Report

Emission factors programme Task 1 – Summary of simple desk studies (2003/4)

A report prepared for the Department for Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland

AEAT/ENV/R/1715/Issue 1
March 2004

Title	Emission factors programme Task 1 – Summary of simple desk studies (2003/4)
Customer	Department for Environment, Food and Rural Affairs
Customer reference	EPG 1/3/195
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File reference	ED47141
Reference number	AEAT/ENV/R/1715/Issue 1

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Executive Summary

This report has been prepared for the Department for the Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland by **netcen** (an operating division of AEA Technology) under the contract EPG 1/3/195 - Emission factors for air pollutants.

The Department for Environment Food and Rural Affairs (Defra) Air and Environment Quality (AEQ) Division is responsible for maintaining the UK National Atmospheric Emissions Inventory (NAEI). The NAEI is maintained by **netcen** on behalf of Defra. As part of the ongoing quality control of the NAEI the quantitative uncertainty in the national emission total of each component pollutant in NAEI is reviewed annually. Based on the findings of this review project EPG 1/3/195 aims to characterise and minimise uncertainty in the emission factors used in the compilation of the NAEI. The project objectives (Tasks) are set and reviewed annually; these comprise data collection and evaluation via literature review, personal contact with industrial representatives, direct source measurement and other means as appropriate.

Task 1 comprises small, simple, pieces of research or information purchases in order to improve areas of detail in the NAEI. The task included the purchase of publications and the gathering of information from industry via telephone contacts with trade associations and industrial process operators.

The research has covered a wide range of areas and, as a result, inventory improvements have been proposed in the following areas:

- Container glass production (PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn);
- Special glass production (PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn);
- Domestic glass production (PM_{10}, As, Cd, Cu, Hg);
- Lead glass production (As, Cr, Cd, Cu, Hg, Se)
- Wood impregnation (VOC);
- Burning of treated wood (Cr, Cu);
- Cement clinker production (All pollutants);
- Film coating (VOC);
- Paper coating (VOC);
- Printing of flexible packaging (VOC);
- Manufacture of pressure sensitive tapes (VOC);
- Adhesives use (VOC);
- Petrol stations and petrol terminals (VOC, benzene, 1,3-butadiene);
- Non-fletton brickworks (PM_{10}, HCl, HF);
- Plaster processes (PM_{10});
- Industrial combustion processes (NOx);
- Tyre manufacture (VOC);
- Slag cement production (PM_{10});
- Foundries (PM_{10}, Cr, As, Cd, Cu, Hg, Ni, Pb, Se, V, Zn, Mn, Sn);
- Copper wire rod plants (CO);
- Sewage sludge incineration (NOx, As, Cd, Hg, Pb, dioxins) ;
- Clinical waste incineration (As, Ni, dioxins)
- Part B processes (PM_{10})

Contents

1 Introduction

This report has been prepared for the Department for the Environment, Food and Rural Affairs; the National Assembly of Wales: the Scottish Executive; and the Department of Environment in Northern Ireland by **netcen** (an operating division of AEA Technology plc) under the contract EPG 1/3/195 - Emission factors for air pollutants.

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This report provides a summary of work undertaken to improve the NAEI using simple desk-based studies to target specific sections of the NAEI with high uncertainty.

2 Methodology

Small, simple, pieces of research were carried out in order to improve areas of detail within the National Atmospheric Emissions Inventory. The task consisted of the gathering of information from industry via telephone contacts with trade associations and industrial process operators as well as via the internet and literature sources.

The research has covered a wide range of areas and, as a result, inventory improvements have been proposed in the following areas:

- Container glass production (PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn);
- Special glass production (PM_{10}, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn);
- Domestic glass production (PM_{10}, As, Cd, Cu, Hg);
- Lead glass production (As, Cr, Cd, Cu, Hg, Se)
- Wood impregnation (VOC);
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- Film coating (VOC);
- Paper coating (VOC);
- Printing of flexible packaging (VOC);
- Manufacture of pressure sensitive tapes (VOC);
- Adhesives use (VOC);
- Petrol stations and petrol terminals (VOC, benzene, 1,3-butadiene);
- Non-fletton brickworks (PM_{10}, HCl, HF);
- Plaster processes (PM_{10});
- Industrial combustion processes (NOx);
- Tyre manufacture (VOC);
- Slag cement production (PM_{10});
- Foundries (PM_{10}, Cr, As, Cd, Cu, Hg, Ni, Pb, Se, V, Zn, Mn, Sn);
- Copper wire rod plants (CO);
- Sewage sludge incineration (NOx, As, Cd, Hg, Pb, dioxins) ;
- Clinical waste incineration (As, Ni, dioxins)
- Part B processes (PM_{10})

Progress in each area is summarised in the following sections.

3 Results and recommendations

3.1 INTRODUCTION

Results are summarised in the following sections. The impact of the changes proposed on NAEI estimates are shown in tables. Generally, emission estimates for the year 2001 are used as a baseline to compare differences between the 2001 version of the NAEI ('2001 NAEI') and the current (2002) version of the NAEI ('2002 NAEI').

3.2 GLASS PRODUCTION

Research has concentrated on obtaining new data regarding emissions of PM_{10} and metals from container and special glass production. As a result of the data collected, new PM_{10} emission factors are proposed for both processes, and further recommendations are made regarding emission factors for metals, including the deletion of a number of metals from the NAEI.

PM_{10} emissions data have been collected from process operators and local authorities for 17 furnaces for container glass production (out of a total of about 34 in the UK), and 3 special glass production sites (out of a UK total of 5). The use of these factors was recommended for the NAEI and they have been incorporated in the 2002 version of the inventory. In the absence of data specific to domestic glass production and, given the low confidence in the existing PM_{10} factor for domestic glass, it was also recommended that the factor derived for container glass was also used for domestic glass. The new PM_{10} emission factors used in the 2002 NAEI are shown in Table 1, together with details of the emission estimates both before and after adoption of these new factors.

Table 1. Emission factors for glass processes

Sector	Factor (kt/Mt glass)	Emission in 2001 (tonnes)		% change
		2001 NAEI	2002 NAEI	
Container glass	0.308	39	542	+1294%
Special glass	0.330	36	118	+229%
Domestic glass (non lead)	0.308	19	8	-58%

Process operators and other industry representatives have supplied data on the use of metals in glass manufacture. From the information provided, it is obvious that many metals are not used but that emission estimates for these metals are included in the NAEI. It has been recommended that these emission estimates are removed from the NAEI and this has occurred for the 2002 version of the inventory. It should be noted that emissions of these metals may occur from glass processes where fuel oil or gas oil are used as fuels but that these emissions are covered elsewhere in the NAEI. The emission estimates which have been removed are shown in Table 2.

Table 2 – Summary of changes to the reporting of metals from glass processes in the 2002 NAEI

Sector	Estimates removed for:
Container glass	As, Cd, Cu, Hg, Ni, Pb, Zn
Special glass	Cr, Cd, Cu, Hg, Se
Domestic glass (non-lead)	As, Cd, Cu, Hg
Domestic glass (lead)	Cr, As, Cd, Cu, Hg, Se

Other metals are used in glass processes and data has been provided by process operators on the use of some of these metals. As a result, updated estimates of metal emissions from glass processes were recommended for, and ultimately included in, the 2002 NAEI. This work continues the process begun last year of updating metal emission estimates for glass processes. Table 3 shows how metal emission factors have changed over the last three versions of the NAEI.

Table 3. Summary of changes in metal emission estimates in recent versions of the NAEI ('NO' - not occurring)

Sector	Emission in 2000 (kg)		
	2000 NAEI	**2001 NAEI**	**2002 NAEI**
Container glass:			
Cr	89	89	374
As	4	4	NO
Cd	6	6	NO
Cu	22	22	NO
Hg	2	2	NO
Ni	70	70	NO
Pb	444	444	NO
Se	666	666	10670
Zn	407	407	NO
Flat glass:			
Cr	3014	NO	NO
As	151	NO	NO
Cd	188	NO	NO
Cu	753	NO	NO
Hg	63	NO	NO
Ni	2386	NO	NO
Pb	15070	NO	NO
Se	22604	1008	1008
Zn	13814	NO	NO
Special glass:			
Cr	231	231	NO
As	12	12	252
Cd	14	14	NO
Cu	58	58	NO
Hg	5	5	NO
Ni	183	183	106
Pb	1155	1155	605
Se	1732	1732	NO
Zn	1058	1058	303
Domestic glass (non lead):			
Cr	31	31	31
As	2	2	NO
Cd	2	2	NO
Cu	8	8	NO
Hg	1	1	NO

Sector	Emission in 2000 (kg)		
	2000 NAEI	2001 NAEI	2002 NAEI
Ni	25	25	25
Pb	155	155	155
Se	232	232	232
Zn	142	142	142
Domestic glass (lead):			
Cr	2	2	NO
As	136	136	NO
Cd	0	0	NO
Cu	1	1	NO
Hg	0	0	NO
Ni	2	2	2
Pb	2624	2624	2624
Se	17	17	NO
Zn	11	11	11
Glass wool:			
Cr	20	65	22
As	2	11	2
Cd	3	4	0
Cu	10	65	20
Hg	1	3	3
Ni	10	65	31
Pb	20	78	24
Se	3	11	3
Zn	342	2099	2099
Glass fibres:			
Cr	2931	3156	3156
As	20	48	22
Cd	NO	NO	NO
Cu	NO	NO	NO
Hg	NO	NO	NO
Ni	NO	NO	NO
Pb	125	297	297
Se	NO	NO	NO
Zn	1670	3296	1848
Frits:			
Cr	NO	NO	NO
As	NO	NO	NO
Cd	19	28	2
Cu	NO	NO	NO
Hg	NO	NO	NO
Ni	NO	NO	NO
Pb	55	80	29
Se	NO	NO	NO
Zn	NO	NO	NO
All glass:			
Cr	6318	3574	3584
As	327	213	277
Cd	232	54	2
Cu	851	154	20
Hg	71	11	3
Ni	2675	345	164
Pb	19647	4832	3733
Se	25255	3667	11914
Zn	17443	7013	4402

This research has shown that emission estimates included in the 2000 NAEI were often very inaccurate - a state of affairs recognised in the uncertainty analysis carried out on that version of the inventory and the subsequent recommendation for research to derive better factors. The current emission estimates are all lower than those given in the 2000 NAEI although in some cases the intermediate 2001 NAEI gave the highest estimates of all three versions of the NAEI. The current emission estimates are considered to be much more reliable than those given in the 2000 NAEI and further research is not recommended except in the case of lead glass where data could usefully be collected for lead and particulate matter.

3.3 WOOD IMPREGNATION

Suppliers of light organic solvent preservatives (LOSP) were able to supply estimates of the relative size of the UK market for these products. The consensus view was that the market now was about 20% of the market of 5-10 years ago. Before the mid 1990s, the market was considered to have been stable. As a result of this information, it has been recommended that the following changes be made to the activity data used for the sector in the NAEI:

- the usage of LOSP between 1995 and 2002 should be assumed to have fallen by 80%, this change occurring linearly;
- before 1995 the usage of LOSP can be assumed to be proportional to output from the wood products industry (using the ONS index of output for the sector).

These changes were made for the 2002 version of the NAEI. The emission factors used for this sector did not change but, due to the change in the activity data, the 2001 emission estimate for this sector decreased by 64% relative to the figure given in the 2001 version of the NAEI.

The wood preservatives market is undergoing major changes at the moment due to impending EU legislation and a further decline in the market for LOSP may occur. It is recommended therefore that this issue is revisited in 2006.

3.4 BURNING OF TREATED WOOD

Suppliers of Copper-Chromium-Arsenic (CCA) based preservatives have been approached for information on UK consumption of these products. The market for these products is undergoing major changes at the moment due to impending EU legislation which will prohibit the use of CCA preservatives for many applications. As a result, the use of CCA products is declining and will continue to decline at least until June 2004 when the EU regulation takes force.

Wood treated with CCA based preservatives should not be burnt since the metals, which are chemically fixed in the wood when the preservative is introduced, are released on burning. The NAEI includes an emission factor for arsenic from burning of treated wood but not for copper or chromium. New emission factors have therefore been developed for copper and chromium.

The existing approach for estimating arsenic emissions from treated wood is based on use of a constant emission estimate of 9 tonnes of arsenic per year. This estimate has been used, together with data on the composition of CCA based preservatives to generate the following estimates of emissions of copper and chromium:

Copper	4.8 tonnes
Chromium	8.7 tonnes

These emission estimates have been recommended for use in the NAEI and were included in the 2002 version of the inventory. Longer-term, it is recommended that consideration be given to whether it is possible to replace these emission estimates with some based on the use of emission factors expressed as emission per mass of wood burnt and reliable estimates of wood burnt. Some very crude activity data are already available, having been generated in order to estimate emissions of POPs due to the burning of waste wood in bonfires/domestic grates/other small-scale waste burning, however these data also cover wood treated with creosote and LOSP. CCA preservative application rates have been suggested by industry contacts. Since the activity data includes wood treated with creosote or LOSP, emissions estimated using this method are 'worst case':

Arsenic	10.0 tonnes
Copper	5.3 tonnes
Chromium	9.7 tonnes

The agreement is surprisingly good although both sets of estimates are subject to very high uncertainty. Nonetheless, the alternative estimates derived above do support the continued use of the current approach for the time being.

If an alternative approach can be developed in the future, it will need to consider a number of important issues:

- levels of CCA usage vary according to application. For example, timber for household use would have lower levels of CCA than timber for ground contact and this would effect the amount of CCA in timbers that were burnt. Thus, treated wood burnt by households (who are perhaps more likely to burn treated wood) may not have as much CCA as suggested by the typical application data presented above. Ideally, data are required for CCA usage by end-use.
- CCA is present in imported products. UK manufacturers know how much preservative they sell to UK and Europe but don't know how much timber is imported.
- CCA treated timbers are burnt at the end of their working life and the emission occurs therefore years after use of the preservative. Some treated timbers can have a 60 year working life. Emissions will depend upon the types of treatment used for old timbers not newly treated timbers. The phase out of CCA based preservatives from June 2004 onwards for many applications will not prevent emissions for many years.

Further work is recommended to improve the quality of estimates for this sector. In particular, more data are needed on the quantity of CCA preservatives used historically by application area.

3.5 CEMENT CLINKER PRODUCTION

The current NAEI approach for estimation of emissions from cement production involves calculation of the fuel burnt by the cement plant. In order to make these estimates, various calculations are made using data taken from the Digest of UK Energy Statistics (DUKES) and various assumptions are made. The current NAEI methodology leads to a significant proportion of fuel use being assumed to be natural gas yet this seemed unlikely.

The British Cement Association were contacted and were able to confirm that natural gas is not used in significant quantities by the cement industry. Coal and petroleum coke are the major fuels for cement clinker production, together with some waste derived fuels such as tyres, waste solvents etc. The waste derived fuels can only be burnt after trials to demonstrate their environmental impact is not worse than conventional fuels, however this is generally true so there is no barrier to using them. The usage of waste derived fuels is about 10% of total, with the split for the remaining 90% being about 4:1 for coal and pet coke respectively. Gas and oil are not used other than for start-up and this fuel usage would be trivial.

In the light of this information, the NAEI methodology has been partially revised. However, it is not possible to reconcile the above information from BCA with national fuel statistics as published in the Digest of UK Energy Statistics (DUKES). Discussions on the source and quality of national fuel statistics between the compilers of DUKES and the NAEI team are ongoing as part of the NAEI research programme and this issue has been considered. For the time being, however, the issue remains unresolved.

3.6 COATING AND OTHER SOLVENT-USING PROCESSES

Updated emission estimates have been generated for a number of coating processes authorised by local authorities and also those that will be subject to Integrated Pollution Prevention and Control (IPPC). NAEI estimates for these processes have been based on bottom-up emission estimates for individual plants for some years but the accuracy of the NAEI depends upon periodic updating of these estimates. Table 4 summarises the changes in emission estimates.

Table 4. Emissions data for coating and other solvent using processes

Sector	**Emission in 2001 (ktonnes)**		**% change**
	2001 NAEI	**2002 NAEI**	
Textile coating	2.1	2.0	-2%
Film coating	2.8	2.6	-7%
Flexible packaging	10.6	9.8	-8%
Pressure sensitive labels	0.3	0.6	+73%
Industrial adhesives	30.5	25.5	-16%
Tyre manufacture	1.5	1.4	-4%

The changes are mostly small but are important since they are all decreases with the exception of pressure sensitive labels. These decreases result from the acquisition of additional data on the use of abatement strategies by process operators within these sectors and thus the estimates are more reliable than previously. The UK has international commitments to reduce emissions of volatile organic compounds to below an emission ceiling of 1200 ktonnes by 2010 and decreases in emissions from sources such as these are necessary in order to reach this target. The historical estimates for many solvent-using sectors are now considered very robust although further data will be needed in future in order to derive robust emission estimates for later years (the main purpose in collecting additional data from local authorities this year was to derive robust estimates for 2002).

3.7 NON FLETTON BRICKWORKS

As a result of other work carried out for Defra aimed at providing emissions data for the European Pollutant Emissions Register (EPER), some emission estimates have been generated for HCl and HF emissions from non-Fletton brickworks. These data are derived from company-wide emissions data for the UK's largest brick producer and assume that emissions from other producers are similar on a mass of bricks basis. Table 5 summarises the emission estimates.

Table 5. Emissions data for non-Fletton brickworks

Pollutant	Emission in 2001 (ktonnes)		% change
	2001 NAEI	2002 NAEI	
HCl	NE	0.24	-
HF	NE	0.31	-

NE - not estimated

3.8 SLAG CEMENT PRODUCTION

As a result of other work carried out for Defra aimed at providing emissions data for the European Pollutant Emissions Register (EPER), some emission estimates had been generated for PM_{10} emissions from the grinding of metal industry slags for use as a Portland cement substitute. These EPER data, which were derived using USEPA emission factors and plant-specific production data, only covered 4 of the UK plants involved in this sector, however a national emission estimate was derived using an estimate of national production of slag cement given in evidence to the House of Commons Select Committee on Environment, Transport & Regional Affairs (1.5 Mtonnes). The national emission estimate was recommended for use in the NAEI since this source has not previously been included in the inventory. Emissions were included in the 2002 version of the NAEI and Table 6 gives details.

Table 6. Emissions data for slag cement grinding

Sector	Emission in 2001 (ktonnes)		% change
	2001 NAEI	2002 NAEI	
Slag cement grinding	NE	0.043	-

NE - not estimated

3.9 AUTOGENERATORS & OTHER LARGE COMBUSTION PLANT

A combustion calculator is being developed as a separate project funded as part of the emission factor programme (Task 8a). The calculator is intended to improve the estimation of emissions of CO, NOx, PM_{10}, B[a]P and PCDD from industrial combustion processes. The calculator is currently under development and is expected to be available for the 2003 version of the NAEI. However, at an early stage, it was possible to derive NO_x emission factors for large combustion plant based on emissions data reported in the Pollution Inventory (PI). By combining these factors with existing, NAEI, literature-based factors for small combustion plant, new emission factors covering all industrial combustion processes could be derived for use in the NAEI. Emission factors for the period 2000 - 2002, derived using this method, were included in the 2002 version of the NAEI and are shown in Table 7.

Table 7. NOx emission factors for industrial combustion plant

Sector	Factor	Emission (ktonnes)		% change
		2001 NAEI	2002 NAEI	
Coal combustion	4.37 kt/Mt	9.44	7.76	-18%
Fuel oil combustion	6.08 kt/Mt	4.62	2.97	-36%
Gas oil combustion	3.41 kt/Mt	7.23	7.13	-1%
Natural gas combustion	8.7 t/Mth	50.1	47.8	-5%

Emission factors for coal-fired generators were derived using PI data for the largest autogenerator, which consumes practically all of the coal supplied to the sector. The emission factors and changes to the emission estimates are shown in Table 8.

Table 8. Emission factors and estimates for coal-fired autogenerators

Pollutant	Factor kg/t	Emission in 2001 (tonnes)		% change
		2001 NAEI	2002 NAEI	
CO	2.20	6609	3605	-45%
NOx	7.01	7496	11098	+48%
As	4.34×10^{-5}	5.60	0.07	-99%
Cd	6.34×10^{-6}	0.14	0.01	-92%
Cr	1.33×10^{-4}	0.41	0.22	-46%
Cu	1.75×10^{-4}	2.67	0.29	-89%
HCl	0.568	3788	930	-75%
Hg	1.23×10^{-5}	0.41	0.02	-95%
Ni	1.41×10^{-4}	8.09	0.23	-97%
Pb	2.30×10^{-3}	8.51	0.38	-96%
Se	1.89×10^{-4}	1.83	0.31	-83%
V	1.05×10^{-4}	7.74	0.17	-98%
Zn	4.73×10^{-4}	25.7	0.78	-97%
PM_{10}	6.17×10^{-2}	4030	101	-97%
Dioxins	5.45×10^{-7}	2.90×10^{-7}	8.93×10^{-7}	+208%
Mn	1.68×10^{-4}	15.8	0.27	-98%
HF	6.57×10^{-2}	145	108	-26%
Be	9.06×10^{-6}	0.45	0.01	-97%

3.10 FOUNDRIES

Emission estimates for PM_{10} and metal emissions from foundries given in the 2001 version of the NAEI suffered from a number of problems:

- they related to emissions from iron foundries only (although these constitute the majority of foundries);
- they were based on activity data which was last published for 1992 and which has been assumed to be constant ever since;
- they were based on emission factors which were very uncertain, sometimes quite old and, in some cases, originally referred to emissions from electric arc furnaces.

The methodology for estimating emissions from foundries has therefore been reviewed and revisions recommended and these were subsequently incorporated in the 2002 version of the NAEI.

The revisions covered three areas: development of activity data for steel foundries and non-ferrous foundries, improvements to the iron foundry activity data, and improvement of emission factors. Activity data for the various types of foundries were obtained from four sources, these data being combined to give a full time series for each foundry type. The sources were the Iron & Steel Statistics Bureau's Annual Statistics, the European IPPC Bureau's Reference Document on Best Available Techniques in the Smitheries and Foundries Industry, the British Geological Survey's UK Minerals Yearbook and, finally, statistics published by the Office of National Statistics as part of their PRODCOM survey of manufacturing output. The new time series for iron foundries showed that activity levels had fallen by over 30% since 1992 thus demonstrating that the existing NAEI activity data (held constant since 1992) needed to be replaced.

The existing PM_{10} emission factors for iron foundries were retained having been incorporated into the NAEI 2 years ago following a review of PM_{10} emission factors undertaken as part of an earlier Defra funded programme of research. The same emission factor was also applied to steel foundries. Factors for non-ferrous foundries were taken from the European IPPC Bureau report referred to above. Reliable, up-to-date metal emission factors were not found but some data on the metallic content of iron and steel foundry dusts were. These data were therefore used to generate metal emission factors for iron and steel foundries from the PM_{10} factors. No account is taken of gaseous mercury emissions so the factor for mercury may significantly underestimate emissions. However, emissions of all metals are higher using the new methodology compared with estimates given in the 2001 version of the NAEI. Table 9 gives details of the factors and emission estimates for selected years.

The new estimates are still highly uncertain and it is recommended that further investigation of this sector be carried out.

Table 9. Emission factors and emission estimates for foundries

Pollutant	Factor kg/t metal	Emission (tonnes)		% change
		2001 NAEI	2002 NAEI	
PM_{10}:				
1990	3.11	4840	5450	+13%
2000	0.71	860	860	0%
Arsenic:				
1990	1.16×10^{-3}	0.146	2.03	+1300%
2000	2.07×10^{-4}	0.028	0.251	+810%
Cadmium:				
1990	7.00×10^{-4}	0.493	1.23	+150%
2000	1.26×10^{-4}	0.078	0.152	+95%
Chromium:				
1990	1.59×10^{-2}	0.534	27.9	+5100%
2000	2.86×10^{-3}	0.100	3.46	+3300%
Copper:				
1990	5.32×10^{-3}	0.728	9.34	+1200%
2000	3.32×10^{-3}	0.688	4.03	+490%
Lead:				
1990	3.75×10^{-2}	3.49	65.8	+1800%
2000	6.72×10^{-3}	0.660	8.15	+1100%
Manganese:				
1990	5.09×10^{-3}	NE	8.94	-
2000	9.13×10^{-4}	NE	1.11	-
Mercury:				
1990	2.69×10^{-3}	0.218	4.72	+2100%
2000	4.83×10^{-4}	0.206	0.585	+180%
Nickel:				
1990	5.70×10^{-3}	0.243	10.0	+4000%
2000	1.02×10^{-3}	0.045	1.24	+2600%
Selenium:				
1990	1.16×10^{-4}	0.073	0.203	+180%
2000	2.08×10^{-5}	0.069	0.025	-63%
Tin:				
1990	2.51×10^{-4}	NE	0.440	-
2000	4.49×10^{-5}	NE	0.054	-
Vanadium:				
1990	1.47×10^{-4}	0.073	0.259	+260%
2000	2.64×10^{-5}	0.069	0.032	-53%
Zinc:				
1990	6.70×10^{-2}	2.43	118	+4700%
2000	1.20×10^{-2}	0.454	14.5	+3100%

NE - not estimated

3.11 PLASTER PROCESSES

Emissions of PM_{10} from plaster manufacturing processes are currently included in the NAEI source 'Other industry (Part B processes)'. Emissions are calculated using a 'per process' emission factor of 1.3 tonnes per process. This factor was originally developed for use in the urban inventory work carried out by RSK Ltd and London Research Centre and was based on limited data for brickworks. Clearly this emission factor, when applied to plaster processes, would be subject to very high uncertainty. Plaster production estimates are available from the Office of National Statistics and there are a small number of processes in the UK. Therefore two possibilities exist for improvement of the emission estimates for this sector:

1. use of literature emission factors expressed in terms of production of plaster;
2. collection of monitoring data for a limited number of UK processes.

Literature factors are available from the USEPA compilation of emission factors known as AP-42 (web version 12 September 2003). This gives emission factors for two variations of plaster process: use of a three-stage dryer/grinder/calciner process and use of a heated impact mill which performs all three stages together. The mean of these emission factors, assuming use of fabric filters for control of dust emissions, is 25.2 g/tonne of plaster. Combining this factor with UK plaster production data suggests an annual PM_{10} emission from plaster processes of 25 tonnes. Given this relatively small calculated emission, no monitoring data has been sought from process operators to improve the estimate further. The emission factor is recommended for use in the 2003 version of the inventory. The current estimate is 15 tonnes so the adoption of this factor will not lead to any significant change in national PM_{10} emission estimates.

It is worth noting that many other types of process are also included in the PM_{10} emission estimates reported as 'Other industry (Part B processes)'. Emissions from some of these are estimated to be much higher than plaster processes e.g. emissions from vehicle refinishing processes are estimated to be about 950 tonnes and emissions from other industrial coating processes are estimated to be about 860 tonnes. These estimates are also very uncertain, being also calculated using RSK 'per process' factors and should be reviewed.

3.12 COPPER WIRE ROD PRODUCTION

Copper wire rod processes produce highly pure copper rod of 16mm diameter or less, which is subsequently drawn to produce copper wire for electrical use. The melting and holding furnaces used by these processes have slightly reducing atmospheres in order to prevent oxidation of the molten copper which would reduce the electrical conductivity of the metal. Emissions from these furnaces can therefore contain relatively high levels of carbon monoxide (CO) although afterburners can be used to control this. Emissions of CO from the UK copper wire rod processes have been included in the 2002 version of the NAEI using data reported to the Pollution Inventory. Table 10 summarises the estimates.

Table 10. CO emissions data for copper wire rod plant

Sector	**Emission in 2001 (tonnes)**		**% change**
	2001 NAEI	**2002 NAEI**	
copper wire rod processes	NE	593	-

NE - not estimated

3.13 WASTE INCINERATION

A recent report by Entec UK Ltd provided a critique of part of the UK dioxins inventory. This recommended that NAEI estimates of dioxin emissions from clinical waste and sewage sludge incineration plant were too high and that data available from process operators could be used to derive more robust estimates. Dioxin emissions from sewage sludge incinerators are reported to the Pollution Inventory and can be used to derive emission factors. Pollution Inventory data for other pollutants were also reviewed and, in some cases, these data were considered to give more reliable emission factors than those used in the NAEI. Revised emission factors based on Entec's recommendations in the case of dioxins from clinical waste incineration, and PI data in the remaining cases were recommended for use in the NAEI and have subsequently been incorporated into the 2002 version. A summary of the changes is given in Table 11.

Table 11. Emissions data for incineration plant

Sector	Factor g/tonne	Emission in 2000 (tonnes)		% change
		2001 NAEI	2002 NAEI	
Clinical waste incineration:				
arsenic	0.202	2.40×10^{-3}	0.050	+2000%
nickel	1.39	5.87×10^{-3}	0.346	+5800%
dioxins	2.1×10^{-6}	24.1×10^{-6}	0.523×10^{-6}	-98%
Sewage sludge incineration:				
NOx	1208	523	243	-54%
arsenic	0.137	0.015	0.028	+83%
cadmium	0.163	0.282	0.033	-88%
mercury	0.299	0.119	0.060	-49%
lead	0.249	0.387	0.050	-87%
dioxins	3.99×10^{-7}	7.71×10^{-6}	0.080×10^{-6}	-99%

3.14 PRINTWORKS

Estimates of VOC emissions from printing processes are generally robust. Two of the most significant sectors are flexible packaging and publication gravure and NAEI emission estimates for these sectors are based on detailed assessment of emissions on a plant by plant basis. Emissions from other sectors such as heatset web offset, coldset web offset and screen printing are based on activity data and emission factors supplied by industry and are considered reliable. A number of areas within the printing industry are, perhaps, less well characterised and would be priorities for further development:

- specialist printing processes (securities, roll label printing etc.);
- printing of paper and cardboard packaging using solvent-borne gravure/flexo inks;
- overprint varnishes;
- print chemicals.

Emissions from specialist printing processes are covered by the NAEI sector 'printing (other inks)' and estimates are made using industry-supplied emission factors and activity data. The emission factor for this source is subject to considerable uncertainty due to the diverse nature of the processes within the sector, many of which will be highly specialised. Improvements to the emission estimates for this sector might be achieved by assessing emissions on a plant by plant basis. These plants would need, however, to be identified first.

A somewhat different situation exists for the printing of paper goods and paper and cardboard packaging using solvent-borne gravure and flexo inks Emissions are nominally included in the source 'printing (other flexography)' and, although the emission factor and activity data for this source are probably reliable, there is a problem regarding the coverage of cardboard packaging printed with solvent-borne inks. These processes (if any still exist in the UK) are probably not covered by the existing NAEI methodology. As with the specialist printers, improvements could be made by assessing emissions on a plant by plant basis if these could be identified.

Emissions from use of overprint varnishes are estimated using industry-supplied emission factors and activity data. These are likely to be reliable, however there is a possibility of some double-counting of emissions. This would occur if any overprint varnishes were used by any of the following processes:

- flexible packaging processes
- metal packaging processes
- film coating processes
- paper coating processes

Emissions from these types of processes are estimated on a plant by plant basis and, since it is not possible to distinguish between different types of emission source at each site, these emissions are assumed not to include any contribution from other sources such as overprint varnish use. More information is required on sectors using overprint varnishes so that any corrections necessary can be made.

Emissions from the use of print chemicals are estimated using industry-supplied data. Due to the wide range of chemicals in use, this method is simplistic and more detailed data would be preferable.

Most of the issues described above could be resolved only with in-depth investigation. However, some preparatory work has been undertaken. In the case of specialist printing processes and packaging printers, some progress has been made towards the identification of printing processes within these sectors. Printworks with significant VOC emissions are regulated by local authorities in England and Wales and by SEPA in Scotland. SEPA can provide details of the processes they authorise, however, in the case of local authority processes, centrally available information is limited to listings of the types of process regulated by each authority, most recently published in the Defra note AQ3(02). Approximately 165 printworks are regulated by local authorities or by SEPA and many of these printworks will be screen printing, heatset web offset or coldset web offset processes. It would be time-consuming to check the nature of each process with each local authority, so an attempt has been made to identify those processes most likely to be specialist printworks or packaging printworks through contacts with trade associations and by using publicly available sources instead (largely internet based information). As a result, it has been possible to identify with reasonable certainty the types of printing carried out by many of the processes regulated as printworks. Results are shown in Table 12.

Table 12. Regulated printing processes

Printing process or sector	No of processes	Printing process or sector	No of processes
Coldset web offset	8	Screen printing	20
Heatset web offset	63	Securities	10
Sheetfed offset	1	Roll labels	5
Flexo/gravure/litho	17	Other	4
Publication gravure	4	Process type unknown	8
Not identified	23		

Further work could be directed at gathering emissions data for those processes listed as 'flexo/gravure/litho', 'securities' and 'roll labels' since these processes would fall into the priority areas identified above. Some further work could also be directed at identifying those remaining 23 printworks known only through inclusion in AQ3(02).

No further information has been found regarding print chemicals or overprint varnishes and opportunities for gathering data on these sources should continue to be sought.

3.15 PETROL STATIONS

Data provided by the United Kingdom Petroleum Industry Association (UKPIA) on the performance of petrol vapour recovery equipment and on the benzene content of petrol has been used to update the historical emission estimates for petrol distribution included in the NAEI. The assumptions regarding the level of use of petrol vapour recovery equipment have also been updated, based on surveys for 2001 and 2002 provided by the Institute of Petroleum. Finally, some of the Reid Vapour Pressure (RVP) data used in the methodology has also been revised in order to harmonise the values with those used for the calculation of road transport emissions. These changes were incorporated in the 2002 version of the NAEI. Revised data are summarised in Table 13.

Table 13. Emissions data for petrol distribution

Sector	Emission in 2001 (tonnes)		% change
	2001 NAEI	2002 NAEI	
Petrol terminals (storage):			
benzene	19.1	6.11	-68%
Petrol stations (petrol delivery):			
VOC	4064	6101	+50%
benzene	21.6	10.3	-52%
1,3-butadiene	0.787	1.18	+50%
Petrol stations (vehicle refuelling):			
VOC	35717	37122	+4%
benzene	189	62.9	-67%
1,3-butadiene	6.91	7.19	+4%
Petrol terminals (tanker loading):			
VOC	1091	752	-31%
benzene	5.79	1.27	-78%
1,3-butadiene	0.211	0.146	-31%
Petrol stations (storage tanks):			
benzene	18.5	5.93	-68%
Petrol stations (spillages):			
benzene	12.3	3.95	-68%

3.16 FIREWORKS

Emission estimates generated as part of last years research were included in the 2002 NAEI. Table 14 summarises the emissions data.

Table 14. Emissions data for fireworks

Pollutant	Emission in 2001 (tonnes)		% change
	2001 NAEI	2002 NAEI	
copper	NE	2.76	-
magnesium	NE	73.2	-
potassium	NE	100	-
sodium	NE	5.48	-

NE - not estimated

3.17 ADHESIVES

The adhesives sector has been an area of more than average uncertainty in the VOC inventory for some years. This is due to a combination of factors:

- a lack of detailed and consistent activity data for adhesives production or consumption;
- an absence of feedback from the adhesives manufacturing industry regarding the quality of NAEI emission estimates;
- a lack of alternative contact points due to the diversity of adhesives applications ensuring that no organisations possess a good overview of the sector.

Emission estimates were based on extrapolation of estimates of solvent supplied to the adhesives sector for four years only. The extrapolation requires consistent sets of activity data but these do not exist. The fragmented data available from different sources do not agree well and make the generation of a time series difficult. Thus, there is considerable uncertainty regarding trends in emissions although emission estimates for some years may be quite good. The emission estimates are based on the assumption that solvent consumed by the sector was all emitted i.e. that there was no destruction or recovery of solvent by adhesives users. This is a reasonable assumption for many adhesives users who tend to be small operations, more likely to use solvent reduction strategies rather than install expensive end-of-pipe equipment. However, some adhesives users would use abatement systems and, by ignoring this, the estimates would be overestimating emissions. For the 2000 version of the NAEI an improvement was made with the separation of the pressure sensitive tapes sector from other adhesives users. This sector consists of a small number of large operators many of whom use end-of-pipe abatement systems to control emissions. Emissions from these processes were estimated on a plant by plant basis, including an assessment of the impact of abatement, and were reported separately in the NAEI. This revision to the NAEI removed the most significant sector likely to abate emissions but uncertainty about any further use of abatement by adhesives users remained.

Therefore, some analysis has been carried out of the adhesive coating processes regulated by local authorities in England and Wales and by SEPA in Scotland. Approximately 140 adhesive coating processes are regulated of which it has been possible to identify 84 (60%). The nature of the processes has been investigated using internet-based directories to determine whether they might use adhesives in a process which would be amenable to the use of end-of-pipe abatement rather than solvent reduction. The results are summarised in Table 15 which gives sector groupings for the processes together with an indication of the probability of end-of-pipe abatement systems being used. The reasoning behind these assessments is given below.

Table 15. Regulated adhesive coating processes

Sector	No of processes	End of Pipe abatement used?
Abrasives	6	Yes
Adhesive labels	3	Probably
Adhesive tapes	8	Yes
Automobile components	6	Maybe
Engineering	8	Maybe
Flooring / upholstery	5	Maybe
Foam products	8	Maybe
Footwear	14	No
Furniture	3	No
Healthcare	4	Probably
Insulation materials	5	Maybe
Lamination	3	Probably
Retreads	5	No
Rubber and plastics	10	Yes
Vehicles (aerospace)	2	Maybe
Vehicles (boats)	1	No
Vehicles (caravans)	1	No

Some sectors can be assumed to comply with authorisation through solvent reduction measures only. Based on general information from trade associations, backed by information on individual cases from regulators, it is highly likely that footwear manufacturers have adopted solvent reduction as the sole means for compliance. This is hardly surprising due to the small-scale and 'hand-crafted' nature of UK footwear manufacturing processes. The retread industry, furniture manufacturers, manufacture of caravans and boats, and precision engineering sectors are also very unlikely to use end-of-pipe abatement for reasons of the small scale of adhesives use by individual processes.

Three sectors are now known to use end-of-pipe abatement systems at some locations at least. Adhesive tapes have already been investigated and reliable emissions data obtained. This study has found that at least some of the processes listed under 'abrasives' and 'rubber and plastics' sectors use end-of-pipe abatement systems. Other sectors which are likely to make use of end-of-pipe abatement in at least some plants are the adhesive labels, healthcare (adhesive bandages), and lamination sectors. All three sectors would use automated coating machines which could contain solvent emissions so it could then be abated. Other sectors listed in the table are perhaps less likely to use abatement being either likely to be small-scale or likely to involve application of adhesives in a less contained manner, but a few of these processes could still be suitable for the use of arrestment technology.

This study has shown that some adhesive coating processes use end-of-pipe abatement systems whereas the current NAEI estimates for the sector assume no abatement of solvent. The number of processes identified is small however data are available for a few processes only. Other processes known to operate adhesive coating processes could use abatement equipment, particularly those processes in the abrasives, adhesive labels, healthcare, lamination and rubber and plastics sectors. NAEI estimates are therefore likely to overestimate actual emissions from adhesive coating. It is therefore recommended that further research is carried out so that plant by plant emission estimates can be made of both solvent consumption and solvent emissions from these plants.

3.18 WASTE OIL COMBUSTION

A number of samples of waste oil have previously been collected as part of the emission factor programme. The samples were mainly waste oils collected from garages or waste recycling centres but one sample of commercial waste oil was also collected. The latter sample was expected to have undergone some treatment such as filtration but to otherwise be broadly similar to the other samples.

All of the samples were analysed for carbon, sulphur, chlorine and metals (As, Be, Ca, Cd, Cr, Cu, Hg, K, Mg, Mn, Na, Ni, Pb, Se, Sn, V, Zn). Emission factors for carbon, sulphur dioxide, hydrogen chloride and metals were derived using the means of the analytical results for each determinand. No factors were derived for arsenic, beryllium or selenium since all of the results were below detection limits. Table 16 shows the emission factors and changes to emission estimates.

Table 16. Emission factors and emission estimates for waste oil combustion

Sector	Factor kg/tonne	Emission in 2001 (tonnes)		% change
		2001 NAEI	2002 NAEI	
Carbon	865	256,000	275,000	+8%
Sulphur dioxide	11.4	892	3,630	+308%
Hydrogen chloride	0.195	NE	62.0	-
Cadmium	2.55×10^{-4}	0.205	0.0813	-92%
Chromium	1.49×10^{-3}	6.25	0.475	-60%
Copper	1.31×10^{-2}	4.14×10^{-2}	4.17	+100000%
Mercury	1.33×10^{-4}	3.18×10^{-5}	0.0423	+130000%
Manganese	2.14×10^{-3}	0.882	0.683	-23%
Nickel	1.75×10^{-3}	3.55	0.557	-84%
Lead	5.57×10^{-2}	6.37×10^{-2}	17.7	+28000%
Tin	1.20×10^{-3}	NE	0.382	-
Vanadium	3.06×10^{-3}	0.0159	0.975	+6000%
Zinc	0.853	4.14×10^{-2}	271	6600000%
Calcium	1.37	NE	435	-
Magnesium	0.140	NE	44.6	-
Potassium	5.64×10^{-2}	NE	18.0	-
Sodium	5.68×10^{-2}	NE	18.1	-

NE - not estimated

The changes in emission estimates resulting from the adoption of new emission factors for waste oil combustion are very large in some cases. Only a relatively small amount of waste oil is burnt annually and so even the largest increases in emissions shown in Table 16 lead to only a small contribution (<5%) to national emissions with the exception of copper, lead, and zinc as shown in Table 17.

Table 17. Contribution of waste oil combustion to national emissions in 2001

Pollutant	% of 2001 emissions	Pollutant	% of 2001 emissions
Zinc	44.5%	Cadmium	1.8%
Lead	9.8%	Sodium	1.4%
Copper	6.9%	Potassium	0.8%
Calcium	4.9%	Chromium	0.6%
Arsenic	3.8%	Others	<0.5%
Magnesium	3.7%		

3.19 MAPPING DATA

Improvements were made to the mapping of some sources of VOC, benzene, 1,3-butadiene and PM_{10} processes. These sources were large petrol stations (VOC, benzene, 1,3-butadiene) and various sources of PM_{10} reported under the NAEI sources 'bricks (non-fletton), 'slag cement grinding' and 'other industry (Part B)'.

The mapping of petrol stations has been limited to those operated by the five largest supermarket operators (Tesco Stores Ltd, J Sainsbury Supermarkets Ltd, Safeway Stores Ltd, Asda Stores Ltd & Wm. Morrisons Supermarkets Ltd) and service stations located on motorways.

Sales of petrol from supermarkets is given in the Digest of UK Energy Statistics so their contribution to UK emissions from petrol retail operations can be estimated. The emissions from individual sites are calculated by estimating each supermarket operators' share of emissions based on the number of petrol nozzles operated by that company and then dividing this emission by the number of sites.

Emissions from motorway service stations were estimated by calculating their share of non-supermarket emissions based on an assumption of 32 petrol nozzles per service station (based on a limited set of actual data) and comparing this with the total number of petrol nozzles operated at non-supermarket petrol stations.

Emissions from brickworks, slag cement grinding processes and various other PM_{10} sources are estimated by dividing national emission totals across the known sites. Where some indication of the size of the process at each site is known (for example certain coating processes where VOC emissions can be used to indicate the scale), these data have been used to determine the share of PM_{10} emissions allocated to each site. In the remaining cases, emissions are allocated evenly to all processes.

A longer-term aim for improvement to NAEI mapping work would be to make use of data on the location of many more Part B processes. A considerable amount of information on these processes has been collected over a period of many years and although it is not yet sufficiently complete or sufficiently up-to-date to be used for this purpose at the moment, it is being improved continually. Ultimately, the data should be suitable for improvements to be made to the mapping of emissions of VOC, PM_{10} and metals in particular. Sources such as waste oil burners, metal processes, mineral processes, petrol stations and coating processes might be mapped using the data by the next version of the NAEI.

4 Conclusions and recommendations

This research has allowed improvements to many areas of the NAEI including the inventories for CO, NO_x , VOC, HCl, HF, PM_{10}, metals and dioxins. The revisions to the metals inventories have generally been the most significant in terms of percentage changes to the national emission totals due to inclusion of the new data, as shown in Table 18.

Table 18. Percentage changes in emission estimates for selected pollutants

Pollutant	Change to emissions	Total emission	% change
Arsenic:			
source emissions increase	+0.57 t		
source emissions decrease	-6.11 t		
overall	-5.54 t	27.8 t	-16.6%
Cadmium:			
source emissions increase	+0.09 t		
source emissions decrease	-0.29 t		
overall	+0.20 t	4.49 t	-4.3%
Copper:			
source emissions increase	+19.21 t		
source emissions decrease	-2.55 t		
overall	+16.66 t	60.7 t	+37.8%
Lead:			
source emissions increase	+24.90 t		
source emissions decrease	-9.15 t		
overall	+15.75 t	181 t	+9.5%
Nickel:			
source emissions increase	+1.50 t		
source emissions decrease	-10.95 t		
overall	-9.45 t	138 t	-6.4%
Selenium:			
source emissions increase	+10.31 t		
source emissions decrease	-3.26 t		
overall	+7.05 t	36.3 t	+24.1%
Zinc:			
source emissions increase	+40.55 t		
source emissions decrease	-26.43 t		
overall	+14.12 t	610 t	+2.4%
PM_{10}:			
source emissions increase	+0.63 kt		
source emissions decrease	-3.91 kt		
overall	-3.28 kt	180 kt	-1.8%
Dioxins			
source emissions increase	+0.6 g		
source emissions decrease	-24.8 g		
overall	-24.2 g	325 g	-6.9%
HCl:			
source emissions increase	+0.30 kt		
source emissions decrease	-2.87 kt		
overall	-2.57 kt	76.1 kt	-3.3%
VOC:			
source emissions increase	+3.23 kt		
source emissions decrease	-17.65 kt		
overall	-14.42 kt	1449 kt	-1.0%

The large changes for metals inventories does reflect the fact that inventories for these pollutants are much more uncertain than those for VOC and NOx in particular. The revisions to the estimates for VOC and PM_{10}, although less significant in percentage terms, are still important especially given the need to monitor UK progress towards meeting national and international obligations such as emission ceilings and exposure limits.

This study has found two areas where more detailed research is recommended. For certain printing processes and adhesive coating processes it is recommended that emissions be estimated on a plant by plant basis as a means of significantly improving the NAEI estimates of VOC from these sources.

The simple studies project has enabled some significant changes to be made to the NAEI, despite expending modest resources on each research area and it is recommend that the simple studies task format is retained for year three of the project.