Appendix 14.9 – Human Health Risk Assessment for Emissions from EfW (of substances which may persist or accumulate in the environment)

SCOPE OF ASSESSMENT

A.1.1 Comparison to European and national air quality standards effectively makes a health risk assessment for those pollutants for which a standard has been derived, as those air quality standards have been developed primarily in order to protect human health via known intake mechanisms, such as inhalation and ingestion. Indeed the Health Protection Agency (HPA) publication 'The Impact on Health of Emission to Air from Municipal Waste Incinerators', September 2009, concluded that:

A.1.2 "Modern, well managed incinerators make only *a small contribution to local concentrations of air pollutants. It is possible that such small additions could have an impact on health but such effects, if they exist, are likely to be very small and not detectable".*

A.1.3 That was based on a review of research undertaken to examine the suggested links between emissions from municipal waste incinerators and effects on health. The HPA's conclusion was based on detailed assessments of the effects of air pollutants on health and on the fact that modern and well managed municipal waste incinerators make only a very small contribution to local concentrations of air pollutants. The HPA also noted that the:

"Committee on Carcinogenicity of Chemicals in Food, Consumer Products and the Environment has reviewed recent data and has concluded that there is no need to change its previous advice, namely that any potential risk of cancer due to residency near to municipal waste incinerators is exceedingly low and probably not measurable by the most modern techniques. Since any possible health effects are likely to be very small, if detectable, studies of public health around modern, well managed municipal waste incinerators are not recommended".

A.1.4 More recently the 'Review of health effects of EfW facilities' January 2012, carried out by AEA Technology for the Environmental Services Association concluded:

"While there is always some uncertainty in the findings of health studies, it is concluded that well-designed EfW facilities as currently operated in the UK are most unlikely to have any significant or detectable effects on cancer incidence, the incidence of adverse birth outcomes (including infant mortality), or the incidence of respiratory disease".

A.1.5 Nevertheless this assessment is to evaluate on a site specific basis, the potential for a health risk to humans from possible exposure to emissions to air from the proposed EfW of substances which may persist and accumulate in the environment, and which may potentially cause adverse health effects through long term cumulative exposure.

Approach

A.1.6 Environmental and health risk assessment is normally based on the pollutant linkage concept, whereby a pollutant linkage comprises a pollutant source, a valid migration pathway and a likely receptor. If a pollutant linkage is demonstrated then there is a potential risk to a receptor, which may or may not require mitigation measures.

A.1.7 In the absence of a prescribe equivalent UK method, the approach adopted for this study is to apply the United States Environment Protection Agency (USEPA) Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities, EPA530-R-05-006 September 2005. That methodology entails:

- Characterizing the facility emissions and compounds of potential concern (COPC).
- Predicting the airborne and deposited concentrations of those COPCs at receptor locations.

- Characterizing the exposure setting and location, and the methodology provides recommended exposure scenarios for possible receptors.
- Estimating media concentrations of the COPCs, for example in air, soil, water and food.
- Quantifying the exposure from inhalation, ingestion and dermal exposure.
- Characterising the risk and hazard by quantitatively estimating the cancer risk and non cancer hazard.
- Interpreting the uncertainty and limitations of the risk assessment process.

A.1.8 This risk assessment has utilised the source-pathway-receptor concept to derive a conceptual model for the site and provide the framework within which assessment of the potential human health risks will be carried out. A conceptual model is used to summarise the potential pollutant sources and the possible hazards, and the processes that affect the transport of contaminants from the potential sources through the various migration pathways to potential receptors.

A.1.9 A pollutant source is generally identified as a potential cause of a hazard or statutory nuisance, and a pathway as a migration route by which the hazard or nuisance may impact a potential receptor. A pollutant linkage is defined as the relationship between a potential hazard or nuisance source (e.g. waste or dust), a pathway (e.g. permeable ground) and a receptor (e.g. humans or groundwater). Without the presence of a link between a hazard or nuisance source, a viable pathway and a receptor, a pollutant linkage does not exist and therefore there cannot be a risk to a receptor.

Conceptual Model

A.1.10 The conceptual model initially applied is summarised as:

- Potential emissions from the EfW which may lead to local ambient air and deposition of compounds of potential concern (COPC) at concentrations which could give rise to an unacceptable human health risk via inhalation, ingestion or dermal exposure to the emitted substances.
- Compounds of potential concern (COPC) are those for which emission limits are specified by the Industrial Emissions Directive and which are included in the HHRAP (2005) companion database of chemical specific parameter values for the assessment of human health effects.
- The ambient air and deposited concentrations will be as predicted from dispersion modelling and utilising appropriate precautionary assumptions.
- Receptor exposure will be as per the HHRAP (2005) recommended long term exposure scenarios, which are for: farmer, farmer child, resident, resident child, fisher, fisher child, for each of those exposure scenarios which are determined to be applicable to the EfW vicinity.
- The evaluation will be based upon conservative assumptions with respect to the emissions and receptor exposure. Initially the risk calculations will be carried out based on the maximum predicted ground level COPC concentrations, and the risk evaluated using default exposure values to indicate the risk to a hypothetical maximally exposed individual (HMEI).

A.1.11 As previously indicated comparison to air quality standards effectively makes a health risk assessment for those pollutants for which a standard has been derived, such as for some metals or metalloids. But some pollutants, such as dioxins and furans, may persist and accumulate in the environment and cause human health impacts at very low ingestion levels for which it is difficult to set a measureable air quality standard to control against, though emission limits apply. Nevertheless for those pollutants, a human health risk model can be utilised to evaluate the potential long term intake.

A.1.12 The subsequent sections consider each aspect of the conceptual model in turn, thereby determining the data and outlining the assumptions used to provide a site specific estimation of the potential human health risk from possible exposure to emissions to air from the proposed EfW, of substances which may persist and accumulate in the environment.

SOURCE – COMPOUNDS OF POTENTIAL CONCERN (COPC)

A.1.13 The substances which have been considered in the assessment are referred to as Compounds of Potential Concern (COPCs) and are mainly those for which emission limits are specified by the Industrial Emissions Directive (IED), and which are included in the HHRAP (2005) companion database of chemical specific parameter values for the assessment of human health effects.

A.1.14 Thallium is included that database, but the database does not include a reference dose, reference concentration or cancer slope factors for the evaluation of human health risk due to thallium. Furthermore the US EPA Integrated Risk Information System (IRIS), a human health assessment program that evaluates quantitative and qualitative risk information on effects that may result from exposure to environmental contaminants, no longer includes toxicity values for thallium. That is based on the US EPA's 'Toxicological Review of Thallium and Compounds', EPA/635/R-08/001F, September 2009, which supports the summary information on IRIS. However that publication acknowledges thallium causes toxicity in a wide range of target organs, and refers to a previous IRIS reference dose (RfD), but states there is insufficient data to derive an inhalation reference concentration (RfC). Nevertheless to ensure a robust appraisal thallium has been included in the risk evaluation using RfD and RfC values reported in an earlier version of HHRAP.

A.1.15 Also although the Industrial Emissions Directive also does not specify an emission limit for polycyclic aromatic hydrocarbons (PAHs), the Department of Environment in Northern Ireland, Planning and Environmental Policy Group publication 'Guidance on: Directive 2000/76/EC on the Incineration of Waste', edition 3, December 2011, Paragraph 6.45, lists sixteen PAHs which should be monitored for.

A.1.16 Therefore the COPCs to be evaluated are certain metals and dioxins and furans, as indicated in the following list, and also the PAH benzo(a)pyrene, there being an air quality limit for that substance in PM10 (particulate matter measuring 10цm or less), as well as for arsenic, cadmium and nickel in PM10.

- Antimony (Sb).
- Arsenic (As).
- Cadmium (Cd).
- Chromium (Cr), Hexavalent.
- Mercury (Hg).
- Lead (Pb).
- Nickel (Ni).
- Thallium (Tl).
- Benzo(a)pyrene.
- Dioxins and furans (individual congeners).

A.1.17 Other metals listed in the IED are cobalt, copper, manganese, and vanadium, but those are excluded from this assessment because they are not included in the HHRAP (2005) companion database and pose little or no hazard in the context of long term human health impacts.

COPC Concentrations

Emission Limits

A.1.18 The design and operation of incinerators is now governed by the European Communities' Industrial Emissions Directive (IED) 2010/75/EC, which requires adherence to emission limits for a range of substances, the limits relevant to this study being detailed in the following table

Table – Air Emission Limit Values specified in Annex VI of the IED (2010/75/EC)

Substance	Emission Limit
	Average values for minimum 30 minutes to maximum 8 hours
Cadmium and its compounds, expressed as Cd, and Thallium and its compounds expressed as Tl (hereafter referred to as Group 1)	Total 0.05
Mercury and its compounds, expressed as Hg (hereafter referred to as Group 2)	Total 0.05
Antimony and its compounds, expressed as Sb, Arsenic and its compounds expressed as As, Lead and its compounds expressed as Pb, Chromium and its compounds expressed as Cr, Cobalt and its compounds expressed as Co, Copper and its compounds expressed as Cu, Manganese and its compounds expressed as Mn, Nickel and its compounds expressed as Ni, Vanadium and its compounds expressed as V (hereafter referred to as Group 3)	Total 0.5
Dioxins and furans	0.0000001 as a 6 to 8 hour average of total concentration calculated using the concept of toxic equivalence in accordance with the IED Annex VI Part 2.
Notes: 1. All values mg/m3 at applicable at: temperature 273K, pressure 101.3kPa, 11% oxygen, dry gas.	

Emission Rates – Metals

A.1.19 As each Group 1 and Group 3 metal cannot be emitted at the IED emission limit values, each of the Group 1 metals to be evaluated has been assumed to be emitted at one ninth of the emission limit value for the total of the nine metals metal in that group, and each Group 1 metal has been assumed to be emitted at half the emission limit value for the two metals in that group. Hence with those assumptions the COPC specific emission concentrations are presented in the following table.

Table – Emissions of Metals for Normal Operating Conditions for the Proposed EfW at design load point LPB

Metal	IED Emission Limit Value[1] (mg/m3)	COPC Assumed Specific Emission Rate (g/s)
Cadmium	0.05	9.72E-04
Thallium		9.72E-04
Mercury	0.05	1.94E-3
Antimony	0.5	2.16E-3
Arsenic		2.16E-3
Chromium		2.16E-3
Lead		2.16E-3
Nickel		2.16E-3
Notes: At temperature 273K, pressure 101.3kPa, 11% oxygen, dry gas.		

A.1.20 As a proportion of chromium emitted could be chromium (VI), it is necessary to consider that possible fraction. The Environment Agency published an update 'Release from municipal waste incinerators Guidance to applicants on impact assessment for group 3 metals' September 2012 version 3. That publication provides a summary of nineteen measurements at thirteen municipal waste incinerators between 2007 and 2009 which indicates that total chromium typically represents on average 2.2% of the Group 3 metals emission limit value, with a range from 0.08% to 10.4%. It also provides a summary of the effective chromium (VI) emission concentration taken from ten municipal waste incinerators in England and Wales as: mean 3.5E-5mg/Nm3, minimum 2.3E-6mg/Nm3 and maximum 1.3E-4mg/Nm3. That data suggest chromium (VI) maybe around 0.3% of the total chromium emitted.

A.1.21 Therefore in the absence of actual data for the proposed EfW at Hightown Quarry, the risk evaluation has been carried out including chromium (VI) based on emissions of total chromium at one ninth of the IED aggregate limit of 0.5mg/m3 for the Group 3 metals, and an emission proportion of 1% of chromium (VI) to total chromium i.e. an emission rate for chromium (VI) of 0.00056mg/Nm3 (2.16E-5g/s). That is four times more than the maximum chromium (VI) emission indicated in the Environment Agency September 2012 guidance for Group 3 metals.

A.1.22 The HHRAP (2005) methodology also recommends accounting for the mercury global cycle, and provides default values for the phase allocation and speciation of mercury in air. Those have been applied for this risk assessment, namely that of the total mercury emitted 51.8% is lost to the global cycle, 48.0% is deposited as divalent mercury and 0.2% is emitted is deposited as elemental mercury. However HHRAP (2005) assumes that human exposure to elemental mercury occurs only through direct inhalation of the vapour phase i.e. it ignores the 0.2% deposited. It assumes exposure to divalent mercury as mercuric chloride occurs via inhalation and ingestion, with 2% speciated into methyl mercury in soil.

Emission Rates – Polycyclic Aromatic Hydrocarbons

A.1.23 The European Commission IPPC Reference Document on the Best Available Techniques for Waste Incineration August 2006, indicates that averages of total PAHs in flue gas from municipal waste incineration plants are likely to be less than 0.01mg/Nm3 and reports that "The available data show values range from <1µg/Nm3 to <0.01µg/Nm3. Here also, a critical analytical remark has to be made about the variability of the reported detection limits of the measurement methods".

A.1.24 For comparison data relating to actual emissions from EfW plants in the UK, has been considered via that reported in the draft Determination of an Application for an Environmental Permit under the Environmental Permitting (England & Wales) Regulations 2010 published 7th September 2012 for permit number EPR/LP3936KF for a 275,000tpa EfW, the New England Quarry Resource Recovery Centre, Ivybridge, Devon. The document reports the Environment Agency extracted monitoring data at a number of UK regulated sites between 2009 and 2011 (totalling 13 samples) which determined there was a maximum total PAH concentration of 1.2µg/Nm3, with a maximum benzo(a)pyrene concentration of 0.087µg/Nm3.

A.1.25 Therefore to provide a robust risk evaluation of PAHs, an emission concentration 2.5 times that maximum 1.2µg/Nm3 total PAH concentration has been used, i.e. 0.003mg/Nm3 (1.17E-4g/s), and those PAH emissions assumed as benzo(a)pyrene because the Air Quality Framework Directive 96/62/EC uses that substance as a marker for the carcinogenic risk of polycyclic aromatic hydrocarbons in ambient air.

Emission Rates – Dioxins and Furans

A.1.26 'Dioxins' is a general term used to refer a group of 210 polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans which have similar chemical structures. The general term dioxins denotes a family of compounds, with each compound composed of two benzene rings interconnected with two oxygen atoms. There are 75 individual dioxins, with each distinguished by the position of chlorine or other halogen atoms positioned on the benzene rings. Furans are similar in structure to dioxins, but have a carbon bond instead of one of the two oxygen atoms connecting the two benzene rings. There are 135 individual furan compounds. Each individual furan or dioxin compound is referred to as a congener and each has a different toxicity and physical properties with regard to its atmospheric behaviour. Most of these compounds pose no health hazard at the levels commonly found but seventeen of them are of more toxicological concern. The most toxic dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and most of the available data refer to that compound.

A.1.27 The IED specifies an emission limit value for the seventeen dioxins and furans of most toxicological concern as a total concentration, calculated using the concept of toxic equivalence in accordance with its Annex VI Part 2, which gives toxic equivalence factors (TEF) as per the International Toxicity Equivalency Factor (I-TEF) system. For the determination of the total concentration of dioxins and furans in relation to the IED emission limit, the mass concentrations of the eight dibenzo-p-dioxins and nine dibenzfurans listed need to be multiplied by the equivalence factors before summing. The toxic equivalence factors (TEF) are in relation to the toxicity of 2,3,7,8 — Tetrachlorodibenzodioxin (TCDD) which has a TEF of 1, the other dioxins and furans having lower TEF values.

A.1.28 Therefore it is necessary to utilise congener specific emission rates, which in the absence of actual measurements necessitates assuming a congener profile. A commonly used congener profile is that from Table 7.2a of Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes, 1996, DOE Contract No. HMIP/CPR2/41/1/181. But since that publication the composition of municipal and commercial waste for disposal by incineration is likely to have changed, and that congener profile may not apply for emissions from a modern incinerator with more technologically advanced flue gas treatment.

A.1.29 A later publication, the AEA Energy and Environment report 'Investigation of Waste Incinerator Dioxins', AET/ENV/R/2563 Issue 1, November 2008, commissioned by the Environment Agency, details more recent dioxin measurements of a large EfW (350,000 tonnes per annum capacity) whose general combustion and pollution abatement technologies are similar to most UK facilities. The report includes a 'Summary of analytical data provided by Harwell Scientifics' as its Table A3-1, and an un-weighted congener profile for normal operation as its Figure A5-1. That alternative congener profile is only based on one facility but would reflect the composition of more recently sourced waste in the UK and more modern incineration and flue gas treatment technology.

A.1.30 An alternative congener profile is that used by the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission for Air Pollutants in Europe (EMEP) is published in its Status Report (3/2012 June 2012) Persistent Organic Pollutants in the Environment, and a Technical Report (4/2012 August 2012) Heavy metals and organic pollutants: New developments, which details recent revision of the congener profile used for dioxin and furan emissions to ensure its model predictions better reflect measured data for airborne and depositing dioxins and furans. For consistency with that overall risk perspective there is logic to using that EMEP 2012 congener profile for emissions from the proposed EfW, though the study acknowledges that the congener composition of emissions in a country strongly depends on contributions of particular source categories to total emission. Hence the EMEP 2012 congener profile is unlikely to representative of emissions solely from an EfW.

A.1.31 The following table provides a comparative list of the congener profiles from the HMIP 1996, AEA 2008 and EMEP 2012 reports, and emission rates based on the AEA 2008 report have been used because they are for a modern EfW. To ensure a robust appraisal sensitivity analysis has been carried out using the other two congener profiles also, and those were found to give a lower estimated average daily intake.

Table – Emissions of Dioxins and Furans

Congener	Percent of Emission			Emission based on AEA 2008 ng/Nm3	IED I-TEF	IED I-TEQ ng/m3	Emission Rate (g/s)
	HMIP 1996	AEA 2008	EMEP 2012				
2,3,7,8-TCDD	0.15	0.06	4.00	0.0022	1.0	0.0022	8.53E-11
1,2,3,7,8-PeCDD	1.24	0.91	15.10	0.0360	0.5	0.018	1.40E-09
1,2,3,4,7,8-HxCDD	1.44	1.14	1.70	0.0450	0.1	0.0045	1.75E-09
1,2,3,6,7,8-HxCDD	1.29	4.72	4.30	0.1867	0.1	0.01867	7.26E-09
1,2,3,7,8,9-HxCDD	1.04	1.14	4.10	0.0452	0.1	0.00452	1.76E-09
1,2,3,4,6,7,8-HpCDD	8.42	19.59	5.20	0.7740	0.01	0.00774	3.01E-08
OCDD	19.82	57.42	0.30	2.2690	0.001	0.002269	8.82E-8
2,3,7,8-TCDF	1.34	0.34	7.60	0.0134	0.1	0.00134	5.21E-10
2,3,4,7,8-PeCDF	2.68	0.76	32.75	0.0301	0.5	0.01505	1.17E-09
1,2,3,7,8-PeCDF	1.39	0.55	1.70	0.0216	0.05	0.0011	8.40E-10
1,2,3,4,7,8-HxCDF	10.90	0.92	7.60	0.0363	0.1	0.00363	1.41E-09
1,2,3,6,7,8-HxCDF	4.01	1.59	5.00	0.0628	0.1	0.00628	2.44E-09
1,2,3,7,8,9-HxCDF	0.21	0.69	1.90	0.0271	0.1	0.00271	1.05E-09
2,3,4,6,7,8-HxCDF	4.31	2.48	6.30	0.0979	0.1	0.00979	3.81E-09
1,2,3,4,6,7,8-HpCDF	21.80	4.34	2.10	0.1715	0.01	0.001715	6.67E-09
1,2,3,4,7,8,9-HpCDF	2.13	1.03	0.35	0.0405	0.01	0.000405	1.57E-09

Congener	Percent of Emission			Emission based on AEA 2008 ng/Nm3	IED I-TEF	IED I-TEQ ng/m3	Emission Rate (g/s)
	HMIP 1996	AEA 2008	EMEP 2012				
OCDF	17.84	2.34	0	0.0923	0.001	0.0000923	3.59E-09
Totals	100	100	100	3.9516	N/A	0.1000	1.54E-07

Prediction of Airborne and Deposited Concentrations

A.1.32 The HHRAP (2005) methodology utilises air dispersion and deposition modelling to predict airborne and deposited concentrations from the vapour and particle phases and for dry and wet deposition. The Environmental Statement Chapter 14 Air Quality included dispersion modelling which was carried out using the US EPA produced AERMOD dispersion modelling software, and the ADMS 5 dispersion modelling software produced by Cambridge Environmental Research Consultants (CERC).

A.1.33 The HHRAP (2005) methodology entails additional input parameters and assumptions, though those can also lead to increased uncertainty. Therefore this assessment has utilised the Environmental Statement Chapter 14 Air Quality dispersion modelling approach and results, but with some simplifying conservative assumptions to application of the HHRAP (2005) methodology.

A.1.34 HHRAP (2005) indicates that COPC emissions to the environment occur in either the vapour of particle phase. It states that in general it can be assumed that:

- "Most metals and organic COPCs with very low volatility (fraction of COPC in vapour phase, Fv, less than 0.05), occur only in the particle phase.
- Highly volatile organic COPCs occur only in the vapour phase (Fv of 1.0)
- The remaining organic COPCs occur with a portion of the vapour condensed onto the surface of particulates (i.e. particle-bound)."

A.1.35 For this assessment that assumption has been applied based on the COPC Fv values assigned in the HHRAP (2005) companion database of chemical specific parameters. An exception is antimony because the HHRAP (2005) companion database assigns a Fv value of 1 for antimony, whereas that is unlikely because antimony has a high boiling point and the HHRAP (2005) Appendix A-2 indicates that metals (except mercury) were assumed to be present predominantly in the particulate phase and not in the vapour phase. Therefore it has been assumed that antimony only occurs in the particle phase.

A.1.36 In order for the dispersion models to predict total gas deposition and deposition of particulate mass, it is necessary to at least assign values for gas deposition velocity, and particle information for each substance, which for example for the latter may require information on the particle density and diameter. The dispersion models have gas deposition algorithms which calculate deposition velocities, however those require further COPC and site related data (e.g. related to the vegetation cover), and hence it is simpler to assign a single gas deposition velocity.

A.1.37 For the proposed EfW there is no measurement data on particle information for each COPC, therefore those values would have to be assigned based on published data. A literature search has indicated that published values such as those in Appendix B of 'Deposition Parameterizations for the Industrial Source Complex (ISC3) Model', Environmental Research Division, Argonne National Laboratory, June 2002, commissioned by the US Department of Energy, could be used, but there is no certainty published values would be in line with the proposed EfW's characteristics i.e. the waste input composition, incineration process or the flue gas treatment systems. HHRAP (2005) recommends a minimum of three particle size categories be used in air modelling, with >10μm, 2-10μm and <2μm being most sensitive to modelling. However it is likely the maximum size of particles passing through the EfW bag filtration system would be no more than 0.1μm, and HHRAP (2005) indicates that in some circumstances a single mean particle size diameter of 1.0μm may be used to represent all mass for modelling of particle or particle bound runs.

A.1.38 The dispersion models can also be set to calculate plume depletion with dry and wet removal, which may provide a different pattern of predicted concentrations compared to the no depletion option, though the latter option will result in overestimates of both concentrations and deposition, and will therefore be conservative. However for wet deposition, the meteorological data must have the necessary precipitation and associated parameters, but those data are not within the meteorological data available and used for the Environmental Statement Chapter 14 Air Quality.

A.1.39 Therefore for simplicity and consistency with the Environmental Statement Chapter 14 Air Quality the following assumptions have been applied:

- The total air concentration from the vapour and particulate phases has been taken as the maximum annual process contribution (PCair) at specific receptor locations as predicted by the dispersion modelling for the Environmental Statement Chapter 14 Air Quality.
- A dry deposition velocity of 0.01m/s has been utilised for inorganic substances (metals), because that accords with the value to be used for screening purposes indicated in the Environment Agency's permitting guidance H1 Annex F – Air Emissions, and the EfW flue gas treatment system should ensure predominantly only very small particles are emitted. As per HHRAP (2005) a dry deposition velocity of 0.029m/s has been utilised for divalent mercury (mercuric chloride) and 0.005m/s for organic substances i.e. benzo(a)pyrene, dioxins and furans.
- Total particulate deposition has been estimated in line with the H1 Annex F – Air Emissions screening guidance, such that PCground = (PCair x RR x deposition velocity x 3 x 86400 x 365.25) / 10^6, where PCground = process contribution as annual deposition rate (g/m2/year. The value 86,400 x 365.25 is a correction factor from per second to per year, and the value 3 is a nominal factor to convert dry deposition to total deposition. Therefore dry deposition has been taken as one third of PCground, and wet deposition as two thirds of PCground.

A.1.40 In line with HHRAP (2005) methodology, the dispersion models run with a unit emission rate (1g/s) gives unitized yearly air concentrations, from which the dry and wet deposition has been estimated using the methodology described for each of the meteorological data years 2004 to 2012. The predicted ground level concentrations for a unit emission rate (1g/s) are provided in Appendix A for site specific receptors. At a specific receptor location the maximum unitized value multiplied by the COPC emission rate (g/s) gives the maximum COPC air or deposited concentrations for each phase at that location.

PATHWAY TO RECEPTORS – EXPOSURE SCENARIOS

Recommended Exposure Scenarios

A.1.41 HHRAP (2005) provides recommended exposure scenarios, as detailed in the following table.

Table – Recommended Exposure Scenarios For a Human Health Risk Assessment

Exposure Pathways	Recommended Exposure Scenarios[1]					
	Farmer	Farmer Child	Resident	Resident Child	Fisher	Fisher Child
Inhalation of Vapours and Particulates	*	*	*	*	*	*
Incidental Ingestion of Soil	*	*	*	*	*	*
Ingestion of Drinking Water from Surface Water Sources	*	*	*	*	*	*
Ingestion of Homegrown Produce	*	*	*	*	*	*
Ingestion of Homegrown Beef	*	*	--	--	--	--
Ingestion of Milk from Homegrown Cows	*	*	--	--	--	--
Ingestion of Homegrown Chicken	*	*	Note 4	Note 4	Note 4	Note 4
Ingestion of Eggs from Homegrown Chickens	*	*	Note 4	Note 4	Note 4	Note 4
Ingestion of Pork	*	*	--	--	--	--
Ingestion of Fish	Note 4	Note 4	Note 4	Note 4	*	*
Ingestion of Breast Milk	Note 3	--	Note 3	--	Note 3	--

Notes: * Pathway is included in exposure scenario. -- Pathway is not included in exposure scenario.

1. Exposure scenarios are defined as a combination of exposure pathways evaluated for a receptor at a specific location.

2. Acute receptor scenario not included (inhalation pathway only) has this assessment is to evaluate health effects which may be caused through long term cumulative exposure.

3. Infant exposure to dioxin and furans via the ingestion of their mother's breast milk is evaluated as an additional pathway separately from the recommended exposure scenarios identified in this table.

4. Site specific exposure setting characteristics may warrant including this exposure pathway to the scenario.

A.1.42 The methodology indicates that if evaluation of receptors using a combination of:

- a recommended exposure scenario expected to overestimate exposure compared to the actual receptor, and
- the maximum modelled air parameter values specific to the location,

A.1.43 suggests that the receptors are protected, then no additional assessment is necessary.

A.1.44 Broadly that is the approach followed by this assessment, as that will indicate the risk to a hypothetical maximally exposed individual (HMEI) at a specific location. The exception is for watershed areas for which the average predicted ground level COPC concentrations within a watershed area has been estimated and utilised, because the maximum predicted ground level COPC concentration would not be representative of a watershed area.

A.1.45 The following sections consider the receptors and pathways for the site specific locality.

Site Specific Receptors: Human

A.1.46 The following table is replicated form the Local Air Quality Assessment and provides details of the nearest potential human receptors which are mainly dwellings and areas utilised by humans, around the Hightown Quarry.

Table – Indicative Receptors

No.	Potential Receptor & Grid Reference	Receptor Type – e.g. Farm or Residence only	Details Relative to EfW Stack		
			Distance (m)	Elevation (mAOD)	Direction
1	35 Boghill Rd. (329050, 381470)	Farm	1294	161.33	N
2	34 Boghill Rd. (329190, 381220)	Residence	1045	169.33	N
3	32 Boghill Rd. (329140, 380990)	Farm	812	184.11	N
4	26 Boghill Rd. (329370, 381110)	Residence	967	173.67	NNE
5	102 Upper Hightown Rd. (330330, 381140) proxy for Newtownabbey	Residence	1551	193.00	NW
6	100 Upper Hightown Rd. (330350, 381130) proxy for Newtownabbey	Farm	1561	193.67	NW
7	62 Upper Hightown Rd. (330120, 380370)	Farm	1025	210.00	E
8	43 Flush Rd. (330130, 379600)	Farm	1170	284.00	SE
9	53 Flush Rd. (329540, 379360)	Farm	923	280.67	SSE
10	85 Flush Rd. (329300, 379520)	Farm	684	262.00	S
11	55 Flush Rd. (329160, 379100)	Residence plus possible industry	1079	279.00	S
12	69 Flush Rd. (329080, 379260)	Farm	919	276.00	S
13	120 Flush Rd. (328620, 380230)	Residence plus possible industry	496	244.67	W
14	133 Flush Rd. (328450, 380510)	Farm	742	223.00	WNW
15	148 Flush Rd. (328250, 380820)	Farm	1076	217.67	NW
16	149 Flush Rd. (328260, 380850)	Residence	1086	218.00	NW
17	151 Flush Rd. (328240, 380900)	Residence	1133	220.00	NW
18	55 Boghill Rd. (328390, 381200)	Residence	1252	206.89	NNW
19	45 Boghill Rd. (328730, 381390)	Residence plus business premises	1271	187.67	NNW
20	40 Boghill Rd. (328860, 381190)	Residence	1043	181.67	NNW

No.	Potential Receptor & Grid Reference	Receptor Type – e.g. Farm or Residence only	Details Relative to EfW Stack		
			Distance (m)	Elevation (mAOD)	Direction
21	Belfast Centre AURN Site 103 (333900,374400)	Belfast monitoring station	7503	5	SSE

Notes: Distance is from centre of EfW stack. Elevation is as interpolated from the terrain data by the dispersion model software (Aermap).

A.1.47 Therefore for the proposed EfW it is necessary to at least evaluate the resident/resident child and farmer/famer child exposure settings. In addition the nearby surface waterbodies Boghill Dam and Hydepark Dam, are thought to be used by anglers, and though notable consumption of fish from those water bodies is unlikely, it will also be prudent to evaluate the fisher adult and child exposure settings.

A.1.48 The maximum predicted ground level concentrations for each dispersion model (Aermod and ADMS 5) run with a unit emission rate (1 g/s) for each meteorological data year are provided in Appendix A for the indicative receptor locations, with maximum modelled values being used in the assessment. For a watershed area the maximum from the average predicted ground level COPC concentrations within a watershed area for each meteorological data year has been utilised.

Site Specific Pathways

A.1.49 The following table provides an overview of the applicability of the recommended exposure scenarios outlined in the HHRAP (2005) methodology to the site specific location.

Table – Overview of Site Specific Exposure Scenarios

Possible Exposure Pathway	Overview of source to pathway validity for the environmental setting of the proposed EfW	Pathway Risk to be Evaluated
Inhalation of vapours and particulates.	Default exposure scenario assumed applicable as can occur irrespective of receptor occupation or locality land use.	Yes
Incidental ingestion of soil.	Default exposure scenario assumed applicable as can occur irrespective of receptor occupation or locality land use.	Yes
Ingestion of drinking water from surface water sources.	Surface water bodies are present in the locality so default exposure scenario assumed applicable, though the exposure scenario – particularly the consumption rate of fish, may not apply wholly to the potential receptors.	Yes
Ingestion of homegrown produce.	Default exposure scenario assumed applicable, though the exposure scenario may not apply wholly to the potential receptors.	Yes
Ingestion of homegrown beef.	Default exposure scenario assumed applicable, though it may not apply wholly to the potential receptors (farmer / farmer child).	Yes
Ingestion of milk from homegrown cows.	Default exposure scenario assumed applicable, though it may not apply wholly to the potential receptors (farmer / farmer child).	Yes

Possible Exposure Pathway	Overview of source to pathway validity for the environmental setting of the proposed EfW	Pathway Risk to be Evaluated
Ingestion of homegrown chicken.	Default exposure scenario assumed applicable, though it may not apply wholly to the potential receptors (farmer / farmer child). The exposure pathway may also apply in part to a resident / resident child exposure scenario and therefore that non default exposure setting has been considered when appraising the uncertainty and limitations of the assessment.	Yes
Ingestion of eggs from homegrown chickens.	Default exposure scenario assumed applicable, though it may apply wholly to the potential receptors (farmer / farmer child). The exposure pathway may also apply to a resident / resident child exposure scenario and therefore that non default exposure setting has been considered when appraising the uncertainty and limitations of the assessment.	Yes
Ingestion of homegrown pork.	Default exposure scenario assumed applicable, though it may not be wholly applicable to the potential receptors (farmer / farmer child).	Yes
Ingestion of fish.	Surface water bodies Boghill Dam and Hydepark Dam are present in the locality so default exposure scenario assumed applicable to the potential default receptors fisher / fisher child.	Yes
Ingestion of breast milk.	Default exposure scenario evaluated.	Yes

A.1.50 The HHRAP (2005) methodology does not include the possible pathways of ingestion of drinking water from ground water sources, dermal exposure to soil and dermal exposure to water. That is because the evidence for most typical situations is that those pathways are unlikely to be present, or are unlikely to be significant contributors to the risk from waste combustion emissions. There is no known evidence for the inclusion of those pathways to receptors for the proposed EfW site situation at Hightown Quarry.

ESTIMATION OF MEDIA CONCENTRATIONS

A.1.51 HHRAP (2005) provides detailed equations and associated parameters for estimating media concentrations which is recommends for use in evaluating the exposure scenarios. In most cases it provides details of the origin and development of each of the equations and the associated parameters.

A.1.52 The COPC parameters i.e. their chemical properties, their bio-transfer factors for plants, their bio-transfer factors for animals, and health parameters are provided in Appendix B, those parameters being sourced from the HHRAP (2005) companion database where available therein, or as otherwise stated and justified.

A.1.53 Non default values for the bioaccumulation factor (BAF) for methyl mercury and the bio-concentration factor (BCF) for thallium have been used. The HHRAP (2005) companion database default BAF value for methyl mercury is believed to align with a BAF for trophic level 4 i.e. top level predators, which was directly estimated by the US EPA from studies and reported in US EPA Draft National Bioaccumulation Factors for Methylmercury, 2000. But the value is higher than the US EPA draft national methyl mercury BAF for trophic level 4 reported in the Water Quality Criterion for the Protection of Human Health: Methylmercury, January 2001, and trophic levels 2 to 3 will be applicable to fish within the Boghill Dam and Hydepark Dam water bodies, though it would be likely that only trophic level 3 fish maybe consumed. Therefore the US EPA draft national BAF value applicable to trophic level 3 has been utilised. The HHRAP (2005) companion database default BCF value for thallium is not consistent with the HHRAP Appendix A2-2.13.4.1 which states that "compounds with a log Kow of less than 4.0 are assumed not to significantly accumulate", the log Kow for thallium being less than 1. Therefore the thallium BCF value reported in the US EPA National Recommended Water Quality Criteria: 2002 Human Health Criteria Calculation Matrix has been utilised.

A.1.54 The site related parameters utilised are provided in Appendix C, most of those being as per the HHRAP (2005) default values except where otherwise stated and justified, namely:

- Average annual precipitation, taken as 110cm/yr estimated from Met Office regional mapped climate averages for 1971-2000.
- Average percentage run off, assumed as 20%.
- Average annual irrigation, assumed as zero.
- Average annual evapotranspiration, assumed as 42% of average annual precipitation, based on the publication 'Modelling the water budget of Ireland – evapotranspiration and soil moisture, G. Mills, Department of Geography, National University of Ireland, Dublin (UCD), published in Irish Geography, Volume 33(2), 2000, 99-116.
- Water body surface area, total 99,757m2 estimated for Boghill Dam and Hydepark Dam combined from ordnance survey map.
- Depth of water column, assumed as 4m on average estimated based on appraisal of the surrounding terrain contours.
- Total watershed area receiving COPC deposition, 8,797,157m2, estimated for Boghill Dam and Hydepark Dam combined.
- Impervious watershed receiving COPC deposition, 4% of total watershed area receiving COPC deposition, based on an estimate of 3% for the water body areas and roads, with 1% being assumed for buildings.
- An annual average wind velocity of 4.22m/s, based on the meteorological data from 2004 for 2012 for Belfast International Airport (Aldergrove) as that data was used for the Environmental Statement Chapter 14 Air Quality.

A.1.55 In estimating the media concentrations, the HHRAP (2005) methodology allows for loss of the COPCs by several mechanisms, including leaching, erosion, runoff, degradation (biotic and abiotic), and volatilization. The methodology includes recommended equations for calculation those losses, and generally default or site specific parameters have been used. However for the universal soil loss equation, parameters quoted in the HHRAP (2005) Table B-4-13 References and Discussion section have been used, namely those recommended in the US EPA 1994 publication 'Guidance for Performing Screening Level Risk Analysis at Combustion Facilities Burning Hazardous Waste'.

EXPOSURE ASSESSMENT

A.1.56 Calculating COPC specific exposure rates for each exposure pathway involves the following, depending on the medium being assessed:

- The estimated COPC media concentrations.
- The consumption rates of the medium.
- The receptor body weight.
- The frequency and duration of exposure.

A.1.57 For exposure via direct inhalation, non-carcinogenic and carcinogenic risks determined by combining the exposure air concentrations with inhalation toxicity factors to estimate a single (lifetime) inhalation risk. The methodology notes that the inhalation exposure concentrations for vapours and particulates can be influenced by the relative amount of time that a receptors spends indoors, it recommends assuming vapour and particulates are inhaled throughout the day, both indoors and outdoors.

A.1.58 Ingestion exposure can occur over a period of time, so to calculate the average exposure per unit time, the total exposure is divided by the time period, and the average exposure is also expressed in terms of body weight. Thus the HHRAP (2005) methodology utilises variations of the following generic equation for calculating ingestion chemical intake:

I = (Cgen x CR x EF x EF) / (BW x AT) where:

- I = Intake – the amount of COPC at the exchange boundary (mg/kg/day). For evaluating exposure to non carcinogenic COPCs, the intake is referred to as average daily dose (ADD); for evaluating exposure to carcinogenic compounds, the intake is referred to as lifetime average daily dose (LADD).
- Cgen = Generic COPC concentration in medium of concern (e.g. mg/kg for soil or mg/L for surface water.
- CR = Consumption rate – the amount of contaminated medium consumed per unit of time or event (e.g., kg/day for soil or L/day for water).
- EF = Exposure frequency (days/year).
- ED = Exposure duration (years).
- BW = Average body weight of the receptor over the exposure period (kg).
- AT = Averaging time – the period over which exposure is averaged (days); for carcinogens, the averaging time is 25,550 days, based on a lifetime exposure of 70 years; for non carcinogens, averaging time equals ED (years) multiplied by 365 days per year.

A.1.59 The exposures calculated using the HHRAP (2005) methodology are intended to represent reasonable maximum exposure (RME) conditions. It states that “studies of the compounding of conservatism in probabilistic risk assessments show that setting as few as two factors at RME levels or high end (e.g., near the 90th percentile), while setting the remaining variables at less protective typical, or ‘central tendency’ values (e.g. near the 50th percentile) results in output insignificantly different from output generated using all input variables at an RME level (e.g. 99th percentile value)”. The methodology recommends setting the following variables at RME levels, and other exposure parameters e.g. body weight, at average levels:

- The highest predicted air concentrations and deposition rates at chosen exposure scenario locations.

- The exposure frequency.
- Exposure duration.

A.1.60 This assessment complies with that approach, utilising the HHRAP (2005) default exposure frequency and duration values, and maximum predicted ground level COPC concentrations at specific receptor locations.

A.1.61 The HHRAP (2005) default consumption rates have also been applied which are specific to home produced foods. Therefore the default assumption that 100% of those home produced foods are contaminated also applies.

A.1.62 The exposure parameters and exposure setting consumption rates used for this assessment are provided in Appendix D.

RISK AND HAZARD EVALUATIONS

Cancer Risk and Non Cancer Hazard

A.1.63 The HHRAP (2005) methodology considers that risk from exposure to waste combustion emissions is the probability that a human receptor will develop cancer, based on a unique set of exposure, model, and toxicity assumptions. It recommends using the slope or unit risk factor in risk assessments to estimate the probability of an individual developing cancer as a result of exposure to a particular level of a COPC. For example, a risk of 1E-5 is interpreted to mean that an individual has up to a one in 100,000 chance of developing cancer during their lifetime from the exposure being evaluated.

A.1.64 In the UK comparison to a lifetime cancer risk level of 1 in 100,000 is often made, that level being applied for the setting of health criteria values for soil contaminants based on minimal risk, and is broadly consistent with similar risk levels applied in the UK and internationally for the protection of health from chemicals in other environmental media (as stated in Guidance on the Legal Definition of Contaminated Land, DEFRA, July 2008, Annex B).

A.1.65 In contrast, HHRAP (2005) considers a hazard as the potential for developing non cancer health effects as a result of exposure to COPCs. A hazard is not a probability but, rather, a comparison (calculated as a ratio) of a receptor's potential exposure relative to a standard exposure level (reference dose or reference concentration). The standard exposure level is calculated over a similar exposure period evaluated for cancer risk, and is estimated to pose no appreciable likelihood of adverse health effects to potential receptors.

A.1.66 Cancer risk is estimated as follows:

- Inhalation Cancer Risk
  - Cancer Risk = EC x URF, where EC = Exposure concentration (g/m3) and URF = Unit risk factor (g/m3$)^{-1}$
- Ingestion Cancer Risk
  - Cancer Risk = LADD x CSF, where LADD = Lifetime average daily dose (mg/kg-day) and CSF = Cancer slope factor (mg/kg-day$)^{-1}$

A.1.67 For exposure to multiple COPCs within an individual exposure pathway, that risk can be summed per pathway, and similarly summation that risk for each pathway indicates the cumulative cancer risk.

A.1.68 Non cancer risk is estimated by:

- Comparing an estimate of ingested exposure to a reference dose (RfD) for oral exposures, and
- comparing an estimated chemical-specific air concentration to a reference concentration (RfC) for direct inhalation exposures.

A.1.69 A RfD is a daily oral intake rate that is estimated to pose no appreciable risk of adverse health effects, even to sensitive receptors, over a 70-year lifetime. Similarly, an RfC is an estimated daily concentration of a chemical in air, the exposure to which over a specific exposure duration poses no appreciable risk of adverse health effects, even to sensitive receptors. The exposure durations assumed for the exposure pathways evaluated range from sub-chronic to chronic in relative length, however the HHRAP (2005) methodology uses chronic RfDs and RfCs to evaluate the exposure pathways. The comparisons of oral and inhalation exposure estimates to RfD and RfC values, are known as hazard quotients (HQ), which are calculated as follows:

- HQ = ADD / RfD or HQ = EC / RfC, where
  - HQ = Hazard quotient (unitless)
  - ADD = Average daily dose (mg/kg-day)
  - RfD = Reference dose (mg/kg-day)
  - EC = Exposure air concentration (mg/m^3)
  - RfC = Reference concentration (mg/m^3)

A.1.70 As for cancer risk, for exposure to multiple COPCs within an individual exposure pathway, the hazard quotient can be summed per pathway, and similarly summation of that hazard quotient for each pathway provides a cumulative hazard index. A hazard quotient or index of less than unity (1.0) indicates that the exposure would not create an adverse non carcinogenic health hazard, and the smaller the hazard quotient or index, the less risk to human health is implied.

Summary of Cancer Risks

A.1.71 The following table presents the total lifetime cancer risk calculated due to potential emissions from the proposed EfW based on the maximum predicted air concentrations and deposition rate for the exposure scenarios applied at each specific receptor location. The total lifetime cancer risk is also presented for the maximum predicted concentrations due to the EfW.

Table – Estimated Total Lifetime Cancer Risk

No.	Potential Receptor & Grid Reference	Receptor Type	Cancer Risk from Ingestion	Cancer Risk from Inhalation
1	35 Boghill Rd. (329050, 381470)	Farmer Farmer Child	7.5E-7 1.8E-7	1.5E-7 2.3E-8
2	34 Boghill Rd. (329190, 391220)	Resident Resident Child	8.6E-8 4.2E-8	1.1E-7 2.2E-8
3	32 Boghill Rd. (329140, 380990)	Farmer Farmer Child	7.4E-7 1.7E-7	1.5E-7 2.2E-8
4	26 Boghill Rd. (329370, 381110)	Resident Resident Child	9.2E-8 4.5E-8	1.2E-7 2.4E-8
5	102 Upper Hightown Rd. (339330, 391140) proxy for Newtownabbey	Resident Resident Child	1.9E-7 9.0E-8	2.6E-7 5.2E-8
6	100 Upper Hightown Rd. (330350, 381130) proxy for Newtownabbey	Farmer Farmer Child	1.7E-6 4.0E-7	3.5E-7 5.2E-8
7	62 Upper Hightown Rd. (330120, 380370)	Farmer Farmer Child	1.2E-6 2.7E-7	2.4E-7 3.6E-8

No.	Potential Receptor & Grid Reference	Receptor Type	Cancer Risk from Ingestion	Cancer Risk from Inhalation
8	43 Flush Rd. (330130, 379600)	Farmer Farmer Child	9.7E-7 2.3E-7	2.0E-7 3.0E-8
9	53 Flush Rd. (329540, 379360)	Farmer Farmer Child	1.4E-6 3.3E-7	2.9E-7 4.4E-8
10	85 Flush Rd. (329300, 379520)	Farmer Farmer Child	1.0E-6 2.5E-7	2.1E-7 3.2E-8
11	55 Flush Rd. (329160, 379100)	Resident Resident Child	6.4E-8 3.1E-8	7.8E-8 1.6E-8
12	69 Flush Rd. (329080, 379260)	Farmer Farmer Child	4.5E-7 1.1E-7	9.0E-8 1.3E-8
13	120 Flush Rd. (328620, 380230)	Resident Resident Child	5.1E-8 2.5E-8	5.9E-8 1.2E-8
14	133 Flush Rd. (328450, 380510)	Farmer Farmer Child	4.6E-7 1.1E-7	9.1E-8 1.4E-8
15	148 Flush Rd. (328250, 380820)	Farmer Farmer Child	6.5E-7 1.5E-7	1.3E-7 2.0E-8
16	149 Flush Rd. (328260, 380850)	Resident Resident Child	8.0E-8 3.9E-8	1.0E-7 2.0E-8
17	151 Flush Rd. (328240, 380900)	Resident Resident Child	8.3E-8 4.0E-8	1.1E-7 2.1E-8
18	55 Boghill Rd. (328390, 381200)	Resident Resident Child	9.6E-8 4.7E-8	1.3E-7 2.5E-8
19	45 Boghill Rd. (328730, 381390)	Resident Resident Child	1.0E-7 5.0E-8	1.4E-7 2.7E-8
20	40 Boghill Rd. (328860, 381190)	Resident Resident Child	9.4E-8 4.6E-8	1.2E-7 2.5E-8
21	Belfast Centre AURN Site 103 (333900,374400)	Resident Resident Child	2.5E-8 1.3E-8	2.0E-8 4.0E-9
	For maximum predicted concentration and maximum of average in watershed catchment to Boghill Dam and Hydepark Dam due to emissions from EfW,	Resident Resident Child Farmer Farmer Child Fisher Fisher Child	2.3E-7 1.1E-7 2.2E-6 5.1E-7 6.6E-7 1.7E-7	3.3E-7 6.6E-8 4.4E-7 6.6E-8 3.3E-7 6.6E-8

A.1.72 The estimated cancer risk from either ingestion or inhalation is well below an annual risk of 1 in 100,000 for each receptor location.

Summary of Non Cancer Hazard

A.1.73 The total lifetime risk calculated for emissions from the proposed EfW for the receptors exposure scenarios are provided in the following table. The total lifetime risk is also presented for the maximum predicted concentrations due to the EfW.

Table – Estimated Hazard Index

No.	Potential Receptor & Grid Reference	Receptor Type	Total Hazard Index	
			Ingestion	Inhalation
1	35 Boghill Rd. (329050, 381470)	Farmer Farmer Child	0.031 0.044	0.0012 0.0002
2	34 Boghill Rd. (329190, 391220)	Resident Resident Child	0.005 0.013	0.0009 0.0002
3	32 Boghill Rd. (329140, 380990)	Farmer Farmer Child	0.030 0.044	0.0012 0.0002
4	26 Boghill Rd. (329370, 381110)	Resident Resident Child	0.005 0.014	0.0009 0.0002
5	102 Upper Hightown Rd. (339330, 391140) proxy for Newtownabbey	Resident Resident Child	0.008 0.020	0.0020 0.0004
6	100 Upper Hightown Rd. (330350, 381130) proxy for Newtownabbey	Farmer Farmer Child	0.066 0.091	0.0027 0.0004
7	62 Upper Hightown Rd. (330120, 380370)	Farmer Farmer Child	0.046 0.065	0.0019 0.0003
8	43 Flush Rd. (330130, 379600)	Farmer Farmer Child	0.039 0.055	0.0015 0.0002
9	53 Flush Rd. (329540, 379360)	Farmer Farmer Child	0.056 0.077	0.0023 0.0003
10	85 Flush Rd. (329300, 379520)	Farmer Farmer Child	0.041 0.059	0.0017 0.0002
11	55 Flush Rd. (329160, 379100)	Resident Resident Child	0.005 0.012	0.0006 0.0001
12	69 Flush Rd. (329080, 379260)	Farmer Farmer Child	0.019 0.030	0.0007 0.0001
13	120 Flush Rd. (328620, 380230)	Resident Resident Child	0.004 0.011	0.0005 0.0001
14	133 Flush Rd. (328450, 380510)	Farmer Farmer Child	0.020 0.030	0.0007 0.0001
15	148 Flush Rd. (328250, 380820)	Farmer Farmer Child	0.027 0.039	0.0010 0.0002

No.	Potential Receptor & Grid Reference	Receptor Type	Total Hazard Index	
			Ingestion	Inhalation
16	149 Flush Rd. (328260, 380850)	Resident Resident Child	0.005 0.013	0.0008 0.0002
17	151 Flush Rd. (328240, 380900)	Resident Resident Child	0.005 0.013	0.0008 0.0002
18	55 Boghill Rd. (328390, 381200)	Resident Resident Child	0.005 0.014	0.0010 0.0002
19	45 Boghill Rd. (328730, 381390)	Resident Resident Child	0.006 0.014	0.0011 0.0002
20	40 Boghill Rd. (328860, 381190)	Resident Resident Child	0.005 0.014	0.0010 0.0002
21	Belfast Centre AURN Site 103 (333900,374400)	Resident Resident Child	0.004 0.009	0.0002 0.00003
	For maximum predicted air and deposited concentrations due to emission from EfW	Resident Resident Child Farmer Farmer Child Fisher Fisher Child	0.009 0.023 0.083 0.114 0.47 0.35	0.0026 0.0005 0.0035 0.0005 0.0026 0.0005

A.1.74 The estimated hazard index from either ingestion or inhalation is below 1.0 for each receptor location.

Comparison of Dioxin and Furan Exposure to Guidelines

A.1.75 HHRAP (2005) states that the US EPA typically evaluates non cancer effects of chemicals by comparing exposure levels to health based reference doses or reference concentrations. However the US EPA has not developed these non-cancer benchmarks for the dioxin or furan congeners, or for TEQ concentrations/doses. Hence one approach the US EPA has taken is to evaluate whether dioxins and furans emitted from hazardous waste combustion facilities are likely to cause significant non cancer health effects is to compare estimated TEQ exposures to national average background exposure levels. HHRAP (2005) quotes those for the US as 1 pg TEQ/kg/day for adults and 60 pg TEQ/kg/day for nursing infants, and notes the pertinent exposure estimate is the average daily dose, experienced over the course of the exposure duration, rather than the average daily dose averaged over a lifetime.

A.1.76 To apply that approach for the UK, reference can be made to the Environment Agency Science report: SC050021/TOX12, Contaminants in soil: updated collation of toxicological data and intake values for humans – Dioxins, furans and dioxin-like PCBs, September 2009. That reports an average (upper bound) dietary intake of dioxins and dioxin-like PCBs of UK adults as 0.7 pg WHO-TEQ per kg bw-day, which is equivalent to 49 pg WHO-TEQ per day for a 70-kg adult, and an adult daily intake via inhalation of about 0.2 pg TEQ per day (or about 0.003 pg TEQ per kg bw-day), based on a 70-kg adult inhaling 20m3 of air per day. It also recommends a TDI of 2 pg WHO-TEQ per kg bw-day, which is the value recommended by the UK Committee on Toxicity (COT) of Chemicals in Food, Consumer Products and the Environment's in its publication COT/2001/07 'Statement on the Tolerable Daily Intake for Dioxins and Dioxin-Like Polychlorinated Biphenyls', October 2001. That value was derived based upon effects on the developing male reproductive system mediated via the maternal body burden, and the UK COT considered that TDI adequate to protect against other possible effects, such as cancer and cardiovascular effects.

A.1.77 Comparison can also be made to the World Health Organization (WHO) Air Quality Guidelines for Europe, 2nd Edition, 2000, which reports a current tolerable daily intake (TDI) value for dioxins and furans of 1 to 4 pg TEQ per kg BW (picogrammes toxic equivalent per kilogram bodyweight per day). An air quality guideline for dioxins and furans is not proposed by the WHO because direct inhalation exposures constitute only a small proportion of the total exposure, generally less than 5% of the daily intake from food.

A.1.78 Hence the average (lifetime) daily intake of dioxins and furans for the receptor types considered is presented in the following table for comparison to those TDIs. Note those TDIs are in terms of WHO TEQ, and the WHO toxic equivalence factors (TEF) are slightly different to the I-TEF used in the IED, the latest WHO TEF being published in 2005.

Table – Estimated Average Daily Intake of Dioxins / Furans

No.	Potential Receptor & Grid Reference	Receptor Type	Estimated Average Daily Intake as pg WHO I-TEQ kg-BW/day
1	35 Boghill Rd. (329050, 381470)	Farmer Farmer Child	0.0061 0.0088
2	34 Boghill Rd. (329190, 391220)	Resident Resident Child	0.0001 0.0003
3	32 Boghill Rd. (329140, 380990)	Farmer Farmer Child	0.0059 0.0086
4	26 Boghill Rd. (329370, 381110)	Resident Resident Child	0.0001 0.0003
5	102 Upper Hightown Rd. (339330, 391140) proxy for Newtownabbey	Resident Resident Child	0.0003 0.0006
6	100 Upper Hightown Rd. (330350, 381130) proxy for Newtownabbey	Farmer Farmer Child	0.0138 0.0199
7	62 Upper Hightown Rd. (330120, 380370)	Farmer Farmer Child	0.0095 0.0137
8	43 Flush Rd. (330130, 379600)	Farmer Farmer Child	0.0079 0.0114
9	53 Flush Rd. (329540, 379360)	Farmer Farmer Child	0.0116 0.0167
10	85 Flush Rd. (329300, 379520)	Farmer Farmer Child	0.0084 0.0122
11	55 Flush Rd. (329160, 379100)	Resident Resident Child	0.0001 0.0002

No.	Potential Receptor & Grid Reference	Receptor Type	Estimated Average Daily Intake as pg WHO I-TEQ kg-BW/day
12	69 Flush Rd. (329080, 379260)	Farmer Farmer Child	0.0036 0.0052
13	120 Flush Rd. (328620, 380230)	Resident Resident Child	0.0001 0.0001
14	133 Flush Rd. (328450, 380510)	Farmer Farmer Child	0.0036 0.0053
15	148 Flush Rd. (328250, 380820)	Farmer Farmer Child	0.0052 0.0075
16	149 Flush Rd. (328260, 380850)	Resident Resident Child	0.0001 0.0002
17	151 Flush Rd. (328240, 380900)	Resident Resident Child	0.0001 0.0003
18	55 Boghill Rd. (328390, 381200)	Resident Resident Child	0.0001 0.0003
19	45 Boghill Rd. (328730, 381390)	Resident Resident Child	0.0001 0.0003
20	40 Boghill Rd. (328860, 381190)	Resident Resident Child	0.0001 0.0003
21	Belfast Centre AURN Site 103 (333900,374400)	Resident Resident Child	0.00002 0.0001
	For maximum predicted air and deposited concentrations due to emission from EfW	Resident Resident Child Farmer Farmer Child Fisher Fisher Child	0.0003 0.0008 0.0177 0.0255 0.0049 0.0040

Notes:

1. Estimated average daily intake has been derived utilising the AEA 2008 congener profile for dioxins and furans. That congener profile gives a slightly higher, by about 10%, estimated average daily intake than either the HMIP 1996 or EMEP 2012 congener profiles.
2. WHO criterion: 1-4 pg/kg BW-day. UK COT criterion: 2 pg/kg BW-day.

A.1.79 The predicted average daily intake of dioxins and furans is less than the lower end of the WHO TDI range.

Infant Breast Milk Exposure to Dioxins and Furans

A.1.80 The HHRAP (2005) methodology recommends evaluation of infant exposure to dioxins and furans via the ingestion of their mother's breast milk as an additional exposure pathway at the recommended adult exposure scenario locations. This is because dioxins and furans are lipophilic (fat soluble) and hence there is a potential they may accumulate in breast milk.

A.1.81 The HHRAP (2005) methodology entails calculating the average daily dose due to an adult receptor breast feeding an infant with an exposure duration and averaging time of one year. Evaluation of the estimated TEQ exposure is the carried out by comparison to national average background exposure levels, and if exposures due to the facility's emissions during the exposure duration of concern are low compared to background exposures, then the emissions aren't expected to cause an increase in non cancer effects.

A.1.82 HHRAP (2005) indicates that in the US the average background level of dioxins and furans in breast milk was eighteen parts per trillion of 2,3,7,8-TCDD TEQ. After normalisation for infant body weight that breast milk concentration would result in an average background intake for an infant of 67 picograms per kilogram per day of 2,3,7,8-TCDD TEQ. The WHO and UK COT criterion are much lower in the range 1-4 pg WHO TEQ kg-BW/day, and the COT 2005 statement 'WHO Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds, reports that surveys analysing infant formula and baby foods indicate that those sources are unlikely to result in dietary intake which exceeds the TDI. However it notes that analysis of a small set of human breast milk samples indicated that infant dietary intakes, when recalculated using 2005 TEF values, are likely to be in the region of 35 pg WHO-TEQ kg-BW/day at two months, falling to 8 pg WHO-TEQ kg- BW/day at 10 months.

A.1.83 The estimated Average Daily Dose (ADD) for potential infants to adults at each indicative receptor location appraised by this study is presented in the following table.

Table – Estimated ADD of Dioxins / Furans to Infant via Breast Milk

No.	Potential Receptor & Grid Reference	Receptor Type	Estimated Average Daily Dose as pg WHO I-TEQ kg-BW/day
1	35 Boghill Rd. (329050, 381470)	Farmer Infant	0.18
2	34 Boghill Rd. (329190, 391220)	Resident Infant	0.003
3	32 Boghill Rd. (329140, 380990)	Farmer Infant	0.17
4	26 Boghill Rd. (329370, 381110)	Resident Infant	0.004
5	102 Upper Hightown Rd. (339330, 391140) proxy for Newtownabbey	Resident Infant	0.008
6	100 Upper Hightown Rd. (330350, 381130) proxy for Newtownabbey	Farmer Infant	0.40
7	62 Upper Hightown Rd. (330120, 380370)	Farmer Infant	0.28
8	43 Flush Rd. (330130, 379600)	Farmer Infant	0.23
9	53 Flush Rd. (329540, 379360)	Farmer Infant	0.34
10	85 Flush Rd. (329300, 379520)	Farmer Infant	0.25
11	55 Flush Rd. (329160, 379100)	Resident Infant	0.002
12	69 Flush Rd. (329080, 379260)	Farmer Infant	0.10
13	120 Flush Rd. (328620, 380230)	Resident Infant	0.002
14	133 Flush Rd. (328450, 380510)	Farmer Infant	0.11
15	148 Flush Rd. (328250, 380820)	Farmer Infant	0.15

No.	Potential Receptor & Grid Reference	Receptor Type	Estimated Average Daily Dose as pg WHO I-TEQ kg-BW/day
16	149 Flush Rd. (328260, 380850)	Resident Infant	0.003
17	151 Flush Rd. (328240, 380900)	Resident Infant	0.003
18	55 Boghill Rd. (328390, 381200)	Resident Infant	0.004
19	45 Boghill Rd. (328730, 381390)	Resident Infant	0.004
20	40 Boghill Rd. (328860, 381190)	Resident Infant	0.004
21	Belfast Centre AURN Site 103 (333900,374400)	Resident Infant	0.001
	For maximum predicted air and deposited concentrations due to emission from EfW	Resident Infant Farmer Infant Fisher Infant	0.010 0.515 0.143

Notes:

1. Estimated average daily intake has been derived utilising the AEA 2008 congener profile for dioxins and furans. That congener profile gives higher, by about 16-49% for residents, about 8-12% for farmers, and about 0.2-1.8% for fishers, estimated average daily intake than either the HMIP 1996 or EMEP 2012 congener profiles.
2. WHO criterion: 1-4 pg/kg BW-day. UK COT criterion: 2 pg/kg BW-day

Increase in Dioxin Emissions

A.1.84 The IED Article 46 Control of emissions provides some operational flexibility to resolve problems on the plant without initiating a complete shutdown, which recognises that some exceedances may be transient such as during start up or shut down, or that there may be less environmental impact if problems can be resolved without initiating a complete shutdown. Abnormal operations typically include incidents such as technically unavoidable stoppages, disturbances or failures of the pollution control equipment or monitoring equipment, though the IED Article 47 requires "in the case of a breakdown, the operator shall reduce or close down operations as soon as practicable until normal operations can be restored".

A.1.85 Consequently the potential effect of abnormal operation for both short term and long term impact has been assessed in the Environmental Statement Chapter 14 Air Quality, except for a potential increase in dioxin emissions, though given that restrictions apply to the duration of abnormal operating conditions, a significant long term environmental impact will not occur.

A.1.86 During abnormal operations the IED emission limits may be transiently exceeded, though the IED Annex VI stipulates that the total dust content of the emissions into the air of a waste incineration plant shall under no circumstances exceed 150 mg/m3 expressed as a half-hourly average and the air emission limit values for carbon monoxide (CO) and gaseous and vaporous organic substances, expressed as total organic carbon (TOC) as daily or half hourly average values shall not be exceeded. The limit for particulates is 150 mg/m3 as a half hourly average is five times the limit in normal operation.

A.1.87 The IED requires that waste incineration plant must not continue to incinerate waste for a period of more than four hours uninterrupted where emission limit values are exceeded, and that the cumulative duration of operation in such conditions over one year must not exceed sixty hours in a year, applying to those furnaces which are linked to one single waste gas cleaning device. To provide a worst case assessment of abnormal operations with elevated emissions of dioxins, an increase of dioxins emission to 10ng/m3 i.e. a hundred times the emission limit value, has been assumed and which is a substantially higher factor than allowed for particulates.

A.1.88 Dioxin emissions at that 10 ng/m3 for the maximum period of abnormal operation, sixty hours per year for every year for the duration of the EfW operation represents a poor operating scenario and in practice is highly unlikely. For that abnormal operation scenario the following estimated increased average daily intake for the maximum predicted concentrations due to emission from the EfW and for the receptor type with the most exposure would not pose a risk to human health:

- Farmer: 0.030 pg WHO I-TEQ kg-BW /day
- Farmer child: 0.043 pg WHO I-TEQ kg-BW / day

UNCERTAINTY AND LIMITATIONS

A.1.89 The HHRAP (2005) methodology entails the use of a wide range of parameters and associated assumptions for which there may be uncertainty or to which the assessment may be sensitive. However in general the application of the HHRAP (2005) default parameters combined with precautionary site specific assumptions applied for this assessment, mean the incremental human risk due to the EfW will be over estimated. Therefore the conclusions drawn will be conservative rather than erroneously misleading.

A.1.90 To further aid understanding of the assessment, a consideration of possible uncertainty, sensitivity and variability, is provided in the following table.

Table – Qualitative Appraisal of Uncertainty, Sensitivity and Variability

Possible Source of Uncertainty or Variability	Potential Impact
Other potentially toxic substances not included in the assessment.	For specific substances of concern emission limits are set by the Industrial Emissions Directive and the EfW will only be able to operate under an environmental permit.
Actual emissions for each substance will be lower on average than those utilised for this assessment.	Assessment will have overestimated the risk.
Assessment carried out using maximum annual average air and deposited concentrations predicted by the dispersion model for a single year of meteorological data, whereas the average for the nine years of meteorological data utilised will be less. Hence the annual average over the exposure duration will be less than utilised in this assessment.	Assessment will have overestimated the risk.
Exposure scenarios may not be wholly applicable, though it is considered more likely that actual exposure will be less than assessed rather than more than assessed.	Likely the assessment will have overestimated the risk.
There may be potential receptors classed as 'resident' to whom the exposure pathways 'Ingestion of Homegrown Chicken' and 'Ingestion of Eggs from Homegrown Chickens' may apply.	The assessment of risk to specific receptor locations classed as 'farmer' includes those exposure pathways. Risk has also been estimated based on the maximum predicted air and deposited concentrations due to emissions from the EfW. Based on those results, the inclusion of the exposure pathways 'Ingestion of Homegrown Chicken' and 'Ingestion of Eggs from Homegrown Chickens' would not lead to risk criteria being exceeded at the potential receptors classed as 'resident'.

ANNEX A Dispersion Model Predictions for Unit Emission Rate

Table – Predictions from AERMOD dispersion model

No.	Potential Receptor & Grid Reference	Receptor Type – e.g. Farm or Residence only	Annual average ground level concentrations (µg/m³) for unit emission rate (1 g/s)								
			2004	2005	2006	2007	2008	2009	2010	2011	2012
1	35 Boghill Rd. (329050, 381470)	Farm	0.0181	0.0197	0.0206	0.0151	0.0121	0.0186	0.0169	*0.0217*	0.0154
2	34 Boghill Rd. (329190, 381220)	Residence	0.0201	0.0206	0.0208	0.0175	0.0142	0.0217	0.0184	***0.0226***	0.0176
3	32 Boghill Rd. (329140, 380990)	Farm	0.0188	0.0196	0.02	0.0162	0.0136	0.0206	0.0187	***0.0215***	0.0167
4	26 Boghill Rd. (329370, 381110)	Residence	0.0222	0.0224	0.0226	0.0212	0.0158	0.0233	0.021	***0.0245***	0.0209
5	102 Upper Hightown Rd. (330330, 381140) proxy for Newtownabbey	Residence	0.0249	0.025	0.0256	0.0286	0.0332	*0.0341*	0.0241	0.0304	0.0241
6	100 Upper Hightown Rd. (330350, 381130) proxy for Newtownabbey	Farm	0.0247	0.0248	0.0253	0.0283	0.033	*0.034*	0.0239	0.0302	0.0238
7	62 Upper Hightown Rd. (330120, 380370)	Farm	0.0284	0.0247	0.0242	0.0275	0.0268	0.0283	0.0303	*0.0327*	0.0249
8	43 Flush Rd. (330130, 379600)	Farm	0.0228	0.0195	0.0199	0.0229	0.0156	0.0157	*0.0234*	0.0228	0.0197
9	53 Flush Rd. (329540, 379360)	Farm	0.0347	0.029	0.029	0.0344	0.0207	0.0145	*0.0382*	0.0258	0.0274
10	85 Flush Rd. (329300, 379520)	Farm	0.0233	0.0211	0.0216	0.0257	0.0168	0.0109	*0.0274*	0.0199	0.0189
11	55 Flush Rd. (329160, 379100)	Residence plus possible industry	0.0113	0.0132	0.011	*0.0139*	0.0112	0.0068	0.0136	0.0103	0.0123
12	69 Flush Rd. (329080, 379260)	Farm	0.0096	0.0126	0.01	*0.0134*	0.0106	0.0054	0.0129	0.0101	0.0132
13	120 Flush Rd. (328620, 380230)	Residence plus possible industry	0.0072	0.0069	0.0074	0.0072	0.0081	0.0054	0.0076	0.0083	*0.0093*
14	133 Flush Rd. (328450, 380510)	Farm	0.0117	0.0074	0.0117	0.0088	0.0111	0.0095	0.0109	0.0122	***0.0138***

No.	Potential Receptor & Grid Reference	Receptor Type – e.g. Farm or Residence only	Annual average ground level concentrations (μg/m^3) for unit emission rate (1 g/s)								
			2004	2005	2006	2007	2008	2009	2010	2011	2012
15	148 Flush Rd. (328250, 380820)	Farm	0.0132	0.0099	0.0144	0.0105	0.0105	0.0115	0.0132	0.0155	*0.0162*
16	149 Flush Rd. (328260, 380850)	Residence	0.0132	0.0102	0.0147	0.0107	0.0104	0.0117	0.0135	0.0159	*0.0161*
17	151 Flush Rd. (328240, 380900)	Residence	0.0131	0.0105	0.0149	0.0107	0.0102	0.012	0.0138	*0.0162*	0.0158
18	55 Boghill Rd. (328390, 381200)	Residence	0.0109	0.0113	*0.0162*	0.0097	0.0093	0.0144	0.0143	0.016	0.0118
19	45 Boghill Rd. (328730, 381390)	Residence plus business premises	0.013	0.0163	*0.0206*	0.011	0.0111	0.0168	0.0165	0.0192	0.012
20	40 Boghill Rd. (328860, 381190)	Residence	0.0147	0.018	*0.0212*	0.0122	0.0119	0.0178	0.0176	0.0204	0.0132
21	Belfast Centre AURN Site 103 (333900,374400)	Belfast monitoring station	*0.0039*	0.0036	0.0026	0.0032	0.0019	0.0017	0.0038	0.003	0.0037
	Maximum - location may vary with Meteorological data year	N/A	0.0663	***0.0672***	0.0429	0.0496	0.0470	0.0397	0.0568	0.0423	0.0478

Notes: Maximum values at a receptor location are highlighted by italic type, and the maximum values from either the AERMOD or ADMS 5 dispersion model are also highlighted in bold type and have been used in the human health risk assessment.

Table – Predictions from ADMS 5 dispersion model

No.	Potential Receptor & Grid Reference	Receptor Type – e.g. Farm or Residence only	Annual average ground level concentrations (µg/m^3) for unit emission rate (1 g/s)								
			2004	2005	2006	2007	2008	2009	2010	2011	2012
1	35 Boghill Rd. (329050, 381470)	Farm	0.0184	0.0203	0.0203	0.017	0.0128	0.0183	0.0158	***0.0231***	0.0157
2	34 Boghill Rd. (329190, 381220)	Residence	0.0162	0.0167	0.0157	0.0152	0.0122	0.0173	0.0137	*0.0178*	0.0132
3	32 Boghill Rd. (329140, 380990)	Farm	0.0144	0.0144	0.0142	0.0134	0.011	0.0153	0.0129	*0.0158*	0.012
4	26 Boghill Rd. (329370, 381110)	Residence	0.0186	0.0192	0.0171	0.0169	0.0135	0.0177	0.0168	*0.0192*	0.0155
5	102 Upper Hightown Rd. (330330, 381140) proxy for Newtownabbey	Residence	0.0386	0.0345	0.038	0.0412	***0.0527***	0.0498	0.0298	0.0434	0.0357
6	100 Upper Hightown Rd. (330350, 381130) proxy for Newtownabbey	Farm	0.0383	0.0342	0.0374	0.0408	***0.0525***	0.0498	0.0297	0.0432	0.0351
7	62 Upper Hightown Rd. (330120, 380370)	Farm	0.0332	0.0276	0.0274	0.0277	0.0299	0.0294	0.0341	***0.0359***	0.0251
8	43 Flush Rd. (330130, 379600)	Farm	0.0295	0.0283	0.0249	0.0292	0.0197	0.0186	***0.0299***	0.0285	0.0251
9	53 Flush Rd. (329540, 379360)	Farm	0.0385	0.0371	0.0322	0.0403	0.0259	0.014	***0.0441***	0.0307	0.0318
10	85 Flush Rd. (329300, 379520)	Farm	0.0247	0.0276	0.0236	0.0306	0.0227	0.0107	***0.0321***	0.0251	0.0227
11	55 Flush Rd. (329160, 379100)	Residence plus possible industry	0.0109	0.0154	0.0108	0.0149	***0.0158***	0.0069	0.0136	0.0107	0.0129
12	69 Flush Rd. (329080, 379260)	Farm	0.0084	***0.0136***	0.0091	0.0131	0.0121	0.0051	0.012	0.0102	0.0132
13	120 Flush Rd. (328620, 380230)	Residence plus possible industry	0.0051	0.0056	0.006	***0.0119***	0.0104	0.0075	0.0055	0.0075	0.0082
14	133 Flush Rd. (328450, 380510)	Farm	0.0101	0.0057	0.0102	0.0083	0.0128	0.0093	0.0105	0.0115	*0.0134*
15	148 Flush Rd. (328250, 380820)	Farm	0.0141	0.0107	0.018	0.0121	0.0145	0.0152	0.0167	***0.0198***	0.0191

No.	Potential Receptor & Grid Reference	Receptor Type – e.g. Farm or Residence only	Annual average ground level concentrations (µg/m^3) for unit emission rate (1 g/s)								
			2004	2005	2006	2007	2008	2009	2010	2011	2012
16	149 Flush Rd. (328260, 380850)	Residence	0.0142	0.0113	0.0188	0.0125	0.0145	0.0161	0.0172	***0.0206***	0.0189
17	151 Flush Rd. (328240, 380900)	Residence	0.0144	0.0121	0.0195	0.0129	0.0146	0.0171	0.0178	***0.0215***	0.0187
18	55 Boghill Rd. (328390, 381200)	Residence	0.0132	0.0156	0.0233	0.0135	0.0169	***0.0255***	0.019	0.0231	0.0142
19	45 Boghill Rd. (328730, 381390)	Residence plus business premises	0.0181	0.021	***0.0278***	0.0173	0.0144	0.0227	0.0214	0.0266	0.0159
20	40 Boghill Rd. (328860, 381190)	Residence	0.0174	0.0193	***0.025***	0.0157	0.0136	0.0211	0.0196	0.0244	0.0151
21	Belfast Centre AURN Site 103 (333900,374400)	Belfast monitoring station	***0.0041***	0.004	0.0028	0.0034	0.0021	0.0016	0.0041	0.0031	0.0037
	Maximum - location may vary with Meteorological data year	N/A	0.0531	0.0523	0.0531	0.0531	*0.0646*	0.0628	0.0514	0.0614	0.0493

Notes: Maximum values at a receptor location are highlighted by italic type, and the maximum values from either the AERMOD or ADMS 5 dispersion model are also highlighted in bold type and have been used in the human health risk assessment.

Annex B – COPC Parameters

Project: arc21 Resdual Waste Treatment Project
Proposed Development of MBT and EfW at Hightown Quarry, Ballutoag
Human Health Risk Assessment

Methodology: US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, 2005
http://www.epa.gov/osw/hazard/tsd/td/combust/risk.htm

(yellow)	Input value - site specific
(grey)	Input value - non default, eg not in HHRAP database, see text

				Antimony	Arsenic	Cadmium	Chromium (III)	Chromium (VI)	Lead	Mercury	Mercuric chloride	Methyl Mercury	Nickel	Thallium	Benzo(a)pyrene
COPC Parameters															
Chemical Properties		**Unit**	**Justification**												
Da	Diffusivity of COPC in air	cm2/s	Default unless shaded	0.0772	0.0772	0.0772	0.1265	0.1265	0.0772	0.0109	0.045313	0.052778	0.0772	0.0772	0.043
Dw	Diffusivity of COPC in water	cm2/s	Default unless shaded	0.00000957	0.00000957	0.00000957	0.0000141	0.0000141	0.00000957	0.0000301	5.25E-06	6.11E-06	9.57E-06	9.57E-06	0.000009
Fv	Fraction of chemical air concentration in vapor phase	unitless	Default unless shaded	0	0.006	0.009	0.009	0.009	0.007	1	0.85	0	0.009	0.009	0.294
H	Henry's Law constant	atm-m3/mol	Default unless shaded	0.025	0.77	0.031	3.35E-15	3.35E-15	0.025	0.0071	7.1E-10	4.70E-07	0.025	4.32E-14	1.10E-06
Kdbs		cm3/g/kg	Default	45	29	75	19	19	900	3000	50000	3000	65	71	38760
Kds	Soil water partition coefficient	cm3/g	Default	45	29	75	19	19	900	1000	58000	7000	65	71	160000
Kdsw		L/kg	Default	45	29	75	19	19	900	1000	100000	100000	65	71	72675
Koc		mL/g	Default												969000
Kow (log)		unitless	Default unless shaded	0.73	0.68	-0.07	0.23	0.23	0.73	0.62	-0.215		-0.57	0.23	6
ksg	COPC loss constrant due to biotic and abiotic degradation	1/yr	Default	0	0	0	0	0	0	0	0	0	0	0	0.48
MW	Molecular weight	g/mol	Default unless shaded	124.77	77.95	112.4	51.996	51.996	209.21	200.59	271.52	216	58.71	205.38	252.32
S		mg/L-water	Default unless shaded	23000	34700	123000	86700	86700	9580	0.06	69000	0	422000	26500	0.0016
Tm		K	Default	903.15	1093.15	593.15	2173.15	2173.15	603.15	234.23	550.1		1773.15	573.15	453.15
Vp		atm	Default unless shaded	0.9	3.3E-12	5.45E-12	5.58E-12	5.58E-12	3.97E-12	0.00000263	0.00012		5.58E-12	5.58E-12	7.24E-12
Biotransfer Factors for Plants				**Antimony**	**Arsenic**	**Cadmium**	**Chromium**	**Chromium(VI)**	**Lead**	**Mercury**	**Mercuric chloride**	**Methyl Mercury**	**Nickel**	**Thallium**	**Benzo(a)pyrene**
Brag		unitless	Default	0.0319	0.00633	0.125	0.00488	0.00488	0.0136		0.0145	0.0294	0.00931	0.000858	0.0132
Brf/s	Plant soil bioconcentration factor for forage/silage	unitless	Default	0.2	0.036	0.364	0.0075	0.0075	0.045		0	0	0.032	0.004	0.0132
Brgrain	Plant soil bioconcentration factor for grain	unitless	Default	0.03	0.004	0.062	0.0045	0.0045	0.009		0.0093	0.019	0.006	0.0004	0.0132
Brroot	Plant soil bioconcentration factor for below ground produce	unitless	Default	0.03	0.008	0.064	0.0045	0.0045	0.009		0.036	0.099	0.008	0.0004	0.0605
Bvag	COPC air to plant biotransfer factor for aboveground produce	(mg/kg)/mg/kg)	Default							0	1800	0			124742
VG	Empirical correction factor for aboveground and belowground produce		Default	1	1	1	1	1	1	1	1	1	1	1	0.01
Bvforage		(mg/kg)/mg/kg)	Default							1	1800	1			124742
RCF		(ug/g)/(ug/mL)	Default												9684
Biotransfer Factors for Animals				**Antimony**	**Arsenic**	**Cadmium**	**Chromium (III)**	**Chromium (VI)**	**Lead**	**Mercury**	**Mercuric chloride**	**Methyl Mercury**	**Nickel**	**Thallium**	**Benzo(a)pyrene**
Babeef		day/kg	Default	0.001	0.002	0.00012	0.0055	0.0055	0.0003	0	0.00522	0.00078	0.006	0.04	0.03756
Baeggs		day/kg	Default			0.0025				0	0.023925	0.003575			0.015816
BAF		L/kg FW	Default unless shaded								0	680000			133048.9
Bamilk		day/kg FW tissue	Default	0.0001	0.00006	0.0000065	0.0015	0.0015	0.00025	0	0.002262	0.000338	0.001	0.002	0.007908
Bapork		day/kg	Default			0.000191				0	0.0000339	0.00000507			0.04547
Bapoult		day/kg	Default			0.10625				0	0.023925	0.003575			0.027678
BCFfish		L/kg FW	Default unless shaded	40	114	907	19	3.16	0.09				78	116	8317.64
BSAFfish	only applied to dioxins/furans	(mg/kg)/mg/kg)	Default												
MF	Metabolism factor		Default	1	1	1	1	1	1	1	1	1	1	1	1
Health Parameters				**Antimony**	**Arsenic**	**Cadmium**	**Chromium (III)**	**Chromium (VI)**	**Lead**	**Mercury**	**Mercuric Chloride**	**Methyl Mercury**	**Nickel**	**Thallium**	**Benzo(a)pyrene**
CSFo	Cancer slope factor	1/mg/kg-day	Default		1.5	0.38			0.0085						7.3
RfC	Reference Concentration	mg/m3	Default unless shaded	0.0014	0.00003	0.0002	5.3	0.000008	0.0015	0.0003	0.0011	0.00035	0.0002	0.000280	
RfDo	Reference Dose	mg/kg-day	Default unless shaded	0.0004	0.0003	0.0004	1.5	0.003	0.000429	0.0000857	0.0003	0.0001	0.02	0.00008	
URFi	Inhalation Unit Risk Factor	1/ug/m3	Default		0.0043	0.0018		0.012	0.000012				0.00024		0.0011
URFo		ug/l			0.00005										0.00021

If RfC not available EPA derived it from RfD x 20m3/day / 70 kg which assumes toxicity via oral exposure same as inhalation exposure.

Project: arc21 Resdual Waste Treatment Project
Proposed Development of MBT and EfW at Hightown Quarry, Ballutoag
Human Health Risk Assessment

Methodology: US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, 2005
http://www.epa.gov/osw/hazard/tsd/td/combust/risk.htm

Input value - site specific
Input value - non default, eg not in HHRAP database, see text

				Dioxins/Furans	TetraCDD, 2,3,7,8-	PentaCDD, 1,2,3,7,8-	HexaCDD, 1,2,3,4,7,8-	HexaCDD, 1,2,3,6,7,8-	HexaCDD, 1,2,3,7,8,9 -	HeptaCDD, 1,2,3,4,6,7,8-	OctaCDD, 1,2,3,4,6,7,8,9-	TetraCDF, 2,3,7,8-	PentaCDF, 1,2,3,7,8-
COPC Parameters													
Chemical Properties		**Unit**	**Justification**										
Da	Diffusivity of COPC in air	cm2/s	Default unless shaded		0.104	0.099	0.094	0.094	0.094	0.09	0.087	0.024	0.022
Dw	Diffusivity of COPC in water	cm2/s	Default unless shaded		0.0000056	0.000008	0.000008	0.000008	0.000008	0.000008	0.000008	0.000006	0.000008
Fv	Fraction of chemical air concentration in vapor phase	unitless	Default unless shaded		0.664	0.12	0.024	0.029	0.016	0.003	0.002	0.77	0.22
H	Henry's Law constant	atm-m3/mol	Default unless shaded		0.0000329	0.0000026	0.000011	0.000011	0.000011	0.000012	0.0000068	0.000014	0.000005
Kdbs		cm3/g/kg	Default		155618.1	107661.4	1556181	492107.5	492107.5	2466380	3908949	31049.88	77993.78
Kds	Soil water partition coefficient	cm3/g	Default		38904.51	26915.35	389045.1	123026.9	123026.9	616595	977237.2	7762.47	19498.45
Kdsw		L/kg	Default		291783.9	201865.1	2917839	922701.6	922701.6	4624463	7329279	58218.53	146238.3
Koc		mL/g	Default		3890451	2691535	38904510	12302690	12302690	61659500	97723720	776247.1	1949845
Kow (log)		unitless	Default unless shaded		6.8	6.64	7.8	7.3	7.3	8	8.2	6.1	6.5
ksg	COPC loss constrant due to biotic and abiotic degradation	1/yr	Default		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
MW	Molecular weight	g/mol	Default unless shaded		321.98	356.42	390.87	390.87	390.87	425.31	460.76	305.98	340.42
S		mg/L-water	Default unless shaded		0.0000193	0.00012	0.0000044	0.0000044	0.0000044	0.0000024	0.000000074	0.00042	0.00024
Tm		K	Default		578.7	513.7	547.2	558.7	516.7	537.7	598.7	500.7	469.4
Vp		atm	Default unless shaded		1.97E-12	5.8E-13	5E-14	4.7E-14	6.4E-14	7.4E-15	1.1E-15	2E-11	3.4E-12
Biotransfer Factors for Plants													
Brag		unitless	Default		0.00455	0.0056	0.0012	0.0023	0.0023	0.00092	0.0007	0.012	0.0068
Brf/s	Plant soil bioconcentration factor for forage/silage	unitless	Default		0.00455	0.0056	0.0012	0.0023	0.0023	0.00092	0.0007	0.012	0.0068
Brgrain	Plant soil bioconcentration factor for grain	unitless	Default		0.00455	0.0056	0.0012	0.0023	0.0023	0.00092	0.0007	0.012	0.0068
Brroot	Plant soil bioconcentration factor for below ground produce	unitless	Default		1.03	1.12	0.6	0.79	0.79	0.55	0.49	1.49	1.21
Bvag	COPC air to plant biotransfer factor for aboveground produce	(mg/kg)/mg/kg)	Default		65500	239000	520000	520000	520000	910000	2360000	45700	97500
VG	Empirical correction factor for aboveground and belowground produce		Default		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bvforage		(mg/kg)/mg/kg)	Default		65500	239000	520000	520000	520000	910000	2360000	45700	97500
RCF		(ug/g)/(ug/mL)	Default		39999	30120	235535	97063	97063	335781	478692	11562	23499
Biotransfer Factors for Animals													
Babeef		day/kg	Default		0.026	0.029	0.011	0.018	0.018	0.0088	0.0069	0.036	0.031
Baeggs		day/kg	Default		0.011	0.012	0.0046	0.0076	0.076	0.0037	0.0029	0.015	0.013
BAF		L/kg FW	Default unless shaded										
Bamilk		day/kg FW tissue	Default		0.005499	0.0061	0.0023	0.0038	0.0038	0.0018	0.0014	0.0077	0.0065
Bapork		day/kg	Default		0.03162	0.035	0.013	0.022	0.022	0.011	0.0083	0.044	0.037
Bapoult		day/kg	Default		0.01924	0.021	0.0081	0.013	0.013	0.0065	0.0051	0.027	0.023
BCFfish		L/kg FW	Default unless shaded		34400	25870	5176	25100	25100	2754	1465	9931	20183
BSAFfish	only applied to dioxins/furans	(mg/kg)/mg/kg)	Default		0.09	0.09	0.04	0.04	0.04	0.005	0.0001	0.09	0.09
MF	Metabolism factor		Default		1	1	1	1	1	1	1	1	1
Health Parameters				**Dioxins/Furans**	**TetraCDD, 2,3,7,8-**	**PentaCDD, 1,2,3,7,8-**	**HexaCDD, 1,2,3,4,7,8-**	**HexaCDD, 1,2,3,6,7,8-**	**HexaCDD, 1,2,3,7,8,9 -**	**HeptaCDD, 1,2,3,4,6,7,8-**	**OctaCDD, 1,2,3,4,6,7,8,9-**	**TetraCDF, 2,3,7,8-**	**PentaCDF, 1,2,3,7,8-**
CSFo	Cancer slope factor	1/mg/kg-day	Default		150000			0.0062	0.0062				
RfC	Reference Concentration	mg/m3	Default unless shaded										
RfDo	Reference Dose	mg/kg-day	Default unless shaded		0.000000001								
URFi	Inhalation Unit Risk Factor	1/ug/m3	Default		13			1.3	1.3				

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(yellow shading)	Input value - site specific
(grey shading)	Input value - non default, eg not in HHRAP database, see text

				PentaCDF, 2,3,4,7,8-	**HexaCDF, 1,2,3,4,7,8-**	**HexaCDF, 1,2,3,7,8,9-**	**HexaCDF, 1,2,3,6,7,8-**	**HexaCDF, 2,3,4,6,7,8-**	**HeptaCDF, 1,2,3,4,6,7,8-**	**HeptaCDF, 1,2,3,4,7,8,9-**	**OctaCDF, 1,2,3,4,6,7,8,9-**
COPC Parameters											
Chemical Properties		**Unit**	**Justification**								
Da	Diffusivity of COPC in air	cm2/s	Default unless shaded	0.022	0.021	0.021	0.021	0.021	0.02	0.02	0.019
Dw	Diffusivity of COPC in water	cm2/s	Default unless shaded	0.000008	0.000008	0.000008	0.000008	0.000008	0.000008	0.000008	0.000008
Fv	Fraction of chemical air concentration in vapor phase	unitless	Default unless shaded	0.27	0.049	0.052	0.09	0.055	0.01	0.057	0.002
H	Henry's Law constant	atm-m3/mol	Default unless shaded	0.000005	0.000014	0.0000073	0.000011	0.000011	0.000014	0.000014	0.0000019
Kdbs		cm3/g/kg	Default	152075.8	246638	246638	246638	246638	619526.7	619526.7	2466380
Kds	Soil water partition coefficient	cm3/g	Default	38018.94	61659.5	61659.5	61659.5	61659.5	154881.7	154881.7	616595
Kdsw		L/kg	Default	285142.1	462446.3	462446.3	462446.3	462446.3	1161612	1161612	4624462.51
Koc		mL/g	Default	3801894	6165950	6165950	6165950	6165950	15488170	15488170	61659500.19
Kow (log)		unitless	Default unless shaded	6.79	7	7	7	7	7.4	7.4	8
ksg	COPC loss constrant due to biotic and abiotic degradation	1/yr	Default	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
MW	Molecular weight	g/mol	Default unless shaded	340.42	374.87	374.87	374.87	374.87	409.31	409.31	444.76
S		mg/L-water	Default unless shaded	0.00024	0.0000082	0.000018	0.000013	0.000013	0.0000014	0.0000014	0.0000012
Tm		K	Default	499.2	499.2	505.7	520.7	512.7	509.7	495.2	532.2
Vp		atm	Default unless shaded	2.2E-12	3.2E-13	2.9E-13	3.7E-13	2.63E-13	4.6E-14	4E-13	4.93E-15
Biotransfer Factors for Plants											
Brag		unitless	Default	0.0046	0.0035	0.0035	0.0035	0.0035	0.002	0.002	0.00092
Brf/s	Plant soil bioconcentration factor for forage/silage	unitless	Default	0.0046	0.0035	0.0035	0.0035	0.0035	0.002	0.002	0.00092
Brgrain	Plant soil bioconcentration factor for grain	unitless	Default	0.0046	0.0035	0.0035	0.0035	0.0035	0.002	0.002	0.00092
Brroot	Plant soil bioconcentration factor for below ground produce	unitless	Default	1.03	0.92	0.92	0.92	0.92	0.75	0.75	0.78
Bvag	COPC air to plant biotransfer factor for aboveground produce	(mg/kg)/mg/kg)	Default	97500	162000	162000	162000	162000	830000	830000	2280000
VG	Empirical correction factor for aboveground and belowground produce		Default	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Bvforage		(mg/kg)/mg/kg)	Default	97500	162000	162000	162000	162000	830000	830000	2280000
RCF		(ug/g)/(ug/mL)	Default	39296	57023	57023	57023	57023	115892	115892	478692
Biotransfer Factors for Animals											
Babeef		day/kg	Default	0.026	0.023	0.023	0.023	0.023	0.016	0.016	0.0088
Baeggs		day/kg	Default	0.011	0.0096	0.0096	0.0096	0.0096	0.0069	0.0069	0.0037
BAF		L/kg FW	Default unless shaded								
Bamilk		day/kg FW tissue	Default	0.0055	0.0048	0.0048	0.0048	0.0048	0.0035	0.0035	0.0018
Bapork		day/kg	Default	0.032	0.028	0.028	0.028	0.028	0.02	0.02	0.011
Bapoult		day/kg	Default	0.019	0.017	0.017	0.017	0.017	0.012	0.012	0.0065
BCFfish		L/kg FW	Default unless shaded	33752	48977	48977	48977	48977	18281	18281	2754
BSAFfish	only applied to dioxins/furans	(mg/kg)/mg/kg)	Default	0.09	0.04	0.04	0.04	0.04	0.005	0.005	0.0001
MF	Metabolism factor		Default	1	1	1	1	1	1	1	1
Health Parameters				**PentaCDF, 2,3,4,7,8-**	**HexaCDF, 1,2,3,4,7,8-**	**HexaCDF, 1,2,3,7,8,9-**	**HexaCDF, 1,2,3,6,7,8-**	**HexaCDF, 2,3,4,6,7,8-**	**HeptaCDF, 1,2,3,4,6,7,8-**	**HeptaCDF, 1,2,3,4,7,8,9-**	**OctaCDF, 1,2,3,4,6,7,8,9-**
CSFo	Cancer slope factor	1/mg/kg-day	Default								
RfC	Reference Concentration	mg/m3	Default unless shaded								
RfDo	Reference Dose	mg/kg-day	Default unless shaded								
URFi	Inhalation Unit Risk Factor	1/ug/m3	Default								

Annex C – Site Parameters

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(yellow)	Input value - site specific
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Site Parameters		Unit	Justification	Value
BD	Soil dry bulk density	g/cm3	Default	1.5
Zs	Soil zone mixing depth (default untilled 2 cm, tilled 20 cm)	cm	Default for tilled	20
Theta_sw	Soil volumetric water content	ml/cm3	Default	0.2
R	Universal gas constant	atm-m3/mol-K	Default	8.205E-05
P	Average annual precipitation	cm/yr	Met Office annual average 1971-2000	110
PR	Average percentage run off		Assumed	0.2
RO	Average annual surface runoff from pervious areas	cm/yr	Calculated P x pr	22
i	Average annual irrigation	cm/yr	Assumed	0
E_v	Average annual evapotranspiration	cm/yr	Assumed	46.2
Ta	Ambient air temperature	K	Default	298
ρ soil	Solids particle density	g/cm3	Default	2.7
Hg_corr	Fraction of mercury emissions NOT lost to the global cycle		Default	0.48
MHg_ag	Fraction of mercury speciated into methyl mercury in produce		Default	0.22
MHg_s	Fraction of mercury speciated into methyl mercury in soil		Default	0.02
Rp	Interception fraction of the edible portion of plant		Default	0.39
Fw	Fraction of COPC wet deposition that adheres to plant surfaces		Default for cations	0.6
kp	Plant surface loss coefficient	1/yr	Default	18
Tp	Length of plant exposure to deposition per harvest of edible portion of plant	yr	Default	0.16
Yp	Yield or standing crop biomass of the edible portion of the plant	kg DW/m2	Default	2.24
p_a	Density of air	g/m3	Default	1200
Rp_forage	Interception fraction edible portion FORAGE		Default	0.5
Rp_silage	Interception fraction edible portion SILAGE		Default	0.46
Tp_forage	Length of plant exposure to deposition per harvest of edible portion of plant FORAGE	yr	Default	0.12
Tp_silage	Length of plant exposure to deposition per harvest of edible portion of plant SILAGE	yr	Default	0.16
Yp_forage	Yield or standing crop biomass of the edible portion of the plant FORAGE	kg DW /m	Default	0.24
Yp_silage	Yield or standing crop biomass of the edible portion of the plant SILAGE	kg DW /m	Default	0.8
VGag_forage	Empirical correction factor for forage		Default	1
VGag_silage	Empirical correction factor for silage		Default	0.5
Fi_beef_forage	Fraction of Forage grown on contaminated soil eaten by CATTLE		Default	1
Fi_beef_silage	Fraction of Silage grown on contaminated soil eaten by CATTLE		Default	1
Fi_beef_grain	Fraction of Grain grown on contaminated soil eaten by CATTLE		Default	1
Qp_beef_forage	Quantity of Forage eaten by CATTLE each day	kg DW / day	Default	8.8
Qp_beef_silage	Quantity of Silage eaten by CATTLE each day	kg DW / day	Default	2.5
Qp_beef_grain	Quantity of Grain eaten by CATTLE each day	kg DW / day	Default	0.47
Qs_beef	Quantity of soil eaten by CATTLE	kg / day	Default	0.5
Bs	Soil bioavailability factor		Default	1
Fi_milk_forage	Fraction of Forage grown on contaminated soil eaten by DAIRY CATTLE		Default	1
Fi_milk_silage	Fraction of Silage grown on contaminated soil eaten by DAIRY CATTLE		Default	1
Fi_milk_grain	Fraction of Grain grown on contaminated soil eaten by DAIRY CATTLE		Default	1
Qp_milk_forage	Quantity of Forage eaten by DAIRY CATTLE each day	kg DW / day	Default	13.2
Qp_milk_silage	Quantity of Silage eaten by DAIRY CATTLE each day	kg DW / day	Default	4.1
Qp_milk_grain	Quantity of Grain eaten by DARIY CATTLE each day	kg DW / day	Default	3
Qs_milk	Quantity of soil eaten by DAIRY CATTLE	kg / day	Default	0.4
Fi_pork_silage	Fraction of Silage grown on contaminated soil eaten by PIGS		Default	1
Fi_pork_grain	Fraction of Grain grown on contaminated soil eaten by PIGS		Default	1
Qp_pork_silage	Quantity of Silage eaten by PIGS each day	kg DW / day	Default	1.4
Qp_pork_grain	Quantity of Grain eaten by PIGS each day	kg DW / day	Default	3.3
Qs_pork	Quantity of soil eaten by PIGS	kg / day	Default	0.37
Fi_chicken	Fraction of Grain grown on contaminated soil eaten by CHICKEN		Default	1
Qp_chicken_grain	Quantity of Grain eaten by CHICKEN each day	kg DW / day	Default	0.2
Qs_chicken	Quantity of soil eaten by CHICKEN	kg / day	Default	0.022
Aw	Water body surface area	m2	Boghill Dam + Hydepark Dam	99757
dwc	Depth of water column	m	Average estimated from terrain	4
dbs	Depth of upper benthic sediment layer	m	Default	0.03
TSS	Total suspended solids	mg/L	Default assumed	10
Al	Total watershed area receiving COPC deposition	m2	To Boghill Dam + Hydepark Dam	8797157
Ai	Impervious watershed area receiving COPC deposition	m2	Assumed as 4% of Al	351886
ERi	Soil enrichment ratio - inorganic COPCs	-	Default	1
ERo	Soil enrichment ratio - organic COPCs	-	Default	3
Twk	Water body temperature	K	Default	298
C_bs	Bed sediment concentration (or bed sediment bulk density)	g/cm3	Default	1
theta_bs	Bed sedminent porosity	-	Default	0.6
f_lipid	Fish lipid content		Default (0.03 to 0.07)	0.07
Oc_sed	Fraction of organic carbon in bottom sediment	-	Default	0.04
Cd	Drag coefficient	-	Default	0.0011
W	Average annual wind speed	m/s	Aldergrove Met Data	4.22
k	von Karman's constant		Default	0.4
λ_z	Dimensionless viscous sublayer thickness	-	Default	4
ц_a	Viscosity of air	g/cm-s	Default	1.81E-04
ρ w	Density of water	g/cm3	Default	1
ц_w	Viscosity of water corresponding to water temperature	g/cm-s	Default	1.69E-02
Theta	Temperature correction factor	-	Default	1.026
RF	USLE rainfall (or erosivity) factor	1/yr	Default, assumed based on US EPA, 1994.	100
K	USLE erodibility factor	ton/acre	Default, assumed based on US EPA, 1994.	0.36
LS	USLE length slope factor	-	Default, assumed based on US EPA, 1994.	1.5
C	USLE cover management factor	-	Default, assumed based on US EPA, 1994.	0.1
PF	USLE supporting practice factor	-	Default, assumed based on US EPA, 1994.	1
h	Half-life of dioxins in adults	days	Default	2555
f1	Fraction of ingested dioxin and dioxin like PCBs that is stored in fat	-	Default	0.9
f2	Fraction of mother's weight that is fat	-	Default	0.3
f3	Fraction of mother's breast milk that is fat	-	Default	0.04
f4	Fraction of ingested COPC that is absorbed	-	Default	0.9
IRmilk	Ingestion rate of breast milk by the infant	kg/day	Default	0.688
EDinf	Exposure duration of infant to breast milk	yr	Default	1
BWinf	Body weight of infant	kg	Default	9.4
ATinf	Averaging time for infant	yr	Default	1

Annex D – Exposure Parameters

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Input value - site specific
Input value - non default, eg not in HHRAP database, see text

Exposure Scenarios	Resident	Resident Child	Farmer	Farmer Child	Fisher	Fisher Child
Inhalation of Vapors and Particulates	Calc	Calc	Calc	Calc	Calc	Calc
Incidential Ingestion of Soil	Calc	Calc	Calc	Calc	Calc	Calc
Ingestion of Homegrown Produce	Calc	Calc	Calc	Calc	Calc	Calc
Ingestion of Homegrown Beef	N/A	N/A	Calc	Calc	N/A	N/A
Ingestion of Mil from Homegrown Cows	N/A	N/A	Calc	Calc	N/A	N/A
Ingestion of Homegrown Chicken	Not applied	Not applied	Calc	Calc	Not applied	Not applied
Ingestion of Eggs from Homegrown Chickens	Not applied	Not applied	Calc	Calc	Not applied	Not applied
Ingestion of Homegrown Pork	N/A	N/A	Calc	Calc	N/A	N/A
Ingestion of Fish	Not applied	Not applied	Not applied	Not applied	Calc	Calc
Ingestion of Drinking Water from Surface Water Sources	Calc	Calc	Calc	Calc	Calc	Calc
Ingestion of Breast Milk	Calc	N/A	Calc	N/A	Calc	N/A

Exposure Parameters		**Unit**	**Justification**	**Value / Sum**
T1	Time period at beginning of combustion	years	Default	0
tD	Time period over which deposition occurs (time period of combustion)	years	Default	30
EDar (T2r_fi)	Exposure duration adult resident / fisher	years	Default	30
EDafa (T2fa)	Exposure duration adult farmer	years	Default	40
EDc (T2c)	Exposure duration child	years	Default	6
ET	Exposure time	Hrs/day	Default	24
EF	Exposure frequency	Days/yr	Default	350
IRa	Inhalation rate adult	m3/hr	Default (20m3/day)	0.83
IRc	Inhalation rate child	m3/hr	UK CLEA	0.49
BWa	Bodyweight adult	kg	Default	70
BWc	Bodyweight child	kg	UK CLEA	13.3
AT	Averaging time carcinogens	year	Default	70
AT(nc)r_fi	Averaging time non carcinogens adult resident / fisher	years	Default	30
AT(nc)fa	Averaging time non carcinogens adult farmer	years	Default	40
AT(nc)c	Averaging time non carcinogens child	years	Default	6

Expsoure Setting Consumption Rates and Fraction Contaminated		**Unit**	**Justification**	**Value / Sum**	Resident	Resident Child	Farmer	Farmer Child	Fisher	Fisher Child
CRsoil	Consumption rate of SOIL	kg/day	Default		0.0001	0.0002	0.0001	0.0002	0.0001	0.0002
Crag	Consumption rate of ABOVEGROUND PRODUCE	kg/kg-day DW	Default		0.00032	0.00077	0.00047	0.00113	0.00032	0.00077
CRpp	Consumption rate of PROTECTED ABOVEGROUND PRODUCE	kg/kg-day DW	Default		0.00061	0.0015	0.00064	0.00157	0.00061	0.0015
CRbg	Consumption rate of BELOWGROUND PRODUCE	kg/kg-day DW	Default		0.00014	0.00023	0.00017	0.00028	0.00014	0.00023
	Consumption rate of BEEF	kg/kg-day FW	Default		0	0	0.00122	0.00075	0	0
	Consumption rate of MILK	kg/kg-day FW	Default		0	0	0.01367	0.02268	0	0
	Consumption rate of PORK	kg/kg-day FW	Default		0	0	0.00055	0.00042	0	0
	Consumption rate of EGGS	kg/kg-day FW	Default		0	0	0.00075	0.00054	0	0
	Consumption rate of POULTRY	kg/kg-day FW	Default		0	0	0.00066	0.00045	0	0
CRfish	Consumption rate of FISH	kg/kg-day FW	Default		0	0	0	0	0.00125	0.00088
CRdw	Consumption rate of DRINKING WATER	L d-1	Default		1.4	0.67	1.4	0.67	1.4	0.67
Fsoil	Fraction contaminated SOIL	--	Default		1	1	1	1	1	1
	Fraction of contaminated ABOVEGROUND PRODUCE	--	Default		1	1	1	1	1	1
	Fraction of contaminated BEEF	--	Default		1	1	1	1	1	1
	Fraction of contaminated MILK	--	Default		1	1	1	1	1	1
	Fraction of contaminated PORK	--	Default		1	1	1	1	1	1
	Fraction of contaminated EGGS	--	Default		1	1	1	1	1	1
	Fraction of contaminated POULTRY	--	Default		1	1	1	1	1	1
	Fraction of contaminated FISH	--	Default		1	1	1	1	1	1
	Fraction of contaminated DRINKING WATER	--	Default		1	1	1	1	1	1