganese exposure at its various sources are similar for BOS and EAF processes.
b) Retrofitting controls will be possible at all vessels and furnaces.
c) Manganese exposure is much less significant at one of the three BOS plants because this plants use much less ferromanganese.

Manganese monitoring costs

5. It is assumed that all BOS plants and three or four out of five EAF plants carry out their own air monitoring. We believe that where this is the case, the frequency of monitoring is sufficient to check control strategies for all of the proposed MELs. It is assumed that a consultant occupational hygienist is employed to carry out air monitoring at two EAF plants and that five samples per visit are taken.

6. The exposure data in Table 1 show that 5 $mg.m^{-3}$ is exceeded by up to 2% of the furnacemen and up to 14% of alloy handlers for a MEL option of 5 $mg.m^{-3}$. However, since the data were obtained, eight hour TWA personal manganese exposure results for alloy handlers have been reduced to 0.2 to 0.5 $mg.m^{-3}$ in the plant which provided the data. In addition, the steelmaking sector have expressed the view that there will no costs associated with complying with a MEL of 5 $mg.m^{-3}$. It is our opinion that the steelmaking sector can comply with a MEL of 5 $mg.m^{-3}$ by relatively minor modifications to the working practices of a small number of employees and that these changes will incur no monitoring or control costs.

7. The initial, one off cost of monitoring is between £1.6k and £4.5k for a MEL of 1,2, 0.5, 0.2 $mg.m^{-3}$ or 0.1 $mg.m^{-3}$. The recurring annual cost is between £0.8k and £2.3k.

Control costs

8. For a MEL of 2 or 5 $mg.m^{-3}$, it is assumed that there are no additional control costs.

9. We believe that the most effective capture of manganese fume generated by EAFs and BOS vessels will be achieved by totally enclosing the furnaces and vessels in “dog houses”. It is difficult to cost accurately. It is assumed that all plants will require new or upgraded dog houses and that some plants will already have suitable extraction systems. Some plants will require new extraction systems. We assume that the number of vessels or furnaces per plant is between one and three and that the average initial cost of a new/upgraded dog house plus new/upgraded extraction is between £1,500k and £5,000k. The total cost of enclosure and extraction is therefore between £1,500k x 1 x 7 = £10,500k and £5,000k x 3 x 7 = £105,000k. The annual recurring costs are assumed to be between £1,050k and £10,500k. This solution is prohibitively expensive and not considered to be reasonably practicable.

10. Therefore for a MEL of 1, 0.5, 0.2 or 0.1 $mg.m^{-3}$, we assume that a range of control measures will be required. These include more effective capture of fume generated by EAFs and BOS vessels, modifying some shovel driver truck cabs and engineering control measures for transport and additions of manganese alloys and the use of RPE for some high exposure tasks.

11. For a MEL of 1 $mg.m^{-3}$ it is assumed that at the 3 BOS plants enclosed and ventilated conveyor systems will be installed as well as improvements to the enclosure and extraction at argon stirring. It is assumed that there will be improvements to the LEV at 5 plants.

12. For a MEL of 0.5 $mg.m^{-3}$ it is assumed that at the 3 BOS plants enclosed and ventilated conveyor systems will be installed as well as improvements to the enclosure and extraction at argon stirring. It is assumed that there will need to be improvements to the LEV at 6 plants. It is assumed that RPE will also be necessary for furnacemen at all plants for high exposure tasks. It is assumed that at three EAF plants ventilation systems will need to be installed into the cabs of the alloy handlers.

13. For a MEL of 0.2 or 0.1 $mg.m^{-3}$ it is assumed that at the 3 BOS plants enclosed and ventilated conveyor systems will be installed as well as improvements to the enclosure and extraction at argon stirring. It is assumed that there will need to be improvements to the LEV at 7 plants. It is assumed that RPE will also be necessary for furnacemen at all plants for high exposure tasks. It is also assumed that at four EAF plants ventilation systems will need to be installed into the cabs of the alloy handlers. For a MEL set at either of these levels we have assumed that the cab ventilation will not be sufficient at three plant and disposable respirators will be have to be worn for high exposure tasks.

14. We assume that power assisted respirators will be sufficient and practical for all furnacemen. The initial, one off cost of a power assisted respirator package is between £250 and £365. We have assumed that each plant will need to buy 40 respirators, therefore the initial cost per plant will be between £10k and 14.6k.

15. The recurring annual costs are:
a) Filters. These cost between £10 to £20 and are assumed to last for five days. A work year is assumed to comprise two hundred and forty days and so the number of filters required annually per furnaceman is 240 days ÷ 5 days per filter = 48 filters. This will cost between 48 x £10 = £480 and 48 x £20 = £960.
b) RPE cleaning. We assume that this is carried out by the furnacemen and that 80 hours per year will be spent on this task. At £11.53 per hour this costs 80 x £11.53 = £922.40.
c) Servicing/inspection. This is assumed to take 12 hours per year. At £11.53 per hour this costs 12 x £11.53 = £138.36.
d) Training. This is assumed to take place every year and to cost £60 per person. The course plus traveling time is assumed to take eight hours and at £11.53 per hour this costs £92.24. The total per person is, therefore, £152.24.

16. The total recurring cost per plant is between £1.7k and £2.2k.

17. To cost controlling manganese fume exposure to a MEL of 1, 0.5, 0.2, or 0.1 $mg.m^{-3}$ during argon stirring in three BOS plants, we assume that suitable extraction is already available. It is assumed that the cost of manufacturing and installing suitable hoods is between 2 x £10k = £20k and 2 x £30k = £60k. The annual recurring costs are assumed to be between £2k and £12k.

18. Fewer shovel driver truck cabs than the exposure data in Table 1 would suggest will require modification, because the cabs at BOS plants have been suitably modified since the data were obtained. We assume that between one and three cabs at each EAF plants will require modification and that this upgrade is possible for all cabs. We assume that the initial one off cost is between £5k to £10k per cab with annual recurring costs of between £0.5k to £1.5k per cab. The total initial one off cost and annual recurring costs per plant are between £5k x1 = £5k and £10k x 3 = £30k and between £0.5k x 1 = £0.5k and £1.5k x 3 = £4.5k respectively.

19. Ventilated cabs may not be sufficient to control exposure for a MEL of 0.2 or 0.1 $mg.m^{-3}$. In these situations the alloy handlers may have to wear RPE. We assume that single use respirators (P2) will be suitable. The recurring annual costs are: a) respirator - these cost approximately £2 and assuming one used per person per work day (240 work days /year). The total cost will be £2 x 240 = £0.48k per person per year; b) training - realistically, the only training received is likely to be reading the user and fitting instructions supplied with the respirators. This is assumed to take around 1 hour per year and at £11.53 per hour the total cost is

£11.53 per person per year. The costs of storage, issue, inspection and monitoring stock levels cannot realistically be estimated.

20. To cost the provision of suitable LEV for a MEL of 1 $mg.m^{-3}$ where additions containing manganese are made during tapping, it is assumed that the number of vessels or furnaces per plant is between one and three. It is assumed that new LEV plant capable of providing suitable extraction at up to three addition points would be suitable for each plant. The initial, one off cost of such LEV plant plus ducting and on site commissioning is between £7k and £10k for each addition point. The recurring annual cost for the LEV plant, including annual maintenance, examination and test plus replacement filters every three years will be between £0.75k and £1.25k. Therefore the initial cost per plant will be between £7k x 1 =£7k and £10k x 3 = £30k. The recurring cost per plant will be between £0.75k x1 = £0.75k and £1.25k x 3 = £3.75k.

21. To cost the provision of suitable LEV for a MEL of 0.5, 0.2 or 0.1 $mg.m^{-3}$ where additions containing manganese are made during tapping, it is assumed that the number of vessels or furnaces per plant is between one and three. It is assumed that new LEV plant capable of providing suitable extraction at up to three addition points would be suitable for each plant. The initial, one off cost of such LEV plant plus ducting and on site commissioning is between £10k and £15k for each addition point. The recurring annual cost for the LEV plant, including annual maintenance, examination and test plus replacement filters every three years will be between £1k and £1.5k. Therefore the initial cost per plant will be between £10k x 1 =£10k and £15k x 3 = £45k. The recurring cost per plant will be between £1k x1 = £1k and £1.5k x 3 = £4.5

22. Suitable enclosure and extraction of addition transport systems (e.g. conveyors and vibrating plate feeders) is also difficult to cost. We assume that the average initial, one off cost of transport system enclosure and extraction per plant is between £50k and £100k. We have assumed that the EAF plants either already have this or do not use conveyor systems. For the three BOS plants the total is between £50k x 3 = £150k and £100k x 3 = £300k. The annual recurring costs for the enclosure and extraction are assumed to be between £10k and £30k.

Casting and metal finishing.

23. The CDC estimate that the majority of costs associated with complying with a MEL for manganese will fall to foundries working with manganese steels. We agree with this.

24. Our estimated costs are set out below.

Manganese monitoring costs

25. Foundries do not monitor for manganese on a routine basis. Most foundries that carry out air monitoring use consultant occupational hygienists. It is assumed that where additional air monitoring is carried out, a consultant is employed and that three samples per visit are taken.

26. For a MEL of 2 or 5 $mg.m^{-3}$, the exposure data (Table 2) suggest that current control strategies are sufficient to comply. It is therefore assumed that no additional monitoring will be carried out in the year after the MEL is set.

27. For a MEL of 1, 0.5 or 2 $mg.m^{-3}$, the exposure data (Table 2) suggest that, for foundries working with manganese steels (six to ten foundries), additional monitoring will need to take place. We assume that this is the case for all foundries working with manganese steels (10). The initial, one off cost is between £9.7k and £22.5k.

28. For a MEL of 0.1 $mg.m^{-3}$, the exposure data (Table 2) show that, with current control strategies, most results (65%) are above 0.1 $mg.m^{-3}$. It is therefore assumed that monitoring will be carried out in the year after the MEL is set by all (approximately 300) foundries. The initial, one off cost is between £291.6k and £676.8k.

29. For a MEL of 1, 0.5 or 0.2 $mg.m^{-3}$, the recurring annual cost is between £4.8k and £11.28k.

30. For a MEL of 0.1 $mg.m^{-3}$, the recurring annual cost is between £145.8k and £338.4k.

Control costs

31. It is difficult to estimate the cost of appropriate control in this business sector without making a number of assumptions. Relevant information on control in this business sector was provided by CDC. The information, which assisted us in formulating our assumptions, is as follows:

Most, but not all, larger electric melting foundries i.e. with furnaces of 5 tonnes capacity or more will have some form of extraction at melting. Newer installations will normally have been fitted with the recommended close capture hoods (~20%) at furnace installation, but older furnaces are more likely to have either side draft hoods (~50%) or canopy (~10%) as it is usually impractical to retrofit a close capture system to established furnaces because of lack of access underneath the furnace platform (due to electrical and cooling water plumbing). If properly set up side draft hoods can be effective at controlling melting (and sometimes tapping) fume, but, unless curtained down to low level, canopy hoods are not usually very effective at protecting the furnacemen, although they are better at preventing fume build-up than roof-fan general ventilation. Foundries melting high manganese steel *are generally aware of the manganese fume and will mostly have the best practicable extraction fitted although in some cases, personal protection will still also be needed in order to meet current limits (1 mg.m^{-3}).*

By contrast, most, but again not all, smaller electric melting foundries currently have no LEV at melting, although a roof-fan for general ventilation to prevent fume build-up will often be provided. Perhaps ~20% will have canopy hoods or side draft hoods fitted. This does not indicate lack of care, but simply that with exposures generally at about one tenth of all current limits, expensive LEV cannot be justified as being required rather than desirable.

Cupola melting foundries will have very little exposure to actual melting fume except for intermittent manual slagging and/or tapping operations as melting fume is led out of the building to atmosphere (via some sort of cleaning).

Except for such control as is given by the furnace extraction (not generally very effective), control at tapping and metal transfer is not usually practicable because of the moving source. For foundries which can utilise a casting loop or track, casting fume is usually controlled effectively by side draft, or less commonly, canopy, hoods. However, for floor moulding foundries, there is no practical control for casting fume, apart from rather ineffective general ventilation.

32. Using the information above, provided by the CDC, and the exposure data in Table 2, we have assumed that control costs will not be incurred by any of the foundries in this business sector by adopting a MEL of 2 or 5 mg.m^{-3}. For a MEL of 1 or 0.5 mg.m^{-3}, we have assumed that only the foundries working with manganese steels will be affected (six to ten foundries). For a MEL of 0.1 or 0.2 mg.m^{-3}, we estimate that additional control costs would be incurred by up to 80% of all foundries. The details are given below:

33. For a MEL of 1 or 0.5 mg.m^{-3}, we assume that current controls are not sufficient to comply in foundries working with manganese steels (six to ten foundries). It is assumed that for some of these foundries appropriate control would be achieved by installing new, dedicated LEV plant, ducting and close capture hoods/fettling benches at operations where exposure originates. For other foundries working with manganese steels, it is assumed that an upgrade of their existing LEV would be sufficient. Assuming an average cost per foundry of new/upgraded LEV of between £5k to £15k, the total initial one off cost is between 6 x £5k = £30k and 10 x £15k = £150k. We assume that there are no additional recurring annual costs for upgraded LEV and that these costs are only incurred for new plant. However, we are unable to estimate the number of foundries requiring either new or upgraded LEV. We therefore assume that the number of foundries requiring new LEV is between six and eight. The recurring annual cost for the ventilation plant, including annual maintenance, examination and test and replacement filters every three years will be between 6 x £0.75k = £4.5k and 8 x £1.25k = £10k.

34. For a MEL of 1 or 0.5 $mg.m^{-3}$, it is further assumed that, even with new or upgraded LEV, it is possible that fettlers working manganese steels will require an upgrade in their RPE. We assume that powered respirators will be sufficient and practical for all fettlers. The initial, one off cost of a power assisted respirator package is between £250 and £365. The total cost for 50 to 100 fettlers will be between 50 x £250 = £12.5k and 100 x £315 = £31.5k.

35. The total initial costs will be between £42.5k and £180.5k.

36. The recurring annual costs are:
a) Filters. These cost between £10 to £20 and are assumed to last for five days. A work year is assumed to comprise two hundred and forty days and fettlers are assumed to spend between 20 and 70% of their time working manganese steels. Therefore, the number of days spent on this work is between 240 days x 20% = 48 days and 240 days x 70% = 168 days. The number of filters required annually is therefore between 48 days ÷ 5 days per filter = 9.6 filters and 168 days ÷ 5 days per filter = 33.6 filters. This will cost between 9.6 x £10 = £96 and 33.6 x £20 = £672. For 50 to 100 fettlers the cost will be between 50 x £96 = £4.8k and 100 x £672 = £67.2k.
b) RPE cleaning. We assume that this is carried out by the fettlers and that 80 hours per year would be spent on this task if 100% of their time were spent working manganese steels. The total amount of time spent RPE cleaning is therefore between 80 hours x 20% = 16 hours and 80 hours x 70% = 56 hours. At £11.03 per hour this costs between 16 x £11.03 = £176.48 and 56 x £11.08 = £617.68. For 50 to 100 fettlers the cost will be between 50 x £176.48 = £8.82k and 100 x £617.68 = £61.77k.
c) Servicing/inspection. This is assumed to take 12 hours per year if 100% of a fettler's time were spent working manganese steels. The total amount of time spent servicing/inspecting RPE is therefore between 12 hours x 20% = 2.4 hours and 12 hours x 70% = 8.4 hours. At £11.03 per hour this costs between 2.4 x £11.03 = £26.47 and 8.4 x £11.03 = £92.90. For 50 to 100 fettlers the cost will be between 50 x £26.47 = £1.32k and 100 x £92.90 = £9.29k.
d) Training. This is assumed to take place every year and to cost £60 per person. The course plus traveling time is assumed to take eight hours and at £11.03 per hour this costs £88.24. The total per person is, therefore, £148.24. For 50 to 100 fettlers the cost will be between 50 x £148.24 = £7.41k and 100 x £148.24 = £14.82k.

37. The total of these annual recurring costs is between £26.85k and £163.08k.

38. We do not believe that control to a MEL of 0.1 or 0.2 $mg.m^{-3}$ is reasonably practicable in all foundries. This is particularly likely for foundries melting and working manganese steels. More assumptions are made in determining the costs of controlling to a MEL of 0.1or 0.2 $mg.m^{-3}$ compared with costing a MEL of 1 or 0.5 $mg.m^{-3}$.

39. It is assumed that new/upgraded LEV would be required in 80% of foundries. Assuming an average cost per foundry of new/upgraded LEV of between £5k to £15k, the total initial one off cost is between 240 x £5k = £1,200k and 240 x £15k = £3,600k. We assume that there are no additional recurring annual costs for upgraded LEV and that these costs are only incurred for new plant. However, we are unable to estimate the number of foundries requiring either new or upgraded LEV. We therefore assume that the number of foundries requiring new LEV is between 100 and 180. The recurring annual cost for the ventilation plant, including annual maintenance, examination and test and replacement filters every three years will be between 100 x £0.75k = £75k and 180 x £1.25k = £225k.

40. It is also assumed that controlling to a MEL of 0.1 or 0.2 $mg.m^{-3}$ will require additional RPE. We assume that powered respirators will be needed for 5% (1500 people) of the exposed workforce. The initial, one off cost will be between 1,500 x £250 = £375k and 1,500 x £315 = £472.5k.

41. The total initial cost will be between £1,575k and £4,072.5k.

42. The recurring annual costs are:
a) Filters. It is assumed that RPE will be used, on average, for 30% of a shift. Therefore, the number of days RPE will be used is 240 days x 30% = 72 days. Filters cost between £10 to £20 and are assumed to last for five days. The number of filters required annually is 72 days ÷ 5 days per filter = 14.4 filters. This will cost between 14.4 x £10 = £144 and 14.4 x £20 = £288. For 1,500 people the cost will be between 1,500 x £144 = £216k and 1,500 x £288 = £432k.
b) RPE cleaning. We assume that this is carried out by the people using the RPE and that 80 hours per year would be spent on this task if RPE were used for the entire shift. The total amount of time spent RPE cleaning is therefore 80 hours x 30% = 24 hours. At £11.28 per hour (the average rate for a fettler and a furnaceman) this costs 24 x £11.28 = £240.72. For 1,500 people the cost will be 1,500 x £240.72 = £406.08k.
c) Servicing/inspection. This is assumed to take 12 hours per year if RPE were used for the entire shift. The total amount of time spent servicing/inspecting RPE is therefore 12 hours x 30% = 3.6 hours. At £11.28 per hour this costs 3.6 x £11.28 = £40.61. For 1,500 people the cost will be 1500 x £40.61 = £60.91k.
d) Training. This is assumed to take place every year and to cost £60 per person. The course plus traveling time is assumed to take eight hours and at £11.28 per hour this costs £90.24. The total per person is therefore £150.24. For 1,500 people the cost will be 1,500 x £150.24 = £225.36k.

43. The total of these annual recurring costs is between £911.35k and £1,493.35k.

Welding.

44. In estimating the costs to this business sector it is assumed that there will be no additional costs associated with any of the MEL options for SAW and TIG welding because manganese exposure is controlled below 0.1 $mg.m^{-3}$. To estimate the number of workshops in Great Britain carrying out welding operations, we assume that each workshop employs between two and eight welders. The number of workshops is therefore between 40,000 ÷ 8 = 5,000 and 30,000 ÷ 2 = 15,000. To take account of the assumption that there will be no additional costs for SAW and TIG welding, we assume a smaller number of workshops will incur costs if a MEL is adopted. Using the information in Table 4 for the relative amounts of welding consumables used in the UK, we assume that the number of workshops affected will be between 5,000 x 90% = 4,500 and 15,000 x 90% = 13,500. It is assumed that this range represents workshops which spend a minimum of around 2 hours per day welding and excludes small garages where intermittent welding operations (up to three jobs per week) are carried out.

Manganese monitoring costs

45. The majority of businesses in this sector who carry out air monitoring, employ consultant occupational hygienists to determine occupational exposure. In addition, most companies adopt the assessment approach outlined in the HSE publication EH54, Assessment of exposure to fume from welding and allied processes. Using the suppliers' fume analysis data, this method is used to calculate the welding fume exposure result ($mg.m^{-3}$) at which each component of the fume reaches its OEL.

46. Following discussions with TWI, it has been estimated that between 5 and 10% of workshops carry out sufficient monitoring to determine if their control measures function effectively. It is assumed that the monitoring regimes at these workshops would be suitable to check controls if any of the proposed MELs were adopted. Therefore, the number of workshops which could potentially incur monitoring costs is between 4,500 x 90% = 4,050 and 13,500 x 95% = 12,150.

47. It is assumed that where additional monitoring is carried out, a consultant is employed and that that three samples per visit are taken. The cost of determining manganese in an air sample is between £7 and £11. The cost of determining welding fume exposure is slightly less at between £7 and £9. However, we shall assume that all workshops request manganese analysis.

48. For MELs of 2 and 5 $mg.m^{-3}$, the exposure data (Table 3) suggest that current control strategies are sufficient to comply for all welding tasks. It is therefore assumed that no additional monitoring will be carried out after the MEL is set.

49. For a MEL of 1 $mg.m^{-3}$, 5% of all results were above 1 $mg.m^{-3}$ (Table 3). It is therefore assumed that 5% of workshops which could potentially incur monitoring costs will monitor in the year after the MEL is set. The initial, one off cost is between £194k and £1,354k.

50. For a MEL of 0.5 $mg.m^{-3}$, 8% of all results were above 0.5 $mg.m^{-3}$ (Table 3). It is therefore assumed that 8% of workshops which could potentially incur monitoring costs will monitor in the year after the MEL is set. The initial, one off cost is between £292k and £2,256k.

51. For a MEL of 0.2 $mg.m^{-3}$, 18% of all results were above 0.2 $mg.m^{-3}$ (Table 3). It is therefore assumed that 18% of workshops which could potentially incur monitoring costs will monitor in the year after the MEL is set. The initial, one off cost is between £729k and £4,964k.

52. For a MEL of 0.1 $mg.m^{-3}$, 43% 0f all results were above 0.1 $mg.m^{-3}$ (Table 3). It is therefore assumed that 43% of workshops which could potentially incur monitoring costs will monitor in the year after the MEL is set. The initial, one off cost is between £1,750k and £11,956k.

53. For a MEL of 1 $mg.m^{-3}$, the recurring annual cost is between £97k and £677k.

54. For a MEL of 0.5 $mg.m^{-3}$, the recurring annual cost is between £146k and £1,128k.

55. For a MEL of 0.2 $mg.m^{-3}$, the recurring annual cost is between £365k and £2,482k.

56. For a MEL of 0.1 $mg.m^{-3}$, the recurring annual cost is between £875k and £5,978k.

Control costs

57. The exposure data in Table 3 indicate that current control methods are suitable and sufficient for a MEL of 2 or 5 $mg.m^{-3}$. The data also indicate that extra costs will be incurred to control to a MEL of 0.5, 0.2 or 0.1 $mg.m^{-3}$. We assume that LEV alone will be required in some workshops to control to a MEL of 0.5 $mg.m^{-3}$. To control to a MEL of 0.2 or 0.1 $mg.m^{-3}$ we assume that engineering control will not be sufficient in some workshops and that RPE will also be required to control residual exposure.

58. To control to a MEL of 1 or 0.5 $mg.m^{-3}$, the type of LEV required will vary considerably between workshops. Totally new LEV plant, ducting and booths/"elephant trunks" will be required in some workshops. Others will only require modifications to existing systems. It is assumed that the average cost of appropriate engineering control is £5k with recurring annual costs of £0.5k. We assume that this control method will be required in an extra 10% of workshops (we assume that 25% of workshops already have LEV). The total initial cost is therefore between:
(4,500 x 10%) x £5k = £2,250k and (13,500 x 10%) x £5k = £6,750k.

The total recurring costs are between £225k and £675k.

59. From Table 3, 52% of the MIG/MAG results, 28% of the MMA results and 67% of the FCW results are above 0.1 $mg.m^{-3}$. To control to a MEL of 0.2 or 0.1 $mg.m^{-3}$, we assume that LEV will be required in an extra 50% of workshops. The total initial cost of this is between: (4,500 x 50%) x £5k = £11,250k and (13,500 x 50%) x £5k = £33,750k. The total recurring costs are between £1,125k and £3,375k.

60. We assume that even with the extra LEV, additional RPE will be required in some workshops for a MEL of 0.1 or 0.2 $mg.m^{-3}$. It is estimated that 10% of all workshops, each employing two to eight welders will embark on an RPE programme, using powered helmets as the principle source of RPE. The total number of welders requiring RPE is between (4,500 x 10%) x 2 = 900 and (13,500 x 10%) x 8 = 10,800. The initial, one off cost of a powered helmet is between £256 and £1,067. The total cost for 900 to 10,800 welders will be between 900 x £256 = £230.4k and 10,800 x £1,067 = £11,523.6k.

61. The recurring annual costs are:

a) Filters. These cost between £3 and £17 and are assumed to last for one day. A work year is assumed to comprise two hundred and forty days and welders are assumed to spend between 20 and 50% of their time welding. Therefore, the number of days spent welding is between 240 days x 20% = 48 days and 240 days x 50% = 120 days. The number of filters required annually is therefore between 48 days ÷ 1 day per filter = 48 filters and 120 days ÷ 1 day per filter = 120 filters. This will cost between 48 x £3 = £144 and 120 x £17 = £2,040. For 750 to 9,000 welders the cost will be between 750 x £144= £108k and 9,000 x £2,040 = £18,360k.

b) Visors. These cost between £3 and £13 and are assumed to last for a month. The number of visors required annually is therefore between 48 days ÷ 28 days per visor = 1.7 visors and 120 days ÷ 28 days per visor = 4.3 visors. For 900 to 10,800 welders the cost will be between (1.7 x £3) x 900 = £4.59k and (4.3 x £17) x 10,800= £789.48k.

c) RPE cleaning. We assume that this is carried out by the welders and that 80 hours per year would be spent on this task if 100% of their time were spent welding. We have assumed that welders spend between 20 and 50% of their time welding and so the total amount of time spent RPE cleaning is therefore between 80 hours x 20% = 16 hours and 80 hours x 50% = 40 hours. At £8.40 per hour this costs between 16 x £8.40 = £134.4 and 40 x £8.40 = £336. For 900 to 10,800 welders the cost will be between 900 x £134.4 = £120.96k and 10,800 x £336 = £3,628.8k.

d) Servicing/inspection. This is assumed to take 12 hours per year if 100% of a welder's time were spent welding. The total amount of time spent servicing/inspecting RPE is therefore between 12 hours x 20% = 2.4 hours and 12 hours x 50% = 6 hours. At £8.40 per hour this costs between 2.4 x £8.40= £20.16 and 6 x £8.40 = £50.40. For 900 to 10,800 welders the cost will be between 900 x £20.16 = £18.14k and 10,800 x £50.40 = £544.32k.

e) Training. This is assumed to take place every year and to cost £60 per person. The course plus traveling time is assumed to take 8 hours and at £8.40 per hour this costs £67.20. The total per person is, therefore, £127.20. For 900 to 10,800 welders the cost will be between 900 x £127.20 = £114.48k and 10,800 x £127.20 = £1,373.76k.

Welding consumable manufacture.

62. The jobs associated with greatest manganese exposure include weighing, blending and transferring powders containing manganese. The duration of dust exposure lasts for most of a shift from a process which is frequently totally or partially enclosed and under LEV. RPE is often used during these tasks.

63. For the purposes of costing, it is assumed that there are two processes per company that result in personal, eight hour TWA manganese exposure slightly higher than 0.5 $mg.m^{-3}$. These processes involve manipulating dry powders containing manganese. All other processes result in personal, eight hour TWA manganese exposures which are below 0.1 $mg.m^{-3}$. The processes resulting in these lower exposures occur after the powder containing manganese has been incorporated into a paste. We have assumed that there will be no costs associated with complying with a MEL of 5, 2 or 1 $mg.m^{-3}$.

Manganese monitoring costs

64. It is assumed that all consumable manufacturing companies who monitor hire consultant occupational hygienists to carry out their air monitoring. It is assumed that where additional monitoring is carried out, the consultant takes three samples per visit.

65. For MELs of 0.5, 0.2 and 0.1 $mg.m^{-3}$, the initial, one off cost of monitoring is between £9.8k and £22.6k.

66. For MELs of 0.5, 0.2 and 0.1 $mg.m^{-3}$, the recurring annual cost is between £4.9k and £11.3k.

Control costs

67. For a MEL of 0.5 $mg.m^{-3}$, we have assumed that increasing the level of enclosure of the processes generating exposure will be sufficient to adequately control exposure. We have assumed an initial cost of between £1k to £2k per process. The total initial cost is therefore between £1k x 2 x 10 = £20k and £2 x 2 x 10 = £40k. The total annual recurring costs are estimated to be between £2k and £4k.

68. For a MEL of 0.2 or 0.1 $mg.m^{-3}$, we have assumed that, in addition to increasing the level of enclosure, new dedicated LEV plant and ducting are installed

to service the processes. The initial and running costs of the increased level of enclosure are £5k to £7k and £1k to £2k respectively. The total initial cost is between £5k x 10 = £50k and £7k x 10 = £70k. The total recurring cost is between £1k x 10 = £10k and £2k x 10 = £20k. We assume that one LEV unit can service two processes per company. The initial cost of the new LEV plant plus ducting and on site commissioning is between £7k and £10k per company. The total initial cost is therefore between £7k x 10 = £70k and £10k x 10 = £100k. The total annual recurring costs for the ventilation plant, including annual maintenance, examination and test and replacement filters every three years will be between £0.75k x 10 = £7.5k and £1.25k x 10 = £12.5k.

Premix manufacture mineral supplement manufacture, and trace element fertiliser manufacture.

69. We have assumed that costs will be incurred for staff training, staff supervision, extra monitoring, vacuum cleaner purchase, vacuum cleaner servicing and engineering control. The estimated costs of complying with the MEL options are detailed below.

Staff training and supervision costs

70. It is assumed that, regardless of the numerical value of any new limit, once a MEL is introduced, costs will be incurred for staff "Health and Safety Training" and increased supervision time. Exposure in these sectors can be reduced by training workers in the correct use of ventilated enclosures with increased supervision to ensure that the training is utilised. It is assumed that all employees are instructed that ripping and tipping should be carried out with the bag well inside the enclosure. If the empty bag is to be stacked outside the enclosure, it should be as empty as possible and flattened whilst inside the enclosure. It is also assumed that employees will receive training about good housekeeping and that an average of 10 minutes at the end of shift is allowed for cleaning (see section on control costs for prices of suitable vacuum cleaners and the cost of cleaning time). It is assumed that the training will be formulated and delivered by employees within the sectors.

71. The assumptions regarding the involvement of various employees within the sectors and the total costs of initial training and supervision are summarised in Table 13.

Table 13: Initial costs of training and supervision in the premix, mineral supplement and fertiliser sectors.

Employee	Total time assumed to be involved with training or supervision	Number of employees involved	Hourly rate	Costs of initial training or supervision (£k)

	(hours)			
Plant manager	20	40 - 50	20.00[a]	16 - 20
Health and Safety manager	20	40 - 50	16.00[a]	12.8 - 16
Supervisor	30 - 60	30 - 60	8.40	7.56 - 30.24
Operator	6	124 - 236	7.31	5.43 - 10.35

[a]*We were uncertain of the hourly rate for this employee category. Verification was attempted by consulting the United Kingdom Agricultural Supply Trade Association Ltd. They were also uncertain, but they suggested that the figures were not unreasonable.*

72. For all of the MEL options, the total initial one off costs of training and supervision for these business sectors is between £41.79k and £76.59k. The assumptions regarding employee involvement with annual refresher training and supervision and the total costs are summarised in Table 14.

Table 14: Costs of annual refresher training and supervision in the premix, mineral supplement and fertiliser sectors.

Employee	Total time assumed to be involved with refresher training or supervision (hours)	Number of employees involved	Hourly rate	Refresher training costs (£k)
Plant manager	3	40 - 50	20.00[a]	2.4 - 3
Health and Safety professional	3	40 - 50	16.00[a]	1.92 - 2.4
Supervisor	15 - 20	30 - 60	8.40	3.78 - 10.08
Operator	3	124 - 236	7.31	2.72 - 5.18

[a]*We were uncertain of the hourly rate for this employee category. Verification was attempted by consulting the United Kingdom Agricultural Supply Trade Association Ltd. They were also uncertain, but they suggested that the figures were not unreasonable.*

73. The total annual recurring costs of refresher training and supervision for these business sectors is between £10.82k and £20.66k, for all of the MEL options.

Manganese monitoring costs

74. It is assumed that, where monitoring is carried out, premix, mineral supplement and fertiliser manufacturers hire consultants to carry out their air monitoring. We assume that an average of four samples per visit are taken and that the total number of plants which could potentially incur monitoring costs is 25.

75. For a MEL of 5 $mg.m^{-3}$, the exposure data (Table 5) suggest that current control strategies are failing to comply; with 11% of the monitoring results above 5 $mg.m^{-3}$. It is therefore assumed that three plants will monitor in the year after the MEL is set. The initial, one off cost is between £3k and £6.9k.

76. For a MEL of 2 $mg.m^{-3}$, the exposure data (Table 5) suggest that current control strategies are failing to comply; with 16% of the monitoring results above 2 $mg.m^{-3}$. It is therefore assumed that four plants will monitor in the year after the MEL is set. The initial, one off cost is between £4k and £9k.

77. For a MEL of 1 $mg.m^{-3}$, the exposure data (Table 5) suggest that current control strategies are failing to comply; with 39% of the monitoring results above 1 $mg.m^{-3}$. It is therefore assumed that ten plants will monitor in the year after the MEL is set. The initial, one off cost is between £9.9k and £22.8k.

78. For a MEL of 0.5 $mg.m^{-3}$, the exposure data (Table 5) suggest that, with current control strategies, 56% of the monitoring results are above 0.5 $mg.m^{-3}$. It is therefore assumed that 14 plants will monitor in the year after the MEL is set. The initial, one off cost is between £13.8k and £31.9k.

79. For a MEL of 0.2 $mg.m^{-3}$, the exposure data (Table 5) suggest that current control strategies are failing to comply; with 61% of the monitoring results above 0.2 $mg.m^{-3}$. It is therefore assumed that fifteen plants will monitor in the year after the MEL is set. The initial, one off cost is between £14.8k and £34.2k.

80. For a MEL of 0.1 $mg.m^{-3}$, the exposure data (Table 5) indicate that, with current control strategies, 67% of the monitoring results are above 0.1 $mg.m^{-3}$. It is therefore assumed that 17 plants will monitor in the year after the MEL is set. The initial, one off cost is between £16.8k and £38.7k.

81. For a MEL of 5 $mg.m^{-3}$, the recurring annual cost is between £1.5k and £3.4k.

82. For a MEL of 2 $mg.m^{-3}$, the recurring annual cost is between £2k and £4.5k.

83. For a MEL of 1 $mg.m^{-3}$, the recurring annual cost is between £4.9k and £11.4k.

84. For a MEL of 0.5 $mg.m^{-3}$, the recurring annual cost is between £6.9k and £15.9k.

85. For a MEL of 0.2 $mg.m^{-3}$, the recurring annual cost is between £7.4k and £17.1k.

86. For a MEL of 0.1 $mg.m^{-3}$, the recurring annual cost is between £8.4k and £19.4k.

Control costs

87. The use of LEV in these business sectors is widespread but dust exposure is still poorly controlled and 11% of the manganese results in Table 5 are above 5 $mg.m^{-3}$. The main form of control during rip-and-tip operations is a ventilated enclosure. We estimate that approximately 50% of these are fitted with waste bag collectors. RPE use is also widespread. We estimate that approximately 30% of employees use powered respirators and that the remainder use RPE with lower Assigned Protection Factors.

88. For a MEL of 5 or 2 $mg.m^{-3}$, the exposure data in Table 5 suggest that current controls are not suitable, with 11%/16% of results above 5/2 $mg.m^{-3}$. However, it is assumed that adopting the training regime covered in the section above on staff training and supervision (and improved cleaning – see below) will be sufficient to control to a MEL of 5 or 2 $mg.m^{-3}$. The costs of this control method will also be incurred for a MEL of 1, 0.5, 0.2 or 0.1 $mg.m^{-3}$.

89. It is assumed that there are a variety of shift patterns and number of operatives at premix, mineral supplement and fertiliser manufacturers and so it is estimated that a cleaning period of 10 minutes per shift equates to between 15 to 30 minutes per plant per day. At £7.31 per hour, for an average of four operatives per plant, for a 240 day work year the total cost is between 0.25 x £7.31 x 4 x 240 x 42 = £73.68k and 0.5 x £7.31 x 4 x 240 x 47 = £164.91k for all MEL options. This cost is incurred each year and is therefore regarded as a recurring cost.

90. For all the MEL options the exposure data (Table 5) suggest that current control strategies are failing to comply; with 11% of the monitoring results above 5 $mg.m^{-3}$, 16% above 2$mg.m^{-3}$, 39% above 1$mg.m^{-3}$, 56% above 0.5$mg.m^{-3}$, 61% above 0.2$mg.m^{-3}$ and 67% above 0.1$mg.m^{-3}$. We assume that industrial vacuum cleaners of between 20 and 35 litre capacity, fitted with an H-type filter and conforming to BS 5415 (Safety of electrical motor-operated industrial and commercial cleaning appliances) will form part of an effective control strategy. We assume that the number of vacuum cleaners required per plant for MELs of 5/2$mg.m^{-3}$, 1$mg.m^{-3}$, 0.5$mg.m^{-3}$ and 0.2/0.1 $mg.m^{-3}$ are one, two, three and four respectively.

91. At a cost of between £633 and £730 per vacuum cleaner, the total initial cost for a MEL of 5 or 2 $mg.m^{-3}$ is between 42 x £633 = £26.59k and 47 x £730 = £34.31k.

92. For a MEL of 1$mg.m^{-3}$, the initial cost is between 42 x £633 x 2 = £53.17k and 47 x £730 x 2 = £68.62k.

93. For a MEL of 0.5 $mg.m^{-3}$, the initial cost is between 42 x £633 x 3 = £79.7k and 47 x £730 x 3 = £102.9k.

94. For a MEL of 0.2 or 0.1mg.m^{-3} , the initial cost is between 42 x £633 x 4 = £106.34k and 47 x £730 x 4 = £137.24k.

95. We assume that each vacuum cleaner will require servicing (consisting of decontamination and a filter change) twice a year at a cost of between £125 and £150 per appliance per service.

96. For a MEL of 5 or 2mg.m^{-3}, the recurring annual cost is between 42 x £250 = £10.5k and 47 x £300 = £14.1k.

97. For a MEL of 1mg.m^{-3}, the recurring annual cost is between 42 x £250 x 2 = £21k and 47 x £300 x 2 = £28.2k.

98. For a MEL of 0.5 mg.m^{-3}, the recurring annual cost is between 42 x £250 x 3 = £31.5k and 47 x £300 x 3 = £42.3k.

99. For a MEL of 0.2 or 0.1 mg.m^{-3}, the recurring annual cost is between 42 x £250 x 4 = £42k and 47 x £300 x 4 = £56.4k.

100. We also assume that engineering control will form part of an effective control strategy for MEL options of 1, 0.5, 0.2 or 0.1mg.m^{-3}.

101. For a MEL of 1 or 0.5 mg.m^{-3}, we assume that additional ventilated enclosures with waste bag collectors would provide an appropriate level of control. We assume that one to two units per plant should be sufficient. The initial, one off costs are between 42 x £4k x 1 = £168k and 47 x £7k x 2 = £658k. We estimate that the recurring annual cost will be between £16.8k and £65.8k.

102. For a MEL of 0.2 or 0.1 mg.m^{-3}, we have assumed that ventilated enclosures at most plants should be replaced with enclosed automatic sack emptying units with integral LEV and waste bag collectors. We estimate that one to two units will be required per plant. The initial, one off costs are between 42 x £21k x 1 = £882k and 47 x £24k x 2 = £2,256k. The recurring annual cost will be between £88.2k and £225.6k.

Animal feed manufacture.

103. In our opinion, this business sector will not incur costs for any of the MEL options.

104. The United Kingdom Agricultural Supply Trade Association (UKASTA) distributed questionnaires on manganese exposure and costs to its members. One company responded, estimating their costs to be £497k for MELs of 0.1 and 0.5 mg.m^{-3}. The estimated cost for a MEL of 5 mg.m^{-3} was £60k. They did not distinguish between initial and recurring costs, although we assume the quoted figures to be initial costs. We do not agree with this because, based on

information supplied by industry, we are of the opinion that the maximum possible eight hour TWA manganese exposure during feed manufacture is 0.07 $mg.m^{-3}$.

105. The company added that: *"A full assessment and analysis would have to be conducted to confirm the level of manganese within the 5 $mg.m^{-3}$ of total dust burden, as once blended the effect of dilution would reduce the overall levels.*

"The equipment and costings are "worst case" levels of controls that would be required."

The company also commented that eight-hour TWA inhalable dust exposure was below 5 $mg.m^{-3}$.

Animal feed use.

106. It is our opinion that this business sector will not be affected by adopting any of the MEL options for manganese and its inorganic compounds.

107. UKASTA received two responses to our questionnaire from member companies. Their responses are summarised in Table 16.

Table 16: Information provided in response to a HSE questionnaire on complying with a variety of MELs.

Company number	Cost for a MEL of 5 $mg.m^{-3}$ (£k)	Cost for a MEL of 0.5 $mg.m^{-3}$ (£k)	Cost for a MEL of 0.1 $mg.m^{-3}$ (£k)
1	No cost	£12k per hand tip point per dust extraction unit. £2k per worker for PPE.	£12k per hand tip point per dust extraction unit. £2k per worker for PPE.
2	No cost	One off cost of £30k.	One off cost of £250k.

108. Under our definition of feed manufacture and use, we assume that these companies are feed manufacturers and not users. We do not agree with their costs because we are of the opinion that manganese exposure is currently controlled sufficiently far below 0.1 $mg.m^{-3}$ in this sector.

109. In response to the section of the questionnaire requesting additional information, Company 1 added: *"Assumed calculations (for costs). There is no knowledge of manganese (concentration) in the dust."*

Trace element fertiliser use.

110. In our opinion, this business sector will not incur costs for the MEL options of 5, 2, 1 and 0.5 $mg.m^{-3}$. The most likely control method that will be selected by farm workers to control to a MEL of 0.2 or 0.1$mg.m^{-3}$ is the disposable filtering facepiece respirator. It is our opinion that, if either of these MEL options is adopted, this control method is unlikely to be used in practice.

111. We assume that, other than the protection offered by an enclosed tractor cab, all farm workers are unlikely to use any other controls during fertiliser spraying.

Control costs

112. We assume that all exposed farm workers will opt for RPE in order to mitigate their manganese exposure during spraying. We assume that single use filtering half masks (FF P3) will be suitable.

The recurring annual costs are:
a) Filtering half masks. These cost approximately £3.50 and will mostly be used once per year. The total cost will be between £3.50 x 3,000 = £10.5k and £3.50 x 7,000 = £24.5k.
b) Training. Realistically, the only training received is likely to be reading the user and fitting instructions supplied with the respirators. This is assumed to take around 1 hour per year and at £7.35 per hour the total cost is between £7.35 x 3,000 = £22.05k and £7.35 x 7,000 = £51.45k.
The costs of storage, issue, inspection and monitoring stock levels cannot realistically be estimated.

113. For a MEL of 0.2 or 0.1$mg.m^{-3}$, the total of these annual recurring costs is between £33k and £76k.

Cleaning preparation manufacture and potassium permanganate use.

114. Estimating the costs to this business sector of adopting a MEL for manganese and its inorganic compounds was more difficult than any other business sector because we determined little regarding numbers exposed and their actual exposures. We were not able to identify a trade association representing any of the businesses handling potassium permanganate. In addition, we were unable to identify an individual who had any useful knowledge of either the business sector as a whole or the “subsections” of the sector, such as metal cleaning.

115. We assume that there are between 20 and 100 businesses handling potassium permanganate and that all are controlling to below 5$mg.m^{-3}$. We estimate that:
at 5 businesses workers are exposed to manganese at up to 2 $mg.m^{-3}$ (eight hour TWA);
at 10 businesses workers are exposed to manganese at up to 1 $mg.m^{-3}$ (eight hour TWA);

at 20 businesses workers are exposed to manganese at up to 0.5 $mg.m^{-3}$ (eight hour TWA);
at 40 businesses workers are exposed to manganese at up to 0.2 $mg.m^{-3}$ (eight hour TWA) and
at 50 businesses workers are exposed to manganese at up to 0.1 $mg.m^{-3}$ (eight hour TWA).

Manganese monitoring costs

116. It is assumed that all companies in this business sector who monitor, hire consultants to carry out their air monitoring. We assume that two samples per visit are taken.

117. For a MEL of 2 $mg.m^{-3}$, we assume that monitoring will be carried out at 5 businesses in the year after the MEL is set. The initial, one off cost is between £4.8k and £11.2k. The recurring annual cost is between £2.4k and £5.6k.

118. For a MEL of 1 $mg.m^{-3}$, we assume that monitoring will be carried out at 10 businesses in the year after the MEL is set. The initial, one off cost is between £9.6k and £22.4k. The recurring annual cost is between £4.8k and £11.2k.

119. For a MEL of 0.5 $mg.m^{-3}$, we assume that monitoring will be carried out at between 20 businesses in the year after the MEL is set. The initial, one off cost is between £19.2k and £44.8k. The recurring annual cost is between £9.6k and £22.4k.

120. For a MEL of 0.2 $mg.m^{-3}$, we assume that monitoring will be carried out at 40 businesses in the year after the MEL is set. The initial, one off cost is between £38.4k and £89.6k. The recurring annual cost is between £19.2k and £44.8k.

121. For a MEL of 0.1 $mg.m^{-3}$, we assume that monitoring will be carried out at between 50 businesses in the year after the MEL is set. The initial, one off cost is between £48k and £111.7k. The recurring annual cost is between £24k and £55.8k.

Control costs

122. It is assumed that new/upgraded enclosures plus new/upgraded/existing LEV plant would be sufficient to control exposure for any of the proposed numbers. Consequently the range of costs at individual businesses will be large because there is a large difference in the cost of an upgraded enclosure plus existing LEV compared with a new enclosure plus new LEV plant. It is assumed that the average cost of engineering control per process is between £3k and £10k.

123. The total initial cost for a MEL of:

$2mg.m^{-3}$ is between £3k x 5 = £15k and £10k x 5 = £50k;
$1mg.m^{-3}$ is between £3k x 10 = £30k and £10k x 10 = £100k;
$0.5mg.m^{-3}$ is between £3k x 20 = £60k and £10k x 20 = £200k;
$0.2mg.m^{-3}$ is between £3k x 40 = £120k and £10k x 40 = £400k;
$0.1mg.m^{-3}$ is between £3k x 50 = £150k and £10k x 50 = £500k;

124. The total annual recurring costs are estimated to be:

between £0.3k x 5 = £1.5k and £1k x 5 = £5k for a MEL of $2mg.m^{-3}$;
between £0.3k x 10 = £3k and £1k x 10 = £10k for a MEL of $1mg.m^{-3}$;
between £0.3k x 20 = £6k and £1k x 20 = £20k for a MEL of $0.5mg.m^{-3}$;
between £0.3k x 40 = £12k and £1k x 40 = £40k for a MEL of $0.2mg.m^{-3}$;
between £0.3k x 50 = £15k and £1k x 50 = £50k for a MEL of $0.1mg.m^{-3}$;

125. We assume that even with improved engineering control, around 30% of the workers would still be exposed to manganese in excess of 0.1 $mg.m^{-3}$ (eight hour TWA). In these cases it is likely that additional RPE will be used to mitigate exposure. We assume that single use filtering half masks (FF P3) will be suitable.

126. The recurring annual costs are:
a) Filtering half masks. These cost approximately £3.50 and we assume that they will be used 10 times (on average) per year by 30% of 50 workers. The total cost will be £3.50 x 15 x 10 = £0.52k.
b) Training. Realistically, the only training received is likely to be reading the user and fitting instructions supplied with the respirators. This is assumed to take around 1 hour per year and at £8.45 per hour for 30% of 50 workers the total cost is £8.45 x 15 = £0.13k.
The costs of storage, issue, inspection and monitoring stock levels cannot realistically be estimated.

127. For a MEL of 0.1 $mg.m^{-3}$, the total of these annual recurring costs is £0.65k.

Manganese octoate and manganese acetate manufacture.

128. Even though the eight hour TWA manganese exposures modelled in the risk assessment using the EASE model were 0.1 to 0.2 $mg.m^{-3}$ for ripping and tipping and 0.05 to 0.5 $mg.m^{-3}$ for bag disposal, we assume that actual exposure will always be below 0.5 $mg.m^{-3}$ and that these business sectors will only incur costs for MEL options of 0.2 or 0.1 $mg.m^{-3}$.

Manganese monitoring costs

129. As far as we have been able to determine, these business sectors have never monitored their employee's manganese exposure.

130. It is assumed that manganese octoate and manganese acetate manufactures will hire consultants to carry out their air monitoring and that three samples per visit are taken.

131. For MELs of 0.2 or 0.1 mg.m^{-3}, the initial, one off cost is between £7.9k and £18.2k. The recurring annual cost is between £3.9k and £9.15k.

Control costs

132. For a MEL of 0.2 or 0.1 mg.m^{-3}, we assume that installing ventilated enclosures with waste bag collectors at all tipping points would provide an appropriate level of control. The initial, one off costs are between 10 x £4k = £40k and 15 x £7k = £105k. We estimate that the recurring annual cost will be between 10 x £0.4k = £4k and 15 x £0.7k = £10.5k.

Battery manufacture.

133. There are only 2 battery manufacturers in the UK. Monitoring is carried out in-house at Company A. The pattern of monitoring they currently use we believe is sufficient to check their control strategy for all of the proposed MELs. However, the method of sampling and analysis will need to be changed. Costs are included for this. Company B uses consultants. As there is very little exposure data from Company B we have assumed that they have similar levels of control as Company A.

134. Both battery manufacturers already provide their employees with RPE for use during the initial stages of manufacture. Therefore, the provision of RPE will not contribute to any additional control costs. The exposure data in Table 7 suggest that there should be no additional control costs for a MEL of 5, 2 or 1mg.m^{-3}.

135. For a MEL of 0.5 mg.m^{-3} we have assumed that a ventilated enclosure would provide an appropriate level of control. Enclosing the bag opening/weighing parts of the process should be sufficient. We estimate that a total of two enclosures with waste bag collectors will be required.

136. For a MEL of 0.2 or 0.1 mg.m^{-3} we have also assumed that ventilated enclosures would also be suitable. They should be used at all points in the process where manganese dioxide is handled as a powder, prior to the addition of liquid which converts the powder into a paste. We estimate that at each manufacturer, three enclosures will be required; one with a waste bag collector. The estimated costs are detailed below.

Manganese monitoring costs

137. Inhalable dust exposure monitoring is carried out in-house at company A. The monitoring frequency of company A has increased year-on-year since 1997. The frequencies, in samples per year, in 1997, 1998 and 1999 were one, seven and twenty respectively. By October 2000 twenty eight samples had been taken for the year 2000. We believe that this pattern of monitoring is sufficient to check their control strategy for all of the proposed MELs. However, the method of sample analysis will need to be changed from measuring inhalable dust exposure to also determining manganese exposure. In addition, the proportion of personal samples should increase because only 21% of their long-term results were from personal samples. The initial, one off costs for company A (who employ a qualified chemist), assuming that thirty samples are analysed in batches of ten in the first year after a MEL is adopted, are:

a) purchasing chemicals and other consumable items £0.2k to £0.3k
b) purchasing glassware £0.2k to £0.3k
c) purchasing lab equipment £0.2k to £0.3k
d) purchasing a hot-plate £0.45k to £0.6k
e) purchasing a suitable analytical method £0.01k to £0.02k
f) chemist's time (at £19.93 per hour) £2.4k to £3.2k
The total initial cost for company A is between £3.46k and £4.72k.

138. If it is assumed that the sampling and analysis regime does not change after the first year the MEL is adopted, the recurring annual costs are:
a) purchasing chemicals and other consumable items £0.2k to £0.3k
b) chemist's time £0.8k to £1.6k
c) equipment maintenance £0.2k to £0.3k
The total of these recurring costs for company A is between £1.2k and £2.2k.

139. Consultants are employed by company B and, to the best of our knowledge, they have only been used once in the past three years. We believe that this monitoring frequency will be insufficient to determine the adequacy of control measures for some of the MEL options. It is therefore assumed that consultant occupational hygienists will be hired for some of the MEL options and that three samples per visit are taken.

140. Only one exposure result is available for company B and so it is also assumed that the exposure data from company A reflects the level of control in company B.

141. The exposure data (Table 7) suggest that current control strategies are sufficient to comply for MELs of 5, 2 and 1 $mg.m^{-3}$. It is therefore assumed that no additional monitoring will be carried out for these MEL options.

142. The exposure data (Table 7) show that, with current control strategies, significant proportions of the results are above the MEL options of 0.5, 0.2 and 0.1 $mg.m^{-3}$. It is therefore assumed that monitoring will be carried out for these options.

The initial, one off cost is between £1k and £2.24k. The recurring annual cost is between £0.5k and £1.1k.

Control costs

143. Both battery manufacturers already provide their employees with RPE for use during the initial stages of manufacture. Therefore, the provision of RPE will not contribute to any additional control costs. The exposure data in Table 7 suggest that there should be no additional control costs for a MEL of 5, 2 or 1mg.m^{-3}.

144. We have assumed that a ventilated enclosure would provide an appropriate level of control for a MEL of 0.5 mg.m^{-3}. Enclosing the bag opening/weighing parts of the process should be sufficient. We estimate that a total of two enclosures with waste bag collectors will be required. The initial, one off costs are between 2 x £4k = £8k and 2 x £7k = £14k. We estimate that the recurring annual cost will be between 2 x £0.4k = £0.8k and 2 x £0.7k = £1.4k.

145. We have assumed that ventilated enclosures would also be suitable for a MEL of 0.2 or 0.1 mg.m^{-3}. They should be used at all points in the process where manganese dioxide is handled as a powder, prior to the addition of liquid which converts the powder into a paste. We estimate that at each manufacturer, three enclosures will be required; one with a waste bag collector. The initial, one off costs are between 4 x £3k = £12k and 4 x £6k = £24k and between 2 x £4k = £8k and 2 x £7k = £14k. We have also assumed that new LEV plant will be required to ventilate each set of three enclosures. Assuming a volume flow of around 4000 m^{3}.h^{-1} for five to fifteen hours per week, a single reverse jet cleaned filter unit should be sufficient. The initial, one off cost of the LEV plant plus ducting and on site commissioning is between 2 x £7k = £14k and 2 x £10k = £20k. The recurring annual cost for the enclosures will be between 6 x £0.3k = £1.8k and 6 x £0.7k = £4.2k. The recurring annual cost for the ventilation plant, including annual maintenance, examination and test and replacement filters every three years will be between 2 x £0.75k = £1.5k and 2 x £1.25k = £2.5k.