REPORT ON THE ANALYSIS OF PCCD/PCDF AND HEAVY METALS IN FOOTPATHS AND SOIL SAMPLES RELATED TO THE BYKER INCINERATOR

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CONTENT

ABBREVIATIONS AND GLOSSARY OF TERMS

AAS	Atom Absorption Spectroscopy*, analytical method for heavy metals*
As	Arsenic
bioavailablity	*The degree to which contaminants are taken up by plants, animals or humans who are exposed*
bottom ash	*fine material from the bottom of an incinerator*
$^{13}C_{12}$	synthetically created, not naturally occurring dioxin/furan containing heavy carbon; *used to assess loss of material during preparation of samples*
Cd	Cadmium
CLEA	Contaminated land exposure assessment; *forthcoming probabalistic exposure model to derive new UK guideline values*
Cr	Chromium
Cu	Copper
Dutch list	*Dutch list of guideline values to assess contaminated land*
fly ash	*Fine and ultrafine material collected in incinerator stack by various filter systems*
Hg	Mercury
HMIP	Her Majesty's Inspectorate of Pollution, *now part of the Environment Agency*
HRGC /HRMS	High resolution gas chromatography, High resolution mass spectroscopy, *analytical method to detect dioxins/furans*
HpCDD	Heptachlorodibenzodioxins; *Dioxin with seven chlorine atoms*
HpCDF	Heptachlorodibenzofurans; *Furan with seven chlorine atoms*
HxCDD	Hexachlorodibenzodioxins; *Dioxin with six chlorine atoms*
HxCDF	Hexachlorodibenzofurans; *Furan with six chlorine atoms*
ICP-OES	Inductive coupled plasma emission spectroscopy; *analytical method to detect heavy metals*
ICRCL	Interdepartmental Committee on the Redeveloment of Contaminated Land; *UK body, which set guideline values for contaminated land in 1987*
I-TEQ	International Toxicity Equivalents; *summary measure of toxic dioxins/furans*
mg/kg	milligram (10^{-3})g per kilogram; *equivalent to a teaspoon of salt in a bathtub*
ng/kg	nanogram (10^{-9}) g per kilogram, *equivalent to a teaspoon of salt in a small lake*
OCDD	Octachlorodibenzodioxins, *Dioxin with eight chlorine atoms*
OCDF	Octachlorodibenzofuran, *Furan with eight chlorine atoms*
Pb	Lead
PCDD/PCDF	Polychlorinated Dibenzodioxin/Polychlorinated Dibenzofuran
PeCDD	Pentachlorodibenzodioxin, *Dioxin with five chlorine atoms*
PeCDF	Pentachlorodibenzofuran, *Furan with five chlorine atoms*
RDF	Refuse derived fuel
slag	*Coarse fraction of residues produced during incineration*
TCDD	Tetrachlorodibenzodioxin, *Dioxin with four chlorine atoms*
TCDF	Tetrachlorodibenzofuran (Furan with four chlorine atoms)
VDI	German Association of Engineers, *VDI 3499 outlines the methodology of the analysis of ash samples*
Zn	Zinc

1. EXECUTIVE SUMMARY

Background and aims: At the request of Newcastle City Council and Newcastle and North Tyneside Health Authority the Environmental Epidemiology Group at the University of Newcastle conducted an independent investigation into the contamination of footpaths by ash from the Byker incinerator.

Newcastle City Council identified 44 sites as having received between 10 and 150 tones of ash between 1994 and 1999. The aims of the investigation were:

1. To assess soil and footpath contamination with PCDD/PCDF and heavy metals in the allotments near the Byker incinerator/heat station,
2. To assess contamination with PCDD/PCDF and heavy metals in selected areas of Newcastle where ash from the Byker incinerator/heat station has been used,
3. To advise Newcastle City Council and Newcastle and North Tyneside Health Authority on potential risks to the public health from past and current operations of the incinerator/heat station.

Methods: 23 sites were selected using a protocol developed on the basis of information received from Newcastle City Council and consideration of possible exposure pathways.

Sixteen samples were taken from footpaths, which had received Byker ash. In one allotment a separate sample was taken from a path, which had not received ash from Byker but from a local coal fired power station.

Four samples were taken from disturbed and undisturbed soil from an allotment in the vicinity of the incinerator, two samples were taken from allotment paths, which were recorded as not having received ash from Byker (controls).

23 samples were analysed for their concentrations of heavy metals and dioxins/furans; they were composite samples of between 2 and 8 individual samples of 2 to 25 cm depth collected in February 2000.

Samples were collected in line with HMIP guidance (*1*). The ergo laboratory, Hamburg, Germany conducted the analysis in accordance with directive VDI 3499.

The concentrations detected in the samples were compared with guideline levels described in the 'Dutch list' (*2*) and in recommendations by Basler as described in the protocol of 8.12.1999, both of which are based on contamination of soil (*3*). The values of the Dutch list are trigger levels for further risk assessment, not trigger levels for remediation.

Results:

Descriptive statistics of 16 Byker ash samples for heavy metals [mg/kg] and PCDD/PCDF in I-TEQ [ng/kg] and guideline values for soil[1]

	Arsenic	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Zinc	I-TEQ
Dutch list[2]	20	1	100	50	0.5	50	50	200	
Basler list[3]							target value		5
Mean	12	5.0	88	1195	0.2	55	399	659	1373
Median	**11**	**5.7**	**93**	**1045**	**0.2**	**45**	**407**	**548**	**918**
Minimum	7	0.4	13	10	0.1	14	17	31	11
Maximum	23	11.0	182	3620	0.6	187	620	1420	4224

[1]This analysis included the sample from near Feversham School, which is unlikely to have received ash from Byker, but was included in the list of sites, [2] Guideline values for further risk assessment for contaminated land from the Netherlands, [3] Target values for PCDD/PCDF contamination of soil

Copper, lead and zinc were major contaminants in the large majority of samples. Levels were in the order of magnitude that could be expected in slag from municipal waste incinerators. 13 out of 16 ash samples showed a characteristic pattern of simultaneous elevated levels of copper, lead and zinc.

Arsenic, mercury, nickel contamination was not a major problem in any samples, chromium contamination was measurable, but not a major problem, cadmium contamination was considerable in a majority of sites.

There was a massive contamination with dioxins/furans in a large majority of Byker ash samples. The median of 16 ash samples was 918 ng/kg I-TEQ, values ranged between 11 and 4224 ng/kg. Contamination with dioxins/furans was in the order of magnitude that would be expected in fly ash from municipal waste incinerators.

Contamination with dioxins/furans was highest in those samples with a high copper content. A characteristic zigzag shaped pattern of the sums of dioxins and furans was found, apparently indicative of Byker derived ash. This pattern was not found in soil samples from the vicinity of the plant, or in the ash from the coal-fired power station.

Conclusions: The contamination found in footpath samples was consistent with the use of a mixture of slag and fly ash.

Contamination of soil and vegetables could not be ruled out without further measurements.

Contamination of soil with copper, lead and zinc and dioxins/furans in four samples from near the incinerator was such that a systemic uptake by consumption of vegetables or animal produce could not be ruled out without further measurements.

The contamination of ash samples from footpaths with heavy metals, especially lead and dioxins/furans require further risk assessment in order to ascertain the potential for risk to the public health.

Recommendations: On March 31, 2000 we recommended further investigations to Newcastle City Council and Newcastle and North Tyneside Health Authority:

1. To consider assessing the likelihood of transfer into soil, animals and vegetables, by sampling of heavy metals and dioxins/furans in soil and vegetables in allotments where elevated levels in ash on footpaths were found,
2. To consider assessing the full extent of the problem by sampling all other sites, which have received Byker ash, not included in the current study for heavy metals,
3. To consider establishing the geographical spread of deposition by sampling of heavy metals and PCDD/PCDF in soil at varying distances from the Byker incinerator
4. To consider establishing the likelihood of PCDD/PCDF uptake by humans by the sampling of eggs, or chicken raised near the incinerator and in allotments, which received Byker ash.

We also recommended in the absence of detailed information about soil contamination based on a precautionary principal:

1. To consider advising parents to keep small children off affected allotment paths and bridle paths until the ash material is removed,
2. To consider advising allotment gardeners not to consume vegetables until results of the further testing for heavy metals in soil are available,
3. To consider establishing a register of allotment gardeners in Newcastle to enable health investigations if they should be required at a later stage,
4. To consider informing affected allotment gardeners as soon as possible.

Postscript: On April 7, 2000 Newcastle and North Tyneside Health Authority and Newcastle City Council issued precautionary advice to the public based on the preliminary report by Newcastle University of 31.3.2000 and after consultation with the Department of Health and the Food Standards Agency. Newcastle University has been asked to develop a protocol for the sampling of soil, vegetables and eggs. 13 egg samples have been collected which are currently being analysed. The sampling strategy for soil and vegetable samples is currently under consultation. Newcastle City Works has agreed to remove all ash from footpaths, which have received material from the Byker incinerator. This work is currently under way.

2. BACKGROUND AND AIMS

In October 1999 residents living near the Byker incinerator/heat station plant expressed concern about the use of ash on allotment footpaths and past stack emissions, and about plans to expand operations from currently 50,000 to 100,000 tons of refuse derived energy equivalents per year.

In November 1999 Newcastle and North Tyneside Health Authority and Newcastle City Council asked the Environmental Epidemiology Group at the Department of Epidemiology and Public Health, Newcastle University to conduct an independent investigation into the concern about the deposition of ash. In consultation with Newcastle Health Authority, Newcastle City Council and with those residents who had raised the concern a protocol was developed with the following aims:

1. To assess soil and footpath contamination with PCDD/PCDF and heavy metals in the allotments near the Byker incinerator/heat station
2. To assess contamination with PCDD/PCDF and heavy metals in selected areas of Newcastle where ash from the Byker incinerator/heat station has been used
3. To advise Newcastle City Council and Newcastle and North Tyneside Health Authority on potential risks to the public health from past and current operations of the incinerator/heat station.

The protocol for the study reported here therefore aimed to assess whether or not a problem had arisen from the use of ash from the Byker incinerator and provide limited evidence of the magnitude of a problem if it existed. The study was not designed to provide detailed measurements at all locations or the basis for a detailed risk assessment.

Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans (PCDD/PCDF) are a family of chemicals which are created as unwanted byproduct of many chemical and industrial processes. When taken up by animals or humans they tend to accumulate in body fat. There are many different dioxins and furans and each has a different level of toxicity for animals and humans. When PCDD/PCDF are measured there are therefore two main methods to help interpretation. Firstly, a summary measure is used of all dioxins and furans that are known to be toxic. These are summarised by Toxicity Equivalents TEQ, in this report the I-TEQ levels are reported. Secondly, the pattern of the totals of all subgroups of PCDD/PCDF (toxic and non-toxic) such as Tetrafurans, Pentafurans etc. are calculated to help the interpretation of the potential source of any contamination.

Newcastle City Council agreed the final version of the protocol on 13.12.1999.

RATIONALE FOR THE SAMPLING STRATEGY

According to records provided by Newcastle City Works approximately 2,000 tons of ash from the Byker incinerator/heat station have been used on sites across Newcastle between 1994 and 1999 (see table 1). Forty-four sites were identified as having received between 10 and 150 tons of ash.

According to Newcastle City Works the incinerator used mainly Waste derived fuel (RDF) produced at the adjacent reclamation plant and some coal and rubber tyres during 1994 to 1999. The incinerator was used for district heating and power generation; since January 1999 only coal has been used.

Newcastle City Council has used the term **ash** for the material delivered to allotment paths and other locations. In this report we are also using this term. However, it must

be pointed out that this term is not used in the scientific literature. The terms used in the scientific literature are:

Slag coarse fraction of residues produced by incineration. This is usually measurably but not highly contaminated material.

Bottom ash fine material from the bottom of an incinerator, derived from slag by mechanical rubbing and directly by the incineration process. This material is usually contaminated but not very severely so.

Fly ash fine and ultrafine material collected in the stack by various filter systems of an incinerator (filter bag, scrubber, electrical filter). The term filter ash is also used for this material. It is always highly contaminated (*4-6*).

According to Newcastle City Works the Byker incinerator has been operating by using a dry lime scrubber to continuously collect fly ash from the incineration process. The collected fly ash was then transported by a conveyer belt and continuously mixed with slag and bottom ash. The material classified as ash in this study therefore would be a mixture of slag, bottom ash and fly ash.

Figure 1 illustrates the possible exposure pathways and populations at risk resulting from stack emissions and the use of ash. The analysis of this figure formed the basis for the sampling strategy adopted in this study. Allotment gardeners in Byker, the population around the incinerator and allotment gardeners across Newcastle were identified as groups most likely at risk if contamination had occurred.

The sampling strategy was designed to enable Newcastle and North Tyneside Health Authority and Newcastle City Council to reassure all residents if no contamination was found. If contamination was detected the protocol outlined in detail on which guidelines any recommendations would be to be based.

Criteria for the identification of allotment and footpath sites sampled

1. One sample from each site, which received ash only once during the years 1994 to 1999. This allowed an evaluation of variation in contamination over time.
2. If more than one site was available that had received ash only at one point in time allotment sites were given preference over other sites, and those having received a higher quantity were given preference over those having received a smaller quantity of ash.
3. All sites having received more than 100 tones were sampled.
4. Feversham School was included in the sampling, because of the potentially vulnerable nature of the users of the site. However, later inspection of the site revealed that it was a footpath near the school rather than the school itself, which had received ash.

Additionally, in Byker itself samples were taken from footpaths in the locations St Michael's a and St Michael's b and two locations each with undisturbed and disturbed soil at the Walker Road allotment. These three allotments are located in the direct vicinity of the incinerator. If fugitive emissions and/or deposition had occurred they would be the locations most likely to show contamination.

For comparison purposes 2 samples were taken from allotments identified by Newcastle City Works as not having received ash. The final list of sampling locations is shown in table 2. Sampling took place between the 8.2. and 10.2.2000.

Table 1 List of locations with ash according to Newcastle City Council November 1999 (in alphabetical order)

No	Category	Name	to of ash	Years
1	O	Big Water	30	96, 97
2	A	Blaney Row[1]	50	97, 98, 99
3	O	Blaney Row	40	97,98
4	A	Blucher	10	95
5	A	Branxton B	30	94, 99
6	A	Brickfield	20	99
7	A	Brunswick	20	99
8	A	Christen Rd	100	97
9	O	Coach Lane Throckley	20	95
10	O	Coronation Road	40	96
11	A	Coxlodge	40	94
12	A	Denton Bank	50	94, 97
13	A	Denton Dene	110	94, 95, 96, 97, 99
14	O	Dinnington Rec	40	96
15	A	Fenham Nursery	150	94, 95, 96, 97, 99
16	F	Feversham School	80	96
17	A	Hulne Terrace	10	98
18	O	Jesmond Old Cementry[2]	10	98
19	A	Jesmond Premier	10	95
20	A	Jesmond Vale	20	94
21	A	Keebeldale Pigeons[3]	10	98
22	F	Lightwood Avenue	40	95
23	A	Little Moor	50	95, 97, 98
24	A	Moorside	50	97, 99
25	O	Other site[5]	40	98
26	A	Nun's Moor	40	94, 98
27	O	NE Mason Farm	80	96
28	O	Newburn Riverside	40	99
29	A	Walkergate Hospital	10	96
30	O	Reith Burn Throckley	40	98
31	A	Ridgewood Crescent	40	97
32	A	Salters Lane	20	94
33	O	Stamfordham Rd	40	96
34	A	St Anthony's[4]	10	99
35	A	St Michael a	20	94
36	A	St Michael b	20	94
37	B	Three Hills	140	95
38	O	UFAMS	90	96, 97
39	O	Walbottle Dene	10	97
40	A	Walkergate Hospital	10	96
41	A	Walkergate 3a	70	95, 96, 97, 99
42	A	Walkergate 3b	100	94, 96, 97, 99
43	A	Westmacott Str	100	94, 95, 96, 97
44	A	Whinneyfield Rd	10	97

A: Allotment, B: Bridle Path, F: Footpath, O: Other, exact nature of site has not been established, [1] Site listed as allotments as well as under other sites [2] According to later information this load was not delivered, [3] Classed as other site on original list and reclassified as allotment following inspection, [4] according to later information no evidence of ash, [5] private property, the owner did not wish the name to be released

Figure 1 Possible exposure pathways and populations at risk Byker incinerator/heat station

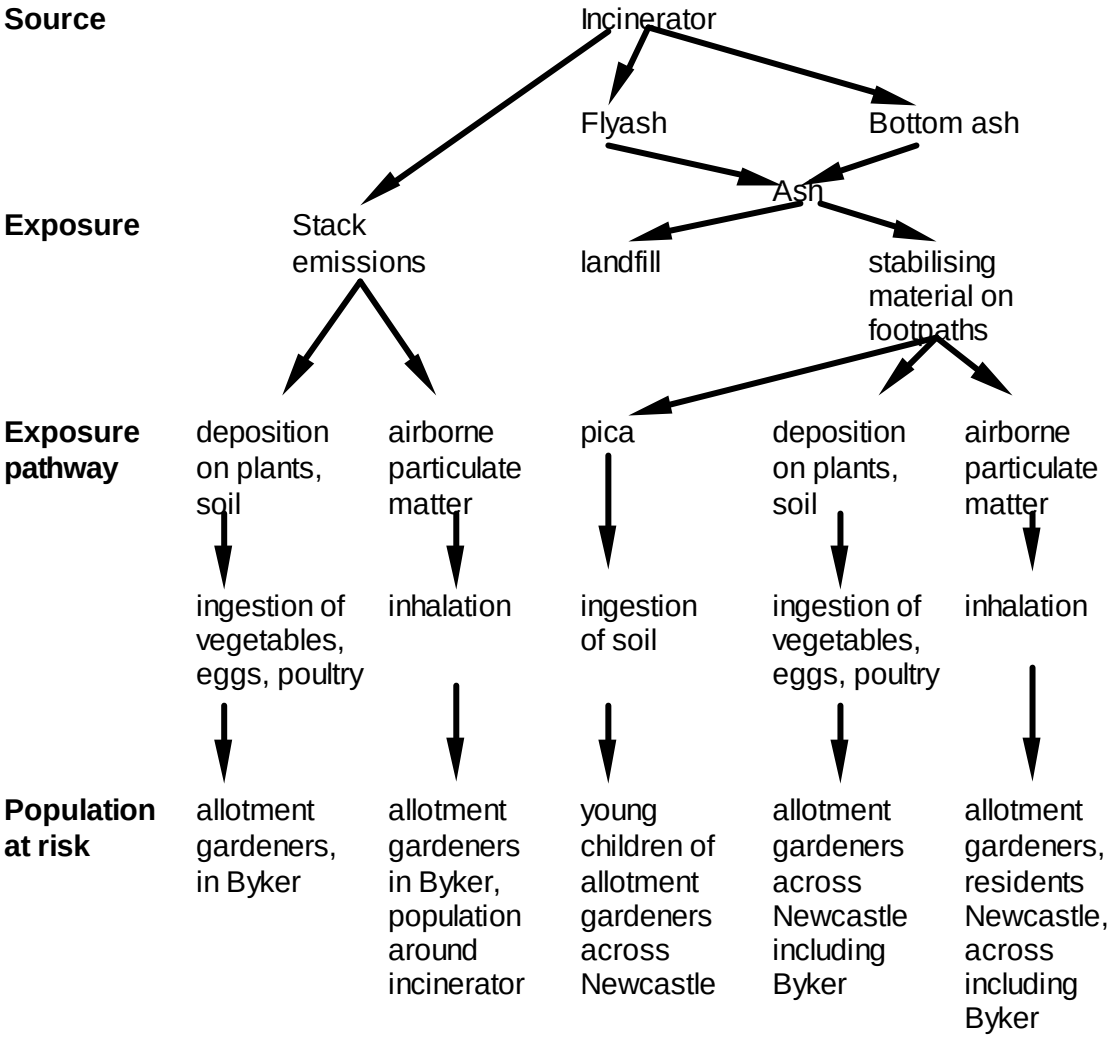


Table 2 Final list of sampling locations[1]

Sample No	Cate-gory	Name	Ash received	Years
1	A	Coxlodge	40	94
2	F	Lightwood Avenue	40	95
3	A	Walkergate Hospital	10	96
4	A	Ridgewood Crescent	40	97
5	A	Keebeldale Pigeons	10	98
6	A	Brunswick	20	99
7	A	Christen Rd	100	97
8	A	Denton Dene	110	94, 95, 96, 97, 99
9	A	Fenham Nursery	150	94, 95, 96, 97, 99
10	A	Walkergate 3b[2]	100	94, 96, 97, 99
11	A	Westmacott Str	100	94, 95, 96, 97
12	B	Three Hills	140	95
13	B	near Feversham School	80	96
14	A	St Michael a	20	94
15	A	St Michael b	20	94
16	A	Walkergate 3a[2]	70	95, 96, 97, 99
17-20[3]	A	Walker Road	no ash from Byker	
22	A	Highbury, Jesmond, Control	no ash	
23	A	Oxnam Crescent, Sandyford,	no ash	

A: Allotment, B: Bridle Path, F: footpath, [1]sample numbers are those used throughout the report, please note that there were two samples from Walkergate hospital A containing ash from Blyth power station, B containing ash from Byker, there was no sample no 21, [2]Walkergate 3a and 3b were included because they were thought to be twin sites, later inspection revealed that this was not the case, and two separate samples were taken, [3] soil samples from allotment near incinerator, which had not received Byker ash.

PUBLIC HEALTH RECOMMENDATIONS

The public health recommendations for PCCD/PCDF agreed in the protocol were based on those established by the joint working group on dioxins in Germany for PCDD/PCDF levels in soil (*3*):

< 5ng I-TEQ/kg soil	target value,
5-<40 ng/kg I-TEQ/kg soil	unrestricted cultivation of food stuff, avoidance of critical land use
40-<100 ng/kg I-TEQ/kg soil	limitation to defined agricultural and horticultural use, unlimited cultivation only of plants with minimum dioxin transfer
>100 ng/kg I-TEQ/kg soil	remediation in playgrounds (sealing, decontamination or soil exchange)
>1000 ng/kg I-TEQ/kg soil	remediation in residential areas

The protocol outlined that our interpretation of these limits in the local context would be to advise against the holding of poultry if levels were found to be 5-<40ng/kg I-TEQ, and to advice against the consumption of root vegetables if levels were 40-<100ng/kg.

The Basler values are not legally binding thresholds, but are recommended levels for further risk assessment, they have been widely used across Europe to inform decisions on how to deal with areas affected by contamination with PCDD/PCDF.

The recommendations for heavy metals were based upon those in use in the 'Dutch list' (*2, 7*). They are trigger values for further risk assessment. While they are not legally binding, they have been applied in the planning process in the UK: Arsenic 20 mg/kg, Cadmium: 1 mg/kg, Copper: 50 mg/kg, Nickel: 50 mg/kg, Lead: 50 mg/kg, Zinc: 200 mg/kg, Mercury: 0.5 mg/kg, Chromium 100 mg/kg. The Dutch list was therefore used in the absence of current evidence based UK values (*8*).

The protocol outlined that recommendations would be for no further action if levels were below the level of the 'Dutch list'. If levels were above these limits we stated that we would recommend a more detailed risk assessment to be conducted which should include consideration of different age groups and activities.

The Dutch list was used for the protocol of this study in the absence of an up to date and scientifically based guidance in the UK. We were aware that legally the Interdepartmental Committee for the Redevelopment of Contaminated Land (ICRCL) guidance was in existence until March 31 2000 (*8*), but it was considered no longer up to date for the protocol. New guidance based on a probabilistic contaminated land exposure assessment model (CLEA) has not yet been released (*9, 10*), but is expected shortly.

3. METHODS

SAMPLING

Sampling was carried out by ERGO in February 2000. Members of Newcastle City Works assisted the sampling on site. At each sampling location core samples were collected using a stainless steel cylinder with a diameter of 5 cm. In all cases the true depth of the ash/ slag layer was sampled (2 to 25 cm).

For samples of cultivated (disturbed) soil a depth of 30 cm was used. Soil samples were taken with a spade. When taking samples of undisturbed soil any overlying vegetation such as leaves etc. was removed and a depth of 5 cm was used.

Each individual sample was divided into two parts:

1. For analysing at ERGO laboratory combined samples of each location were created at Newcastle University and taken to Hamburg
2. A back-up of each individual sample (but not of pooled samples) was stored at Newcastle University.

Sampling was done at nineteen different locations. Representative samples were collected. Samples were stored as single samples in pre-cleaned brown glasses with screw cap jars directly after sampling. Aluminium foil was placed under the screw cap.

The sampling procedure was documented in note format, by labeling sampling locations on a map of the site and by taking photographic evidence of each location.

An overview of the sampling locations is presented in table 3. Maps with individual sampling locations can be found in the technical appendix, an example is given on page 12.

Table 3 Description of sampling locations

Sampling No, Location	Kind of sample No of single samples	Visual description of sample
1 Coxlodge	Ash/slag, n=7	Depth 3-5 cm, high proportion of very fine material
2 Lightwood Avenue	Ash/slag, n=6	5-7 cm, limestone or dolomit below
3 Walkergate (Hospital) A	Ash/slag, n=4	No Byker ash/slag, ash from Blyth,
3 Walkergate (Hospital) B	Ash/slag, n=4	Ash from Byker, partially burned RDF
4 Ridgewood Crescent	Ash/slag, n=2	Partially burned and unburned rubber tyres, high proportion of very fine material, potholes only
5 Keebledale Pigeons	Ash/slag, n=3	5-10 cm
6 Brunswick	Ash/slag, n=4	1+2 material different from 3+4, pooled sample 1-4
7 Christon Road	Ash/slag, n=7	3-25 cm
8 Denton Dene	Ash/slag, n=5	3- 8 cm, small footpath in gardens (not sampled)
9 Fenham Nursery	Ash/slag, n=6	5-20 cm
10 Walkergate 3b	Ash/slag, n=4	2-5 cm, high proportion of very fine material
11 Westmacott Street, Plot 69 and Plot 12	Ash/slag, n=7	no ash on main paths, ash only on individual plots, 11/5 partially burned RDF material in heap (used to heat green-houses in the past), not included in composite sample
12 Three Hills	Ash/slag, n=6, no ash on marked path (see map)	2-5 cm, different materials, high proportion of very fine material, slag, klinker (not included in composite sample)
13 near Feversham School	Ash/slag, n=5	0.5-1 cm, samples adjacent to football ground 200-300 m from school
14 St. Michael's a	Ash/slag, n=5	3-10 cm, anecdotal evidence of up to 30 cm in some places, high proportion of very fine material
15 St. Michael's b	Ash/slag, n=7	3-8 cm, high proportion of very fine material
16 Walkergate 3b	Ash/slag, n=8	3-10 cm, a lot of the material directly on small footpaths in the gardens
17 Walker Road, Plot 123/124	Soil, n=5	Undisturbed, 5 cm sampled, no ash from Byker
18 Walker Road, Plot 52	Soil, n=3	Undisturbed, 5cm sampled, no ash from Byker
19 Walker Road, Plot 29	Soil, n=5	Disturbed, 30 cm sampled, no ash from Byker
20 Walker Road, Plot 115	Soil, n=4	Disturbed, 30 cm sampled, no ash from Byker
22 Highbury Jesmond	Soil, n=6	Control, footpath with lawn
23 Oxnam Crescent	Ash/slag, n=5	Control, no Byker ash/slag 5 cm depth sampled

Analytical method

Polychlorinated Dibenzodioxins and Dibenzofurans

Ash/slag samples were digested with acid treatment (VDI 3499 Part 1) and extracted with toluene.

In line with best laboratory practice soil samples were initially air dried and the 2 mm fraction was prepared using a 2 mm sieve. Subsequently soil samples were digested with acid and extracted with toluene.

The clean up of the extract of the sample was done by a combination of multi-columns applying neutral, acidic and basic silica, florisil and carbopac on celite. The analyses were conducted using HRGC (High Resolution Gas Chromatography)/ HRMS (High Resolution Mass Spectrometry) (VG AutoSpec) on two silica columns coated with DB 5 and SP 2331. For each congener two isotope masses were measured. The identification and quantification was performed using the isotope dilution method. The recovery standard used was 1,2,3,4-TCDD ($^{13}C_{12}$). The analytical method follows the procedures of VDI 3499 Part 1: Measurement of polychlorinated dibenzo–p-dioxins and dibenzofurans. Samples were spiked with $^{13}C_{12}$ internal standards before extraction.

Heavy Metals

For the analyses of heavy metal, samples were prepared using total digestion with hydrofluoric acid. Soil samples were air dried and the 2 mm fraction was prepared using a 2 mm sieve.

The level of heavy metal in the digestion solution was performed by ICP-OES (Inductive coupled Plasma Emission Spectroscopy) or by AAS (Atom Absorption Spectroscopy). The element mercury was always determined by AAS using the cold vapor technique.

Data analysis

Data on PCDD/PCDF are presented as “ fingerprint” of the isomeric distribution pattern of the toxic 2,3,7,8 isomers and as total amounts of Tetra, Penta, Hexa, Hepta and Octafurans and dioxins. Data are presented in **ng**/kg of dry matter. The I-TEQ was calculated in **ng**/kg dry matter.

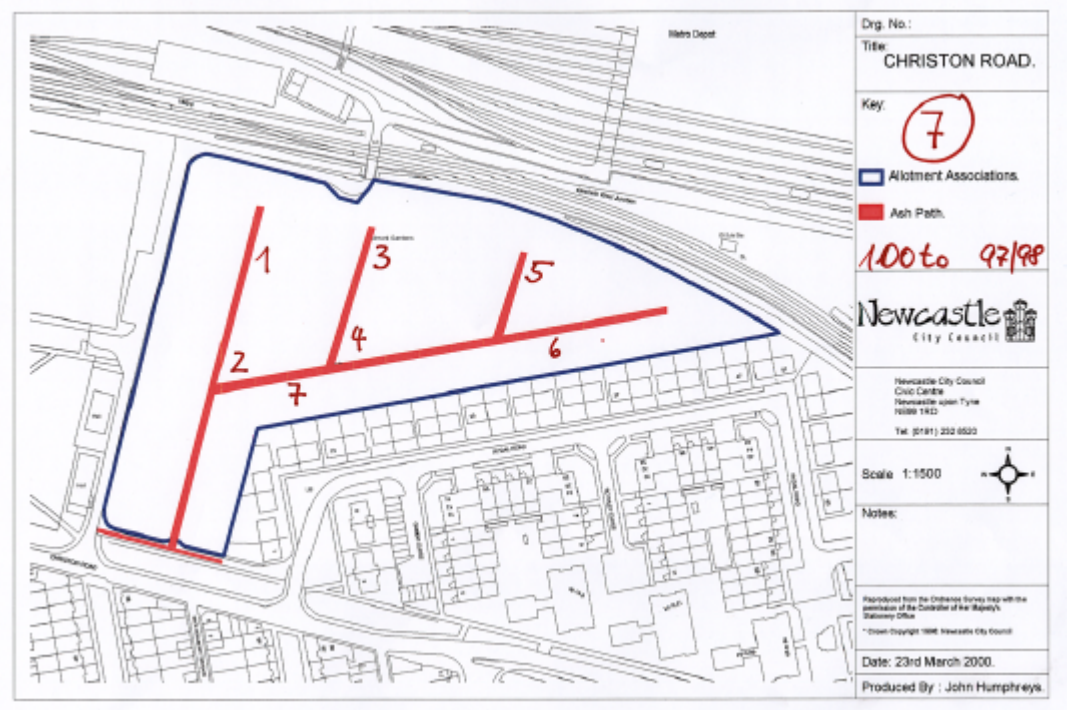
Heavy metal results are expressed as **mg**/kg based on dry matter. Data for each sampling location can be found in the appendix. The content of heavy metals and I-TEQ PCDD/PCDF, the percentage of individual heavy metal per sample, and the Isomer content are presented.

4. RESULTS

SAMPLING LOCATIONS

A full set of maps can be found in the technical appendix. Below there is one example of the documentation of sampling locations.

Example of map marking individual sampling locations



Footpath in Westmacott Street Allotment

ANALYSIS OF HEAVY METALS AND PCDD/PCDF

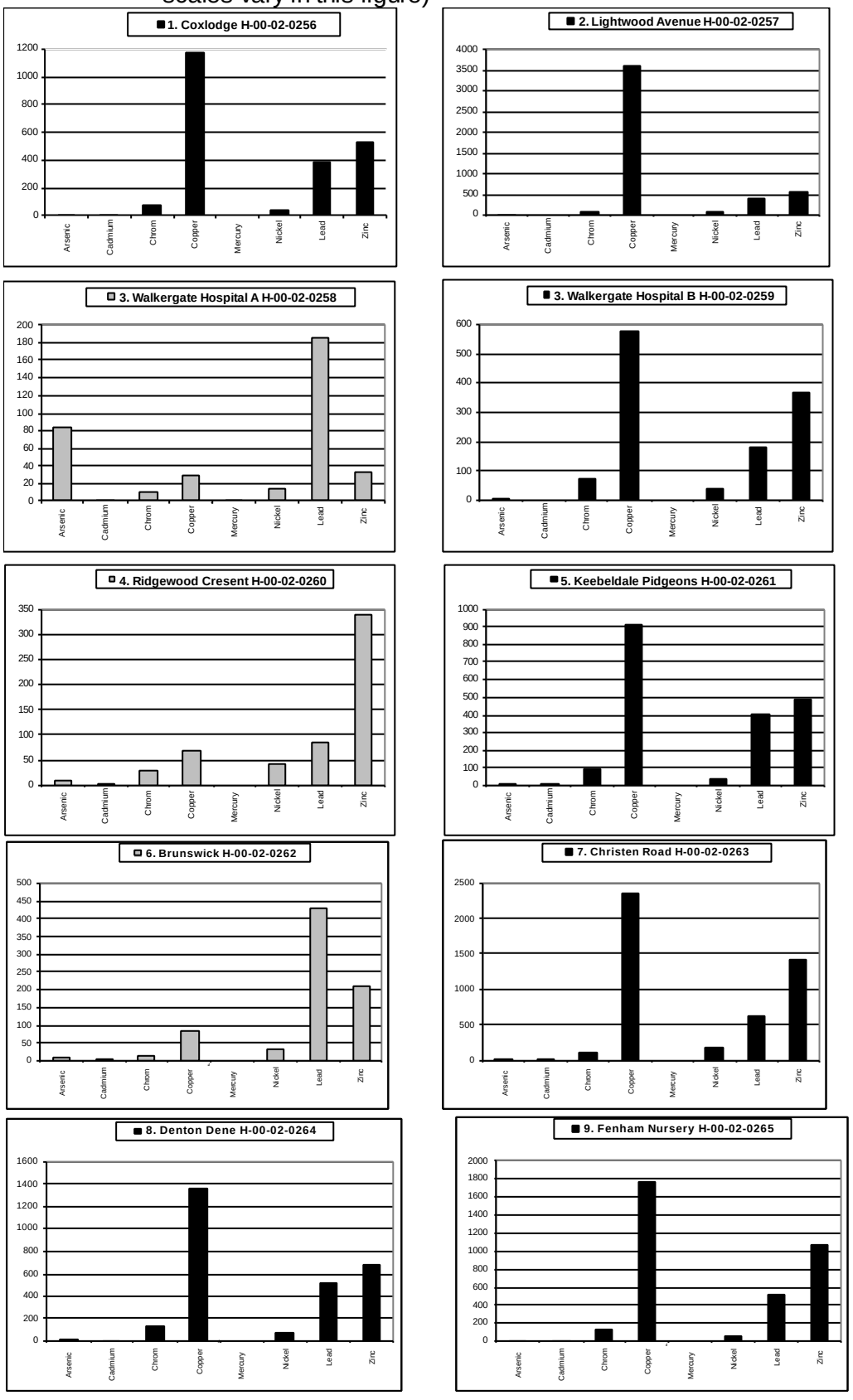
Table 4 summarises the levels of heavy metals and dioxins/furans from each sampling location. Figure 2 shows the patterns of heavy metal contamination, figure 3 the patterns of dioxin/furan contamination. Table 5 shows the association of heavy metal concentration and dioxin/furan contamination, table 6 contains the descriptive statistical analysis of the 16 Byker ash samples.

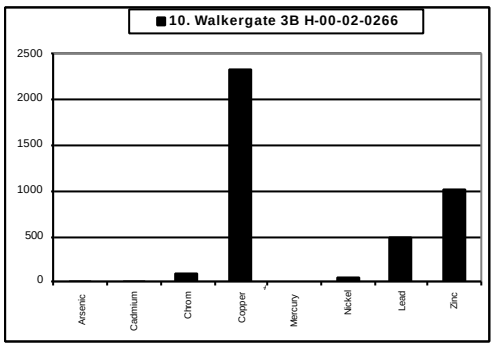
Table 4 Arsenic and heavy metal concentrations in mg/kg, PCDD/PCDF content in ng/kg I-TEQ

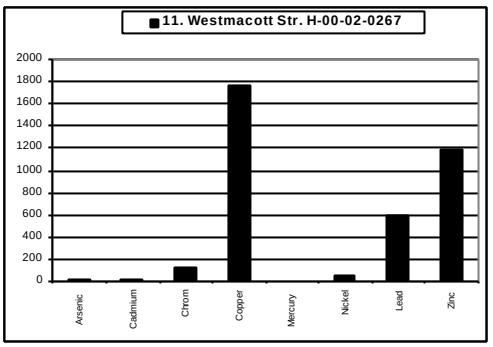
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	PCDD/ PCDF
ASH SAMPLES FROM ACROSS NEWCASTLE										
1	Coxlodge	10	5.4	78	1180	0.2	37	390	529	4224
2	Lightwood Av	10	6.7	101	3620	0.2	86	397	567	2015
3A	Walkergate Hospital A	84	0.7	10	30	1.0	15	186	32	16
3B	Walkergate Hospital B	8	1.0	73	576	0.2	39	183	369	35
4	Ridgewood Crescent	10	1.0	30	70	0.2	43	85	339	88
5	Keebledale P	9	4.3	93	912	0.1	40	409	490	440
6	Brunswick	10	2	13	84	0.1	33	430	209	373
7	Christen Rd	12	11	104	2350	0.1	187	619	1420	3535
8	Denton Dene	12	5.4	141	1360	0.3	77	51	676	1636
9	Fenham Nursery	12	7.2	126	1770	0.2	57	515	1070	2521
10	Walkergate 3b	15	5.9	93	2330	0.2	44	481	1010	976
11	Westmacott Street	10	7.8	115	1770	0.2	45	590	1180	2123
12	Three Hills	13	6.0	96	1070	0.2	46	399	952	415
13	Feversham School	7	0.4	13	10	0.1	14	17	31	11
16	Walkergate 3a	23	4.2	91	605	0.3	54	404	504	1932
ASH SAMPLES FROM NEAR INCINERATOR										
14	St Michael a	15	5.7	182	1020	0.6	47	620	731	783
15	St Michael b	16	6.4	61	400	0.3	34	338	446	860
SOIL SAMPLES FROM WALKER ROAD										
17	Pl123/124 u	38	2.5	81	292	1.1	136	1000	1830	26
18	Pl 52 u	22	1.4	58	172	0.8	43	480	402	34
19	Pl 29 d	26	1.7	57	430	1.0	58	722	772	36
20	Pl 115 d	24	1.4	68	207	0.6	45	693	431	88
CONTROL SAMPLES										
22	Highbury	10	0.6	53	62	1.2	40	278	214	13
23	Oxnam Cr	18	0.8	41	155	0.3	70	579	334	16

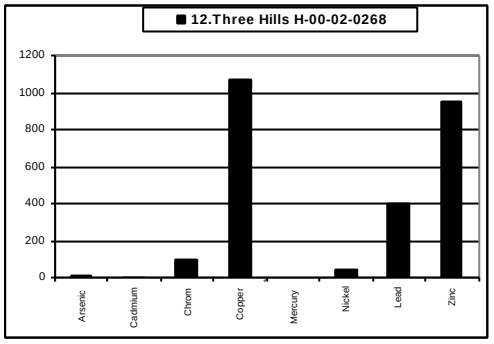
As: Arsenic, Cd: Cadmium, Cr: Chromium, Cu: Copper, Hg: Mercury, Ni: Nickel, Pb: Lead, Zn: Zinc, PCDD/PCDF: dioxins and furans; u = undisturbed soil, d = disturbed soil

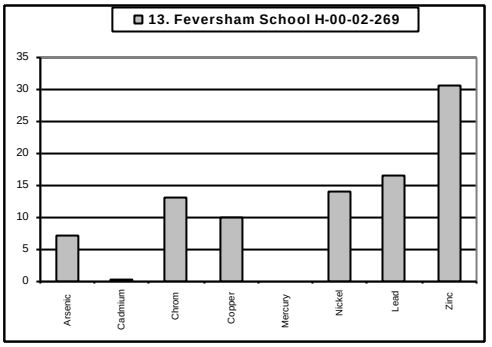
Figure 2 **Pattern of Heavy metals** (Black bars indicate a Byker typical pattern, striped bars patterns other than Byker, please note that scales vary in this figure)

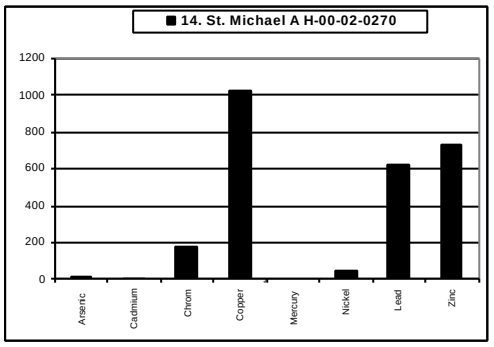


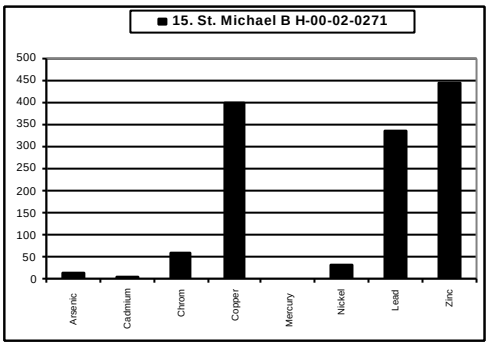

10. Walkergate 3B H-00-02-0266
2500
2000
1500
1000
500
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

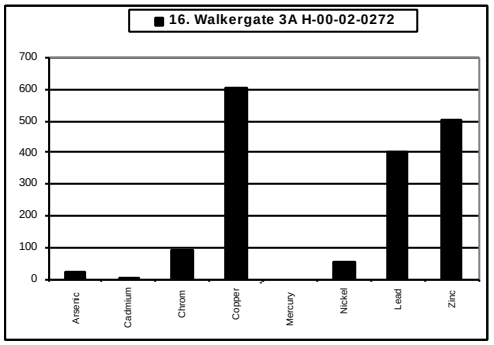

11. Westmacott Str. H-00-02-0267
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

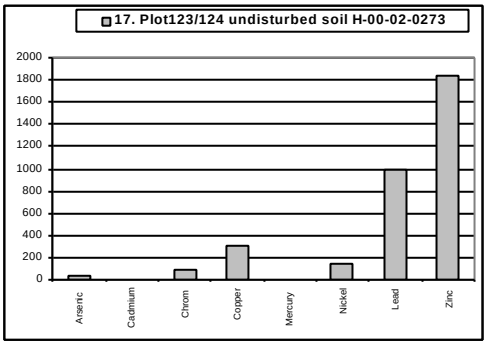

12.Three Hills H-00-02-0268
1200
1000
800
600
400
200
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

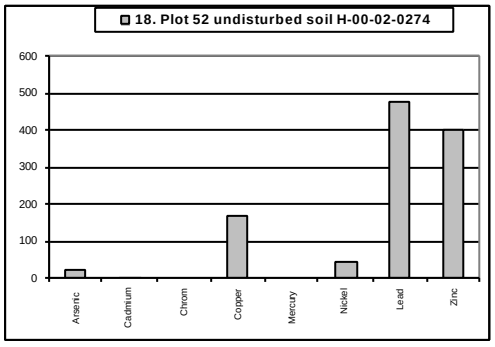

13. Feversham School H-00-02-269
35
30
25
20
15
10
5
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

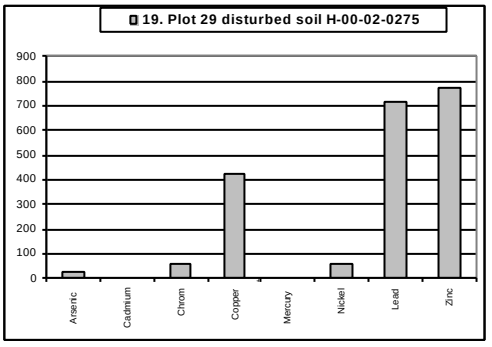

14. St. Michael A H-00-02-0270
1200
1000
800
600
400
200
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

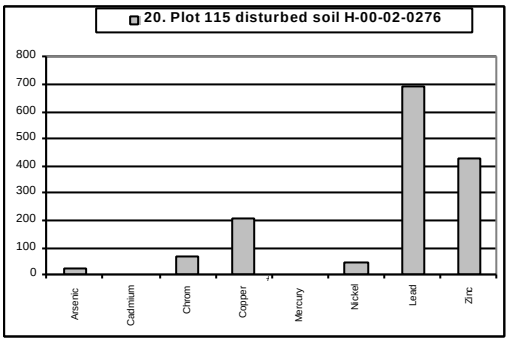

15. St. Michael B H-00-02-0271
500
450
400
350
300
250
200
150
100
50
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

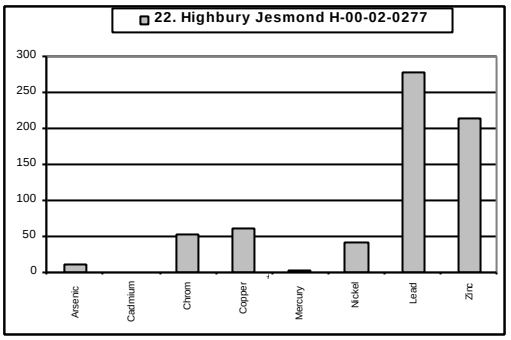

16. Walkergate 3A H-00-02-0272
700
600
500
400
300
200
100
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc


17. Plot123/124 undisturbed soil H-00-02-0273
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc


18. Plot 52 undisturbed soil H-00-02-0274
600
500
400
300
200
100
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc


19. Plot 29 disturbed soil H-00-02-0275
900
800
700
600
500
400
300
200
100
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc


20. Plot 115 disturbed soil H-00-02-0276
800
700
600
500
400
300
200
100
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc


22. Highbury Jesmond H-00-02-0277
300
250
200
150
100
50
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

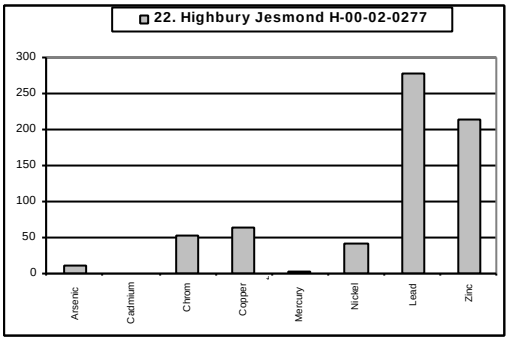
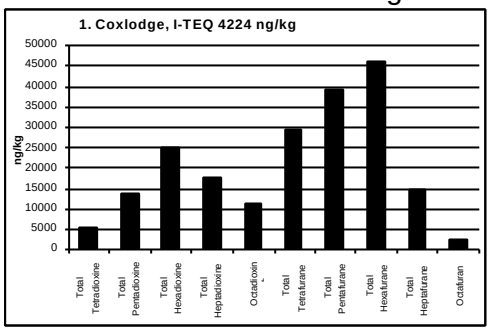
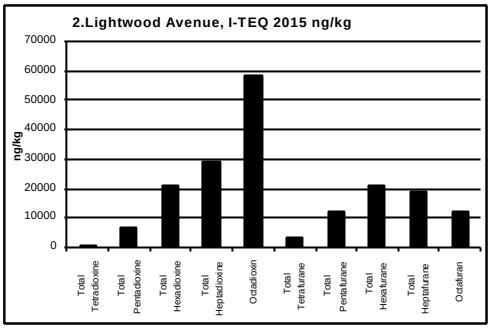
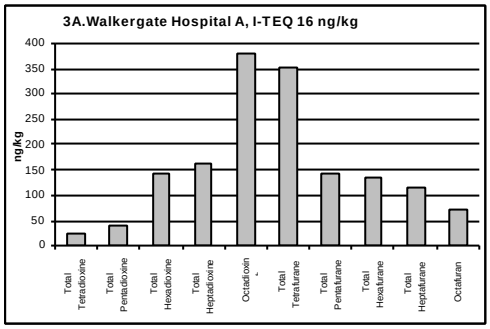
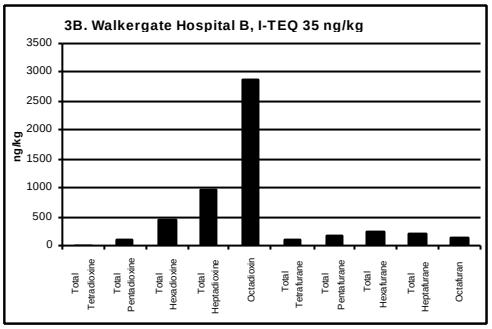

22. Highbury Jesmond H-00-02-0277
300
250
200
150
100
50
0
Arsenic
Cadmium
Chrom
Copper
Mercury
Nickel
Lead
Zinc

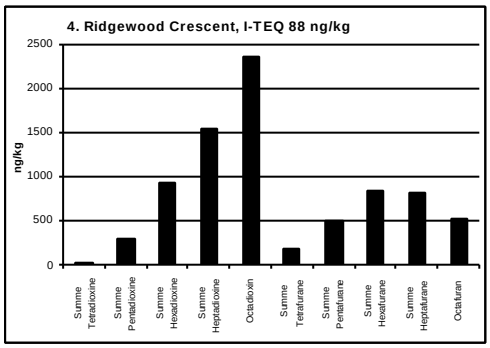
Figure 3 **Pattern of PCDD/PCDF** (Black bars indicate a Byker typical pattern, striped bars patterns other than Byker, please note that scales in this figure vary)

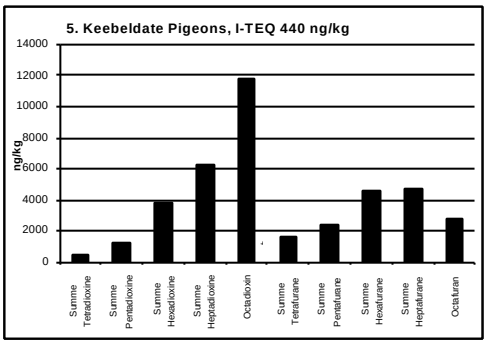


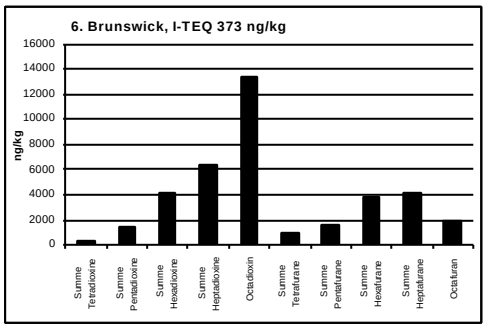


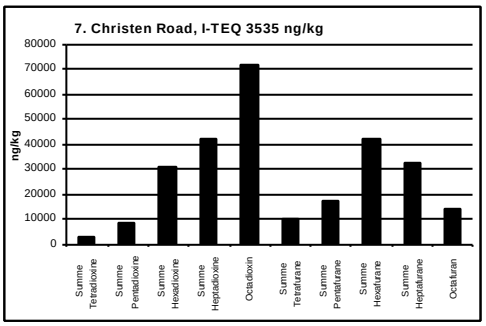


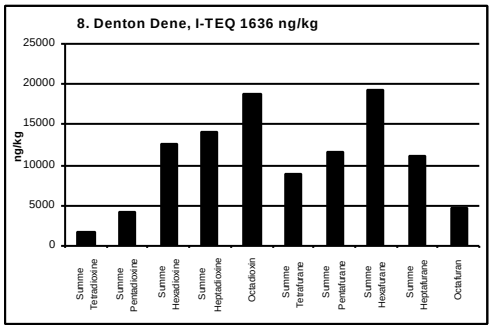


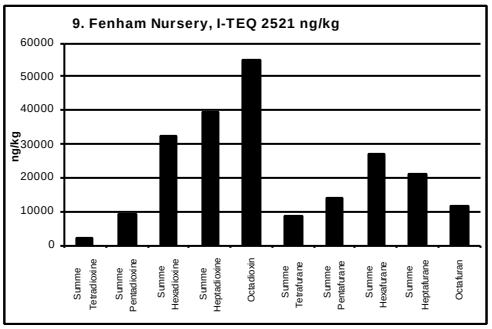


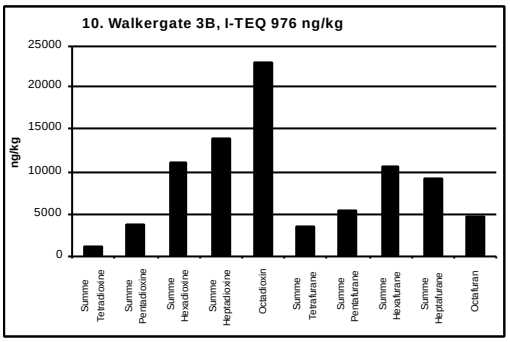


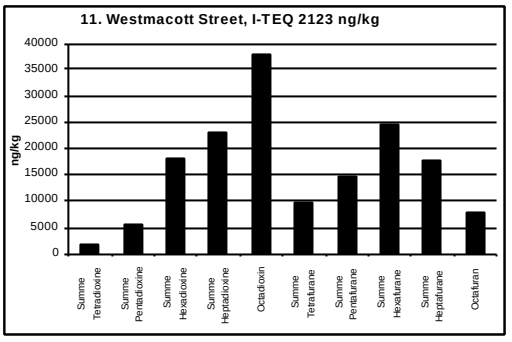


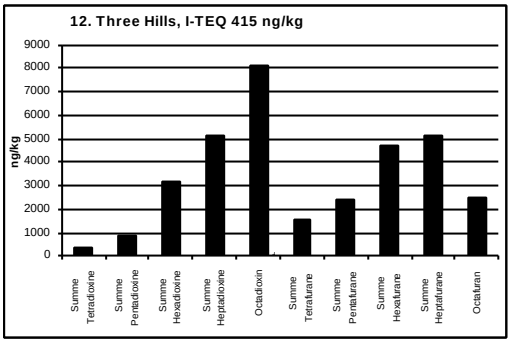


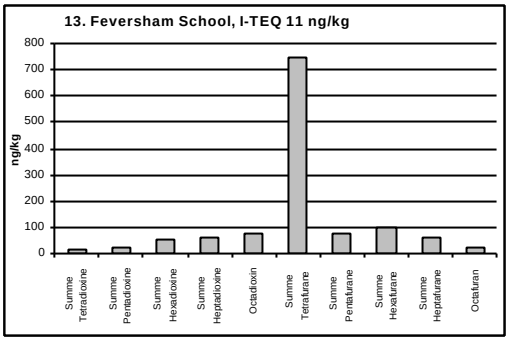


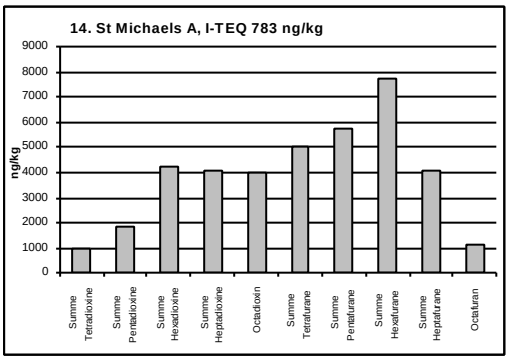


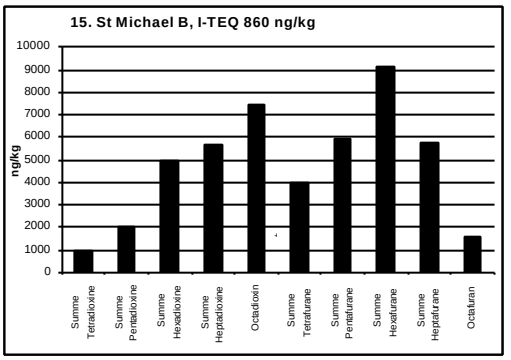

10. Walkergate 3B, I-TEQ 976 ng/kg
ng/kg
25000
20000
15000
10000
5000
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

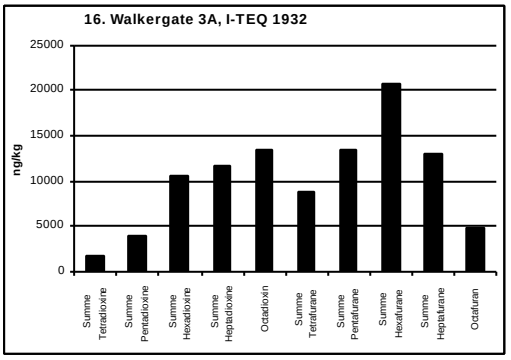

11. Westmacott Street, I-TEQ 2123 ng/kg
ng/kg
40000
35000
30000
25000
20000
15000
10000
5000
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

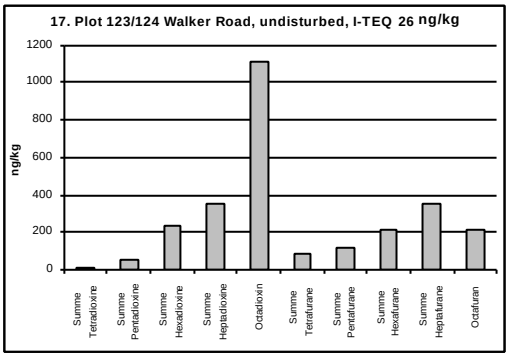

12. Three Hills, I-TEQ 415 ng/kg
ng/kg
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

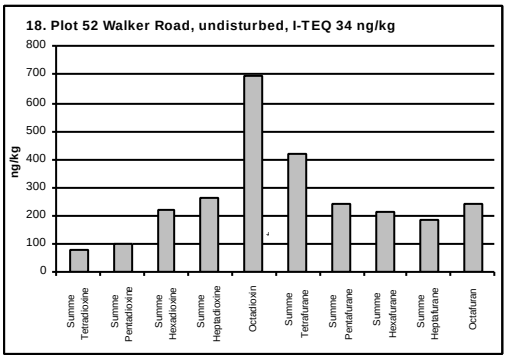

13. Feversham School, I-TEQ 11 ng/kg
ng/kg
800
700
600
500
400
300
200
100
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

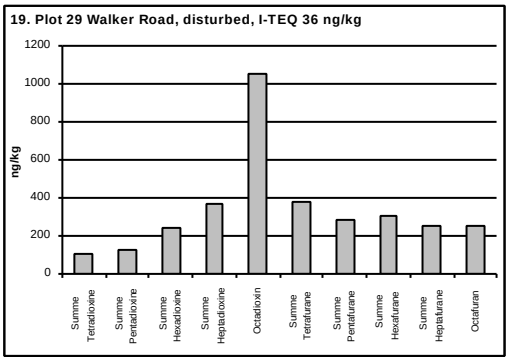

14. St Michaels A, I-TEQ 783 ng/kg
ng/kg
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

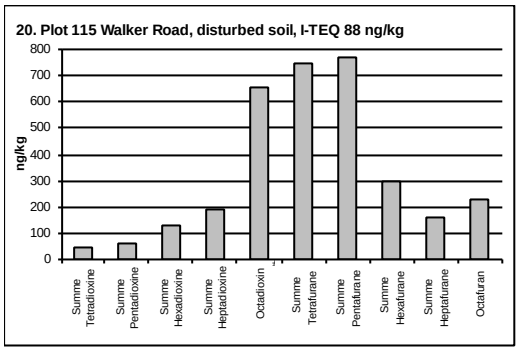

15. St Michael B, I-TEQ 860 ng/kg
ng/kg
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

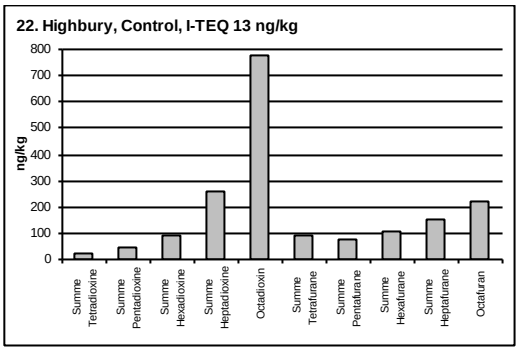

16. Walkergate 3A, I-TEQ 1932
ng/kg
25000
20000
15000
10000
5000
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran


17. Plot 123/124 Walker Road, undisturbed, I-TEQ 26 ng/kg
ng/kg
1200
1000
800
600
400
200
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran


18. Plot 52 Walker Road, undisturbed, I-TEQ 34 ng/kg
ng/kg
800
700
600
500
400
300
200
100
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran


19. Plot 29 Walker Road, disturbed, I-TEQ 36 ng/kg
ng/kg
1200
1000
800
600
400
200
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran


20. Plot 115 Walker Road, disturbed soil, I-TEQ 88 ng/kg
ng/kg
800
700
600
500
400
300
200
100
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran


22. Highbury, Control, I-TEQ 13 ng/kg
ng/kg
800
700
600
500
400
300
200
100
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

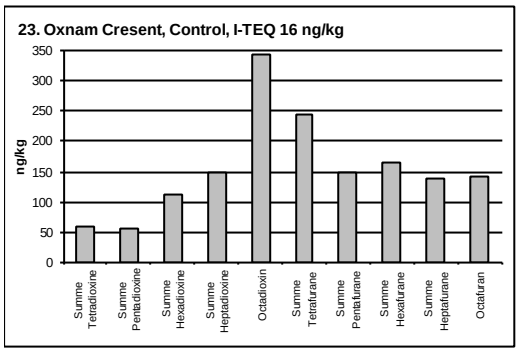

23. Oxnam Cresent, Control, I-TEQ 16 ng/kg
ng/kg
350
300
250
200
150
100
50
0
Summe Tetradioxine
Summe Pentadioxine
Summe Hexadioxine
Summe Heptadioxine
Octadioxin
Summe Tetrafurane
Summe Pentafurane
Summe Hexafurane
Summe Heptafurane
Octafuran

Table 5 Pattern of heavy metal contamination by sampling location and I-TEQ in ng/kg

No	Cate-gory	Name	tons of ash	Years	Pattern	I-TEQ
1	A	Coxlodge	40	94	Cu,Pb,Zn	4224
2	F	Lightwood Avenue	40	95	Cu	2015
3	A	Walkergate Hospital	10	96		16
		A Blyth ash			A: Pb,	35
		B Byker ash			B: Cu,Pb,Zn	
4	A	Ridgewood Crescent	40	97	Zn	88
5	A	Keebeldale Pigeons	10	98	Cu,Pb,Zn	440
6	A	Brunswick	20	99(coal)	Pb,Zn	373
7	A	Christen Rd	100	97/98	Cu,Pb,Zn	3535
8	A	Denton Dene	110	94, 95, 96, 97, 99	Cu,Pb,Zn	1636
9	A	Fenham Nursery	150	94, 95, 96, 97, 99	Cu,Pb,Zn	2521
10	A	Walkergate 3b	100	94, 96, 97, 99	Cu,Pb,Zn	976
11	A	Westmacott Str	100	94, 95, 96, 97	Cu,Pb,Zn	2123
12	B	Three Hills	140	95	Cu,Pb,Zn	415
13	B	near Feversham School	80	96	Zn	11
14	A	St Michael A	20	94	Cu,Pb,Zn	783
15	A	St Michael B	20	94	Cu,Pb,Zn	860
16	A	Walkergate 3A	70	95, 96, 97, 99	Cu,Pb,Zn	1932
17	A	Walker Road u	no ash from Byker		Pb,Zn	26
18	A	Walker Road u			Pb,Zn	34
19	A	Walker Road d			Cu,Pb,Zn	36
20	A	Walker Road d			Cu,Pb,Zn	88
22	A	Highbury, Jesmond, Control	no ash		Pb,Zn	13
23	A	Oxnam Crescent, Sandyford,	no ash		Pb,Zn	16

A: Allotment, B: Bridle Path, F: footpath

Table 6 Descriptive statistics of 16 Byker ash samples for heavy metals [mg/kg] and PCDD/PCDF in I-TEQ [ng/kg][1]

	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	I-TEQ
Dutch list	20	1	100	50	0.5	50	50	200	
Basler list							Target value		5
Mean	12	5.0	88	1195	0.2	55	399	659	1373
Median	**11**	**5.7**	**93**	**1045**	**0.2**	**45**	**407**	**548**	**918**
Minimum	7	0.4	13	10	0.1	14	17	31	11
Maximum	23	11.0	182	3620	0.6	187	620	1420	4224

[1]This analysis included the sample from near Feversham School, which is unlikely to have received ash from Byker, but was included in the list of sites,

The results are summarised by individual substance and by an analysis of the overall pattern of contamination of heavy metals and dioxins/furans. Levels were compared with the values of the Dutch list, which are trigger levels for further risk assessment as outlined in the protocol. In the discussion section other more detailed guidelines values are considered presented including the UK ICRCL values.

Arsenic - Sites above 20mg/kg: Walkergate A (Blyth ash) 84, Walkergate 3a 23, undisturbed soil 38,22, 2 out of 18 ash samples were affected, maximum exceedence of Dutch list value 4 times;

Summary: Overall arsenic contamination was not a major problem, the value at Walkergate is likely to be related to the arsenic content of the coal that was burned at Blyth at the time when the ash was created. The high arsenic content of this ash was consistent with the anecdotal evidence from allotment gardeners that no weeds have ever grown on the path for ten years.

Cadmium - Sites above 1mg/kg: Coxlodge 5, Lightwood Avenue 7, Keebledale 4, Brunswick 2, Christen Road 11, Denton 5, Fenham 5, Walkergate 3A 6, Westmacott 8, Three Hills 6, St Michael a 6, St Michael b 6, Walkergate 3a, 4, u: 2.5, d: 2. 13 out of 18 ash samples were affected, maximum exceedence of Dutch list value 11 times.

Summary: Cadmium contamination was considerable in a majority of sites.

Chromium - Sites above 100mg/kg: Lightwood Avenue 101, Christen Road 104, Denton 141, Fenham 126, Westmacott 115, St Michael a 182; 6 out of 18 ash samples were affected, the maximum exceedence of the Dutch list was two times.

Summary: Chromium contamination was measurable but was with one exception only just above the 100mg/kg. Overall chromium contamination was not a major problem in the ash samples. It is however noteworthy that in Lightwood Ave, Christen Road, Denton Dene and St Michael a the elevated chromium levels coexisted with elevated Nickel levels, possibly indicating a chromium/nickel source.

Mercury - Sites above 0.5 mg/kg: Walkergate 1, Highbury 1.15, undisturbed soil Walker Rd 1.13, 0.83, disturbed 0.98, 0.58, St Michael's 0.58. 1 out of 18 ash samples was affected with twice the level of the Dutch list, and the control site at Highbury.

Summary: Mercury contamination was not a major problem in any of the ash samples. The contamination at the control sites requires further clarification regarding possible sources.

Nickel - Sites above 50mg/kg: Lightwood 86, Christen Rd 187, Denton 77, Fenham 57, Walkergate 3a 54, Oxnam 70, u (17) 136. 6 out of 18 ash samples were affected; the maximum exceedence of the Dutch list was 3 times.

Summary: Nickel contamination was not a major problem. However, it coexisted with chromium contamination at those sites, which were affected indicating a possible chromium/nickel source.

Copper - Sites above 50mg/kg: Coxlodge 1180, Lightwood 3620, Walkergate Hospital B 576, Ridgewood 70, Keebledale 912, Brunswick 84, Christen Rd 2350, Denton 1360, Fenham 1770, Walkergate 3B 2330, Westmacott 1770, Three Hills 1070, St Michael's a 1020, St Michael's b 400, Walkergate 3a, 605, Oxnam Cr 155, u

(17): 292, u (18) 172, d (19) 430, d (20) 207. Samples not containing copper contamination or comparatively low contamination were Walkergate Hospital A (Blyth ash), Ridgewood Crescent (1997 rubber tyres), Brunswick (1999 Byker burning coal), Feversham School (overall very low 1996 delivery), Highbury. 16 out of 18 ash samples were affected, the maximum exceedence of the Dutch list was more than 70 times, and many exceedences were at least 20 times.

Summary: Copper was a major contaminant in the large majority of samples. Cu was massively elevated in those ash samples that were from the Byker incinerator before 1999. Those samples containing less Copper were those from Blyth ash, when rubber tyres or coal were burnt and from one control site.

Lead - Sites above 50mg/kg: Coxlodge 390, Lightwood 397, Walkergate Hospital A 186, Walkergate Hospital B 183, Keebledale 409, Brunswick 430, Christen Rd 619, Denton 512, Fenham 515, Walkergate 3b 481, Westmacott 590, Three Hills 399, St Michael's a 620, St Michael's b 338, Walkergate 3A 404, Oxnam Cr 579, Highbury 278, u (17): 1000, u (18) 480, d (19) 722, d (20) 693. 16 out of 18 ash samples were affected, the maximum exceedence of the Dutch list was 12 times, and many exceedences were at least 7 to 8 times.

Summary: Lead was a major contaminant in the large majority of samples. This included both Control samples in Sandyford and Jesmond

Zinc - Sites above 200mg/kg: Coxlodge 529, Lightwood 567, Walkergate Hospital B 369, Ridgewood 339, Keebledale 490, Brunswick 209, Christen Rd 1420, Denton 676, Fenham 1070, Walkergate 3b 1010, Westmacott 1180, Three Hills 952, St Michael's a 731, St Michael's b 446, Walkergate 3a 504, Oxnam Cr 334, Highbury 214, u (17): 1830, u (18) 402, d (19) 772, d (20) 431. 16 out of 18 ash samples were affected; the maximum exceedence of the Dutch list was 7 times.

Summary: Zinc was a major contaminant in the large majority of samples. This included both control samples in Sandyford and Jesmond.

Summary heavy metals and arsenic

13 out of 18 ash samples showed a characteristic pattern of simultaneously elevated levels of copper, lead and zinc. Levels were in the order of magnitude that would be expected in slag of municipal waste incinerators. There was no correlation between the quantity of ash delivered and the contamination with heavy metals. The sample from the path near Feversham School was distinctively different suggesting possibly a different origin other than the Byker incinerator. Walkergate Hospital A (ash from coal fired power station in Blyth), the sample from Ridgewood Crescent (rubber tyres) and Brunswick (Byker 1999 coal ash) all showed elevated levels of lead and zinc without elevated levels of copper. This may indicate that the copper, lead, zinc pattern found in other ash samples was characteristic for the Byker incinerator when it was operating by using refuse derived fuel.

The four soil samples from near the incinerator showed elevated levels of lead and zinc with slightly elevated levels of copper. This could be indicative of the localised influence.

PCDD/PCDF

Sites above 5ng/kg: Coxlodge 4224, Lightwood 2015, Walkergate Hospital A 16, Walkergate Hospital B 35, Ridgewood 88, Keebledale 440, Brunswick 373, Christen Rd 3535, Denton 1636, Fenham 2521, Walkergate 3b 976, Westmacott 2123, Three

Hills 415, Feversham School 11, St Michael's a 783, St Michael's b 860, Walkergate 3a 1932, Oxnam Cr 16, Highbury 13, u (17): 26, u (18) 34, d (19) 36, d (20) 88.

18 out of 18 ash samples had PCDD/PCDF levels above 5 ng/kg. The two Control samples and the sample near Feversham School were the lowest with just over 10ng/kg typical for background levels in industrialised conurbations. The maximum exceedence was more than 800 times over the target value of the Basler list. Levels of PCDD/PCDF were in line what could be expected in fly ash of municipal waste incinerators (*4, 11*). There was no correlation between the quantity of ash delivered and the contamination with PCDD/PCDF.

The pattern of the sums of dioxins and furans in most ash samples was zigzag shaped: increasing levels of dioxins towards higher levels of chlorination, low levels of total tetrafurans, increasing towards hexafurans, then decreasing again towards hepta and octa furans. 14 out of 16 Byker ash samples showed this pattern.

The sample taken near Feversham School had a completely different pattern, again indicating that the material put down there was possibly not derived from the Byker incinerator. The sample at St Michael's A did not show the pattern typical of the other sites, which received Byker ash. Its pattern could possibly be a combination of a deposition pattern and a Byker ash specific pattern.

Three out of four samples from near the incinerator of undisturbed and disturbed soil showed a typical bell shaped deposition pattern; the forth sample shows a mixed pattern of bell-shaped and zigzag pattern. PCDD/PCDF levels appear to correlate with high values of copper.

The two control samples showed pattern that were different from the other samples. The Highbury sample had very high levels of OCDD and a pattern that would be expected if metal processing had occurred on the site. The Oxnam Crescent sample showed a typical deposition pattern.

Summary

There was a massive contamination with PCDD/PCDF in a large majority of ash samples. Many values fell into the category where remediation of playgrounds or remediation of residential areas would be advised in addition to restrictions of agricultural use. There was no association of the contamination with the quantity of ash received, no trend over time was apparent. High PCDD/PCDF levels occurred together with high levels of copper.

5. DISCUSSION

While the protocol for the sampling of footpaths outlined that guideline values for soil were to be used as a basis for public health recommendations, it needs to be pointed out, that the project was concerned with an unusual exposure scenario. This was because exposure is from footpaths, not from soil. A similar exposure situation has not been previously reported. All existing guideline values and even the forthcoming UK CLEA guidelines for contaminated land do not specifically deal with scenarios similar to that found in Newcastle. It was however considered reasonable to use guideline values for soil in the absence of more specific information.

The Dutch list has been criticised for a lack of consideration of the type of use that any soil is put to. Some recent lists of guideline values for heavy metals have included consideration of the specific use of land (*12, 13*). Examples for the use of land as

playground, allotment or garden, sports fields, parks, and agriculture are shown in table 7. The forthcoming CLEA guidelines are also expected to incorporate a suitable for use principle (*9*).

It appears to be justified to consider the footpaths in allotment gardens to fall in the category allotment garden of these guidelines. The following picture emerged for the 16 samples of Byker ash: Arsenic: No samples exceeded 40 mg/kg, Cadmium: 12/16 samples exceeded 2 mg/kg, Chromium: 6/18 samples exceeded 100 mg/kg, Mercury: No samples exceeded 2 mg/kg, Copper: 15/16 samples exceeded 50 mg/kg, Lead: 13/16 samples exceeded 300 mg/kg, Zinc: 14/16 samples exceeded 300 mg/kg.

This consideration therefore further supports the recommendations given on March 31, 2000 with regard to children's activities on the footpaths and with regard to the requirement for further sampling of soil and vegetables.

Table 7 Recommended levels of heavy metals in soil with different uses (*8, 12, 13*)[1] in mg/kg soil (ICRCL in brackets)

	Play-ground	Allotment or garden	Sport field	Park	Agriculture
Arsenic	20-25	20-40 (10)	35 (40)	40 (40)	40
Cadmium	2-10	1-2 (3)	2 (15)	4 (15)	2
Chromium	50-200	70-100 (600)	150 (1000)	150 (1000)	200
Copper	50	50 (130)	100	200	50
Mercury	0.5-10	2 (1)	0.5 (20)	5 (20)	10
Nickel	40-70	70-80 (70)	100	100	100
Lead	200	200-300 (500)	200 (2000)	500 (2000)	500
Zinc	300	300 (300)	300	1000	300

[1] The ICRCL list distinguishes between contaminants which may pose a hazard: Arsenic, Cadmium, Chromium, Lead, Mercury, and those that are phytotoxic but not normally hazards to health: copper, nickel, zinc

With regard to PCDD/PCDF it is known since 1977 that fly ash from municipal waste incinerators contains PCDD/PCDF (*14*). Since then a number of studies have reported correlations between particle size and PCDD/PCDF concentration and between heavy metal concentration and PCDD/PCDF concentration (*11, 15-17*). The levels found in this study are well in line with those previously reported from fly ash of municipal waste incinerators (*4-6, 11*). Buekens and Huang reported a PCDD/PCDF content of filter ash of 4000 ng/kg; boiler ash 200 ng/kg, bottom ash 30 ng/kg and municipal solid waste 90 ng/kg, Broeker reported for German municipal waste incinerators before the introduction of more stringent control measures 100-800 ng/kg I-TEQ in bottom ash and 1000 to 28000 ng/kg in electro filter ash (*4*), Fiedler reported an average of 50 ng/kg I-TEQ for bottom ashes and 13000 ng/kg I-TEQ for fly ashes from municipal waste incinerators. On the other hand a new municipal waste incinerator was reported to have only 19 ng/kg I-TEQ in its bottom ash and 1100 ng/kg I-TEQ in its flyash (*6*).

The distribution of PCDD/PCDF around hazardous waste incinerators has been measured at a number of locations. While the number of samples in the current study was very small (n=4) the comparison with previously reported levels provides an indication of the order of magnitude that can be expected by deposition and fugitive emissions from waste incinerators. Deister and Pommer reported for municipal waste incinerator in a rural location in Germany PCDD/PCDF levels of between 0.2

and 4.4 ng/kg in 15 samples at distances between 350 and 750 m from the plant (*18*). Schumacher et al. reported in 1997 on PCDD/PCDF concentrations near a Spanish waste incinerator. They found 44 ng/kg at a distance of 750m (*19*). Abbott et al. reported in a study of dioxins around four waste incinerators in Hampshire in the UK between 0.6 and 160 ng/kg I-TEQ (*20*).

While analysis in this study has not taken into account a separation by particle size, the observations on particle size noted at the time of the sample collection supported the view that the material used on footpaths in Newcastle was a combination of slag and fly ash. This is consistent with the description of the process of waste incineration, which we received from Newcastle City Works, which indicted that fly ash and bottom ash/slag were combined.

Another consideration was UK background levels of soil. In 1989 Creaser et al reported on 78 samples taken from a 50-km grid across England, Scotland and Wales (*1, 20*), which were analysed for PCDD/PCDF. The median of these 78 samples are shown in table 8 alongside the levels of the six non Byker ash samples analysed in this study. The HMIP report also lists individual levels from urban locations in London and Birmingham which were higher than the averages. Another survey in rural and urban locations in 1995 reported a mean of 5.2 ng/kg I-TEQ (n=11) for rural locations and 28 ng/kg I-TEQ (n=5) for urban locations. From the vicinity of the Coalite Works in Bolsover 29 ng/kg I-TEQ (n=46) have been reported (*6, 21*). While the sample from Highbury in Jesmond (No 22) was mostly below the average background levels, samples from Walker Road (No 17-20, d = disturbed, u = undisturbed) were mainly well above those levels. This provided further indication of an elevation of levels in the vicinity of the incinerator. The levels in the sample from Oxnam Crescent (No 23) indicated contamination even though no ash from Byker was delivered there.

Table 8 PCDD/PCDF concentrations in 78 soil samples from England, Wales and Lowland Scotland in ng/kg (*1*)

Congener	Median	Standard deviation	Current study Sample Number (Code)					
			17 (WRu)	18 (Wru)	19 (WRd)	20 (WRd)	22 (HB)	23 (OC)
Total TCDD	6	36	10	77	107	51	27	58
Total PeCDD	5	22	55	101	128	65	45	57
Total HxCDD	31	86	235	225	243	134	95	111
Total HpCDD	55	96	356	265	372	195	259	148
OCDD	140	290	1110	694	1035	657	775	343
Total TCDF	16	83	88	417	382	742	94	246
Total PeCDF	17	83	122	239	287	771	76	150
Total HxCDF	32	88	220	217	312	298	107	166
Total HpCDF	15	65	354	189	253	164	156	139
OCDF	15	100	217	239	258	226	221	142

WR= Walker Road, u = undisturbed soil, d = disturbed soil, HB = Highbury, OC = Oxnam Crescent

For heavy metals the British Geochemical atlas provides maps of a 1-km grid of stream sediments (*22, 23*). Stream sediment levels can generally be expected to contain slightly higher concentrations of heavy metals than the soils through which they run. The levels for the Newcastle area are as follows: Arsenic 14-15 mg/kg, Cadmium 1-1.2 mg/kg, Copper 20-30 mg/kg, Nickel 50-60 mg/kg with hotspots around Blyth and the coal field, Lead 70 mg/kg with hotspots around Blyth with up to 300 mg/kg, Zinc 200 mg/kg away from industry, up to 600 mg/kg near industry, Chromium 100-150 mg/kg. From the comparison of data from ash paths and soil with these data the influence of both the fact that heavy metals occur naturally and the industrial heritage of the area became apparent. However, we believe that the consistency of the lead-copper-zinc pattern of contamination found in many samples which received Byker ash indicated the influence of the specific source, rather than being a reflection of an elevation of background levels in Newcastle.

A consideration for future risk assessment of the situation created by using ash on footpaths will be the bioavailability of any contamination. From the literature there is only one case of contamination, which may possibly resemble the situation in the current study. This is the usage of the copper slag ‘Kieselrot’ on playgrounds and sports fields in Germany (*24, 25*). 800,000 tones of slag from ore mining had been used during the 1950s and 1960s. This material was found to contain 64,500 ng/kg I-TEQ. In garden soil in the vicinity of a highly contaminated sports field a concentration of 154 ng/kg was detected. However, the bioavailability was found to be low: when the body burden of people with extensive recreational and occupational exposure to dust from Kieselrot slag was analysed only slightly elevated levels were detected (*26*).

An estimation of the daily intake of heavy metals and PCDD/PCD from the currently available data would be inappropriate due to too limited available samples. However, if further samples are to be taken from paths, which received ash, from soil, vegetable and egg samples this would be possible. The estimated daily intake attributable to Byker could then be compared with established daily intake figures and with the acceptable daily intakes set by various agencies.

6. KEY FINDINGS

1 13 out of 16 Byker ash samples showed a consistent pattern of very heavily elevated levels of copper, lead and zinc
2 There was considerable contamination with cadmium in a majority of ash samples
3 The contamination patterns of heavy metals varied in those samples, which had received ash only in one year
4 No serious copper contamination was found in samples from Blyth ash, rubber tyre ash, Byker 1999 coal ash, deposition samples and samples from Highbury and Oxnam Crescent
5 The high levels of contamination with copper were likely to be related to ash from Byker before 1999 (not deposition)
6 There was no correlation between the quantity of ash delivered and the level of contamination with heavy metals or PCDD/PCDF
7 Contamination with PCDD/PCDF was in the order of magnitude which would be expected in flyash
8 Contamination with PCDD/PCDF was highest in those samples with high copper contamination
9 Contamination with PCDD/PCDF in soil near the incinerator was much lower than in the ash, but still considerable; their pattern was different from ash samples, there was no correlation with heavy metal contamination
10 There was a consistent pattern of PCDD/PCDF in most ash samples indicating a Byker ash typical zigzag pattern.
11 The control sites in Highbury, Jesmond and Oxnam Crescent, Sandyford showed low contamination with PCDD/PCDF, the pattern in Sandyford was a typical deposition pattern, the one in Jesmond was typical of metal reprocessing.
12 Heavy metal and PCDD/PCDF concentrations on allotment and bridle paths were elevated to levels that a relevant uptake by small children who ingest material could not be ruled out.

7. CONCLUSIONS

- Contamination of soil by transfer from airborne dust, rainwater, and ash itself could not be ruled out especially in those allotments with a high contamination and a wide spread of ash across many paths
- Contamination of vegetables by deposition, inclusion of particles and systemic transfer (heavy metals only) could not be ruled out especially in those allotments with a high contamination and a wide spread of ash across many paths
- Contamination of soil with Cu,Pb,Zn and PCDD/PCDF in four samples from near the incinerator was such that a systemic uptake by consumption of vegetables or animal produce could not be ruled out.
- There was no serious contamination in ash samples and deposition samples with Arsenic, Chromium, Mercury or Nickel.

8. RECOMMENDATIONS (made to Newcastle and North Tyneside Health Authority and Newcastle City Council on March 31, 2000)

The contamination of ash samples from footpaths with heavy metals, especially lead and PCDD/PCDF was such that further risk assessment will be necessary in order to ascertain the potential for risk to the public health (aim 3). This study has identified that contamination exists on footpaths, which have received ash from the Byker incinerator.

The following recommendations were therefore made for further investigations:

1. To consider assessing the likelihood of transfer into soil, animals and vegetables, by sampling of heavy metals and dioxins/furans in soil and vegetables in allotments where elevated levels in ash on footpaths were found.
2. To consider sampling all other sites not included in the current protocol for heavy metals, which have received Byker ash,
3. To consider establishing the geographical spread of deposition by sampling of heavy metals and PCDD/PCDF in soil at varying distances from the Byker incinerator
4. To consider establishing the likelihood of PCDD/PCDF uptake by humans by the sampling of eggs, or chicken raised near the incinerator and in allotments which received Byker ash[1].

In the absence of detailed information about soil contamination in allotments where ash was used the following recommendations for the protection of the public health were made based on a precautionary principal:

- To consider advising parents to keep small children off affected allotment paths and bridle paths until the ash material is removed
- To consider advising allotment gardeners not to consume vegetables this year until results of the further testing for heavy metals in soil are available
- To consider establishing a register of allotment gardeners in Newcastle to enable health investigations if they should be required at a later stage
- To consider informing affected allotment gardeners as soon as possible.

9. PROGRESS SINCE MARCH 31, 2000

On April 7 2000 Newcastle Health Authority and Newcastle City Council issued precautionary advice following consultation of the findings and recommendations of the research team with the Department of Health, the Environment Agency and the Food Standards Agency:

- Children aged 2 and under should not play in the named allotments in order to avoid contact with the ash
- Eggs and poultry and other animal produce from the named allotments should not be consumed until further notice
- All produce from the named allotments should be thoroughly washed and root vegetables peeled before eating.

[1] this recommendation was slightly reworded after 31.03.200 to correct an error

At the same time Newcastle City Council asked the University of Newcastle to develop a protocol for further ash, soil, vegetable and egg sampling. A protocol for the sampling of eggs was agreed on April 14 2000 and 13 pooled egg samples from 11 allotments, which received ash and two control allotments are currently being analysed. The protocol for the sampling of ash, soil and vegetables are currently under consideration.

There are three differences between the recommendation of the research team and the precautionary advice issued by Newcastle City Council and Newcastle and North Tyneside Health Authority. With regard to vegetables the City Council agreed to sample but did advice thorough washing and peeling, with regard to eggs the City Council agreed to sample but also advised not to consume the eggs until sampling results are available. The precautionary advice issued by Newcastle City Council and Newcastle and North Tyneside Health Authority covered all named allotments, which had received ash, but not bridle paths. The recommendation of the research team had included footpaths in allotments and bridle paths. The research team considers these differences as non-substantive. The recommendations by the research team and the precautionary advice by Newcastle City Council and Newcastle and North Tyneside Health Authority were made following initial limited data using a precautionary principle and were therefore made with a high level of uncertainty about the true magnitude of the problem. The data of this study have revealed that a problem exists, however the extent of the problem needs to be assessed in future more detailed investigations.

10. REFERENCES

1. HMIP (Her Majesty's Inspectorate of Pollution). Determination of polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in UK soils ISBN 011 7522686. London: HMSO, 1989.
2. Niederlaendisches Ministerium fuer Wohnungswesen. Leirad Bodensanering, Prueftabelle. Gravenhage: Staatsuitgeverij's, 1984 as quoted in Hein 1999 (7)
3. Basler A. Dioxins and related compounds - Status and regulatory aspects in Germany. Environmental Science and Pollution Research 2:117-121(1995).
4. Broeker G, Bruckmann P, Hiester E, Krause G, Quass U. Belastung der Atmosphaere mit Dioxinen und Furanen: Emissionen und Imissionen. In: Handbuch Dioxine. Quellen, Vorkommen, Analytik (Oehme M, ed). Heidelberg:Spektrum Akademischer Verlag, 1998.
5. Buekens A, Huang H. Comparative evaluation of techniques for controlling the formation and emission of chlorinated dioxins/furans in municipal waste incineration. Journal of Hazardous Materials 62:1-33(1998).
6. Fiedler H, Buckley-Golder D. Compilation of EU Dioxin exposure and health data task 2 - Environmental levels Technical annex
http://europa.eu.int/comm/environment/dioxin/index.htm,
AEA Technology for the European Commission DG Environment and The Department of the Environment, Transport and the Regions (DETR), 1999.
7. Hein H, Schwedt. Richt und Grenzwerte Luft-Wasser-Boden-Abfall, Vogel 1999.
8. ICRCL Guidance on the assessment and redevelopment of contaminated land, 1987.
9. Earl N, Ferguson C. Human health risk assessment with particular reference to the CLEA model. In: Paper presented at seminar on contaminated land, Teesside, March 2000. Environment Agency, 2000.

10. Baker B, Kibblewhite M. New Legislation-New Opportunities Future regulation of contaminated land. In: Paper presented at seminar on contaminated land, Teesside, March 2000. Environment Agency, 2000.
11. Chang M-B, Chung Y-T. Dioxin contents in fly ashes of MSW incineration in Taiwan. Chemosphere 36:1959-1968(1998).
12. Eikmann T, Kloke A. Nutzungs und Schutzbezogene Orientierungswerte fuer Schadstoffe im Boden. In: Bodenschutz-ergaenzbares Handbuch der Massnahmen und Empfehlungen fuer Schutz, Pflege und Sanierung von Boeden, Landschaft und Grundwasser (Rosenkranz D, Einsele G, Harres M, eds). Berlin, 1993.
13. Barkowski D, Machtolf M. Bewertungsleitfaden Kleingaerten und Altablagerungen (Guidance for the assessment of allotments on contaminated land) W 980151. Bielefeld, Bitterfeld: IFUA Institute for Environmental Analysis, 1998.
14. Olie K, Vermeulen P, Hutzinger O. Chlorodibenzo-p-dioxins and chlorodibenzofurans are trace components of fly ash and flue gases of some municipal ininerators in the Netherlands. Chemosphere 6:455-459(1977).
15. Hinton W, Lane A. Characteristics of municipal solid waste incinerator fly ash promoting the formation of polychlorinated dioxins. Chemosphere 22:473-483(1991).
16. Hinton W, Lane A. Effect of zinc,copper, and sodium on formation of polychlinated dioxins on MSW incinerator fly ash. Chemosphere 25:811-819(1992).
17. Fiedler H. Quellen, Reservoire und Umwelrbelastungen von Boeden und Sedimenten. In: Handbuch Dioxine. Quellen, Vorkommen, Analytik (Oehme M, ed). Heidelberg, Berlin:Spektrum Akademischer Verlag, 1998;1-72.
18. Deister U. Distribution of PCDD/F in the vicinity of the hazardous waste incinrator at Schwabach. Chemosphere 23:1643-1651(1991).
19. Schumacher M, Granero S, Xifro A, Domingo J, Rivera J, Eljarrat E. Levels of PCDD/F in soil samples in the vicinity of a municipal waste incinerator. Chemosphere 37:2127-2137(1998).
20. Abbott J, Baker S, Coleman P, Dyke P, Fernandes A, Watterson J. A study of dioxins and trace metals in soil around four municipal waste incinerators in Hampshire Part 1: PCDD and PCDFs. Culham: Environment Agency Report HO-7/97-160-C-AZLM, 1997.
21. HMIP. Determination of PCB's, PCDD and PCDF in UK soils 2nd Technical report, HMSO quoted in Fiedler 1999, 1995.
22. British Geological Survey . Regional geochemistry of north-east England: Keyworth, 1996.
23. British Geological Survey. Regional geochemistry of Southern Scotland and part of Northern England: Keyworth, 1993.
24. Theisen J, Maulshagen A, Fuchs J. Organic and inorganic substances in the copper slag 'Kieselrot'. Chemosphere 26:881-896(1993).
25. Fiedler H, Hutzinger O, Lau C, Cikryt P, Hosseinpour J. Case study of a highly dioxin contaminated sports field: Environmental risk assessment and human exposure. Journal of Hazardous materials 43:217-227(1995).
26. Hygiene Institut des Ruhrgebiets Bd-I. Kieselrot-Studie Humanmedizinische Untersuchungen: Ministry for Health, Labour and Welfare Northrhine Westphalia, Germany, 1991.

11. TECHNICAL APPENDIX OF THE REPORT ON THE ANALYSIS OF PCCD/PCDF AND HEAVY METALS IN FOOTPATHS AND SOIL SAMPLES RELATED TO THE BYKER INCINERATOR

Maps of sampling locations

Results for each sampling location