COMMITTEE ON TOXICITY OF CHEMICALS IN FOOD, CONSUMER PRODUCTS AND THE ENVIRONMENT

SECOND STATEMENT ON LANDFILL SITES – FINAL DRAFT

Please find attached the fourth draft of the second statement on landfill sites, for Members' consideration. The statement has been amended following comments at the last meeting and, subsequently, further comments from the Chairman.

Please note that, in running a check of the statement against the chemicals measured in the Environment Agency's main study, it was found that four chemicals analysed in that study had not been assigned project-specific HCVs by the study authors and so the results for these had not been assessed by the Secretariat as described in paragraphs 17 to 20 of Appendix A. The four chemicals concerned were 2-methyl furan, acenaphthylene, benzo(ghi)perylene and phenanthrene. A check has been run of the available toxicological data on these chemicals and we can confirm that there is insufficient data on any of them to set a health-based reference concentration or to assess the significance of the results. An additional two paragraphs have been included in the statement, after paragraph 93, to cover this (unnumbered, in case the Committee considers they would be more appropriate elsewhere in the statement). 2-methyl furan was included in a group of furan-substituted aliphatic hydrocarbon flavourings which was recently reviewed by JECFA. For information, the comments and evaluation from the JECFA monograph are attached at Appendix B (please note that the single dose study referred to in which 2-methylfuran was hepatotoxic was by the intraperitoneal route). The full JECFA monograph can be found at: http://whqlibdoc.who.int/publications/2009/9789241660600_eng.pdf.

Members are now asked if they can approve the attached statement for publication.

Secretariat
December 2009

NOTE: this paper was added to the website on 11 January 2011. The paper includes track changes so that it is clear what changes have been incorporated.

SECOND STATEMENT ON LANDFILL SITES (fourththird draft)

Background

1.   In 1998, the COT was asked by the Department of Health to comment on the findings of an epidemiological study called the EUROHAZCON study [1]. This was a case-control study, which investigated the risk of congenital anomalies (birth defects) around 21 landfill sites in Europe, ten of which were in the UK. The combined results from the 21 sites suggested that women who lived within 3 kilometres (km) of a landfill site were more likely to have a fetus with a congenital anomaly than women living further away from the site. The Committee commented that the EUROHAZCON study was well conducted, but agreed with the authors that "there is a need for further investigation of whether the association of raised risk of congenital anomaly and residence near landfill sites is a causal one".

2.   In 2001, the COT published a statement on a study from the Small Area Health Statistics Unit (SAHSU)[1] on health outcomes in populations living around landfill sites [2-4]. This study compared the frequency of birth outcomes and of certain cancers in populations living within 2 km of a known open or closed landfill site in Great Britain with that in the rest of the population. The COT noted that it is widely recognised that there are intrinsic limitations in ecological studies of this kind, and that there were also limitations in both the landfill data and health statistics data sets used in the study. Nevertheless the Committee considered the SAHSU study to have been well conducted. Slightly increased relative risks were found for all congenital anomalies (1.01 and 1.07 around all waste sites and around hazardous waste sites, respectively), low birth weight (1.05 and 1.05, respectively) and very low birth weight (1.04 and 1.03, respectively). The CommitteeIt noted that the risk ratios for the adverse birth outcomes in this study were all close to unity, but commented that the finding of a risk ratio of 1.07 for congenital anomalies overall for populations living around hazardous waste landfill sites, whether or not it was related to the presence of the landfill sites, merited further investigation. The cancers studied - childhood and adult leukaemias, hepatobiliary cancers, and cancers of bladder and brain - were selected either to test hypotheses arising from previous studies of cancer risk around landfill sites or on the basis of the established human carcinogenicity of certain chemicals known to be present in them. The COT concluded that, taking the limitations of the study design into account, the finding of no excess risk for those living within 2 km of a landfill site for each of the cancer types studied provided a degree of reassurance.

3.   The Committee was also informed that a programme of research and reviews was underway on congenital anomalies and landfill sites, and that this included a project to measure emissions of chemicals, common air pollutants and biohazards from landfill sites, and to assess exposures of people living nearby. Further, SAHSU proposed that it would be possible to investigate whether there are individual sites (or some a subset of sites) which significantly affect the health of the local population. This could be done by detailed mapping and statistical

---

[1] A full list of abbreviations and acronyms is given at the end of the statement.

analysis of ~~the~~ existing data to provide an indication of any systematic variation in rates and to analyse any resulting variations in relation to possible explanatory variables (e.g. landfill characteristics, geology, other exposure sources, deprivation). The Committee agreed that this could be a useful way forward but noted that the value of further analyses of ~~the~~ existing datasets m~~ay~~ight be limited by the known problems of some of these datasets [3]. Both the emission study and further SAHSU studies have now been completed. We were asked to comment on both the SAHSU studies and on the results of the emission study in respect of the levels of chemicals detected[2]~~chemical emissions~~. We reviewed these during the period 2007 to 2009 and our views are given below.

Exposure Assessment

Preliminary work on exposure assessment

4.   We were informed that, as a result of the findings of the EUROHAZCON study, a monitoring programme was initiated for substances potentially associated with congenital anomalies.   Early in 2001, the Environment Agency began an intensive monitoring campaign at a single landfill site [5]. A mobile monitoring station was set up and used to monitor methane, oxides of nitrogen (NOx), particulates (PM_{10}) and hydrogen sulphide, together with the trace pollutants benzene and chloroethene (also known as vinyl chloride). Monitoring was carried out during two periods - an initial twenty days from January to February, followed by 88 days between July and October. The results showed that:

- methane, PM_{10}, NOx, benzene and hydrogen sulphide were all detectable at the downwind boundary of the landfill;
- NOx levels exceeded the annual average standard for the protection of vegetation and ecosystems from the National Air Quality Standard (NAQS) (2000);
- concentrations of chloroethene were all below the detection limit of 10 ppb.

However, as these substances are often present in air at similar levels to those measured and as monitoring only took place downwind, it was not possible to conclude how much the landfill site was contributing to the levels that were monitored.

5.   The Environment Agency also commissioned a review of information on the trace components in landfill gas. The chemicals from these analyses were categorised and prioritised according to their toxicity and odour potential [6]. As a follow-on to this work, the Environment Agency commissioned sampling and analysis of landfill gas trace components at six different types of landfill site [6].

6.   A review was commissioned by the Department of Health to assess the potential for developmental toxicity of chemicals known or expected to be released from landfill sites [7]. This classified a number of volatile organic compounds (VOCs) into four groups with regard to developmental toxicity: chemicals of possible interest, chemicals of less likely interest, chemicals of no/unlikely interest,

---

[2] The study also measured a number of air pollutants and microbiological hazards (see Annex 1). It is outside the remit of the COT to advise on the health significance of these.

and those with insufficient data for classification (Table 1). The information from these two reviews was used to inform further monitoring work.

Table 1: Classification of chemicals according to their developmental toxicity (after Sullivan et al, 2001) [7]

Classification	Substance
Chemicals of possible interest	benzene, 1,3-butadiene, carbon disulphide, chloroform, 1,2-dichloroethene, ethylbenzene, formaldehyde[3], chloromethane, tetrachloroethylene, trichloroethene, chloroethene
Chemicals of less likely interest	alpha-terpinene, dichlorobenzene, 2-ethyl-1-hexanol, hydrogen sulphide, 2-butanone, toluene, xylenes
Chemicals of no/unlikely interest	acetone, 2-butanol, carbon tetrachloride, dichloromethane, ethanol, limonene, 1-propanol, styrene, vinyl acetate
Chemicals with insufficient data for classification	1,1-dichloroethane, dichlorofluoromethane, ethanethiol, methanethiol, 2-methyl furan, nitromethane

Landfill sites

7.   Landfill sites taking biodegradable waste are complex microbiological, chemical and biochemical reactors, wherein waste continues to degrade, often for more than 100 years. The degradation process is mainly anaerobic and produces a gas, which consisting mainly of methane and carbon dioxide. Rainfall which infiltrates the waste will dissolve substances to form leachate, a polluting liquid which collects at the base of the site and which contains high levels of ammonia and dissolved organic carbon [8].

8.   Both leachate and landfill gas have to be controlled by the operator under permits issued by the Environment Agency. Leachate is typically collected and treated biologically before being discharged to sewer or, occasionally, to surface waters. Landfill gas is pumped from the waste mass and combusted in flares or in engines which power electricity generators.

9.   The main sources of emissions from landfill sites are as follows:

- the waste materials as they are brought onto site, normally in heavy goods vehicles;

- emissions from this transport and any heavy plant used on site;

---

[3] Note: IUPAC name for formaldehyde is "methanal"; however, as the term "formaldehyde" is in common usage, this was used in the report.

- ~~the~~ waste blown by the wind as it is~~materials as they are~~ tipped or deposited at~~placed into~~ the landfill site;

- dust generated from the surface of the landfill and when waste is tipped or unloaded;

- ~~from tipping and the surface of the landfill;~~

- the waste materials which have previously been deposited in the landfill site;

- any gas generated as the waste breaks down, which is not collected and treated;

- any ~~combustion~~ plant used to burn~~handle~~ landfill gas, including gas flares or engines;

- any leachate produced as the waste breaks down;

- the discharges from any processes used to treat the leachate.

We were advised that, as areas of the site are filled, waste is deposited in new areas and, therefore, the location and nature of these sources vary throughout the lifetime of the site, which makes a~~ny~~ representative survey of emissions extremely difficult.

2002-2005 landfill study

10.   In 2008, we were asked to consider the toxicological aspects of a report of a project commissioned by the Environment Agency which monitored emissions over two years from two municipal waste landfill sites [9]. We were informed that the two landfill sites (termed Sites A and B) were typical of the population of currently operated landfill sites in England and Wales and were selected on the basis of pre-defined criteria i.e. of a reasonable size, with landfill gas controls, near to population, with groundwater within 10 metres of the site base and surface water within 50 metres of the site boundary. All the potential pathways for exposure of the local population to emissions from landfill sites were identified and prioritised as part of a screening risk assessment. In the light of this, a detailed study of airborne levels of substances potentially emitted from the landfill sites was carried out.

11.   The study provided the following:

- data on the concentrations of the principal chemicals expected to be emitted from the two landfill sites in air samples at the boundaries;
- health-based reference concentrations for these substances in air *(see paragraph 15 below)*;
- a comparison of the concentrations of the substances found against these reference concentrations and an assessment of how frequently they were found;

- an assessment of the risks to health posed by possible releases of waterborne pollutants;
- an estimate of exposure to polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans by both direct exposure from air and indirect exposure from modelled uptake into produce grown around the landfill sites.

12.   All the known potential sources of pollution at the landfill site and their potential pathways to humans ~~receptors~~ were considered. The risks associated with each potential source of pollution were screened and the sources which were most significant were subject to detailed monitoring and assessment. The pathways of greatest potential concern were identified as groundwater and air (both for landfill gas and for particulates). A groundwater risk assessment was carried out, but the authors considered that this showed no significant risk to the surrounding populations. Therefore, the main focus of the monitoring work was airborne emissions which were viewed as having the highest potential for exposure of the population.

13.   The study used both continuous and discrete atmospheric sampling. The pollutants studied were based on the prioritisation from the three studies reported in paragraphs 4 to 6 above, which categorised trace components in landfill gas according to their potential impacts on developmental toxicity and their concentrations. Both sites were monitored extensively for some 22 months over the study period (2002 and 2003). This included continuous monitoring for NOx, PM_{10} and total VOCs at the northeast boundary of both sites throughout the study. Continuous measurements were also carried out for these determinands for shorter periods at the southwest boundary of each site. These determinands were chosen as indicators of combustion and fugitive emissions. During the shorter survey periods, continuous measurements were also made of sulphur dioxide and hydrogen sulphide~~This included continuous monitoring for NO_x, PM_{10} and total VOCs at the northeast boundary of both sites and, additionally, for shorter periods at the southwest boundary. Some 60,000 measurements were taken across the two sites. These were mainly measurements at the site boundaries of NO_x, PM_{10} and total VOCs as indicators both of combustion and fugitive emissions.~~ In addition, over 1200 site boundary measurements were made of substances of specific concern to this c~~C~~ommittee. The concentrations measured at the boundaries were highly variable, possibly depending on the time of day, meteorology and longer-term changes in the location and nature of operations at the sites.

14.   Two problems were identified which affected the interpretation of the study results. Firstly, the prevailing wind direction at one site was different from that expected, which limited the amount of time the monitoring points were directly upwind and downwind from the site. To address this, the authors of the study estimated the significance of the potential health effects ~~were estimated~~ using the maximum ~~levels~~ concentrations measured at the site boundary over an appropriate sampling period. Secondly, the concentrations were very low, often at or below the limit of detection. ~~For some substances, detection limits were improved during the course of the study and, where it was difficult to provide advice because of the inability to measure some substances, we asked for further measurements to be carried out, with the aim of improving limits of detection (see paragraph 16).~~

15.   The study also sought to establish health-based reference concentrations for substances in air at which it was expected that there would be either no risk of health effects over a lifetime or, in the case of non-threshold substances[4], a minimal risk to health. These were termed "Health Criteria Values (HCVs)". In this statement we have referred to them as "project-specific HCVs" to distinguish them from the HCVs published by the Environment Agency for use in the risk assessment of contaminants in soil [10][10]. The project-specific HCVs were applied in relation to the measured concentrations of these substances at the site boundaries.

Subsequent study

16.   Following an initial review of the 2002-2005 study results, we requested further measurements of a number of the substances measured in the 2002-2005 study. The aim was to generate improved data for this subset of substances. These measurements were carried out during 2009 at two further typical landfill sites (termed Sites C and D) which were selected to be typical of landfill sites accepting household waste), and two background locations (general warehousing bordering a river and a non-industrial business park). Fewer measurements were taken at these locations, but the measurements were more closely targeted and, in some cases, involved greater analytical sensitivity. We have considered the results of this subsequent survey alongside the results of the 2002-2005 study in our statement.

Summary and discussion of results of both studies

Initial review of results

17.   The main study considered over 60 chemicals or chemical groups (see Annex 1 to this statement). The maximum measured concentrationss for each chemical at both sites wereere compared to the project-specific HCV. analysed to identify concentrations over an appropriate averaging period, having regard to the health endpoint of potential concern. For some substances, the average concentration measured during the course of the study was the appropriate value. For other substances, the highest measured concentration was more appropriate. After comparison of the measured concentrations at the site boundaries with the project-specific HCVs, Twenty-three23 of these substances were not considered further because the maximum measured concentrations at both sites were below 1% of the HCV (see the list at the end of this paperAnnex 1).

18.   The remaining substances were prioritised on the basis of the ratios of the if measured concentrations to their project-specific HCV. This is a conservative approach, because the concentrations to which members of the public are likely to be exposed are lower than those measured at the boundary of a landfill site. We considered in detail the following substances whose average measured boundary

---

[4] Most toxicological effects are expected to exhibit a dose threshold i.e.there is a dose below which the adverse effect does not occur. However, for some chemicals, there is no identifiable dose threshold and it is assumed that a toxic effect may occur at any dose. These are referred to as "non-threshold" chemicals. Non-threshold toxicity most notably occurs in the case of chemicals which damage DNA i.e.genotoxic chemicals.

concentrations at one or both sites were at, or above, 75% of the project-specific HCV over the relevant averaging period.

- Arsine
- Chromium
- 1,2-Dichloroethane
- Dimethyl disulphide
- Dimethyl sulphide
- Formaldehyde
- Methyl mercaptan (methane thiol)
- Polycyclic aromatic hydrocarbons
- Stibine
- Styrene
- Toluene

19.   A limited review was carried out on the project-specific HCVs for the other chemicals by comparing them to the Health and Safety Executive Workplace Exposure Limit (WEL) for that chemical, adjusted to 24 hour, 7 days per week exposure, and divided by an additional uncertainty factor of 10 to allow for wider interindividual variation in the general population than in the workforce [11][11]. Where the value derived from the WEL was similar to, or higher than, the project-specific HCV, no further action was taken, as this indicated that the HCV was likely to be conservative. In cases where the value derived from the WEL was lower than the project-specific HCV, the concentrations measured in the monitoring study were checked to see if they exceeded, or were close to, the value derived from the WEL and, if so, the derivation of the project-specific HCV was examined in more detail. This was the case only for nickel where the maximum concentration at Site B slightly exceeded the value derived from the WEL. A closer evaluation of the project-specific HCV for nickel, which was based on a recommendation by the EU Scientific Committee on Toxicity, Ecotoxicity and the Environment, indicated that it was sufficiently precautionary [12][12]. For 4 chemicals there was no project-specific HCV and no WEL. These were: 2-methyl furan, acenaphthylene, benzo(ghi)perylene and phenanthrene. These are discussed in paragraphs ? to ? below. For all other chemicals, the concentrations measured at the boundaries of the sites were not considered to be a cause for concern.

20.   We noted that, although the average concentrations of chloroethene at both Sites A and B were well below the project-specific HCV of 1 ug m^{-3}, the maximum concentration found at Site B was 4.9 ug m^{-3}. We therefore included this compound in our more detailed review.

21.   Finally, we were asked to consider the health significance of estimated exposures to polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, both via inhalation and via consumption following deposition on, or incorporation into, locally produced food.

Detailed review

Introduction

22.   When reporting below the concentrations of chemicals measured at the boundaries of the landfill sites, we have presented the 50th percentile values of the measurements made for each chemical at each site, together with the maximum concentration detected. Two values are given for the 50th percentile: firstly, the value calculated by assuming that all concentrations below the detection limit were zero and, secondly, the value calculated by assuming that all concentrations below the detection limit were present at the detection limit. This is explained in more detail in Annex 2 to this statement.

23.   Also, for all chemicals examined in detail, we considered whether the project-specific HCV established in the main study report (see paragraph 15) was reasonable given currently available data on the toxicity of the chemical. In some cases, we concluded that this was not the case and derived our own health-based reference concentration. Where this was done, the derivation of the revised health-based reference concentration is described below.

Arsine

242.   The concentrations of arsine measured in the main study and the subsequent study are summarised in Table 2 below. Note that for all chemicals given below, two 50th percentile values were calculated. The first was calculated on the basis that, if a chemical was not detected in a sample, its concentration was zero. The second was calculated on the assumption that the chemical was present in the sample at the limit of detection of the analytical method.

Table 2: Arsine concentrations in main and subsequent monitoring studies (ng m^{-3})

	50th percentile (ng m^{-3})		Maximum detected concentration (ng m^{-3})	Detection limit (ng m^{-3})	No. Detects/ No. Measure-ments
	Assuming all non-detects were zero	Assuming all non-detects were present at detection limit			
Main study **- Site A** **- Site B**	0 0	440 630	<700 530	300-700 <370-1100	0/16 2/8 [a]
2009 Study **- Site C** **- Site D**	0 0	2 10	<2 <10	2 10	0/6 0/6

a: The second 'detected' level was 370 ng m^{-3}

253.   Arsine is a colourless, non-irritatanting gas with a mild, garlic-like odour. Exposure to arsine is most likely to occur in an occupational setting. The project-specific Health Criteria Value (HCV) for arsine was 7 ng m^{-3}. This had been based on the assumption that arsine is completely metabolised in humans to arsenic and, therefore, that it was appropriate to apply the WHO AAir QQuality GGuideline for Europe for arsenic of 6.6 ng m^{-3} to arsine. This Long-term exposure to this concentration of arsenic was had been estimated from occupational studies to

carry a 1 in 10^5 lifetime risk of lung cancer [13][~~13~~]. (It should be noted that the UK Expert Panel on Air Quality Standards (EPAQS) has recently recommended an ~~a~~air ~~q~~quality guideline for total inorganic arsenic for use in regulating emissions of from industrial plant. This is 3 ng m^{-3} in the PM$_{10}$ size fraction, as an annual mean [14][~~14~~]).

2~~6~~64.   Limited information is available on the metabolism of arsine. There is some qualitative evidence of conversion to arsenic in experimental animals but there are no quantitative estimates of the extent of conversion [15][~~15~~]. The ~~study~~ authors of the main study [9] assumed 100% conversion as a worst case, but we consider that this may be excessively conservative.

27~~5~~.   No genotoxicity studies have been reported for arsine; such studies would be difficult in view of its high volatility and low water solubility [16][~~16~~]. Arsine is excreted in the urine as dimethylarsinate, monomethylarsonate, trivalent arsenic, and, to a lesser extent, pentavalent arsenic, which are also metabolites of other arsenic compounds. Thus it may well have carcinogenic potential [16][~~16~~]. There are no adequate reproductive or chronic toxicity studies of arsine in humans or animals. It is highly acutely toxic and health-based guideline values are usually recommended on the basis of its acute effects. A 2001 WHO Concise International Chemical Assessment Document (CICAD)[5] recommended a guideline value of 50 ng m^{-3}, which was based on the ~~N~~no ~~O~~observed ~~A~~adverse ~~E~~effect ~~C~~level ~~oncentration ~~(NOAE~~C~~L) for haemolysis in short-term animal studies [15][~~15~~]. However, we do not consider that it would be appropriate to use this to assess the risks from chronic exposure to arsine.

28~~6~~.   We agree that concentrations of arsine at or below 50 ng m^{-3} are unlikely to give rise to acute toxic effects. However, given the lack of information on metabolism, genotoxicity or carcinogenicity of arsine, it is not possible for us to recommend a reference concentration of arsine in air which will protect against chronic health effects.

Discussion of results for arsine

29~~7~~.   In the main study, arsine was detected on two occasions at Site B at concentrations of 530 and 370 ng m^{-3}. These results are of some concern but the values were close to the detection limits of the analytical method used (500 to 1100 ng m^{-3}) and, therefore, it is not clear how reliable they are. No arsine was detected at Site A, but the detection limit was again high (400 to 700 ng m^{-3}). In the subsequent study, no arsine was detected above detection limits of 2 ng m^{-3} (Site C) or 10 ng m^{-3} (Site D), which is reassuring. It is difficult to provide an informative assessment from these limited data. We might be able to provide further advice if more sensitive sampling or analytical methods were to be~~are~~ developed and further monitoring data obtained from the boundaries of landfill sites. Also, there is a need for quantitative information on the conversion of arsine to arsenic in an appropriate experimental species.

---

[5] CICADS are written as part of the WHO/ILO/UNEP International Programme on Chemical Safety.

Chloroethene (vinyl chloride)

30   28.   The concentrations of chloroethene measured in the main study and the additional monitoring exercise are summarised in Table 3 below.

Table 3: Chloroethene concentrations in main and subsequent monitoring studies (µg m^{-3})

| | 50th percentile (µg m^{-3}) | | Maximum (µg m^{-3}) | Detection limit (µg m^{-3}) | No. Detects/ No. Measure-ments |
	Assuming all non-detects were zero	Assuming all non-detects were present at detection limit			
Main study **- Site A** **- Site B**	0 0	0.010 0.015	0.46 4.9	0.01 – 5 0.01 – 7	5/43 8/48
2009 study **- Site C** **- Site D**	0 0	0.06 0.04	<0.06 <0.07	0.06 0.03 – 0.07	0/6 0/6

2931. Chloroethene is a gas which is used in the plastics industry for the production of polyvinyl chloride (PVC). It has also been reported to be produced from the degradation of other chlorinated compounds in landfill sites [17][17]. Epidemiological studies have revealed a strong association between occupational exposure to chloroethene by inhalation and angiosarcoma of the liver, and it is classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans [18][18].

32 0.   The project-specific HCV for chloroethene was 1 µg m^{-3}, which was the concentration estimated from occupational studies to present a 1 in 10^{6} cancer risk, cited in the WHO Air Quality Guidelines for Europe [13][13]. We agree that this is an appropriate reference concentration against which to assess the risks from emissions of chloroethene from the monitored landfill sites.

33 1.   We note that chloroethene was classified by Sullivan *et al* (2001) as a "chemical of possible interest" with regard to its developmental toxicity (see Table 1) [7]. Sullivan *et al* (2001) concluded that chloroethene was not teratogenic in laboratory animals by inhalation and is embryotoxic only at maternally toxic doses. The evidence concerning human occupational or environmental exposure to chloroethene and malformations or spontaneous abortions was considered to be inconclusive. An inhalation NOAECL for embryotoxicity of 130 mg m^{-3}, administered for 7 hours per day, was identified in mice. This is well above the concentrations detected in the monitoring studies.

34 2.   Background concentrations of chloroethene in air are reported to be usually less than 3 µg m^{-3} although higher concentrations have been observed near chloroethene production sites and waste disposal sites (up to 100 µg m^{-3} and 1000 µg m^{-3}, respectively) [19][19]. The background level in the 2009 monitoring survey was below the detection limit of 0.06 µg m^{-3}.

Discussion of results for chloroethene

35~~3~~.   The concentrations measured in the main monitoring study do not give rise to concern in relation to either angiosarcoma of the liver ~~n~~or developmental effects. Occasional concentrations above the HCV, while undesirable, are likely to be associated with ~~at most~~ a negligible risk of carcinogenicity. Chloroethene was not detected in the further monitoring exercise.

Chromium

36~~4~~.   The concentrations of chromium measured in the main study and the subsequent study are summarised in Table 4 below. In the main study, total chromium was measured but, in the subsequent study, concentrations of hexavalent chromium (see below) alone were measured.

Table 4: Chromium concentrations in main and subsequent monitoring studies ~~(ng m^{-3})~~

	50th percentile (ng m^{-3})		**Maximum (ng m^{-3})**	**Detection limit (both sites) (ng m^{-3})**	**No. Detects/ No. Measure-ments**
	Assuming all non-detects were zero	Assuming all non-detects were present at detection limit			
Main study **- Site A** **- Site B**	0.40 (total Cr) 1.0 (total Cr)	1.0 (total Cr) 1.0 (total Cr)	3.9 (total Cr) 28 (total Cr)	0.1 – 1.0 (total Cr)	19/32 28/32
2009 Study **- Site C^{a}** **- Site D**	0 (CrVI) 0 (Cr VI)	6 (CrVI) 1000 (Cr VI)	<6 (CrVI) <1000 (CrVI)	6 (CrVI) 1000 (CrVI)	0/3 0/6

a: Results for Site C should be viewed with caution because the methodology has not been validated

37~~5~~.   Chromium is a metal which commonly exists either in the trivalent form [chromium (III)] or the hexavalent form [chromium (VI)]. The toxicity of chromium varies depending on its valency state~~;~~: hexavalent chromium is more toxic than trivalent chromium, which is an essential trace element. Hexavalent chromium and its compounds are oxidizing agents capable of directly inducing tissue damage. Epidemiological studies have found an association between exposure to hexavalent chromium and lung cancer and IARC has classified chromium (VI) as carcinogenic to humans [20]~~[20]~~.

38~~6~~.   The project-specific HCV was 2.5 ng m^{-3} total chromium. This was equivalent to the guideline value for inhalation of chromium from soil recommended by the UK Government in 2002 [21]~~[21]~~. This in turn was the concentration of Cr(VI) estimated from occupational studies to present a 1 in 10^{4} cancer risk, cited in the WHO Air Quality Guidelines for Europe [13]~~[13]~~. The choice of a risk estimate of 1 in 10^{4} rather than 1 in 10^{5} for chromium in soil is not explained but probably reflects the fact that the estimate is for chromium (VI), not total chromium, and therefore the risk from total chromium in soil will be lower than for the same

quantity of chromium (VI). We were informed that there is little readily available information on the speciation of chromium at landfill sites, but the reducing environment, together with the presence of readily oxidisable organic compounds, would be expected to be more conducive to its presence as chromium (III) than chromium (VI). We agree that 2.5 ng m^{-3} is an appropriate reference concentration for total chromium. We note that EPAQS has recently published a new guideline for chromium in ambient air of 0.2 ng m^{-3} chromium as chromium (VI) for use in regulating ~~the~~ emissions ~~of these substances~~ from industrial plant. This was derived from the Lowest Observed Adverse Effect ~~Level~~ Concentration (~~LOAEL~~LOAEC) for mortality from lung cancer in occupational studies [14]~~[14]~~.

3~~7~~9. There are no studies in the literature on developmental effects in humans or animals after inhalation exposure to chromium or its compounds [22]~~[22]~~. There is some evidence of developmental effects in animal studies in which chromium (VI) was administered by the oral route but the effects were observed at relatively high doses (≥35 mg kg bw^{-1} day^{-1}) and were usually associated with maternal toxicity [22]~~[22]~~.

~~38~~40. Background concentrations of particulate total chromium in air in the UK have been reported to be 0.2 to 0.7 ng m^{-3} in rural areas and 4.1 to 17.2 ng m^{-3} in urban areas [23]~~[23]~~. During the 2009 survey, the background concentration at an urban location was reported to be less than 6 ng m^{-3}. ~~EPAQS has commented "at current upper UK urban levels of chromium of around 15 ng m^{-3} containing an estimated 4 ng m^{-3} of Cr (VI), the increased risk of lung cancer would amount to a little under 1 in 10,000 which is comparable to the rate of death from lung cancer in non-smokers derived from a 20 year follow-up of male British doctors" [14].~~

Discussion of results for chromium

~~39~~41. In the main study, the maximum concentrations of total chromium at both sites A and B exceeded the HCV of 2.5 ng m^{-3} by up to 11-fold but the 50th percentile concentrations were well below the HCV and below current urban background concentrations of chromium. It is the long-term average concentration of chromium which is of most concern when considering the risk of lung cancer. It is not possible to draw reliable conclusions about potential health risks because of lack of information on speciation and inadequacies of available measurement techniques. However, it is relevant to note ~~It is the average exposure to chromium which is of most concern when considering risk of lung cancer and, therefore, we do not consider~~ that ~~these findings indicate a major cause for concern.~~ EPAQS has commented that "at current upper UK urban levels of chromium of around 15 ng m^{-3} containing an estimated 4 ng m^{-3} of Cr (VI), the increased risk of lung cancer would amount to a little under 1 in 10,000 which is comparable to the rate of death from lung cancer in non-smokers derived from a 20 year follow-up of male British doctors" [14]. We note that the detection limits for chromium (VI) at sites C and D were 6 and 1000 ng m^{-3}, respectively, which are higher than the new EPAQS guideline of 0.2 ng chromium (VI) m^{-3}. Therefore, it is not known whether the emissions at these sites exceeded the guideline or not. We recommend that, should techniques be developed to measure chromium (VI) in air at lower detection limits, it would be appropriate to use these in future monitoring.

1,2-dichloroethane

4~~0~~2.   The concentrations of 1,2-dichloroethane measured in the main study and the subsequent study are summarised in Table 5 below.

~~41.   1,2-dichloroethane is a volatile, synthetic chemical with no known natural sources [24]. 1,2-dichloroethane has demonstrated genotoxic potential both *in vitro* and *in vivo* [26]. The project-specific HCV for 1,2-dichloroethane was 0.36 µg m^{-3}. This was derived from a 1998 assessment by an international expert group of a 1978 oral carcinogenicity study in rats and mice which, although of poor quality, indicated dose-related increases in tumours at multiple sites in both species [24, 25].~~

Table 5: Concentrations of 1,2-dichloroethane in main and subsequent monitoring studies ~~(µg m^{-3})~~

	50th percentile (µg m^{-3})		Maximum (µg m^{-3})	Detection limit (µg m^{-3})	No. Detects/ No. Measure-ments
	Assuming all non-detects were zero	Assuming all non-detects were present at detection limit			
Main study **- Site A** **- Site B**	0 0.045	0.077 0.050	2.4 1.5	0.01 – 1 0.01 – 0.6	17/55 29/36
2009 study **- Site C** **- Site D**	0 0	0.06 0.02	0.2 0.13	0.06 0.02 – 0.03	1/6 1/6

43.   1,2-dichloroethane is a volatile, synthetic chemical with no known natural sources [24]. It has demonstrated genotoxic potential both *in vitro* and *in vivo* [25]. The project-specific HCV for 1,2-dichloroethane was 0.36 µg m^{-3}. This was derived from a 1998 assessment by an international expert group of a 1978 oral carcinogenicity study in rats and mice which, although of poor quality, indicated dose-related increases in tumours at multiple sites in both species [24, 26].

4~~2~~4.   We note that a good quality inhalation carcinogenicity study on 1,2-dichloroethane was published recently by Nagano et al [27]~~[27]~~. In this study, groups of F344 rats and BDF1 mice were exposed to 1,2-dichloroethane vapour or 'clean air' (controls) for 6 hours per day, 5 days per week for 104 weeks. These exposures are equivalent to 7.1, 28.6 and 114.3 mg m^{-3} in rats and 7.1, 21.4 and 64.3 mg m^{-3} in mice when averaged over ~~a~~ 24 hours per day, 7 days per week ~~basis~~ (referred to as Time Weighted Average (TWA) exposures). Treatment-related increases in cancer incidence were seen at several sites in both species. We carried out Benchmark Concentration (BMC) calculations for those neoplastic endpoints which showed a statistically significant dose-related trend, for a Benchmark Response of 10%, using the US EPA BMDS 2.0 software. The lowest BMCL$_{10}$[6] values were 24.05 mg m^{-3} for subcutaneous fibroma in male rats and

---

[6] BMCL$_{10}$: lower 95% confidence limit of the benchmark concentration for a 10% response.

12.95 mg m^{-3} for combined mammary adenoma, fibroadenoma and adenocarcinoma in female rats (all values are TWA doses). We then divided the lowest BMCL$_{10}$ value by the concentrations of 1,2-dichloroethane measured at the landfill sites to give the Margin of Exposure (MOE). The results are given in Table 6 below.

Table 6: Margins of Exposure for concentrations of 1,2-dichloroethane

	For 50th percentile concentration assuming all non-detects at DL	For maximum concentrations
Main study **- Site A** **- Site B**	170,000 260,000	5,400 8,600
2009 study **- Site C** **- Site D**	220,000 650,000	65,000 100,000

45~~3~~. 1,2-dichloroethane was not reviewed by Sullivan *et al* (2001). However, the weight-of-evidence from studies in animals indicates that no adverse reproductive or developmental effects would be expected at the exposures reported in the monitoring studies [25]~~[26]~~.

46~~4~~. Few data are available on background concentrations of 1,2-dichloroethane. The background levels measured during the further monitoring exercise were below the detection limits of 0.06 and 0.03 ug m^{-3}.

Discussion of results for 1,2-dichloroethane

47~~5~~. To assess the significance of the MOEs in Table 5, we used the banding system recommended by the Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment (COC) to assist with the risk management and risk communication of the health significance of genotoxic contaminants in food and the environment [28]~~[28]~~. This is given in Table 7 below. Using this system, the 50th percentile concentrations measured in both the main and subsequent studies are unlikely to be a concern. The maximum concentrations measured in the main study may be a concern if present on a continuous basis, but the risk of carcinogenic effects following exposure to occasional concentrations of this magnitude is ~~negligible~~highly unlikely to be a concern.

Table 7: MOE banding approach agreed by COC

MOE Band	Interpretation
<10,000	May be a concern
10,000-1,000,000	Unlikely to be a concern
>1,000,000	Highly unlikely to be a concern

Dimethyl sulphide and dimethyl disulphide

4~~8~~6.   The concentrations of dimethyl sulphide (DMS) and dimethyl disulphide (DMDS) measured in the main study and in the subsequent study are summarised in Table 8 below.

47.   DMS and DMDS are similar substances both chemically and toxicologically and have, therefore, been considered together. They are foul-smelling compounds, with odour thresholds of 6.5 and 15.2 µg m^{-3}, respectively. There are limited toxicity data on these compounds. The project-specific HCV for both compounds was 5 µg m^{-3}. We note that this was derived from a subchronic inhalation study on DMS in rats quoted in [29]. A good quality subchronic inhalation study has recently been published on DMDS in which rats were exposed to DMDS vapour by whole body exposure at TWA concentrations of 3.5, 17.2 or 86.0 mg m^{-3}[30]. The TWA NOAEL was 3.5 mg m^{-3}. Changes in biochemical parameters and organ weights were seen above this level. An uncertainty factor (UF) of 125 (2.5 for interspecies toxicodynamics, 10 for intraspecies differences and 5 for the limited database) applied to the TWA NOAEL gave a reference concentration in air of 28 µg m^{-3}. We used this to assess the risk of the combined concentrations of both substances.

Table 8: Concentrations of DMS and DMDS in main and subsequent monitoring studies (µg m^{-3})

	50th percentile (µg m^{-3})		Maximum (µg m^{-3})	Detection limit (µg m^{-3})	No. Detects/ No. Measure-ments
	Assuming all non-detects were zero	Assuming all non-detects were present at detection limit			
DMS Main study					
- Site A	0	2	375	0.07 – 5	21/44
- Site B	0	2.7	59	0.07 – 7	21/48
DMS 2009 study					
- Site C	0	0.06	<0.06	0.06	0/6
- Site D	0	0.21	<0.3	0.2 – 0.3	0/6
DMDS Main study					
- Site A	0.04	0.75	56	0.07 – 5	22/44
- Site B	0	1.7	16	0.07 – 7	21/48
DMDS 2009 Study					
- Site C	0	0.06	<0.06	0.06	0/6
- Site D	0	0.02	<0.03	0.02 – 0.03	0/6

49.   DMS and DMDS are similar substances both chemically and toxicologically and have, therefore, been considered together. They are foul-smelling compounds, with odour thresholds of 6.5 and 15.2 µg m^{-3}, respectively. There are limited toxicity data on these compounds. The project-specific HCV for both compounds was 5 µg m^{-3}. We note that this was derived from a subchronic inhalation study on DMS in rats quoted in [29]. A good quality subchronic

inhalation study has recently been published in which rats were exposed to DMDS vapour by whole-body exposure at TWA concentrations of 3.5, 17.2 or 86.0 mg m^{-3} [30]. The TWA NOAEC was 3.5 mg m^{-3}. Changes in biochemical parameters and organ weights were seen above this level. An uncertainty factor (UF) of 125 (2.5 for interspecies toxicodynamics[7], 10 for intraspecies differences and 5 for the limited database) applied to the TWA NOAEC gave a reference concentration in air of 28 µg m^{-3}. We used this to assess the risk of the combined concentrations of both substances.

4850. We could find no reproductive or developmental toxicity data on DMS or DMDS nor any reliable data on background concentrations of these substances in the UK, although they are both likely to be present as a result of industrial and biological processes.

Discussion of results for dimethyl sulphide and dimethyl disulphide

5149. In the main study, the 50th percentile concentrations were well below the new health-based guideline valuereference concentration of 28 ug m^{-3}. Therefore, on the basis of the limited data available, we would anticipate no adverse health effects from chronic exposure to DMS or DMDS. The combined maximum measured concentrations of DMS and DMDS at both sites A and B exceeded the reference concentration health-based guideline value but we consider it unlikely that these concentrations would pose an acute risk to those on or near the site in view of the minor effects seen above the NOAECL in the recent subchronic inhalation study. Moreover, the maximum concentrations exceeded the odour thresholds, which is likely to deter individuals from staying in the vicinity. In the subsequent monitoring exercise, which used detection limits of 0.02 to 0.3 ug m^{-3}, no DMS or DMDS was detected.

Formaldehyde (methanal)

520.   The concentrations of formaldehyde measured in the main study and the subsequent monitoring exercise are summarised in Table 9 below.

Table 9: Concentrations of formaldehyde found in main and subsequent monitoring studies (µg m^{-3})

	50th percentile (µg m^{-3})		Maximum (µg m^{-3})	Detection limit (µg m^{-3})	No. Detects/ No. Measure-ments
	Assuming all non-detects were zero	Assuming all non-detects at detection limit			
Main Study - Site A - Site B	0 64[a]	38 64[a]	213 487	5 – 47 10 – 21	3/8 6/8
2009 Study					

[7] The usual uncertainty factor of 4 for interspecies toxicokinetics was not applied. Rats have a higher respiratory rate than humans and are exposed to 4 times more of a compound for a given air concentration (European Chemicals Agency. Guidance on information requirements and chemical safety assessment: Chapter R.8. May 2008).

- Site C	38 [a]	38 [a]	46	1.2	3/3
- Site D	1.6 [a]	1.6 [a]	4.6	1.2	5/6

5~~3~~4. Formaldehyde is widely present in most living systems and in the environment. Exposure also arises from vehicle emissions, from building and household materials, from tobacco smoke and in some occupational activities. Most formaldehyde released to the environment is rapidly degraded.

5~~4~~2. Formaldehyde is an irritant and can cause nose and throat irritation and is a weak allergen [31]. ~~It is a direct acting, *in vitro* mutagen and e~~Epidemiological studies have found an association between exposure to formaldehyde and cancer of the nasopharynx. IARC has classified it as carcinogenic to humans [32]~~[31]~~. The Committee on Mutagenicity of Chemicals in Food, Consumer Products and the Environment (COM) advised in 2007 that there was no convincing evidence from *in vivo* mutagenicity studies in experimental animals, nor from biomonitoring studies of genotoxicity in workers exposed to formaldehyde, for a direct *in vivo* systemic mutagenic effect of inhaled formaldehyde [33].

55. The project-specific HCV of 10 µg m^{-3} was derived from a US Agency for Toxic Substances and Disease Registry (ASTDR) chronic duration inhalation exposure Minimal Risk Level for mild damage to the nasal epithelium following occupational exposure to formaldehyde [31] ~~[32]~~. However, ~~we note that,~~ according to the WHO Air Quality Guidelines for Europe, damage to the nasal mucosa in workers exposed to formaldehyde may have been caused by concomitant exposures to other substances [13]~~[13]~~. Therefore, we consider that it would be more appropriate to use the WHO Air Quality Guideline for formaldehyde of 100 µg m^{-3} (as a 30-minute average) to assess the significance of the concentrations found in the monitoring studies. This guideline is set on the basis that, provided the respiratory tract tissue in humans is not repeatedly damaged, exposure to low, noncytoxic concentrations of formaldehyde will be associated with a negligible cancer risk. This is considered consistent with epidemiological findings. Therefore, the guideline is based on the lowest reported threshold for nose and throat irritation in the general population i.e. 100 µg m^{-3}.

~~53~~56. ~~We note that the Committee on Mutagenicity of Chemicals in Food, Consumer Products and the Environment (COM) advised in 2007 that there was no convincing evidence from *in vivo* mutagenicity studies in experimental animals, or from biomonitoring studies of genotoxicity in workers exposed to formaldehyde, for a direct *in vivo* systemic mutagenic effect of inhaled formaldehyde [33].~~

~~54.~~ Formaldehyde was classified by Sullivan *et al* (2001) as a "chemical of possible interest" with regard to its developmental toxicity (see Table 1) [7]. The authors concluded that "while animal studies suggest absence of teratogenic potential even at very high exposures, there is evidence of effects on fetal weight at high exposures" (24 mg m^{-3} and above). They further concluded "in humans, there is consistent evidence of an increase in spontaneous abortion rates of up to 2-fold and limited evidence of reduced fertility at airborne exposure levels at or just above those currently permitted in the workplace (1.2 mg m^{-3})".

575. Background concentrations of formaldehyde have been reported to be from 1 to 20 µg m^{-3} in ambient air, 30 to 60 µg m^{-3} in a conventional home [13][13] and 4 to 800 µg m^{-3} in mobile homes [34]. The background levels measured as part of the 2009 monitoring exercise were 1.2 to 4 µg m^{-3}.

Discussion of results for formaldehyde

5658. In the main study, the 50th percentile concentrations were below the WHO Air Quality Guideline for Europe although maximum concentrations exceeded it. We do not consider that these results raise any concerns about chronic health effects or adverse developmental effects, but some individuals close to landfill sites might experience some irritant effects at the maximum concentrations reported. In the subsequent study, both 50th percentile and maximum concentrations were below the guideline, which is reassuring.

Methyl mercaptan

5759. The concentrations of methyl mercaptan measured in the main study and the additional monitoring exercise are summarised in Table 10 below.

Table 10: Concentrations of methyl mercaptan found in main and subsequent monitoring studies (µg m^{-3})

	50th percentile (µg m^{-3})		Maximum (µg m^{-3})	Detection limit (µg m^{-3})	No. Detects/ No. Measure-ments
	Assuming all non-detects were zero	Assuming all non-detects at detection limit			
Main study **- Site A** **- Site B**	0.33 0.23	2.0 2.3	22 7.5	0.07 – 5 0.1 – 7	27/43 27/48
2009 Study[a] **- Site D**	0	0.21	<0.2	0.2	0/6

a: No measurements were made at Site C

5860. Methyl mercaptan is a colourless gas with the smell of rotten cabbage. The odour threshold is 3.1 µg m^{-3}. There are limited toxicity data on methyl mercaptan. The project-specific HCV was 4 µg m^{-3} and was derived from a non-standard study in which rats were exposed at 3 dose levels by inhalation 7 hours per day, 5 days per week for 3 months [35][34]. To derive the HCV, the lowest dose of 4 mg m^{-3} was designated a "minimum LOAECL" and an UF of 1000 applied. The authors of the monitoring report did not adjust for dose was not adjusted for continuous exposure – this would have given a HCV of 0.83 µg m^{-3}.

5961. We reviewed the relevant study and noted that, although occasional statistically significant changes in clinical chemistry parameters were seen in all dose groups when compared with the control group, the only dose-related trend was a decrease in albumin concentrations, which was not statistically significant. We consider that the NOAECL was the mid dose of 33 mg m^{-3} which was equivalent to a TWA concentration of 6.9 mg m^{-3}. A statistically significant

reduction in terminal body weight was seen at the high dose (TWA concentration 23.2 mg m^{-3}). Applying an UF of 125 (see paragraph 4~~9~~6 for rationale) to the NOAE~~C~~L gives a reference concentration of 55.2 µg m^{-3}.

6~~0~~2.   With regard to its developmental toxicity, methyl mercaptan (methane thiol) was classified by Sullivan *et al* (2001) as a "chemical with insufficient data for classification".

6~~1~~3.   Few data were found on background concentrations of methyl mercaptan. The annual mean concentrations a~~A~~round paper mills in South Karelia, Finland, ~~the annual mean concentrations of methyl mercaptan~~ were estimated to be 2 to 5 µg m^{-3} and the highest daily average concentration to be 50 µg m^{-3} [36]~~[35]~~. During the 2009 survey, background levels of methyl mercaptan at a non-industrial business park were found to be less than 0.2 µg m^{-3}. Methyl mercaptan is a product of biological processes and a component of bad breath [37]~~[36]~~.

Discussion of results on methyl mercaptan

6~~2~~4.   The monitoring data indicate that all measured concentrations of methyl mercaptan were below our recommended health-based ~~guideline value~~reference concentration of 55.2 ug m^{-3}. Thus, although the available data are limited, they do not indicate any health concerns from the concentrations measured in the emissions study. Moreover, methyl mercaptan has a low odour threshold, which is likely to deter the public from undertaking prolonged exposure to emissions.

Polycyclic aromatic hydrocarbons (PAHs)

65.   Polycyclic aromatic hydrocarbons (PAHs) are a large group of structurally similar chemicals which are ubiquitous in the environment, where they are found both as gases and associated with particulates. Environmental exposure of humans is always to complex mixtures of different PAH constituents. Epidemiological studies have found an association between exposure to mixtures of certain PAHs and tumours of the lung, skin and possibly bladder and other sites. In addition, several PAHs have been shown to be carcinogenic in experimental animals when tested individually [38]. However, extensive toxicity data are available for only one PAH, benzo(a)pyrene (B(a)P), and thus the evaluation of health risks from mixtures of PAHs is difficult.

66~~3~~.   In the main 2002-2005 study, ~~T~~the concentrations were measured of six carcinogenic ~~polycyclic aromatic hydrocarbons~~ (PAHs~~)~~ commonly found as air pollutants. The results~~found in the 2002 - 2005 study~~ are summarised in Table 11. In~~ and the concentrations in~~ the subsequent monitoring exercise, another carcinogenic PAH, dibenzo(a,l)pyrene, was also measured. The results from the subsequent study are given in Table 12.

Table 11: Concentrations of PAHs found in main monitoring study ~~(ng m^{-3})~~

	Concentrations found in study (ng m^{-3})			No. detects[a]/ no.
	50th	50th	Maximum	

	percentile assuming all non-detects were zero	percentile assuming all non-detects at detection limit		measure-ments
Benzo(a)pyrene				
- Site A	0	0.12	1.32	14/32
- Site B	0	0.10	0.58	6/32
Benzo(a)anthracene				
- Site A	0	0.22	3.83	15/32
- Site B	0	0.11	1.00	14/32
Benzo(b,k) fluoranthene				
- Site A	0.11	0.14	0.92	21/32
- Site B	0.1	0.16	1.23	18/32
Chrysene				
- Site A	0.11	0.15	4.09	20/32
- Site B	0.10	0.12	1.51	19/32
Dibenz(a,h)anthracene				
- Site A	0	0.11	0.29	4/32
- Site B	0	0.10	0.81	7/32
Indeno(123-cd)pyrene				
- Site A	0	0.11	0.40	11/32
- Site B	0	0.10	0.81	6/32

a: we are informed that the range of detection limits was 0.01 to 0.6 ng m^{-3}

Table 12: Concentrations of PAHs in subsequent monitoring study ~~(ng m^{-3})~~

	Concentrations found in study (ng m^{-3})			No. detects/ no. measure-ments
	50th %ile assuming all non-detects at zero	50th %ile assuming all non-detects at detection limit	Maximum	
Benzo(a)pyrene				
- Site C	0	0.06	0.06	1/3
- Site D	0.11	0.11	0.11	2/2
Benzo(a)anthracene				
- Site C	0	0.11	<0.11	0/3
- Site D	0.16	0.16	0.22	2/2
Benzo(b,k) fluoranthene				
- Site C	0	0.13	0.13	1/3
- Site D	0.22	0.22	0.22	2/2
Chrysene				
- Site C	0	0.14	<0.14	0/3
- Site D	0.56	0.56	1.01	2/2

Dibenz(a,h)anthracene				
- Site C	0	0.06	0.07	1/3
- Site D	0.06	0.11	0.11	1/2
Indeno(123-cd)pyrene				
- Site C	0	0.08	0.08	1/3
- Site D	0.11	0.11	0.11	2/2
Dibenzo(a,l)pyrene[a]				
- Site C	0	0.07	<0.07	0/3

a: Not measured at Site D

64.   ~~PAHs are a large group of structurally similar chemicals which are ubiquitous in the environment, where they are found both as gases and associated with particulates. Environmental exposure of humans is always to complex mixtures of different PAH constituents. Epidemiological studies have found an association between exposure to mixtures of certain PAHs and tumours of the lung, skin and possibly bladder and other sites. In addition, several of the individual substances present in PAH mixtures have been shown to be carcinogenic in experimental animals when tested individually [37]. However, extensive toxicity data are available for only one PAH, benzo(a)pyrene (B(a)P), and thus the evaluation of health risks from mixtures of PAHs is difficult.~~

6~~5~~7.   The project-specific HCV for PAHs was 0.25 ng m^{-3} B[a]P as an annual average, which was recommended as a UK ~~Air~~ air ~~q~~Quality ~~s~~Standard by EPAQS in 1999 [38]~~[37]~~. This standard was derived using B[a]P as a marker for the carcinogenic risk from all 7 PAHs commonly found in air and was based on the incidence of lung cancer in workers at an aluminium smelter. Carcinogenic potencies of the other 7 PAHs relative to B[a]P were derived from limited animal studies. The potencies are given in Table 13 below. Using this approach, the estimated contribution of BaP to the total carcinogenicity of the 7 PAH compounds was found by EPAQS to be similar in ambient air at two UK municipal sites, where it was calculated to be 44.6% and 37.5%, and the aluminium smelter, where it was calculated to be 49.3%. The studies at the smelter were therefore considered to form a suitable basis for recommending an air quality standard.

Table 13: Relative potencies for PAHs found in the monitoring studies, after EPAQS [38]~~[37]~~

PAH	Relative Potency
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b,k)fluoranthene	0.11
Chrysene	0.03
Dibenz(a,h)anthracene	1.91
Indeno(123-cd)pyrene	0.08

6~~6~~8.   Using the relative potencies estimated by EPAQS and the values for average measured concentrations of PAHs at landfill sites A and B in the main study, the contribution of BaP to the carcinogenicity of PAHs at Site A was calculated to be 45.1% which is similar to that at the aluminium smelter. Therefore,

we consider that it is appropriate to use the EPAQS aAir qQuality sStandard to assess the risk from PAH emissions at Site A. However, the relative concentrationcontribution of BaP to the carcinogenicity of PAHs at Site B was only 15.7%, approximately one-third of that atin the smelter. It is therefore appropriate to compare the concentration of BaP at this site with 15.7/45.1 of the aAir qQuality sStandard i.e. 0.08 ng m^{-3} B[a]P as an annual average.

6967. A similar exercise was not carried out for the measurements recorded in the subsequent study at Sites C and D, in view of the small number of samples for each PAH. However, we note that the concentrations measured at these sites were generally lower than those measured in the main study.

6870. Other air pollution monitoring in the UK has detected the presence of the PAH dibenzo(a,l)pyrene (DB(a,l)P) in a number of samples. DB(a,l)P is rarely measured in environmental studies because of the lack of a suitable analytical method and was monitored for at only Site C, where it was not detected (limit of detection: 0.07 ng m^{-3}). The COC has advised that DB(a,l)P should be considered as a highly potent genotoxic carcinogen in experimental animals and that it is 10 to 1000 times more potent than B(a)P on the basis of results in short-term studies by non-inhalation routes [39][38]. There were insufficient data to draw any conclusions about its relative potency by the inhalation route.

6971. No inhalation studies were found on the reproductive or developmental toxicity of PAHs and only limited oral studies are available. Low Observed Adverse Effect Levels (NLOAELs) in these studies ranged from 10 to 133.3 mg kg bw^{-1} day^{-1} BaP [40][39].

720.   Background concentrations of PAHs in air, measured at an urban and a semi rural site, are given in Table 14 below.

Table 14: Background concentrations of PAHs in air (ng m^{-3}), 2007 data [41][40]

PAH	London Brent (urban background)	Hazelrigg (semi rural)
Benzo[a]pyrene	0.085	0.084
Benz[a]anthracene	0.086	0.13
Dibenz[ah]anthracene + Dibenz[ac]anthracene	0.040	0.019
Benzo[b]fluoranthene + Benzo[j]fluoranthene	0.26	0.30
Benzo[k]fluoranthene	0.079	0.073
Indeno[123cd]pyrene	0.20	0.13
Chrysene	0.19	0.33

Discussion of results for PAHs

73+.   In the main study, the 50th percentile exposure to B(a)P at Site A was below the EPAQS standard but the maximum exposure exceeded it. At Site B, the emissions of B(a)P should be compared with a concentration of 0.08 ng m^{-3} B[a]P (see above). This concentration is slightly exceeded by the 50th percentile

concentration when calculated using the assumption that all the non-detects were at the detection limit and is exceeded 7-fold by the maximum concentration detected. Also, we note that measurements at Site B might have underestimated the concentrations emitted as the monitoring point was not always downwind of the site. Since the aAir qQuality gGuideline for B(a)P should be applied as an annual average, the concentrations measured at these sites are not a major cause for concern. Nevertheless, it would be desirable to ensure that the average concentrations are below the reference concentration wherever possible.

Stibine (antimony trihydride)

742.   Concentrations of stibine were only analysed only in the main study because analytical standards were no longer available when the subsequent study was carried out.. These findings are summarised in Table 15 below.

Table 15: Stibine concentrations in main study (µg m^{-3})

| | 50th percentile (µg m^{-3}) | | Maximum (µg m^{-3}) | Detection limit (µg m^{-3}) | No. Detects/ No. Measure-ments |
	Assuming all non-detects were zero	Assuming all non-detects at detection limit			
Main study - Site A - Site B	82 0	82 10	222	14 – 35 7 – 18	10/16 0/8

753.   Stibine is a colourless gas with an odour like rotten eggs. There are few toxicity data for stibine. It is haemolytic, but lethal doses concentrations are in the order of several hundred mg m^{-3} (see [9], Volume 2). The project-specific HCV was 5 µg m^{-3} and was based on a former Ooccupational eExposure sStandard of 0.52 mg m^{-3}. However, there is currently no occupational standard for stibine in the UK.

Discussion of results for stibine

764.   We consider that there are insufficient data to set a health-based reference concentration. We note that stibine concentrations at Site B were below the detection limit of 20 µg m^{-3}, but that it was present at up to 10 times this level at Site A. We are unable to assess the significance of this level until further information becomes available on the toxicity of stibine.

Styrene

775.   Concentrations of styrene were only analysed in the main study. The findings are summarised in Table 16 below.

Table 16: Styrene concentrations in main study (µg m^{-3})

| | 50th percentile (µg m^{-3}) | | Maximum (µg m^{-3}) | Detection limit (µg m^{-3}) | No. Detects/ No. Measure- |
	Assuming all non-detects	Assuming all non-detects at			

	were zero	detection limit			ments
Main study					
- Site A	0.1	1.0	109	0.01 – 1.0	32/55
- Site B	0.27	0.3	4.6	0.01 – 0.4	32/36

786.   Styrene is a volatile, oily liquid with a sweet smell. The W The project-specific HCV for styrene was 70 µg m^{-3},. The the WHO Air Quality Guidelines for Europe, recommended in 2000 that the air quality guideline for styrene could be either 0.26 mg m^{-3} as a weekly average, based on LOAECs for subtle neurotoxic effects in occupationally exposed populations, or 70 µg m^{-3} as a 30-minute average, based onwas set in 2000 at the odour detection threshold for styrene [13][13]. WHO also recommended that the Air Quality Guideline could be based on 0.26 mg m^{-3} as a weekly average, based on LOAELs for subtle neurotoxic effects in occupationally exposed populations [13]. Subsequently, the neurobehavioural studies on styrene were reviewed comprehensively by the Health and Safety Executive (HSE) in a European Union Risk Assessment Report (RAR) on styrene [42][41]. This review criticised the available neurotoxicity studies and concluded that the crucial issue in relation to the impact of styrene on the nervous system is the need to avoid acute CNS depressant effects and associated symptomatology. The NOAECL for such effects was considered to be 428 mg m^{-3} for 7 hours exposure, with minor impairment seen at 856 mg m^{-3} for 1 hour. We agree with this assessment.

7779. Carcinogenicity studies have been carried out on styrene in the mouse by the inhalation and oral routes and the rat by the oral route. In both mouse studies, styrene caused lung neoplasms [42][41]. However, we agree with HSE that this finding is not relevant to humans because of differences in the metabolism of styrene in mouse and man. No treatment-related tumours were seen at any other site. There is no evidence from extensive epidemiological investigations that long-term exposure to styrene has produced lung damage or lung cancer in humans and styrene has shown no evidence of carcinogenicity in several bioassays in the rat when administered by the oral or inhalation route. Colleagues on the COC and the Committee on Mutagenicity of Chemicals in Food, Consumer Products and the Environment (COM) have advised that it is unlikely that styrene poses a mutagenic risk leading to adverse health consequences in humans [43, 44][42, 43].

780.   We reviewed the NOAECs and NOAELs for other toxicological endpoints as given in the HSE review. These were corrected for continuous exposure and an appropriate uncertainty factor was applied to give a possible health-based guideline valuereference concentration based on that endpoint. The results are given in Table 17.

Table 17: Toxicological endpoints for styrene, and corresponding possible reference concentrations

Health endpoint (species)	NOAEC or NOAEL	Proposed guideline valuesreference concentration (mg m^{-3}) (correction factors and uncertainty factor (UF))
Skin and respiratory	433 mg m^{-3} for 7 h	43.3 (not adjusted to 24 h

tract irritation (humans)		exposure, UF=10)
Ototoxicity (active rat)[a]	1300 mg m^{-3} for 12 h day^{-1}, 5 d week^{-1} for 4 weeks	~~4.64~~18.6 (adjusted to 24 h exposure; UF=~~100~~25)_[a]
(sedentary rat)[a]	2165 mg m^{-3} for 6 h day^{-1}, 5 d week^{-1} for 4 weeks	~~3.87~~15.5 (adjusted to 24 h exposure; UF=~~100~~25)_[a]
Systemic effects 　　Rat 　　Mouse	1000 mg kg^{-1} day^{-1} 150 mg kg^{-1} day^{-1}	~~8.69~~34.8[b] (UF= ~~100~~25)[b] 7.52[e]_ (UF = 10)[cd]
Developmental effects (rat)	650 mg m^{-3} for 6 h day^{-1}, 7 d week^{-1}~~1e~~1 d	1.6 (adjusted to 24 h exposure; UF = 100)

a: It may not be appropriate to convert this to 24 hour exposure

b: Assumptions: 100% absorption by both routes and rat 24 hour respiratory volume of 1.15 m^3 kg^{-1} bw_. For UF, see paragraph 49.

c: Assumptions: 100% absorption by both routes and mouse 24 hour respiratory volume of 1.995 m^3 kg^{-1} bw_.

~~d:~~ Endpoint based on liver toxicity:_ ~~t~~The RAR states that "in extrapolation to humans careful consideration has to be taken of the specifics of mouse metabolism and the high sensitivity of this species for liver toxicity as compared to eg the rat"_ ~~[44]~~[42]. Therefore, no intraspecies UF has been used.

~~d~~e: Postnatal developmental delays and decreased body weight. No structural anomalies seen.

~~79~~81. Styrene was classified by Sullivan et al (2001) as a "chemical of no/unlikely interest" with regard to reproductive effects. The authors concluded that there was little evidence that styrene exerts any reproductive or developmental toxicity. However, Table 17 includes the results of a recent, good quality study which demonstrated postnatal developmental delays and effects on body weight at a TWA concentration of 541 mg m^{-3}. The TWA NOAE~~L~~C was 163 mg m^{-3} ~~[45]~~[45] .

Discussion of results for styrene

8~~0~~2.   Both the 50th percentile and maximum concentrations of styrene recorded in the main study were below the lowest proposed reference concentrations in Table 17 and we consider that there are unlikely to be any health concerns associated with these emissions.

<u>Toluene</u>

83~~1~~.   Concentrations of toluene were only analysed in the main study. The findings are summarised in Table 18 below.

Table 18: Toluene concentrations in main study ~~(µg m^{-3})~~

	50th percentile (µg m^{-3})		Maximum (µg m^{-3})	Detection limit (µg m^{-3})	No. Detects/ No. Measure-ments
	Assuming all non-detects were zero	Assuming all non-detects at detection limit			

Main study					
- Site A	7.3	7.3	923	0.01 – 1	53/55
- Site B	1.1	1.1	41	0.01 – 1	36/36

8284. Toluene is a clear liquid with a distinctive smell. It is an aromatic hydrocarbon which has a number of industrial uses. There are substantial data on the effects of toluene in occupationally exposed humans. The weight-of-evidence from these studies indicates neurologic effects as the most sensitive endpoint. The project-specific guideline for toluene was 0.26 mg m^{-3} and was equivalent to the WHO Air Quality Guideline for Europe [13][13], which was set on the basis of neurobehavioural effects in a small occupational exposure study [46, 47][46, 47].

8385. In 2005, the US Environmental Protection Agency (USEPA) updated its more extensive review of toluene and identified a number of new epidemiological studies which clarify the dose-response for neurotoxicity in epidemiology studies [48][48]. It identified a mean NOAECL from 4 occupational studies of 128 mg m^{-3} (TWA exposure). This was converted from occupational to continuous exposure[8], giving an adjusted concentration of 46 mg m^{-3}. An uncertainty factor of 10 was applied for interindividual variation, giving a RfC[9] of 5 mg m^{-3}. We consider that this RfC should be used as the health based guideline value in assessing the significance of toluene emissions from landfill sites.

864.   Toluene was classified by Sullivan et al (2001) as a "chemical of less likely interest." This was based on observations of fetotoxicity, but not teratogenicity, in mice and rats; behavioural deficits and disturbances in brain development in mice and rats; limited studies suggesting an increase in menstrual disorders and, possibly, reduced fecundity and an increase in spontaneous abortions, in women exposed occupationally to toluene; and substantial evidence of a characteristic toluene embryopathy in babies born to women abusing toluene by recreational sniffing, where exposures can be extremely high, in the range 18750 to 45000 mg m^{-3} [7]. The US EPA concluded that reproductive effects occurred at higher exposures than those which caused other effects [48][48].

Discussion of results for toluene

875.   Both the 50th percentile and maximum concentrations of toluene recorded in the main study were below concentrations which might give cause for concern.

Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans

8688. Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans are collectively known as "dioxins". They are persistent and widely dispersed environmental contaminants. Dioxins are produced in a number of thermal reactions and as trace contaminants during the synthesis of many organochlorine

---

[8] The conversion was made using the assumption that a worker would inhale 10 m^3 of air over an 8-hour shift and works five days a week, and an adult member of the public inhales 20 m^3 over a 24 hour period.

[9] RfC: inhalation reference concentration. A US term for aAn estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

compounds and during some industrial processes. Concentrations of dioxins were only analysed in the main study. The results are given in Table 19 below. The concentrations are expressed as "WHO-Toxic Equivalents" (TEQ) [49] [49].

Table 19: Dioxin concentrations in main study (fg WHO-TEQ m^{-3})

	50th percentile (fg WHO-TEQ m^{-3})		Maximum (fg WHO-TEQ m^{-3})	Detection limit (typical) (fg m^{-3})	No. Detects/ No. Measure-ments
	Assuming all non-detects at zero	Assuming all non-detects at dDetection lLimit			
Main study - Site A - Site B	15 15	15 15	77 1839	<4 – 6	32/32 27/32

8879. In addition to the airborne measurements made above, the ~~likely~~ potential exposure to dioxins of individuals living near the landfill sites was ~~modelled~~ assessed using the Environment Agency's ~~model~~ "Dioxin Risk and Exposure Assessment Model" (DREAM) version 1.0x (see [9], section 5.4.1). This model provides estimated exposures to dioxins, based on a given airborne concentration profile, applying a set of detailed assumptions about the consumption of different types of food, body weights and other variables. Using this information, the model provides estimated exposures for individuals aged 1.5-2.5 years, 2.5-3.5 years, 3.5-4.5 years, school children and adults. The estimated exposures by all routes (direct inhalation together with indirect pathways) are set out in Table 20 below. The results for Site B were dominated by a single high value in the summer survey. According to the study authors, no reason was found for this but it was considered unlikely to be typical of emissions from Site B.

Table 20: Estimated exposures of local residents to dioxins from local produce

Population group	Site A	Site B	Site B (excluding single high value)
	Dioxin exposures (pg WHO-TEQ per kg body weight)		
Children aged 1.5 -2.5	1.80	7.74	1.63
Children aged 2.5 -3.5	1.52	6.52	1.37
Children aged 3.5 -4.5	1.35	5.77	1.22
School children	0.56	2.47	0.52
Adults	0.30	1.29	0.27

9088. No airborne project-specific HCV was set for dioxins. In general, inhalation is considered to be a minor route of exposure to environmental dioxins and it is

accumulation in food, and subsequent consumption, which is considered to be the important route [50].

891.   In 2001, we recommended a Tolerable Daily Intake (TDI) for dioxins and dioxin-like polychlorinated biphenyls of 2 pg WHO-TEQ kg bw^{-1} day^{-1}, based on effects on the developing male reproductive system mediated via the maternal body burden [51][50]. This TDI is appropriate for assessing the risk to health of intakes via all routes, including inhalation and oral intakes.

920.   Background concentrations in food can be obtained from analysis of samples of the food groups that made up the 2001 Total Diet Survey. The estimated average intakes of the sum of dioxins and dioxin-like PCBs from the UK diet for adults and schoolchildren were 0.9 pg WHO-TEQ kg bw^{-1} day^{-1} and 0.7-1.8 pg WHO-TEQ kg bw^{-1} day^{-1}, respectively, with younger children being at the upper end of the range for schoolchildren [52][51]. (Dioxin-like PCBs were monitored in the main monitoring study but none was detected above the typical detection limit of 5 fg m^{-3}).

Discussion

93.   The estimated exposures of local residents to dioxins in food as a result of emissions from Site A are similar to background levels for 2001 and below the TDI of 2 pg WHO-TEQ kg bw^{-1} day^{-1} for all age groups. At Site B, the estimated exposures were considerably higher as a consequence of a single high measurement. The reason for this high concentration is unknown, but we note that it occurred only once in over 60 measurements. To provide context, the level of dioxins and furans at a distance of 20 metres from a bonfire burning domestic waste was recorded to be up to 580 fgTEQ/m^{3}, about a third of the single high value recorded at Site B [53]. If this value is excluded, estimated exposures are similar to those at Site A. The main concern about dioxins is accumulated exposure leading to a high body burden. The reliability of the DREAM model has not been tested under the circumstances of a single high exposure, as recorded at Site B, and consequently the validity of the model findings are subject to some uncertainty.

Chemicals with no project-specific HCV

2-methyl furan

The maximum concentration of 2-methyl furan found in the main study was 2.0 ug m^{-3} [9]. 2-methyl furan is used in food as a flavouring agent and was evaluated together with other furan-substituted aliphatic hydrocarbons by the WHO/FAO Joint Expert Committee on Food Additives (JECFA) in 2008 [54]. JECFA noted that furan is carcinogenic and its carcinogenicity is believed to involve a reactive genotoxic metabolite formed by epoxidation and operning of the furan ring. It also noted that there is evidence from studies *in vitro* and *in vivo* that 2-methyl furan undergoes bioactivation to a reactive ring-opened metabolite that binds covalently to both protein and DNA. However, there are no standard toxicological studies on 2-methyl furan by the oral or inhalation routes and the few available genotoxicity data have produced conflicting results [54]. We confirm that

it is not possible to set a health-based reference concentration for this compound and, therefore, it is not possible to assess the significance of the levels of 2-methyl furan measured in the study.

Acenaphthylene, Benzo(ghi)perylene and Phenanthrene

The maximum concentrations of acenaphylene, benzo(ghi)perylene and phenanthrene found in the main study were 1.72, 0.48 and 15.11 ng m^{-3}, respectively [9]. These compounds are PAHs but it is not known whether they are carcinogenic . Acenaphthylene and phenanthrene are considered not to be genotoxic [40]. There are some studies indicating that benzo(ghi)perylene may be genotoxic but ATSDR concluded that the data were insufficient to draw sound conclusions [40]. There are inadequate data to evaluate other potential toxicological effects, including carcinogenicity. We confirm that it is not possible to set a health-based reference concentrations for these substances nor to assess the significance of the levels of emitted in the study.

Discussion

91.   The estimated exposures of local residents to dioxins in food as a result of emissions from Site A are similar to background levels for 2001 and below the TDI of 2 pg WHO-TEQ kg bw^{-1} day^{-1} for all age groups. At Site B, the estimated exposures were considerably higher as a consequence of a single high measurement. The reason for this high concentration is unknown, but we note that it occurred only once in over 60 measurements. If this value is excluded, estimated exposures are similar to those at Site A. The main concern about dioxins is accumulated exposure leading to a high body burden. The reliability of the DREAM model has not been tested under the circumstances of a single high exposure, as recorded at Site B, and consequently the validity of the model findings are subject to some uncertainty.

Recent epidemiological studies by the Small Area Health Statistics Unit (SAHSU)

Geographic density of landfill sites and risk of congenital anomalies in England [55][52]

9̶4̶2.   This study investigated the risk of congenital anomalies in relation to an index of geographic density of landfill sites across 5 x 5 km grid squares in England using postcoded data from the National Congenital Anomalies Database and on terminations of pregnancy for serious congenital anomalies. In total, 8,804 landfill sites were included in the study; these had been operational at some time between 1982 and 1997. A landfill exposure index was calculated to represent the geographic density of landfill sites within 2 km of births[10] for each grid square, and was derived separately for landfill sites handling special, and non-special or unknown, waste. For each group of landfills, the index was classified into four categories of intensity, and risks for the second, third and top categories were

---

[10] "Births" refers to the postcode of the mothers whose livebirths, stillbirths or terminations of pregnancy were included in the study. This is the term used in epidemiological research.

compared to the bottom category, which comprised areas with no such landfill site within 2 km. For special waste sites[11], after adjustment for confounding, there was a small but significantly increased risk of all anomalies combined and of cardiovascular defects for the third category [odds ratios 1.08 (95% credible interval[12] 1.02, 1.13) and 1.16 (1.00, 1.33) respectively] but not the top category; and of hypospadias and epispadias for the third and top categories [odds ratios 1.11 (1.02, 1.21) and 1.12 (1.02, 1.22)] respectively. No excess risk was found in relation to other types of landfill sites.

9~~3~~5.   This ecological study suffered from the same limitations that the COT highlighted in its 2001 statement. In particular, the National Congenital Anomalies Database used in this study suffers from poor ascertainment [56][~~53~~]. This has potential to introduce substantial bias into epidemiological studies. It is difficult to know what effect, if any, this might have on the observed results but there is no evidence that ascertainment problems vary systematically with landfill site locations. We understand that the national database now includes data from most of the local and regional congenital anomaly registers. Results from the study were similar when analysis was restricted to areas covered by a local register, but these areas accounted for only a small proportion of all births in England. We recommend that a high quality national register should be established, to facilitate good quality epidemiological research on the aetiology of congenital anomalies.

9~~4~~6.   It is always difficult to interpret the results of epidemiological studies which report an apparent small increased relative risk, no matter how well conducted, because of the possibility of uncontrolled bias and residual confounding. Bias may arise from the data sources used, as described above, or because exposure to the key hazard has not been assessed accurately by the methods used in the study [55][~~52~~]. Confounding occurs when another variable is associated with ~~both~~ the exposure of interest and independently determines risk of the ~~disease of concern~~health outcome of concern. Confounding factors can be ~~adjusted for~~taken into account at the design stage or the analysis stage but complete adjustment is not always possible, particularly in ecological studies. However, we note that the few increased risks reported in this study were small, and that an exposure-response relationship was only evident for one category of anomaly. Occasional positive findings of this sort can be expected to occur simply by chance. Therefore, we conclude that the results of this study do not give grounds for any specific concerns or recommendations relating to the health of pregnant women or those wishing to start a family who live in the vicinity of a landfill site.

Down syndrome in births near landfill sites [57][~~54~~]

~~95~~97. This study found no excess risk of giving birth to a child with Down syndrome in populations living within 2 km of a landfill site in England and Wales. Again, there are limitations ~~in~~to the study due to its ecological design and the possibility of residual confounding. The study used a good quality Down syndrome register as the source of health data but did not include data on miscarriages

---

[11] Special waste sites were landfill sites which received wastes now classed as both hazardous and non-hazardous waste.
[12] An interval that includes the true parameter with probability 0.95; the Bayesian analogue to the frequentist 95% confidence interval.

because there is no adequate database. It is estimated that over 50% of fetuses with trisomy 21 are spontaneously aborted and, therefore, it is unfortunate that these data could not be included in the study. Nevertheless, despite the limitations, we regard these results as reassuring.

Overall conclusions and recommendations

986.   A considerable body of work has been carried out in relation to landfill sites since the initial publication of the EUROHAZCON study in 1997. In overall terms, we find the findings of this work reassuring. In particular, we have found no causes for concern for health of families with infants or for couples who live in the vicinity of landfill sites and who are considering having a baby.

9997. We welcome the monitoring work by the Environment Agency which, we believe, comprises the most detailed survey of landfill emissions carried out to date. In considering the relevance of the results to earlier epidemiological studies, we note that Sites A and B had gas control measures, in line with all new sites which accept biodegradable waste. Older sites, which have not implemented such measures, should already have passed peak methane emission levels. The results of this research may not necessarily apply to hazardous waste sites or those which accepted both hazardous and municipal waste (co-disposal sites). However, we are also informed that hazardous waste is unlikely to degrade biologically to generate significant quantities of gaseous emissions and that emissions are likely to vary according to what is deposited in the site. Co-disposal, which could lead to production ofwhere substantial quantities of gas, were produced which may possibly carrying with it hazardous waste, is now bannedceased in July 2004. Sites A and B could not necessarily be considered representative and there are other, larger sites which could have greater emissions. Nevertheless, the landfill gas composition at these two sites was reported to be broadly typical of the composition in the national database in respect of compounds which are of particular concern because they have the potential to cause reproductive or developmental effects [7].

98100.   There are a number of limitations to this monitoring work and our assessment of it. Only a small number of sites have been surveyed and only a limited number of measurements were made at Sites C and D. Little or no information is available on the reproductive toxicity of several of the monitored chemicals and a small number have too few toxicity data overall for us to assess the significance of the concentrations found.   Nevertheless, Overalin general, we consider that the results of this study are reassuring. The monitoring work indicated that the levels at which most of the measured substances were emitted would not be expected to cause developmental or other chronic health effects, and there were no major concerns in relation to any findings. However, wWe have formed specific conclusions and recommendations in relation to the following chemicals:

Arsine: It is difficult to provide an informative assessment on arsine from the limited data available. We recommend that more sensitive sampling or analytical methods beare developed and then further monitoring data obtained from the

boundaries of landfill sites. Also, there is a need for quantitative information on the conversion of arsine to arsenic in an appropriate experimental species.

Chromium: It is not possible to draw reliable conclusions because of a lack of information on speciation and inadequacies in available measurement techniques. We recommend that, should techniques be developed to measure chromium (VI) in air at lower detection limits, it would be appropriate to use these in future monitoring. While there is no indication from this work of a major cause for concern, we recommend that, should techniques be developed to measure chromium (VI) in air with lower detection limits, it would be appropriate to use these in future monitoring.

Dimethyl sulphide and dimethyl disulphide: On the basis of the limited toxicological data available on these compounds, no adverse health effects are anticipated expected for the concentrations measured in the study. However, there are no data on reproductive or developmental toxicity nor on carcinogenicity and, therefore, it is not possible to give definitive advice.

Formaldehyde: The results raise no concerns about chronic health effects or adverse reproductive or developmental effects, but the maximum concentrations reported might result in some short-term irritant effects in some individuals at the boundary of landfill sites.

Methyl mercaptan: On the basis of the limited toxicological data available on this compound, no adverse health effects are expected forom the concentrations measured in the study. However, there are no data on reproductive or developmental toxicity nor on carcinogenicity and, therefore, it is not possible to give definitive advice.

Polycyclic aromatic hydrocarbons: Tthe concentrations measured in the study are not a major concern with respect to the critical toxic effect, which is carcinogenicity. However, we note that only limited reproductive and developmental toxicity data are available on these compounds.

Stibine: There are insufficient toxicity data to assess the significance to health of the results.

Dioxins: The results indicate that estimated intakes from eating locally grown produce are, in most cases, comparable to background exposures, below the tolerable daily intake for these compounds, and unlikely to be of concern. The reason for a single high value concentration among emissions at Site B has not been identified but we note that it occurred only once in over 60 measurements.

101.	In addition, we recommend:

- that a high quality national register should be established, to facilitate good quality epidemiological research on the aetiology of congenital anomalies,.

- the development of improved sampling and analytical techniques for monitoring the concentrations of trace substances emitted to the environment generally.

102~~0~~. We have now reviewed a number of studies of ecological design which have investigated the association between adverse health outcomes and landfill sites. The risk estimates which were derived from these studies are small and, as explained above, it is not possible to discriminate effects due to confounders and bias from those which might be causally associated with the hazard under investigation. We therefore consider that there would be little value in undertaking further studies of this type.

103~~1~~. In 2001, the COT recommended that case-control or cohort studies could be carried out. It has also been suggested that studies on personal uptake of pollutants by residents living near landfill sites and, possibly, on exposure of workers on landfill sites could usefully inform such studies. However, the findings in this study do not point to any specific health outcomes or exposures which need to be examined in such studies. ~~given that the EA study showed that most chemicals emitted from landfill sites are common in the environment, and that concentrations near the sites are, in most cases, similar to background levels, it may not be possible to identify specific biomarkers of exposure to emissions from landfill sites. There are, therefore, likely to be significant difficulties in interpreting the outcomes from such studies.~~

References

1. Dolk H Vrijheid M Armstrong B Abramsky L Bianci F Garne E et al, *Risk of congenital anomalies near hazardous-waste landfill sites in Europe: the EUROHAZCON study.* Lancet, 1998. ~~352~~: p. 423-427.**352**

2. Elliott PE Briggs D Morris S de Hoogh C Hurt C Kold Jensen T Miatland I Richardson S Wakefield Jarup L, *Risk of adverse birth outcomes in populations living near landfill sites.* BMJ 2001. **323**: p. 363-368.

3. Committee on Toxicity of Chemicals in Food Consumer Products and the Environment (COC), *COC/00/S1*, in *COT statement on a study by the Small Area Health Statistics Unit (SAHSU) on health outcomes in populations living around landfill sites.* 2001.

4. Jarup, L., et al., *Cancer risks in populations living near landfill sites in Great Britain.* Br J Cancer, 2002. **86**(11): p. 1732-6.

5. Environment Agency, *A study of ambient air quality at a landfill site in Llandullas, Publication Ref NCAS/TR/2001/021.* 2001.

6. Environment Agency, *Investigation of the composition emissions and effects of trace components in landfill gas, R&D Publication Ref P1-438.* 2002, Environment Agency.

7. Sullivan FM Barlow SM and McElhatton PR, *A review of the potential teratogenicity of substances emanating from landfill sites. A project commissioned by the Department of Health under the Joint Research Programme on the Possible Health Effects of Landfill Sites.* 2001.

8. Coleman T Environment Agency, *Presentation on landfill sites,.* 2 September 2008.

9. Environment Agency, *Exposure assessment of landfill sites, Draft R&D Technical Report Ref P1-396* August 2008, Environment Agency.

10. Environment Agency, *Human health toxicological assessment of contaminants in soil. Final SC050021/SR2.* 2009.

11. Health and Safety Executive. *Table 1: List of approved Workplace Exposure Limits* October 2007 [cited 2009 June 3]; Available from: http://209.85.229.132/search?q=cache:cycYIG4aQTwJ:www.hse.gov.uk/coshh/table1.pdf+Workplace+exposure+limits&hl=en&ct=clnk&cd=1&gl=uk.

12. Scientific Committee on Toxicity Ecotoxicity and Environment (CSTEE), *Opinion on: Position Paper on Ambient Air Pollution by Nickel Compounds. Opinion expressed at the 22nd CSTEE Penary Meeting, Brussels, 6/7 March 2001,* European Commission, Editor. 2001.

13. World Health Organisation (WHO), *Air quality guidelines for Europe. WHO Regional Publications, European Series, No. 91. 2nd edition.* . 2000, WHO Regional Office for Europe: Copenhagen.

14. Expert Panel on Air Quality Standards, *Metals and Metalloids.* 2009, Department of Environment, Food and Rural Affairs: London.

15. International Programme on Chemical Safety (IPCS), *Arsine: Human Health Aspects. Concise International Chemical Assessment Document 47.* 2002, WHO: Geneva.

16. Carter DE Aposhian HV and Gandolfi AJ, *The metabolism of inorganic arsenic oxides, gallium arsenide and arsine: at toxicochemical review.* Tox Appl Pharmacol, 2003. **193**: p. 309-334.

17. Eduljee G, *Assessment of risks to human health from landfilling of household wastes.*, in *Risk Assessment and Risk Management*, Hester RE and Harrison RM, Editor. 1998, Royal Society of Chemistry: Cambridge.

18. International Agency for Research on Cancer (IARC), *1,3-Butadiene, Ethylene Oxide and Vinyl Halides (Vinyl Fluoride, Vinyl Chloride and Vinyl Bromide)*, in *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. 2008, IARC: Lyon.

19. IPCS, *Vinyl Chloride, Environmental Health Criteria Document No 215*. 1999, WHO: Geneva.

20. International Agency for Research on Cancer (IARC), *Chromium and chromium compounds. Vol 49*, in *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. 1990, IARC: Lyon.

21. Department of Environment Food and Rural Affairs and Environment Agency, *Contaminants in Soil, Collation of toxicological data and intake values for humans. Chromium*. 2002, Environment Agency,: Bristol.

22. Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological profile for chromium. Draft for public comment.* September 2008, US Department of Health and Human Services: Atlanta, US.

23. Rowbotham A L Levy LS and Shuker L.K, *Chromium in the environment: an evaluation of exposure in the UK general population and possible adverse health effects*. J Toxicol Environ Health B Crit Rev, 2000. **3**(3): p. 161-200.

24. International Programme on Chemical Safety (IPCS), *Concise International Chemical Assessment Document No.1. 1,2-Dichloroethane*. 1998, World Health Organisation: Geneva.

25. Environment Agency, *1,2-Dichloroethane*, in *Contaminants in soil. Collation of toxicological data and intake values for humans*. 2004.

26. National Cancer Institute, *Bioassay of 1,2-dichloroethane for possible carcinogenicity*. 1978, US Department of Health Education and Welfare, Public Health Services, National Institutes of Health: Bethesda MD.

27. Nagano K Umeda Y Senoh H Gotoh K Arito H Yamamoto S and Matsushima T, *Carcinogenicity and chronic toxicity in rats and mice exposed by inhalation to 1,2-dichloroethane for two years*. J Occupat Health, , 2006. **48**(424-436).

28. Committee on the Carcinogenicity of Chemicals in Food Consumer Products and the Environment, *Risk Communication*, in *Annual Report*. 2007.

29. Opdyke DLJ, *Fragrance raw materials monographs*. Fd Cosmet Toxicol, 1979. **17**: p. 365-368.

30. Kim HY, L.S., Chung YH, Lim CH, Yu IJ, Park SC, Shin JY, Kim SH, Shin DH and Kim JC,, *Evaluation of subchronic inhalation toxicity of dimethyl disulfide in rats*. Inhalation Toxicology, 2006. **18**: p. 395-403.

31. Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological Profile for Formaldehyde*. July 1999, US department of Health and Human Services: Atlanta, US.

32. International Agency for Research on Cancer (IARC), *Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol. Volume 88*, in *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. 2006, IARC: Lyon.

33. Committee on the Mutagenicity of Chemicals in Food Consumer Products and the Environment (COM). *Formaldehyde: Evidence for systemic mutagenicity (COM/07/S5)*. 2007 [cited 2009 18 August]; Available from: http://iacom.org.uk/statements/Formaldehyde.htm.

34. Centre for Disease Control and Prevention, *Final Report on Formaldehyde Levels in FEMA-Supplied Travel Trailers, Park Models, and Mobile Homes*. July 2008: Atlanta, USA.

35. Tansy MF, K.F., Fantasia J, Landin WE and Oberly R,, *Acute and subchronic toxicity studies of rats exposed to vapors of methyl mercaptan and other reduced-sulfur compounds.* J Toxicol and Environ Health, 1981. **8**: p. 71-88.

36. Jaakkola JJ, V.V., Marttila O, Jäppinen P, Haahtela T,, *The South Karelia air pollution study. The effects of malodorous sulfur compounds from paper mills on respiratory and other symptoms* Am Rev Respir Dis, 1990. **142**(6 Pt 1): p. 1344-50.

37. Van den Velde, S., et al., *Detection of odorous compounds in breath.* J Dent Res, 2009. **88**(3): p. 285-9.

38. Expert Panel on Air Quality Standards, *Polycyclic aromatic hydrocarbons.* 1999, The Stationery Office London.

39. Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment. *Carcinogenicity of dibenzo(a,l)pyrene. COC/03/S5.* November 2003 [cited 2009 June 11]; Available from: http://www.iacoc.org.uk/statements/dibenzoalpyrene.htm.

40. Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological profile for polycyclic aromatic hydrocarbons (PAHs).* August 1995, US Department of Health and Human Services: Atlanta, US.

41. UK Air Quality Archive. *Annual PAH, 2007.* [cited 2009 17 August]; Available from: http://www.airquality.co.uk/data_and_statistics.php.

42. United Kingdom, *European Union Risk Assessment Report, Styrene, Draft for Submission to SCHER.* November 2007. http://ecb.jrc.ec.europa.eu/esis/.

43. Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment (COC). *Styrene: Mode of action evaluation: Lung tumours in mice (COC/05/15)* [cited 2008 31 December]; Available from: http://www.iacoc.org.uk/papers.

44. Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment (COC). *Minutes of COC meeting 14 July 2005.* [cited 2008 31 December]; Available from: http://www.iacoc.org.uk/meetings.

45. Cruzan, G., et al., *Developmental neurotoxicity study of styrene by inhalation in Crl-CD rats.* Birth Defects Res B Dev Reprod Toxicol, 2005. **74**(3): p. 221-32.

46. Foo, S.C., J. Jeyaratnam, and D. Koh, *Chronic neurobehavioural effects of toluene.* Br J Ind Med, 1990. **47**(7): p. 480-4.

47. Foo, S.C., et al., *Neurobehavioral effects in occupational chemical exposure.* Environ Res, 1993. **60**(2): p. 267-73.

48. US Environmental Protection Agency (US EPA), *Toluene. Integrated Risk Information Service (IRIS).* 2005, US EPA: Washington DC.

49. Van den Berg, M., et al., *The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds.* Toxicol Sci, 2006. **93**(2): p. 223-41.

50. Travis, C.C. and H.A. Hattemer-Frey, *Human exposure to dioxin.* Sci Total Environ, 1991. **104**(1-2): p. 97-127.

51. Committee on Toxicity of Chemicals in Food Consumer Products and the Environment. *Statement on the Tolerable Daily Intake for dioxins and dioxin-like polychlorinated biphenyls.* 2001 [cited; Available from: http://cot.food.gov.uk/pdfs/cot-diox-full.pdf.

52. Food Standards Agency. *Dioxins and dioxin-like PCBs in the UK diet: 2001 Total Diet Study samples (Number 38/03).* Food Survey Information Sheet 2003 [cited 2009 24 August]; Available from: http://www.food.gov.uk/science/surveillance/fsis2003/fsis382003.

53.	Wevers, M., R. De Fre, and M. Desmedt, *Effect of backyard burning on dioxin deposition and air concentrations.* Chemosphere, 2004. **54**(9): p. 1351-6.

54.	FAO/WHO Joint Expert Committee on Food Additives, *Safety Evaluation of certain food additives*, in *WHO Food Additives Series*. 2009, World Health Organisation: Geneva.

55.	Elliott P Richardson S Abellan JJ Thomson A de Hoogh C Jarup L and Briggs DJ, *Geographic density of landfill sites and risk of congenital anomalies in England.* Occup Environ Med doi:10.1136/oem.2007.038497 December 2008.

56.	Boyd, P.A., et al., *Congenital anomaly surveillance in England--ascertainment deficiencies in the national system.* BMJ, 2005. **330**(7481): p. 27.

57.	Jarup L Morris S Richardson S Briggs D Cobley N de Hoogh C Gorog K and Elliott E, *Down syndrome in births near landfill sites.* Prenat Diag, 2007. **27** (13): p. 1191-6.

1.	Dolk H Vrijheid M Armstrong B Abramsky L Bianci F Garne E et al, *Risk of congenital anomalies near hazardous-waste landfill sites in Europe: the EUROHAZCON study.* Lancet, 1998. **352**: p. 423-427.

2.	Elliott PE Briggs D Morris S de Hoogh C Hurt C Kold Jensen T Miatland I Richardson S Wakefield Jarup L, *Risk of adverse birth outcomes in populations living near landfill sites.* BMJ 2001. **323**: p. 363-368.

3.	Committee on Toxicity of Chemicals in Food Consumer Products and the Environment (COC), *COC/00/S1*, in *COT statement on a study by the Small Area Health Statistics Unit (SAHSU) on health outcomes in populations living around landfill sites.* 2001.

4.	Jarup, L., et al., *Cancer risks in populations living near landfill sites in Great Britain.* Br J Cancer, 2002. **86**(11): p. 1732-6.

5.	Environment Agency, *A study of ambient air quality at a landfill site in Llandullas, Publication Ref NCAS/TR/2001/021.* 2001.

6.	Environment Agency, *Investigation of the composition emissions and effects of trace components in landfill gas, R&D Publication Ref P1-438.* 2002, Environment Agency.

7.	Sullivan FM Barlow SM and McElhatton PR, *A review of the potential teratogenicity of substances emanating from landfill sites. A project commissioned by the Department of Health under the Joint Research Programme on the Possible Health Effects of Landfill Sites.* 2001.

8.	Coleman T Environment Agency, *Presentation on landfill sites,*. 2 September 2008.

9.	Environment Agency, *Exposure assessment of landfill sites, Draft R&D Technical Report Ref P1-396* August 2008, Environment Agency.

10.	Environment Agency, *Human health toxicological assessment of contaminants in soil. Final SC050021/SR2.* 2009.

11.	Health and Safety Executive. *Table 1: List of approved Workplace Exposure Limits October 2007* [cited 2009 June 3]; Available from: http://209.85.229.132/search?q=cache:cycYIG4aQTwJ:www.hse.gov.uk/coshh/table1.pdf+Workplace+exposure+limits&hl=en&ct=clnk&cd=1&gl=uk.

12.	Scientific Committee on Toxicity Ecotoxicity and Environment (CSTEE), *Opinion on: Position Paper on Ambient Air Pollution by Nickel Compounds. Opinion expressed at the 22nd CSTEE Penary Meeting, Brussels, 6/7 March 2001*, European Commission, Editor. 2001.

13. World Health Organisation (WHO), *Air quality guidelines for Europe. WHO Regional Publications, European Series, No. 91. 2nd edition.* . 2000, WHO Regional Office for Europe: Copenhagen.

14. Expert Panel on Air Quality Standards, *Metals and Metalloids*. 2009, Department of Environment, Food and Rural Affairs: London.

15. International Programme on Chemical Safety (IPCS), *Arsine: Human Health Aspects. Concise International Chemical Assessment Document 47*. 2002, WHO: Geneva.

16. Carter DE Aposhian HV and Gandolfi AJ, *The metabolism of inorganic arsenic oxides, gallium arsenide and arsine: at toxicochemical review*. Tox Appl Pharmacol, 2003. **193**: p. 309-334.

17. Eduljee G, *Assessment of risks to human health from landfilling of household wastes.*, in *Risk Assessment and Risk Management*, Hester RE and Harrison RM, Editor. 1998, Royal Society of Chemistry: Cambridge.

18. International Agency for Research on Cancer (IARC), *1,3-Butadiene, Ethylene Oxide and Vinyl Halides (Vinyl Fluoride, Vinyl Chloride and Vinyl Bromide)*, in *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. 2008, IARC: Lyon.

19. IPCS, *Vinyl Chloride, Environmental Health Criteria Document No 215*. 1999, WHO: Geneva.

20. International Agency for Research on Cancer (IARC), *Chromium and chromium compounds. Vol 49*, in *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. 1990, IARC: Lyon.

21. Department of Environment Food and Rural Affairs and Environment Agency, *Contaminants in Soil, Collation of toxicological data and intake values for humans. Chromium*. 2002, Environment Agency,: Bristol.

22. Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological profile for chromium. Draft for public comment.* September 2008, US Department of Health and Human Services: Atlanta, US.

23. Rowbotham A L Levy LS and Shuker L.K, *Chromium in the environment: an evaluation of exposure in the UK general population and possible adverse health effects*. J Toxicol Environ Health B Crit Rev, 2000. **3**(3): p. 161-200.

24. International Programme on Chemical Safety (IPCS), *Concise International Chemical Assessment Document No.1. 1,2-Dichloroethane*. 1998, World Health Organisation: Geneva.

25. Environment Agency, *1,2-Dichloroethane*, in *Contaminants in soil. Collation of toxicological data and intake values for humans*. 2004.

26. National Cancer Institute, *Bioassay of 1,2-dichloroethane for possible carcinogenicity*. 1978, US Department of Health Education and Welfare, Public Health Services, National Institutes of Health: Bethesda MD.

27. Nagano K Umeda Y Senoh H Gotoh K Arito H Yamamoto S and Matsushima T, *Carcinogenicity and chronic toxicity in rats and mice exposed by inhalation to 1,2-dichloroethane for two years*. J Occupat Health, , 2006. **48**(424-436).

28. Committee on the Carcinogenicity of Chemicals in Food Consumer Products and the Environment, *Risk Communication*, in *Annual Report*. 2007.

29. Opdyke DLJ, *Fragrance raw materials monographs*. Fd Cosmet Toxicol, 1979. **17**: p. 365-368.

30. Kim HY, L.S., Chung YH, Lim CH, Yu IJ, Park SC, Shin JY, Kim SH, Shin DH and Kim JC,, *Evaluation of subchronic inhalation toxicity of dimethyl disulfide in rats*. Inhalation Toxicology, 2006. **18**: p. 395-403.

31. Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological Profile for Formaldehyde*. July 1999, US department of Health and Human Services: Atlanta, US.

32. International Agency for Research on Cancer (IARC), *Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol. Volume 88*, in *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. 2006, IARC: Lyon.

33. Committee on the Mutagenicity of Chemicals in Food Consumer Products and the Environment (COM). *Formaldehyde: Evidence for systemic mutagenicity (COM/07/S5)*. 2007 [cited 2009 18 August]; Available from: http://iacom.org.uk/statements/Formaldehyde.htm.

34. Centre for Disease Control and Prevention, *Final Report on Formaldehyde Levels in FEMA-Supplied Travel Trailers, Park Models, and Mobile Homes*. July 2008: Atlanta, USA.

35. Tansy MF, K.F., Fantasia J, Landin WE and Oberly R,, *Acute and subchronic toxicity studies of rats exposed to vapors of methyl mercaptan and other reduced-sulfur compounds*. J Toxicol and Environ Health, 1981. **8**: p. 71-88.

36. Jaakkola JJ, V.V., Marttila O, Jäppinen P, Haahtela T,, *The South Karelia air pollution study. The effects of malodorous sulfur compounds from paper mills on respiratory and other symptoms* Am Rev Respir Dis, 1990. **142**(6 Pt 1): p. 1344-50.

37. Van den Velde, S., et al., *Detection of odorous compounds in breath*. J Dent Res, 2009. **88**(3): p. 285-9.

38. Expert Panel on Air Quality Standards, *Polycyclic aromatic hydrocarbons*. 1999, The Stationery Office London.

39. Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment. *Carcinogenicity of dibenzo(a,l)pyrene. COC/03/S5*. November 2003 [cited 2009 June 11]; Available from: http://www.iacoc.org.uk/statements/dibenzoalpyrene.htm.

40. Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological profile for polycyclic aromatic hydrocarbons (PAHs)*. August 1995, US Department of Health and Human Services: Atlanta, US.

41. UK Air Quality Archive. *Annual PAH, 2007*. [cited 2009 17 August]; Available from: http://www.airquality.co.uk/data_and_statistics.php.

42. United Kingdom, *European Union Risk Assessment Report, Styrene, Draft for Submission to SCHER*. November 2007. http://ecb.jrc.ec.europa.eu/esis/.

43. Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment (COC). *Styrene: Mode of action evaluation: Lung tumours in mice (COC/05/15)* [cited 2008 31 December]; Available from: http://www.iacoc.org.uk/papers.

44. Committee on Carcinogenicity of Chemicals in Food Consumer Products and the Environment (COC). *Minutes of COC meeting 14 July 2005*. [cited 2008 31 December]; Available from: http://www.iacoc.org.uk/meetings.

45. Cruzan, G., et al., *Developmental neurotoxicity study of styrene by inhalation in Crl-CD rats*. Birth Defects Res B Dev Reprod Toxicol, 2005. **74**(3): p. 221-32.

46. Foo, S.C., J. Jeyaratnam, and D. Koh, *Chronic neurobehavioural effects of toluene*. Br J Ind Med, 1990. **47**(7): p. 480-4.

47. Foo, S.C., et al., *Neurobehavioral effects in occupational chemical exposure*. Environ Res, 1993. **60**(2): p. 267-73.

48. US Environmental Protection Agency (US EPA), *Toluene. Integrated Risk Information Service (IRIS)*. 2005, US EPA: Washington DC.

49.	Van den Berg, M., et al., *The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds.* Toxicol Sci, 2006. **93**(2): p. 223-41.

50.	Travis, C.C. and H.A. Hattemer-Frey, *Human exposure to dioxin.* Sci Total Environ, 1991. **104**(1-2): p. 97-127.

51.	Committee on Toxicity of Chemicals in Food Consumer Products and the Environment. *Statement on the Tolerable Daily Intake for dioxins and dioxin-like polychlorinated biphenyls.* 2001 [cited; Available from: http://cot.food.gov.uk/pdfs/cot-diox-full.pdf.

52.	Food Standards Agency. *Dioxins and dioxin-like PCBs in the UK diet: 2001 Total Diet Study samples (Number 38/03).* Food Survey Information Sheet 2003 [cited 2009 24 August]; Available from: http://www.food.gov.uk/science/surveillance/fsis2003/fsis382003.

53.	Elliott P Richardson S Abellan JJ Thomson A de Hoogh C Jarup L and Briggs DJ, *Geographic density of landfill sites and risk of congenital anomalies in England.* Occup Environ Med doi:10.1136/oem.2007.038497 December 2008.

54.	Boyd, P.A., et al., *Congenital anomaly surveillance in England - ascertainment deficiencies in the national system.* BMJ, 2005. **330**(7481): p. 27.

55.	Jarup L Morris S Richardson S Briggs D Cobley N de Hoogh C Gorog K and Elliott E, *Down syndrome in births near landfill sites.* Prenat Diag, 2007. **27** (13): p. 1191-6.

ABBREVIATIONS

ATSDR	US Agency for Toxic Substances and Disease Registry
B(a)P	benz(a)pyrene
BMC	benchmark concentration
$BMCL_{10}$	lower 95% confidence limit of the benchmark concentration for a 10% response
bw	body weight
CICAD	Concise International Chemical Assessment Document
COM	Committee on the Mutagenicity of Chemicals in Food, Consumer Products and the Environment
COC	Committee on the Carcinogenicity of Chemicals in Food, Consumer Products and the Environment
DB(a,l)P	dibenz(a,l)pyrene
DMS	dimethyl sulphide
DMDS	dimethyl disulphide
EA	Environment Agency
EPAQS	Expert Group on Air Quality Standards
EU	European Union
FAO	Food and Agriculture Organisation
fg	femtogram i.e. 10^{-12} grams
HCV	health criteria value
HSE	Health and Safety Executive
JECFA	Joint FAO/WHO Expert Committee on Food Additives
LOAEL	lowest observed adverse effect level
kg	kilogram(s) i.e. 10^3 grams
km	kilometre(s) i.e. 10^3 metres
LOAEC	lowest observed adverse effect concentration
LOAEL	lowest observed adverse effect level
m^{-3}	per cubic metre
mg	milligram(s) i.e. 10^{-3} grams
MOE	margin of exposure
NAQS	National Air Quality Standard
ng	nanogram(s) i.e. 10^{-9} grams
NOAEL	no observable adverse effect concentration
NOAEL	no observable adverse effect level
Nox	oxides of nitrogen
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-*para*-dioxin
PCDF	polychlorinated dibenzofuran
PM_{10}	particulate matter with a diameter of less than 10 micrometres
ppb	parts per billion
SAHSU	Small Area Health Statistics Unit
TEQ	toxic equivalent
TWA	time weighted average
µg	microgram(s) i.e. 10^{-6} grams
US EPA	US Environmental Protection Agency

VOC	volatile organic compound
WEL	workplace exposure limit
WHO	World Health Organisation
WHO-TEQ	toxic equivalent calculated using factors published by ~~the~~ W~~orld~~ H~~ealth~~ O~~rganisation~~

LIST OF CHEMICALS

~~Substances~~ Chemicals measured in main landfill study~~considered by COT~~

1,1,1-Trichloroethane	Dichlorodifluoromethane~~Dichlorobenzene~~
1,1-Dichloroethane	Dichlorofluoromethane~~Dichlorodifluoromethane~~
1,2-Dichloroethane	Dichloromethane~~Dichlorofluoromethane~~
1,2-Dichloroethene	Dimethyl disulphide~~Dichloromethane~~
1,3-butadiene	Dimethyl sulphide~~Dimethyl disulphide~~
2-butanone	Ethyl mercaptan~~Dimethyl sulphide~~
2-Ethyl-1-hexanol	Ethylbenzene ~~Polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans and dioxin-like polychlorinated biphenyls (PCBs)~~
2-Methylfuran	Fluoranthene~~Ethyl mercaptan~~
Acenaphthene	Fluorene~~Ethylbenzene~~
Acenaphthylene	Formaldehyde~~Fluoranthene~~
alpha-Terpinene	Indeno (123-cd) pyrene~~Fluorene~~
Anthracene	Lead~~Formaldehyde~~
Antimony	m+p Xylene~~Indeno (123-cd) pyrene~~
Arsenic	Manganese~~Lead~~
Arsine	Mercury~~m+p Xylene~~
Benzene	Methyl mercaptan~~Manganese~~
Benzo (a) anthracene	Naphthalene~~Mercury~~
Benzo (a) pyrene	Nickel~~Methyl mercaptan~~
Benzo (b/k) fluoranthene	Nitromethane~~Naphthalene~~
Benzo (ghi) perylene	o Xylene~~Nickel~~
Cadmium	Phenanthrene~~Nitromethane~~
Carbon disulphide	Polychlorinated biphenyls (PCBs)~~o Xylene~~
Chlorobenzene	Polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans (PCDDs and PCDFs)~~Phenanthrene~~
Chlorodifluoromethane	Pyrene
Chloroethane~~Chlorodifluoromethane~~	Stibine~~Pyrene~~
Chloroethene~~Chloroethane~~	Styrene~~Stibine~~
Chloroform~~Chloroethene~~	Tetrachloroethene~~Styrene~~
Chloromethane~~Chloroform~~	Thallium~~Tetrachloroethene~~
Chromium~~Chloromethane~~	Tin~~Thallium~~
Chrysene~~Chromium~~	Toluene~~Tin~~
Cobalt~~Chrysene~~	Trichloroethene~~Toluene~~
Copper~~Cobalt~~	Trimethylbenzene~~Trichloroethene~~
Dibenzo (ah) anthracene~~Copper~~	Vanadium~~Trimethylbenzene~~
Dichlorobenzene ~~Dibenzo (ah) anthracene~~	~~Vanadium~~

Chemicals screened out because the maximum concentrations measured were below 1% of the project-specific HCV

Acenaphthene	Dichlorodifluoromethane
Anthracene	Fluoranthene
Antimony	Fluorene
2-Butanone (methyl ethyl ketone)	Mercury
Chlorobenzene	Naphthalene
Chloroethane	Nitromethane
Chlorodifluoromethane	Pyrene
Chloromethane	Thallium
Dichlorobenzene	Tin
1,1-Dichloroethane	Trimethylbenzene
1,2-Dichloroethene	Vanadium
Dichlorofluoromethane	

Chemicals whose maximum concentrations were ≥1% and average concentrations were below 75% of the project-specific HCV and which were not reviewed in depth by COT

1,3-butadiene	Dichloromethane
2-Ethyl-1-hexanol	Ethyl mercaptan
1,1,1-Trichloroethane	Ethylbenzene
alpha-Terpinene	Lead
Arsenic	m+p Xylene
Benzene	Manganese
Cadmium	Nickel
Carbon disulphide	o Xylene
Chloroform	Trichloroethene
Cobalt	Tetrachloroethene
Copper	

Chemicals whose average concentrations were at or above 75% of the project-specific HCV and which were reviewed in depth by COT

Arsine	Methyl mercaptan
Chromium	Potentially carcinogenic polycyclic aromatic hydrocarbons (PAHs)*
1,2-Dichloroethane	Stibine
Dimethyl disulphide	Styrene
Dimethyl sulphide	Toluene
Formaldehyde	

* Benzo(a)pyrene, benzo(a)anthracene, benzo(b,k)fluoranthene, chrysene, dibenz(a,h)anthracene, Indeno(123-cd)pyrene

Other chemicals reviewed by COT

Chloroethene	Polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans
2-methylfuran	Benzo (ghi) perylene

| Acenaphthylene | Phenanthrene |

Other substances measured in study

Aspergillus fumigatus	Nitrogen dioxide
Endotoxins	PCBs
Entrobacteriaceae	Penicillia
Fibres	PM_{10}
Fungi and yeasts	Sulphur dioxide
Gram negative bacteria	Thermophilic bacteria
Hydrogen sulphide	Thermophilic fungi
Mesophilic aerobes	Yeasts
Moulds	

How we have reported measurements

1.   In this statement, when reporting the concentrations of chemicals measured at the boundaries of the landfill sites, we have presented the 50th percentile value of the measurements made for each chemical at each site, together with the maximum concentration detected. The 50th percentile is the middle value of a set of numbers in order of their size. It is often used when the data are not evenly distributed about the average.   For example, it is used when there are a few values that are much higher than the other measurements and when to quote the average (arithmetic mean) of the values would give undue weight to these high readings.

2.   Consider a set of 9 numbers.

Number	5	27	44	7	87	55	73	18	172

The average of these would be 54. The 50th percentile is the middle value. If we arrange the numbers in ascending order, we can see this is 44.

Number	5	7	18	27	**44**	55	73	87	172

3.   When concentrations of chemicals are measured, the instruments may not be sufficiently sensitive to measure some low levels. The lowest level we can measure is known as the limit of detection or detection limit (DL). This can vary over the course of the study, for example, as different techniques are used. In the example below, the DL was initially 100 micrograms per cubic metre (µg per m^3) and, in August, was reduced to 10 µg per m^3.

Date	21/5	23/6	20/7	20/8	21/9	19/10	20/11	18/12	23/1
True concentration	5	27	44	7	87	55	73	18	172
Detection limit (DL)	100			10					

4.   Where a value is below the DL, it is not known whether the substance is or is not present. In our statement, we have reported the median concentrations both with the assumption that the substance was not present (concentration assumed to be 0) and with the assumption that the substance was present at the DL prevailing at the time. The true concentration of the chemical lies at or between these levels. This is shown in the table below.

Date	21/5	23/6	20/7	20/8	21/9	19/10	20/11	18/12	23/1
True value	5	27	44	7	87	55	73	18	172
Measurement	<100	<100	<100	<10	87	55	73	18	172
Assuming all non-detects are 0	0	0	0	0	87	55	73	**18**	172
Assuming all non-detects are at the DL	100	100	100	10	**87**	55	73	18	172

We can see that, if we report the values below the detection limit as 0, the 50th percentile will be 18. However, if we report the values as the prevailing limit of detection, the 50th percentile is 87. The true value lies at or between 18 and 87.

5.   Note that if none of the values measured for a chemical were above the detection limit, the 50th percentile level calculated by assuming that all non-detected levels were present at the DL will not be zero. Instead, it will be the 50th percentile value of the detection limits used to take those measurements.

Extract from JECFA monograph on Furan-substituted Aliphatic Hydrocarbons

3. COMMENTS

As stated above, the main concern with this group arises primarily from the carcinogenicity of furan itself, which is believed to involve a reactive genotoxic metabolite formed by epoxidation and opening of the furan ring. Furan is not a member of this group of flavouring agents, but all the members of the group contain a furan ring with either one or two substituents of varying complexity. In some flavouring agents, a substituent is present on one side of the furan ring only, whereas in others, substituents are present on both sides. The presence of an extended side-chain attached to the furan ring would reduce the potential for epoxidation of the double bond and provide a site for detoxication via metabolism and elimination. The flavouring agent that has the simplest structure and would be predicted to have the greatest potential for ring oxidation is 2-methylfuran (No. 1487); there is evidence from studies in vitro and in vivo that this compound undergoes bioactivation to a reactive ring-opened metabolite that binds covalently to both protein and DNA. Data are not available on the influence of the nature and position of the ring substitution on potential for metabolic activation and adduct formation. After administration of a single dose, 2-methylfuran produced liver toxicity in rats from 50 mg/kg bw, but hepatotoxicity has not been reported for other members of this group in more extensive studies.

Testing for genotoxicity has been performed on eight members of this group of flavouring agents. The results of the studies of genotoxicity/mutagenicity in vitro that were already available to the Committee at its previous meeting were both positive and negative, with most positive results reported for chromosomal aberration. These, however, were less frequent in the presence of metabolic activation, indicating possible metabolic detoxication rather than bioactivation. 2-Methylfuran (No. 1487), for example, produced chromosomal aberrations in vitro, but the clastogenic activity was lower in the presence of a metabolizing system. The limited data available on genotoxicity in vivo showed no evidence of chromosomal
aberration in mouse bone marrow or spermatocytes for 2-methylfuran. 2-Furyl methyl ketone (No. 1503) also induced no chromosomal aberrations in mouse spermatocytes, but a weak, transient increase in chromosomal aberrations was observed in mouse bone marrow, associated with mitodepression. *O*-Ethyl-*S*-(2-furylmethyl)thiocarbonate (No. 1526) appeared not to induce micronucleus formation in mouse bone marrow.

The new data on 2-furyl methyl ketone (No. 1503) available to the Committee at its present meeting were a study on UDS in cultured hepatocytes in vitro, a study on UDS in rat liver in vivo/in vitro and a test for SCEs in mouse bone marrow in vivo.   2-Furyl methyl ketone did not induce UDS either in vitro or in vivo/in vitro. However, it did induce SCEs, confirming the concern for clastogenicity as expressed by the Committee at its previous meeting. The Committee at its present meeting therefore considered that the new data available did not resolve the concerns expressed previously.

4. EVALUATION

The Committee concluded that the Procedure for the Safety Evaluation of Flavouring Agents could not be applied to this group because of the unresolved toxicological concerns. Studies that would assist in the safety evaluation include investigations of the influence of the nature and position of ring substitution on metabolism and on covalent binding to macromolecules. Depending on the findings, additional studies might include assays related to the mutagenic and carcinogenic potential of representative members of this group.