PCCD/PCDF AND HEAVY METALS IN VEGETABLE SAMPLES FROM NEWCASTLE ALLOTMENTS:

ASSESSMENT OF THE ROLE OF ASH FROM THE BYKER INCINERATOR

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UNIVERSITY OF NEWCASTLE

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ABBREVIATIONS AND GLOSSARY OF TERMS

AAS	
As	
Bioavailability	
Body burden	
Bottom ash	
13C12	
Cd	
Cr	

AAS Atomic Absorption Spectroscopy*, analytical method for heavy metals*
As Arsenic
Bioavailability *The degree to which contaminants are taken up by plants,*
Animals, or humans that are exposed to them
Body burden *Total amount of a chemical substance in the human body*
Bottom ash *Fine material from the bottom of an incinerator*
13C12 A synthetically created dioxin/furan containing heavy carbon. *This substance* was *used to assess loss of material during preparation of samples*
Cd Cadmium
Cr Chromium
Cu Copper
Fly ash *Fine and ultrafine ash collected in incinerator stack by various filter systems*
Hg Mercury
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 Inductively coupled plasma emission spectroscopy; *analytical method to detect heavy metals*
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, this is the same as pg/g*
OCDD Octachlorodibenzodioxins, *Dioxin with eight chlorine atoms*
OCDF Octachlorodibenzofuran, *Furan with eight chlorine atoms*
Pb Lead
PCCD/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*
Stage 1 Initial investigation to assess whether ash on footpaths, which had received Byker ash was contaminated with dioxins/furans and heavy metals
TCDD Tetrachlorodibenzodioxin, *Dioxin with four chlorine atoms*
TCDF Tetrachlorodibenzofuran (Furan with four chlorine atoms)
Zn Zinc

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FOREWORD FROM THE BYKER ASH STEERING GROUP

This report outlines the results of an independent investigation into levels of dioxins and heavy metals in samples of vegetables grown in

allotments across Newcastle where ash from the Byker Incinerator/Heat Station had been used on footpaths. This report should be read in conjunction with the full technical report of "*PCCD/PCDF and Heavy Metals in Soil and Egg samples from Newcastle Allotments*" published earlier this year. The report will be shared with allotment gardeners, to give them the opportunity to consider the report and ask any questions. The main conclusions of the report are that there was no evidence for any measurable transfer of dioxins/furans into vegetables on the allotments, which had received Byker ash and that there was little evidence of any transfer of heavy metals from soil into vegetables.

The testing of soil, eggs and vegetables was instigated following the publication last summer of the report on the analysis of "*PCCD/PCDF and Heavy Metals in Footpaths and Soil Samples related to the Byker Incinerator".* This independent report produced by the University of Newcastle upon Tyne showed greatly raised levels of dioxins and some heavy metals in ash samples taken from allotment footpaths at a number of locations across the city.

As a response to that report, the Director of Public Health for Newcastle and North Tyneside Health Authority and the Head of Public Health and Environmental Protection for Newcastle City Council issued the following precautionary advice:

- Children aged two 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 should be peeled before eating.

This precautionary advice remains in place but will shortly be replaced by good practice guidelines which will be provided to all allotment holders whether or not they have been affected by the distribution of ash from the Byker Incinerator. The purpose of this new guidance is to provide general advice to all allotment holders about matters such as accident prevention, prevention of infection and avoidance of harmful chemicals.

The Steering Group for further investigations in relation to ash from the Byker Incinerator/Heat Station includes representatives from the Health Authority, City Council, Byker and Newcastle Waste Group, allotment gardeners, Environment Agency and the University of Newcastle. This group has overseen the investigation into this problem over the last few months. All of these agencies have contributed to the progress that has been made through robust and detailed discussion and although decisions have not always been unanimous, divergent opinions have been carefully considered and formally minuted.

1. SUMMARY

In May 2000, the University of Newcastle reported on the investigations into the contamination of footpaths on allotments by ash from the Byker incinerator. We reported considerable contamination with the heavy metals copper, lead, zinc, and with dioxins/furans.

As a result of these initial findings of ash on footpaths a range of follow-up investigations were carried out. These aimed to assess the extent to which the contamination of ash on footpaths had resulted in a transfer into soil and foods.

This is the second follow-up report. It covers the investigation of the possible transfer of dioxins/furans and heavy metals from ash and soil into vegetables.

We analysed 65 vegetable samples from 20 allotments. All sixty-five samples were analysed for heavy metals; thirty-two were analysed for dioxin/furans. The vegetables analysed were cabbage, carrot, turnip, courgette, beetroot, potato, parsnip and swede.

The average levels of all heavy metals in all types of vegetables were low. They were well below recommended guideline values for commercially grown foods and lower or well in line with levels in a National Total Diet Study from 1997. All levels of dioxin/furan were very low. This included courgettes, which are known to accumulate them.

We concluded that there was no evidence for any measurable transfer of dioxins/furans into vegetables on allotments, which had received Byker ash, and that there was little evidence for any transfer of heavy metals from soil into vegetables. We further concluded that regular consumption of vegetables from allotments, which had received Byker ash, would have resulted only in a minimal increase in the body burden for PCCD/PCDF. This is a similar minimal increase as would occur from eating vegetables from a supermarket. We recommend that no further investigations of vegetables grown on allotments or indeed allotment gardeners are required.

2. BACKGROUND AND AIMS

In May 2000, the University of Newcastle reported on the investigations into the contamination of footpaths on allotments by ash from the Byker incinerator [1, 2]. It contained data from 24 samples taken from 19 allotments. Sixteen of these samples were from footpaths of allotments that had received ash from the Byker Incinerator. Samples were analysed for their concentrations and patterns of heavy metals and dioxins/furans (PCCD/PCDF). 13 out of 16 ash samples showed

characteristic patterns of elevated levels of Copper, Lead and Zinc. Levels were consistent with those found in bottom ash (slag) from incinerators. The ash samples also showed massive contamination with dioxins/furans, with a median level of 918mg/kg I–TEQ (range 11 to 4224mg/kg I-TEQ). This level of contamination was consistent with levels expected in fly ash. The dioxin contamination showed a characteristic zigzag pattern in 14 out of 16 samples of Byker ash. This contrasts with a characteristic bell shaped curve normally associated with deposition from industrial processes such as incinerator emissions.

One of the main conclusions of the first report was that the contamination of ash samples especially with lead and dioxin/furans required further risk assessment. The report recommended that the likelihood of transfer into soil, animal and vegetables should be assessed in allotments, which had received Byker ash. Investigations into the transfer from ash into soil and eggs are already complete and the results have been published in as Executive Summary [3] and a Full Technical Report [4]. The key findings were that in 18 of 32 allotments sampled there was evidence of transfer of PCCD/PCDF into soil. Contamination of eggs was also demonstrated, with 17 out of 19 egg samples showing the influence of ash in the pattern of dioxins contamination. Although the heavy metals detected in the ash were also detected in soil samples the evidence suggested that this contamination was mainly not related to the deposition of Byker ash. It was more likely to be linked with previous land use or geological features.

The present report is the second follow-up report of the findings of contamination of ash. It covers the possible transfer of heavy metals and PCCD/PCDF from ash and soil into vegetables.

Aim

The aim of the current investigation was to assess transfer of PCCD/PCDF and heavy metals from ash and soil into vegetables.

Objective

The objective of the current investigation was to investigate levels (and pattern if appropriate) of contamination of vegetables with heavy metals and PCCD/PCDF.

The underlying hypothesis was that if contamination had occurred, levels of PCCD/PCDF and heavy metals in vegetables would be elevated.

Interpretation of the concentrations of heavy metals and PCCD/PCDF in food

When assessing the levels of PCCD/PCDF and heavy metals in vegetables we can compare levels with those documented in previous studies and we can compare them against relevant standards set by National and International bodies.

Table 1 shows the heavy metal data from the 1997 Total Diet Study conducted by the Ministry of Agriculture Food and Fisheries and the Department of Health [5].

Table 1 Results of the UK 1997 Total Diet Study in mg/kg [5]

Food group								
	As *10-3	**Cd** *10-3	**Cr**	**Cu**	**Pb** *10-3	**Hg** *10-3	**Ni** *10-3	**Zn**
Green vegetables	3	23	0.2	0.84	61	0.4	88	3.9
Potatoes	2	26	0.1	1.30	3	1.0	62	3.3
Other vegetables	5	11	0.1	0.91	15	0.6	78	2.4
Canned vegetables	1	6	0.1	1.50	12	0.9	31	4.2
Fresh fruit	2	2	<0.1	0.94	3	0.6	38	0.9
Fruit products	2	1	<0.1	0.73	18	0.8	48	0.7

Table 2 summarises guidelines relevant to the produce from allotment gardens. While these are useful as a yardstick for comparison, allotment produce, which is not commercially sold, would not fall under this legislation.

Table 2 Summary of relevant food legislation and guidelines for commercially sold vegetables

Heavy metal	**Level in mg/kg (fresh weight)**	**Legislation or guideline**
Arsenic	**1**	UK Arsenic in Food (Amendment) Regulations 1973
Cadmium	No UK or EU level **0.05** (vegetables and fruits excluding, leafy vegetables, fresh herbs, all fungi, stem vegetables, root vegetables and potatoes), **0.2** (leafy vegetables, fresh herbs, celeriac and all cultivated fungi), **0.1** (root vegetables and potatoes, excluding celeriac. For potatoes the maximum level applies to peeled potatoes)	EC Regulation 466/2001 will set limits for lead and cadmium from March 2002
Chromium	No UK or EU level	

Copper	**20**	Food Standards Committee guideline 1950
Lead	**1** **0.1** (vegetables excluding brassica, leafy vegetables, fresh herbs and all fungi. For potatoes the maximum level applies to peeled potatoes, **0.3** (brassica, leafy vegetables, and all cultivated fungi), **0.25** for potatoes	Lead in Food (Amendment) Regulations 1985 EC Regulation 466/2001 will set limits for lead and cadmium from March 2002
Mercury	No UK or EU level	
Nickel	No UK or EU level	
Zinc	**50**	Food Standards Committee guideline 1950
PCCD/ PCDF	No UK or EU levels	

3. Methods

Vegetable samples were collected from 20 allotments. Sixteen were allotments, which had received Byker ash, two were control allotments, for which soil data are available, and two were other allotment sites not included in the soil investigation and not having received ash. The sample collection took place between August 18 and November 1, 2000. A senior environmental health officer visited allotment holders at these sites. He collected fresh vegetable samples, recording the allotment plot number, the allotment holder's name, the length of time they had gardened the plot, and whether or not ash had been used on the plot (See table 3).

The type of vegetables collected was determined by knowledge of the transfer of heavy metals and PCCD/PCDF into vegetables. For instance, courgettes are known to accumulate dioxins via their root system and were therefore chosen to represent a worst case scenario (6). Leafy vegetables are subject to both deposition and uptake from the soil, and cabbages are known to incorporate soil particles as they grow. Those vegetables most likely to take up contaminants were selected. These were: Courgettes and cabbage for the analysis of PCCD/PCDF, leek, potato and carrot for the analysis of heavy metals.

Because the availability of specific vegetables was less than expected due to the very wet weather conditions throughout the summer of 2000 a range of different root vegetables were collected and analysed for heavy metals. In addition to the requirements of the study protocol the laboratory analysed all samples for heavy metals and some vegetables

other than courgettes or cabbage for PCCD/PCDF.

All vegetable samples were prepared in a way, which would normally be adopted for human consumption. This meant that all vegetables were washed, courgettes were topped and tailed, for cabbage the outer leaves were removed, leeks were topped and tailed, carrots were peeled and topped and tailed, potatoes were peeled. It had been intended to also include un-peeled potatoes in the analysis, however this did not happen. After preparation samples were deep-frozen and stored at minus 20oC. They were transported to the laboratory in a frozen state.

3.1 Analytical method

Vegetable, Preparation and Extraction
Vegetable samples were freeze-dried and subsequently extracted with hexane/acetone (1:1).

Polychlorinated Dibenzodioxins and Dibenzofurans
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 a silica column coated with DB 5. 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 (13C12). The analytical method follows the procedures of VDI 3499 Part 1: Measurement of polychlorinated dibenzo–p-dioxins and dibenzofurans. Samples were spiked with13C12 internal standards before extraction.

Heavy Metals
Samples were prepared using total digestion with hydrofluoric acid. 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 vapour technique.

3.2 Sampling locations

Table 3 shows the sampling locations of vegetables and documents details about the allotment plot, figures 1 and 2 illustrate the documentation of the collection of vegetable samples.

Table 3 Sampling locations and type of vegetables sampled

Name of allotment	Plot no.	Ash as soil con-ditioner	Type of vegetable sampled	Distance from ash path in cm

		[Y/N]		
Allotments which received Byker ash				
Branxton B	5/6, 7/8	NK	Cabbage (pooled)	100, 600
Brunswick	3	NK	Carrot	NK
	4	NK	Turnip	NK
	5	NK	Leek	NK
Christen Road	18, 33, 51	No	Cabbage (pooled)	800, 200, 500
	12, 41, 48	No	Courgette (pooled)	200, 75, 150
Coxlodge	31, 52/53	NK	Cabbage (pooled)	400, 300
Denton Bank	79	NK	Turnip	NK
	64	NK	Beetroot	NK
	50	NK	Turnip	NK
	46	NK	Turnip	NK
Denton Dene	23	NK	Potato	NK
	26	NK	Carrot	NK
	39	NK	Leek	NK
	40	NK	Leek	NK
	19, 26, 38	No	Cabbage (pooled)	NK
Fenham Model	30	NK	Potato	NK
(Nursery)	14b	NK	Leek	NK
	17	NK	Leek	NK
	17	NK	Turnip	NK
	9, 25, 35b	No	Cabbage (pooled)	100, 200, 200
Iris Brickfield	31	No	Turnip	NK
	10	No	Potato	300
	53	No	Turnip	NK
	18	No	Carrot	100
	18, 21	No	Courgette (pooled)	100, 100,270
Jesmond Vale Premier	6	No	Courgette	32
	NK	NK	Leek	NK
	NK	NK	Parsnip	NK
	NK	NK	Turnip	NK

.	NK	NK	Turnip	NK
Little Moor	106, 112	No	Courgette (pooled)	160, 210
.	125,114, 120	Yes	Cabbage (pooled)	NK
Nuns Moor	122	NK	Turnip	NK
.	68	NK	Turnip	NK
.	64	NK	Turnip	NK
.	1	NK	Leek	NK
.	88, 104, 118	No	Cabbage (pooled)	NK

Table 3 continued on next page

Table 3 continued from previous page

Tweed Street	5	NK	Turnip	NK
.	5	NK	Carrot	NK
.	1	NK	Leek	NK
Walkergate 3a	13	NK	Turnip	NK
.	15	NK	Leek	NK
.	8	NK	Potato	NK
.	9	NK	Carrot	NK
Walkergate 3b	6	NK	Courgette (pooled)	1170
.	8	NK	Parsnip	NK
.	8	NK	Swede	NK
.	8	NK	Beetroot	NK
.	7, 14	No	Cabbage (pooled)	300, 400
Walkergate Hospital	9, 10, 18	No	Cabbage (pooled)	80, 300, 150
.	13, 19, 25	NK	Courgette (pooled)	670, 120, 450
Westmacott Street	46, 54	No	Courgette (pooled)	27, 46
.	12	No	Cabbage	200
Allotments used as controls in the soil/egg investigation	.	.	.	.
Highbury North	2a	NK	Parsnip	NK
.	20a	NK	Swede	NK

	25	NK	Leek	NK
Oxnam Crescent	24	NK	Parsnip	NK
	13	No	Beetroot	NK
	19	No	Carrots	NK
	1	NK	Turnip	NK
Allotments which did not receive ash without soil data				
Longstone Square	8a	N/A	Cabbage	NK
	Not recorded	N/A	Courgette	NK
Three Mile	48	NK	Courgette	NK
	23	NK	Cabbage	NK

NK = Not known

Figure 1 and 2 Examples of the documentation of vegetable sampling

4. RESULTS AND DISCUSSION

We report results of a total of 65 vegetable samples, all of which were analysed for heavy metals, 32 were analysed for PCCD/PCDF. The breakdown by vegetable type was as follows:

Vegetable type	Total number of samples	Number of samples analysed for heavy metals	Number of samples analysed for PCCD/PCDF
Cabbage	12	12	12
Courgette	9	9	9
Carrot	6	6	1
Turnip	15	15	2
Swede	2	2	1
Parsnip	4	4	2
Beetroot	3	3	2
Potato	4	4	1
Leek	10	10	2
All	**65**	**65**	**32**

Fifteen results were from pooled samples, 45 were from single vegetables. Table 4 shows the median values and the range of the concentrations in vegetables in milligrams per kilogram fresh weight, table 5 shows the number of vegetable samples exceeding current and forthcoming guideline values for commercially grown vegetables.

The median levels of all heavy metals in all types of vegetables were low and well below current guideline values for commercially grown vegetables where these exist. They were lower or well in line with the

levels found in the 1997 Total Diet Study carried out by MAFF and DOH with the exception of arsenic. For arsenic levels in our Newcastle study were comparatively higher (though still low). One potato sample from plot 23 in Denton Dene allotment exceeded the recommended lead concentration of 1mg/kg fresh weight. The other three potato samples were below the detection limit. This resulted in a median value of four potato samples of 0.29mg/kg. As Denton Dene allotment does not have high soil levels of lead and because all other vegetables from Denton Dene allotment had low lead levels we recommend that the owner of plot 23 be interviewed to explore potential sources of lead in vegetables from this allotment plot.

All levels of PCCD/PCDF in all types of vegetables were very low. This also included courgettes, which are known to be able to accumulate PCCD/PCDF [6].

Table 4 Descriptive statistics of vegetable contamination with heavy metals (mg/kg)* and dioxins/furans (I-TEQ in ng/kg fresh-weight)

		Median (range)			
	As	**Cd**	**Cr**	**Cu**	**Pb Hg Ni Zn PCCD/ PCDF**
Beetroot	**0.02**	**0.02**	**0.03**	**0.79**	**0.070.00060.037.10.019**
	(0.019-0.024)	(0.0-0.02)	(0.010-0.050)	(0.75-0.94)	(0.04-0.08)(0.0006-0.0008)(0.01-0.09)(2.8-10.7)(0.017-0.020)
Cabbage	**0.01**	**0.01**	**0.03**	**0.20**	**0.010.00080.041.80.01**
	(0.01-0.01)	(<0.01-0.01)	(0.012-0.094)	(0.11-0.35)	(0.01-0.09)(0.0005-0.017)(0.02-0.20)(0.7-3.9)(<0.01-0.07)

Carrot	**0.02**	**0.012**	**0.01**	**0.31**	**0.060.00070.031.90.15**
	(0.02-0.03)	(<0.01-0.03)	(0.01-0.04)	(0.2-0.94)	(0.01-0.16)(0.0005-0.0008)(0.01-0.11)(1.6-4.4)1 sample only
Courgette	**0.01**	**0.001**	**0.02**	**0.37**	**0.010.00040.022.40.02**
	(0.01-0.01)	(0.01-0.002)	(0.01-0.05)	(0.25-0.49)	(0.004-0.067)(0.0001-0.0006)(0.01-0.04)(1.5-3.3)(0.01-0.03
Leek	**0.02**	**0.008**	**0.01**	**0.41**	**0.010.00050.032.40.02**
	(0.01-0.02)	(0.01-0.011)	(0.007-0.023)	(0.23-1.30)	(0.01-0.03)(0.0003-0.0007)(0.01-0.08)(1.6-4.0)(0.01-0.03)
Parsnip	**0.03**	**0.007**	**0.02**	**0.38**	**0.020.00100.074.00.05**
	(0.027-0.033)	(<0.01-0.01)	(0.017-0.037)	(0.02-1.13)	(0.01-0.09)(0.0009-0.0017)(0.02-0.12)(3.3-4.6)(0.02-0.07)
Potato	**0.03**	**0.006**	**0.05**	**0.92**	**0.290.00100.052.60.02**
	(0.03-0.04)	(<0.01-0.01)	(0.01-0.08)	(0.73-1.30)	(0.02-1.12)(0.0008-0.0012)(0.02-0.05)(2.1-3.0)1 sample only
Swede	**0.02**	**0.005**	**0.02**	**0.14**	**0.020.00050.021.10.06**
	(0.019-0.02)	(<0.01-0.01)	(0.01-0.03)	(0.12-0.15)	(0.01-0.02)(0.0005-0.0006)(0.01-0.03)(1.1-1.2)1 sample only
Turnip	**0.03**	**0.002**	**0.01**	**0.17**	**0.010.00050.031.30.01**
	(0.01-0.13)	(0.001-0.003)	(0.01-0.1)	(0.09-0.33)	(0.01-0.13)(0.0004-0.0005)(0.01-0.13)(0.8-4.5)(0.01-0.01)

* Levels below the detection limit were included in the calculation of the median with half the detection limit

While lead contamination in soil was reported for 18 out of 34 allotments [3], only six root vegetables from six allotments out of a total

of 65 vegetable samples from 20 allotments exceeded the future more stringent guideline value for lead in commercially grown vegetables. These were from Oxnam Crescent, Nuns Moor, Jesmond Vale Premier, and Tweed Street, all four of which are allotments with high levels of lead in the soil, which were unlikely to be linked to the deposition of Byker ash on the allotments [4]. Also, the exceedence of the lead guideline value in the potato sample from Denton Dene is unlikely to be linked to soil contamination with lead.

Table 5 Number of vegetable samples exceeding guidelines

Heavy Metal	Level in mg/kg (fresh weight)	Number of exceedences
Arsenic	1	0
Cadmium	0.1	0
Chromium	No UK or EU limit	N/A
Copper	20	0
Lead	1 0.1	1 6 (potato at Denton Dene 1.12) (potato at Denton Dene 1.12) (turnip at Nuns Moor 0.13) (parsnip at Oxnam Cres 0.51) (parsnip at Jesmond Vale Premier 0.12) (beetroot at Oxnam Cres 0.48) (carrot at Tweed Street 0.16)
Mercury	No UK or EU limit	N/A
Nickel	No UK or EU limit	N/A
Zinc	50	0
PCCD/PCDF	No UK or EU limit	N/A

Table 6 shows the levels of heavy metals and PCCD/PCDF for vegetables in individual allotments alongside the previously reported levels in ash and soil.

Table 6 Levels of heavy metals [in mg/kg] and PCCD/PCDF [in ng/kg I-TEQ] for individual allotments (in alphabetical order)

Branxton B			
Ash	**Soil**	**Cabbage**	
30cm	**150cm**		
Arsenic	20	28	27<0.02
Cadmium	13	1.9	2.1<0.005
Chromium	160	60	60<0.047
Copper	870	147	142<0.26
Lead	760	767	774<0.02

Mercury0.311.10.002
Nickel13041780.07
Zinc1100613584<0.02
PCCD/PCDF3000272900.010
Brunswick
AshSoilCarrotLeekTurnip
30cm150cm
Arsenic1035530.03<0.03<0.3
Cadmium1.81.32.30.010.03<0.002
Chromium1372820.0120.0090.117
Copper8467840.200.330.17
Lead430276369<0.020.02<0.02
Mercury0.10.20.20.002<0.001<0.001
Nickel3336300.020.040.08
Zinc2093275252.153.312.04
PCCD/PCDF37311NSTSNASNASNA
Christen Road
AshSoilCabbageCourgette
30cm150cm
Arsenic121413<0.02<0.01
Cadmium110.90.80.0020.0008
Chromium10447370.0940.019
Copper235080910.200.44
Lead6194063420.03<0.01
Mercury0.10.50.60.0010.00004
Nickel18735320.050.02
Zinc14203753301.802.5
PCCD/PCDF353551190.0090.010

SNA= Sample not analysed for PCCD/PCDF
< = Less than (these numbers indicate readings below the detection limit)

Table 6 continued on next page

Table 6 continued from previous page Heavy metals in mg/kg, PCCD/PCDF in ng/kg I-TEQ

Coxlodge				
AshSoilCabbage				
30cm150cm				
Arsenic101817	<0.02			
Cadmium5.40.80.80.01				
Chromium7848480.014				
Copper118069980.22				
Lead390380516	<0.01			
Mercury0.20.30.50.001				
Nickel3731300.05				
Zinc5292724831.57				
PCCD/PCDF422427280.009				
Denton Bank				
AshSoil				
30cm150cm				
Arsenic151212				
Cadmium160.50.5				
Chromium1703331				
Copper6306161				
Lead720234234				
Mercury<0.21.31.1				
Nickel1102220				
Zinc1200219240				
PCCD/PCDF31003524				
BeetrootTurnip 1Turnip 2Turnip 3				
Arsenic<0.04	<0.03	<0.04	<0.03	
Cadmium0.010.0020.0050.002				
Chromium0.0260.0320.0250.021				
Copper0.79	<0.001	<0.001	0.17	
Lead0.04	<0.02	<0.02	<0.02	
Mercury<0.001	<0.001	<0.001	<0.001	
Nickel0.090.030.050.13				
Zinc2.791.071.261.13				
PCCD/PCDFSNASNASNASNA				

SNA= Sample not analysed for PCCD/PCDF
< = Less than (these numbers indicate readings below the detection limit)

Table 6 continued on next page

Table 6 continued from previous page Heavy metals in mg/kg, PCCD/PCDF in ng/kg I-TEQ

Denton Dene
AshSoilCabbage
30cm150cm
Arsenic121213<0.03
Cadmium5.40.90.70.01
Chromium14135320.034
Copper136069580.15
Lead512310252<0.02
Mercury0.31.01.10.002
Nickel7725240.04
Zinc6763042411.27
PCCD/PCDF163634210.035
CarrotLeek 1Leek 2Potato
Arsenic<0.05<0.03<0.03<0.08
Cadmium0.0030.0070.0090.008
Chromium<0.0160.0210.023<0.025
Copper0.220.410.510.74
Lead0.03<0.02<0.021.12
Mercury<0.001<0.001<0.001<0.003
Nickel0.06<0.020.080.05
Zinc1.602.252.172.13
PCCD/PCDFSNASNASNASNA
Fenham Model (Nursery)
AshSoilCabbage
30cm150cm
Arsenic121214<0.02
Cadmium7.21.10.60.006

Chromium12634400.028
Copper117069540.15
Lead515222229<0.01
Mercury0.20.70.80.0006
Nickel5726270.03
Zinc10702362351.19
PCCD/PCDF2521113180.008
Leek 1Leek 2PotatoTurnip
Arsenic<0.05<0.03<0.07<0.04
Cadmium0.0140.006<0.0040.003
Chromium<0.0160.0100.0430.012
Copper0.230.560.920.18
Lead<0.03<0.02<0.04<0.02
Mercury<0.001<0.001<0.002<0.001
Nickel<0.030.04<0.040.02
Zinc3.262.022.422.92
PCCD/PCDF0.0130.0320.0230.012

SNA= Sample not analysed for PCCD/PCDF
< = Less than (these numbers indicate readings below the detection limit)

Table 6 continued on next page

Table 6 continued from previous page Heavy metals in mg/kg, PCCD/PCDF in ng/kg I-TEQ

Highbury North (Control)
Footpath (soil under grass cover**)Soil**
30cm150cm
Arsenic101211
Cadmium0.60.50.6
Chromium532930
Copper624547
Lead278210348
Mercury1.20.40.4
Nickel402624
Zinc214161175
PCCD/PCDF13910
LeekParsnipSwede
Arsenic<0.04<0.07<0.03

Cadmium0.0030.0110.006
Chromium0.0130.0210.035
Copper0.411.130.15
Lead<0.030.07<0.02
Mercury<0.001<0.002<0.001
Nickel<0.030.090.03
Zinc2.454.581.16
PCCD/PCDFSNASNASNA
Iris Brickfield
AshSoilCarrot
30cm150cm
Arsenic181615<0.05
Cadmium1.40.90.90.012
Chromium12022270.035
Copper1501011040.43
Lead8005054010.10
Mercury<0.21.31.9<0.002
Nickel12028320.04
Zinc3403473713.01
PCCD/PCDF1402121SNA
CourgettePotatoTurnip 1Turnip 2
Arsenic<0.02<0.07<0.03<0.03
Cadmium<0.003<0.065<0.028<0.028
Chromium0.0220.0860.0090.093
Copper0.380.920.190.33
Lead0.02<0.04<0.020.02
Mercury<0.0001<0.002<0.001<0.001
Nickel0.010.040.030.04
Zinc2.383.011.954.46
PCCD/PCDF0.029SNASNASNA

SNA= Sample not analysed for PCCD/PCDF, < = Less than (these numbers indicate readings below the detection limit),

Table 6 continued on next page

Table 6 continued from previous page Heavy metals in mg/kg, PCCD/PCDF in ng/kg I-TEQ

Jesmond Vale Premier
AshSoilCourgette

30cm150cm
Arsenic162016<0.02
Cadmium231.11.00.001
Chromium12029260.016
Copper61089830.26
Lead11001000756<0.01
Mercury0.30.90.80.0005
Nickel9946360.02
Zinc16009465261.49
PCCD/PCDF280017NS0.018
LeekParsnipTurnip 1Turnip 2
Arsenic<0.03<0.06<0.03<0.03
Cadmium0.0090.006<0.002<0.002
Chromium0.0120.0190.0200.010
Copper0.360.580.100.01
Lead0.030.12<0.02<0.02
Mercury<0.001<0.002<0.001<0.001
Nickel0.060.120.040.03
Zinc3.994.290.800.90
PCCD/PCDFSNASNASNASNA
Little Moor
AshSoilCabbageCourgette
30cm150cm
Arsenic131414<0.03<0.02
Cadmium151.30.60.007<0.003
Chromium12028290.0160.051
Copper520101660.230.21
Lead7103422550.050.03
Mercury520101660.0010.001
Nickel10022210.030.02
Zinc13003222541.892.37
PCCD/PCDF1800243210.0080.018
Longstone Square (Control)
Foot-pathSoilCabbageCourgette
30cm150cm
ArsenicNSTNSTNST<0.03<0.02
CadmiumNSTNSTNST0.002<0.001
ChromiumNSTNSTNST0.0270.013
CopperNSTNSTNST0.150.49
LeadNSTNSTNST<0.02<0.01

MercuryNSTNSTNST0.0010.001
NickelNSTNSTNST0.020.01
ZincNSTNSTNST1.342.46
PCCD/PCDFNSTNSTNST0.0110.016

SNA= Sample not analysed for PCCD/PCDF, <= Less than (these numbers indicate readings below the detection limit), NST= No sample taken, because not part of stage 1 Table 6 continued on next page
Table 6 continued from previous page Heavy metals in mg/kg, PCCD/PCDF in ng/kg I-TEQ

Nuns Moor
AshSoilLeek
30cm150cm
Arsenic192121<0.03
Cadmium111.41.40.007
Chromium11039330.010
Copper6401471330.48
Lead1400209012300.03
Mercury0.30.81.0<0.001
Nickel883833<0.02
Zinc12006626182.13
PCCD/PCDF11003438SNA
Turnip 1Turnip 2Turnip 3Cabbage
Arsenic<0.03<0.03<0.03<0.03
Cadmium0.002<0.0020.0020.008
Chromium0.0110.0110.0100.018
Copper0.190.130.160.23
Lead<0.020.070.130.09
Mercury<0.001<0.001<0.0010.001
Nickel<0.020.03<0.020.09
Zinc1.541.111.122.06
PCCD/PCDFSNASNASNA0.007
Oxnam Crescent (Control)
AshSoil
30cm150cm
Arsenic182223
Cadmium0.81.21.4
Chromium413535
Copper155108109
Lead5798751260
Mercury0.30.81.1
Nickel703637

Zinc334437615
PCCD/PCDF161415
BeetrootCarrotParsnipTurnip
Arsenic<0.04<0.04<0.05<0.03
Cadmium0.0150.0200.009<0.002
Chromium<0.0140.0130.017<0.011
Copper0.940.280.640.15
Lead0.480.080.51<0.02
Mercury<0.001<0.0010.002<0.001
Nickel<0.03<0.03<0.04<0.02
Zinc7.051.683.721.25
PCCD/PCDF0.0170.0150.0210.014

SNA= Sample not analysed for PCCD/PCDF
< = Less than (these numbers indicate readings below the detection limit)

Table 6 continued on next page

Table 6 continued from previous page Heavy metals in mg/kg, PCCD/PCDF in ng/kg I-TEQ

Three Mile (Control)
Foot-pathSoilCabbageCourgette
30cm150cm
ArsenicNSTNSTNST<0.02<0.01
CadmiumNSTNSTNST0.0040.009
ChromiumNSTNSTNST0.0120.018
CopperNSTNSTNST0.110.36
LeadNSTNSTNST<0.01<0.01
MercuryNSTNSTNST0.0010.0004
NickelNSTNSTNST0.020.04
ZincNSTNSTNST0.712.80
PCCD/PCDFNSTNSTNST0.0090.014
Tweed Street
AshSoilCarrotLeekTurnip
30cm150cm
Arsenic95329<0.05<0.02<0.04
Cadmium0.62.21.50.0270.0010.002
Chromium19052370.0150.0140.012

Copper661621440.410.260.14
Lead11011307520.160.01<0.02
Mercury<0.20.60.7<0.001<0.001<0.001
Nickel13039420.110.080.05
Zinc1807976404.371.611.87
PCCD/PCDF1919NSTSNASNASNA
Walkergate 3a
AshSoil
30cm150cm
Arsenic232823
Cadmium4.22.01.5
Chromium915049
Copper605139135
Lead404511537
Mercury0.30.50.4
Nickel545048
Zinc504971616
PCCD/PCDF193235NST
CarrotLeekPotatoTurnip
Arsenic<0.03<0.04<0.05<0.03
Cadmium0.0090.0110.005<0.002
Chromium0.010<0.0150.0540.023
Copper0.200.371.30.15
Lead0.05<0.03<0.03<0.02
Mercury<0.001<0.001<0.002<0.001
Nickel0.020.030.050.07
Zinc1.433.672.821.84
PCCD/PCDFSNASNASNASNA

SNA= Sample not analysed for PCCD/PCDF
< = Less than (these numbers indicate readings below the detection limit)
NST = No sample taken, because not part of stage 1

Table 6 continued on next page

Table 6 continued from previous page Heavy metals in mg/kg, PCCD/PCDF in ng/kg I-TEQ

Walkergate 3b
AshSoilBeetroot
30cm150cm
Arsenic152424<0.05
Cadmium5.91.71.40.022

Chromium9353650.050
Copper23301401480.75
Lead4814705870.07
Mercury0.21.42.0<0.002
Nickel4443430.03
Zinc101068270010.69
PCCD/PCDF97669680.020
CabbageCourgetteParsnipSwede
Arsenic<0.03<0.015<0.05<0.045.9
Cadmium0.004<0.0030.0050.003
Chromium0.0250.020.0400.012
Copper0.350.310.600.12
Lead0.020.040.020.02
Mercury0.020.00040.002<0.001
Nickel0.030.010.05<0.02
Zinc1.911.733.281.12
PCCD/PCDF0.0730.0140.0730.006
Walkergate Hospital (B=Byker ash)
AshSoilCabbageCourgette
30cm150cm
Arsenic8.42521<0.03<0.01
Cadmium1.01.31.10.003<0.002
Chromium7351490.0170.04
Copper5761571370.260.25
Lead183453408<0.020.02
Mercury0.20.70.50.0010.0004
Nickel3943400.200.01
Zinc3694974503.041.51
PCCD/PCDF3521NST0.0110.020
Westmacott Street
AshSoilCabbageCourgette
30cm150cm
Arsenic107.78.7<0.02<0.02
Cadmium7.80.60.70.0040.001
Chromium11529360.0260.012
Copper177043490.170.48
Lead177043490.17<0.01
Mercury0.20.20.20.0010.001
Nickel590198221<0.010.03
Zinc11803213301.973.26

PCCD/PCDF212345200.010.021

SNA= Sample not analysed for PCCD/PCDF, <= Less than (these numbers indicate readings below the detection limit), NST= No sample taken, because not part of stage 1

Table 7 Impact of consumption of vegetables from allotment, which received Byker ash on the human body burden of PCCD/PCDF

Assumptions	Results
• Person weighs 70kg	.
• 20% fat content of body = 14kg • Background body burden 15 pg/g fat I-TEQ	• Eating 500g of vegetable for 100 days (no excretion) adds 3.5ng to the body burden, total body burden 214ng = 15.3pg/g fat I-TEQ
• 1000 pg = 1ng	.
• Total background body burden: • 14 x 15 = 210ng	• Eating 500g of vegetable for 1000 days (no excretion) adds 35ng to the body burden, total body burden 245ng = 17.5pg/g fat I-TEQ
• Maximum PCCD/PCDF concentration 0.07ng/kg I-TEQ (worst case)	.
• Person consumes 500grams of potato and vegetable per day (worst case)	.

Table 7 shows the estimation of the impact of the occasional (100 days) and regular (1000 days) consumption of vegetables from allotments, which received Byker ash. We used a worst case scenario with the following assumptions: The highest detected PCCD/PCDF concentration found in the 32 vegetable samples of 0.07ng/kg I-TEQ was used, a portion size of 500g to reflect consumption of both potato and vegetables, and no excretion or metabolisation of PCCD/PCDF. The calculations show that vegetables from allotments, which received ash from the Byker incinerator showed negligible levels of uptake of both heavy metals and PCCD/PCDF indicating a low bioavailability of these compounds.

Key Findings 1, 2, and 3

There was no evidence for any measurable transfer of PCCD/PCDF into vegetables on allotments, which had received Byker ash

There was very little evidence of any transfer of heavy metals from soil into vegetables

Regular consumption of vegetables from allotments, which had received Byker ash, would have resulted only in a minimal increase in the body burden for PCCD/PCDF. This is a similar minimal increase as would occur from eating vegetables from a supermarket.

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Table 8 shows levels of heavy metals reported in a selection of other studies for comparison.

Table 8 Heavy metal and PCCD/PCDF levels from literature in those types of vegetables sampled in this study

Type of vegetable	Level (mg/kg fresh wt)	Source of data
Arsenic		
Cabbage	0.12	[7]
Courgette	0.11	[7]
Leek	0.07	[7]
Potato	0.07	[8]
	0.01	[9]
Cadmium		
Beetroot	0.05[10]	
Cabbage	<0.01[11]	
	0.095[12]	
	0.007(11)	
	0.01[10]	
Carrot	0.03[11]	
	0.52 dry weight[13]	
	0.04[14]	
Courgette	0.03[7]	
Leek	0.03[7]	
	0.05[10]	
Potato	0.12(9)	
	0.03[11]	
Copper		
Beetroot	0.8[10]	
Carrot	0.7[10]	
Leek	0.5[10]	
Potatoes	1.3[10]	

Lead		
Beetroot	0.2	[10]
Cabbage	0.006	[11]
	0.09	[10]
Carrot	0.04	(11)
	0.2	[10]
	0.06	[14]
Leek	0.07	[10]
Potato	0.02	[9]
	0.08	[12]
	0.03	[11]

Mercury	
Cabbage	0.003(7)
Carrot	<0.01[11]
Leek	0.001[7]
Potato	<0.01[9]
	<0.01[11]

Nickel		
Potato	0.68	[12]
Cauliflower	2.68	[12]
Cabbage	1.05	[12]

Zinc	
Cabbage	22[12]
Carrot	3.5[14]
Cauliflower	55[12]
Potato	12[12]

PCCD/F	**ng/kg I-TEQ**
Carrot	Control: 0.04 Contaminated: 0.10-0.12[15]
Courgette	0.3[16]
	0.5 to 55

	(dry weight)[17]
Fruit and vegetable	0.004-0.09[18]
Potato	0.3[16]

5. CONCLUSIONS

The investigation of the levels PCCD/PCDF and heavy metals in vegetables from allotments which received ash from the Byker incinerator showed negligible transfer of contaminants from ash and soil into vegetables.

6. RECOMMENDATIONS

We recommend that in the light of these findings the City Council and Health Authority review the precautionary advice regarding the consumption of vegetables grown on the allotments known to have received as from the Byker Incinerator. We also recommend that no further investigation of the vegetables grown on the allotments or of the allotment gardeners is required.

7. OVERALL CONCLUSIONS FROM REPORTS RELATED TO INVESTIGATIONS OF USE OF ASH ON FOOTPATHS

Stage 1 (May 2000):

- 13 out of 16 Byker ash samples showed a consistent pattern of very heavily elevated levels of copper, lead and zinc
- Contamination with PCCD/PCDF was in the order of magnitude which would be expected in flyash
- Contamination of soil by and vegetables could not be ruled out especially in those allotments with a high contamination and a wide spread of ash across many paths

Stage 2,3 (February 2001):

- **Transfer of PCCD/PCDF from ash into soil**: There was evidence for a transfer of PCCD/PCDF in 18 out of 32 allotments. Levels of contamination were such that limitation of agricultural use should be considered in nine allotments, consideration of remediation is required in five
- However, no clear link was demonstrated between the contamination with heavy metals and the deposition of Byker ash
- **Transfer of PCCD/PCDF into eggs:** 17 out of 19 egg samples from allotments, which had received Byker ash, showed the influence on the pattern of dioxin contamination. It was estimated that regular consumption of Byker eggs would have measurably elevated the body burden of PCCD/PCDF, while occasional consumption would have only had a minimal effect
- **Transfer of heavy metals from ash into soil:** There was little evidence for a transfer of heavy metals from ash to soil. However, there was considerable contamination in more than half of the allotments. These were likely to come from other unknown sources, and required consideration of further action

Stage 3 (July 2001)

• **Transfer of PCCD/PCDF into vegetables:** The transfer of PCCD/PCDF and heavy metals from soil and ash into vegetables was negligible.

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