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# MODELLING OF PCDD/F INTAKE FOR RINGASKIDDY RESOURCE RECOVERY CENTRE 2015

Technical Report Prepared For

**Arup Consulting Engineers**

Technical Report Prepared By

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## EXECUTIVE SUMMARY


Soil sampling and ambient air monitoring data, was used to establish a baseline for PCDD/F (hereafter referred to as 'dioxins and furans') intake for a theoretical Maximum At Risk Individual (MARI) in the vicinity of the proposed Ringaskiddy Waste to Energy plant.

The MARI was assumed to live at the point of maximum dioxin and furan deposition from the proposed development and to be a subsistence farmer, who obtained all their meat, milk and vegetables from a 100m diameter site, upon which the maximum deposition flux impacted.

The annual average dioxin and furan emissions under maximum operating conditions (worst case emissions) and assuming that both municipal solid waste and hazardous waste facilities were operating at maximum permitted dioxin concentration in the flue gas, maximum permitted flue gas exhaust flow rates and maximum throughput, were used to model soil PCDD/F concentrations over the operating life of the facility.

This was a very conservative assumption as it assumed the plant operated 24 hours per day, 365 days per year at the maximum emission concentration and flue gas flow rate.

The modelled soil and air values were then added to the baseline value for dioxin and furans and input to the RISC HUMAN Model.

The predicted increase in dioxin and furan intake for the MARI was determined to be only ~~2.2%~~ 1.5% of the EC TWI of 14 pg WHO-TEQ /kg body weight. The TWI was set by the EU in order to protect human health and was based on applying a safety factor to the LOAEL (Lowest Observed Abnormal Effect Levels) for dioxin and furans.

It was therefore concluded that the proposed municipal solid waste and hazardous waste-to-energy facilities will have no significant impact on dioxin and furan intake for even the theoretical MARI and that, with respect to dioxin and furan intake, the facility will have no impact on human health.


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# CONTENTS

## 1.0 INTRODUCTION

AWN Consulting was instructed by Arup Consulting Engineers, on behalf of Indaver Ireland, to undertake a mathematical modelling study to assess the potential impact of dioxin and furan emissions from the proposed Ringaskiddy Waste to Energy facility on human dioxin and furan intake.

## 2.0 MODELLING PHILOSOPHY

It was proposed to model the impact of the emissions on human health and the environment following the methodology defined by the US EPA for hazardous waste facilities [1].

The modelling philosophy was as follows:

Develop a (Conceptual Site Model) CSM to assess the potential dietary intake of dioxin and furans for the theoretical Maximum at Risk Individual (MARI);

Select most appropriate background soil and ambient air dioxin and furan concentration;

Model dioxin and furan intake using background concentrations in soil and air;

Obtain data on deposition rates for dioxin and furans from proposed WTE facility (assuming municipal waste to energy and hazardous waste facilities operating simultaneously and at maximum licensed limits) ;

Model impact of deposition rates on soil concentrations of dioxin and furans over 30 year operating life of facility;

Model increase in ambient air concentrations;

Model impact of facility related dioxin and furan deposition rates and increased ambient air concentrations on dietary intake of dioxin and furans for the MARI.

# 3.0 CONCEPTUAL SITE MODEL AND MAXIMUM AT RISK INDIVIDUAL

## 3.1 Conceptual Site Model

The Conceptual Site Model (CSM) was developed, using the methodology presented in the relevant US EPA Modelling Guidance [1].

The methodology chosen also follows the UK recommended methodology "Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes, HMIP/CPR2/41/1/181, London 1996" in that it considers all likely pathways for dioxin and furan intake in a human and examines the impact of dioxin and furan deposition rate on soil dioxin and furan concentrations and subsequently food dioxin and furan concentrations.

The UK methodology uses the concept of the Hypothetically Maximum Exposed Individual (HMEI), in which the individual is assumed to live in the area of predicted maximum impact from the WTE facility and whose entire food intake is also assumed to be from this area (worst case scenario).

The US EPA Methodology uses the concept of the MARI (Maximum at Risk Individual), which is identical to the HMEI. The US EPA Methodology was chosen as it includes a mathematical model which allows calculation of average dioxin and furan concentrations over the lifetime of the facility, taking into account the natural processes which affect dioxin and furan concentrations in the soil over time, such as leaching, volatilisation and degradation.

Background concentrations of the 17 PCDD/F of interest are principally transferred to a human receptor by the following pathways (It should be noted that there are 75 polychlorinated dibenzo-p-dioxins and 135 polychlorinated dibenzo furans and only 17 of these have been shown to be toxic to laboratory animals, hence these 17 are considered appropriate for further assessment).

- Inhalation indoor air
- Inhalation outdoor air
- Ingestion of soil

- Dermal contact with soil
- Inhalation of soil dust
- Ingestion of drinking water
- Dermal contact with shower water
- Inhalation of water vapour in the shower
- Ingestion of meat
- Ingestion of milk
- Ingestion of vegetables
- Ingestion of surface water
- Ingestion of suspended matter in water
- Dermal contact with surface water

The CSM assumes all of the dioxin and furans emitted deposited on the ground and is available for uptake, apart from the fractions which are removed through volatilisation, surface water run off, erosion and degradation. These elements are calculated for each of the 17 dioxin and furan congeners.

The CSM then assumes the remainder of the dioxin and furans deposited is available for uptake through the pathways listed above.

The group of 17 dioxin and furan congeners vary widely in molecular weight and chemical characteristics and behave quite differently with respect to the fraction which absorbs to soil, is present in the vapour phase or accumulates in meat or milk. It is therefore not valid to model the dioxin and furan concentrations as I-TEQ values and each congener must be modelled separately.

## 3.2 Maximum At Risk Individual (MARI)

In order to conduct a conservative assessment of the potential impact of dioxin and furan emissions on a theoretical individual, the following assumptions were made for the MARI (these assumptions are based on the MARI as used by the US EPA for hazardous waste facility assessment) [1].

- The MARI lives at the point where the dioxin and furan deposition rate predicted to be generated by the facility when operating at maximum capacity impacts on the ground.
- The MARI is a subsistence farmer, who spends 16 hours per day, 7 days per week, 50 weeks per year outside in the field where the deposition occurs;
- The MARI spends 6 years as a child and 60 years as an adult living on the site;
- The MARI only eats vegetables grown on this soil, milk from a cow grazing on the site and meat from cattle raised on the site;

## 4.0 SOIL AND AMBIENT AIR BACKGROUND CONCENTRATIONS

**Soil concentrations**

A monitoring survey conducted by AWN found the background soil dioxin concentration in the immediate vicinity of the Ringaskiddy Waste to Energy site in the area likely to be the close to the location of maximum deposition was Sampling Site E, which is located on the high ground adjacent to the Ringaskiddy Waste to Energy Plant site The measured PCDD/F Concentration for this site was 0.3 ng/kg I-TEQ. It was proposed to use this concentration to define the baseline dioxin exposure for the MARI.

**Ambient Air Concentrations**

AWN also conducted an ambient air quality survey at the site, which is reported in the Air Chapter of the Ringaskiddy Waste to Energy EIS. The highest background air concentration measured was 0.0014 pg/m$^3$ TEQ. It was therefore decided that the ambient air dioxin concentration for the background on the site inhabited by the MARI would be 0.0014 pg/m$^3$ TEQ.

# 5.0 BASELINE PCDD/F INTAKE

## 5.1 Model Selection and Set up

The RISC Human Model Version 3.2 (May 2005) package was chosen to model intake of dioxin and furans. The model was developed by the Dutch National Institute of Public Health and Environmental Protection (RIVM), on behalf of the Dutch Ministry for Spatial Planning, Housing and the Environment and has been used to model the Dutch Soil standards for protection of human health [2].

The model consists of series of equations which allow each of the pathways listed in Section 3.1 to be modelled mathematically. The principal model variables used to calculate total exposure are presented as Attachment A.

The equations used to calculate each variable are presented in Attachment B.

The values selected for the model variables and the justification for selecting these values is presented as Attachment C.

The model data base contains many of the necessary chemical parameters such as the octanol-water coefficient, Henry's coefficient and the water solubility, which are necessary to model the behaviour of substances in soil and water environments. Where these parameters were not available from the model database, The Handbook of Physical Chemistry [3] and Appendices A – J of the US EPA Human Health and Ecological Risk Assessment Report [1] were used.

## 5.2 Model Results

The Model Output Report, for each of the 17 PCDD/F congeners for each intake pathway is presented as Attachment D. The modelled WHO TEF intake value for the MARI, in pg/kg body weight/day, is presented in Table 5.1.

| | mg/kg/d | pg/kg/d | TEF | TEF | pg/kd/d | pg/kg/d |
|---|---|---|---|---|---|---|
| PCDD Congeners | | | NATO CCMS | WHO | NATO CCMS | WHO |
| 2,3,7,8-TCDD | 3.3~~7~~1E-11 | 3.3~~7~~1E-02 | 1 | 1 | 3.3~~7~~1E-02 | 3.3~~7~~1E-02 |
| 1,2,3,7,8-PeCDD | 8.45E-11 | 8.45E-02 | 0.5 | 1 | 4.23E-02 | 8.45E-02 |
| 1,2,3,4,7,8-HxCDD | 7.~~01~~<br>32E-11 | 7.~~01~~<br>32E-02 | 0.1 | 0.1 | 7.~~01~~<br>32E-03 | 7.~~01~~<br>32E-03 |
| 1,2,3,6,7,8-HxCDD | 1.56E-10 | 1.56E-01 | 0.1 | 0.1 | 1.56E-02 | 1.56E-02 |
| 1,2,3,7,8,9-HxCDD | 1.01E-10 | 1.01E-01 | 0.1 | 0.1 | 1.01E-02 | 1.01E-02 |
| 1,2,3,4,6,7,8-HpCDD | 1.50E-09 | 1.50E+00 | 0.01 | 0.01 | 1.50E-02 | 1.50E-02 |
| OCDD | 1.18E-08 | 1.18E+01 | 0.001 | 0.0003 | 1.18E-02 | 3.54E-03 |
| PCDF Congeners | | | | | | |
| 2,3,7,8-TCDF | 3. ~~0~~434E-11 | 3. ~~0~~434E-02 | 0.1 | 0.1 | 3. ~~0~~434E-03 | 3. ~~0~~434E-03 |
| 1,2,3,7,8-PeCDF | 6.~~9~~09E-11 | 6.~~9~~09E-02 | 0.05 | 0.03 | 3.~~4~~05E-03 | ~~2.07~~1.83E-03 |
| 2,3,4,7,8-PeCDF | 6.09E-11 | 6.09E-02 | 0.5 | 0.3 | 3.05E-02 | 1.83E-02 |
| 1,2,3,4,7,8-HxCDF | 2.50E-10 | 2.50E-01 | 0.1 | 0.1 | 2.50E-02 | 2.50E-02 |
| 1,2,3,6,7,8-HxCDF | 1.99E-10 | 1.99E-01 | 0.1 | 0.1 | 1.99E-02 | 1.99E-02 |
| 1,2,3,7,8,9-HxCDF | 6.61E-11 | 6.61E-02 | 0.1 | 0.1 | 6.61E-03 | 6.61E-03 |
| 2,3,4,6,7,8-HxCDF | 2.74E-10 | 2.74E-01 | 0.1 | 0.1 | 2.74E-02 | 2.74E-02 |
| 1,2,3,4,6,7,8-HpCDF | 1.44E-09 | 1.44E+00 | 0.01 | 0.01 | 1.44E-02 | 1.44E-02 |
| 1,2,3,4,7,8,9-HpCDF | 1.95E-10 | 1.95E-01 | 0.01 | 0.01 | 1.95E-03 | 1.95E-03 |
| OCDF | 1.41E-09 | 1.41E+00 | 0.001 | 0.0003 | 1.41E-03 | 4.23E-04 |
| | | | | | | |
| pg/kg bw/day | | | | | 0. ~~9070~~268675 | 0.29 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Base air | | | | | | 0.00035 |
| | | | | | | |
| Total | | | | | | 0.29 |
| | | | | | | |
| pg/kg bw/wk | | | | | | 2.03 |

***Table 5.1*** Modelled baseline PCDD/F intake for MARI– using WHO TEF

The total predicted background dose, combining both inhaled and ingested dioxin and furans is therefore 2.~~02~~03 pg/kg body weight/week (WHO TEQ).

This is considerably less than the EU TWI value of 14 pg WHO-TEQ/kg body weight/wk (from Opinion of the Scientific Committee on the Risk Assessment of Dioxins and Dioxin-like PCBs in Food 22/11/2000 (SCF/CS/CNTMDIOXIN/ 8 Final)).

The TWI was set by the EU in order to protect human health and was based on applying a safety factor to the LOAEL (Lowest Observed Abnormal Effect Levels) for dioxin and furans.

## 6.0 DEPOSITION RATE OF PCDD/F FROM WTE EMISSIONS AND CALCULATION OF PREDICTED SOIL AND AIR CONCENTRATIONS

Air emissions from the proposed WTE facility were modelled by AWN Consulting, using the USEPA AERMOD Model, with the proposed municipal waste to energy and hazardous waste facilities operating at maximum capacity. Details of the modelling study are provided in the Air Quality Chapter of the EIS.

The annual predicted deposition rate under maximum operating conditions, assuming both municipal solid waste and hazardous waste facilities were operating simultaneously at maximum capacity (maximum exhaust gas flow rates and maximum permitted PCDD/F concentration of 0.1 ng/m$^3$ I-TEQ), for each of the 17 PCDD/F congeners was used to predict the soil concentration over the exposure duration period, by applying the model used by the US EPA for Assessment of Hazardous Waste Facilities [1].

The model enables increases in soil concentrations due to aerial deposition of dioxin and furans to be calculated, over a set time period and includes for natural processes such as volatilisation and sediment removal by surface water run-off, which reduce dioxin and furan concentrations in soil.

The model equation to predict the increase in soil concentration of dioxin and furans, resulting from aerial deposition is:

$$Sc_1 = \frac{Ds}{ks \quad (Tc - T_1)} \left[ \left( Tc + \frac{\exp(-ks \quad Tc)}{ks} \right) - \left( T_1 + \frac{\exp(-ks \quad T_1)}{ks} \right) \right] for\ 0 < T_1 < Tc$$

Equation terms are defined in Attachment E.

Ks, the soil loss constant due to all processes, is calculated using the following equation;

$$ks = ksl + kse + ksr + ksg + ksv$$

Equation terms and the equations used to calculate each of the "Ks" terms, are defined in Attachment F.

Ds, the dioxin and furan deposition term, expressed in terms of mg/kg/yr, is calculated as per Attachment G.

A radius of 50m was used to calculate the Ds values used in the modelling study. This assumes that the deposition occurs over a 100m diameter area, inside which the MARI spends all their time.

Tc, the time period over which the emissions occur, has been set at 30 years, as it has been assumed that the facility will have a 30 year operational lifetime
and $T_1$ = Tc – ED (where ED is the exposure duration).

The calculation of predicted soil concentration over the exposure period is presented as Attachment H.

Ambient air dioxin and furan concentrations were also modelled using the AERMOD model and were used to calculate the dioxin and furan intake from inhalation.

## 7.0 MODELLING OF IMPACT OF EMISSIONS ON PCDD/F INTAKE

The predicted ambient air concentrations and predicted soil concentrations were used to model the impact of WTE Emissions on dioxin and furan intake for the MARI, using the methodology and modelling tools outlined in Section 2.0 and Section 3.0 of this report.

The Model output, for each of the 17 PCDD/F congeners for each intake pathway is presented as Attachment J. The modelled dioxin and furan intake (for all ingestion sources) for the impact of emissions on dioxin and furan intake for the MARI, in pg/kg body weight/day, is presented in Table 7.1.

| | mg/kg/d | pg/kg/d | TEF | TEF | pg/kd/d | pg/kg/d |
|---|---|---|---|---|---|---|
| PCDD Congeners | | | NATO CCMS | WHO | NATO CCMS | WHO |
| 2,3,7,8-TCDD | ~~5.2~~3.32E-11 | ~~5.2~~3.32E-02 | 1 | 1 | ~~5.2~~3.32E-02 | ~~5.2~~3.32E-02 |
| 1,2,3,7,8-PeCDD | 8.~~41~~72E-11 | 8.~~41~~72E-02 | 0.5 | 1 | 4.~~21~~36E-02 | 8.~~41~~72E-02 |
| 1,2,3,4,7,8-HxCDD | 7.~~44~~79E-11 | 7.~~44~~79E-02 | 0.1 | 0.1 | 7.~~44~~79E-03 | 7.~~44~~79E-03 |
| 1,2,3,6,7,8-HxCDD | 1.~~58~~65E-10 | 1.~~58~~65E-01 | 0.1 | 0.1 | 1.~~58~~65E-02 | 1.~~58~~65E-02 |
| 1,2,3,7,8,9-HxCDD | 1.~~13~~18E-10 | 1.~~13~~18E-01 | 0.1 | 0.1 | 1.~~13~~18E-02 | 1.~~13~~18E-02 |
| 1,2,3,4,6,7,8-HpCDD | 1.5~~0~~7E-09 | 1.5~~0~~7E+00 | 0.01 | 0.01 | 1.5~~0~~7E-02 | 1.5~~0~~7E-02 |
| OCDD | 1.~~17~~23E-08 | 1.~~17~~23E+01 | 0.001 | 0.0003 | 1.~~17~~23E-02 | 3.~~52~~69E-03 |
| PCDF Congeners | | | | | | |
| 2,3,7,8-TCDF | 3.~~48~~36E-11 | 3~~48~~.36E-02 | 0.1 | 0.1 | 3.~~48~~36E-03 | 3~~48~~.36E-03 |
| 1,2,3,7,8-PeCDF | 6.~~32~~44E-11 | 6.~~32~~44E-02 | 0.05 | 0.03 | 3.~~19~~22E-03 | 1.9~~9~~3E-03 |
| 2,3,4,7,8-PeCDF | 6.~~67~~88E-11 | 6.~~67~~88E-02 | 0.5 | 0.3 | 3.~~3~~44E-02 | 2.0~~0~~6E-02 |
| 1,2,3,4,7,8-HxCDF | 2.~~81~~93E-10 | 2.~~81~~93E-01 | 0.1 | 0.1 | 2.~~81~~93E-02 | 2~~81~~.93E-02 |
| 1,2,3,6,7,8-HxCDF | ~~1.99~~2.18E-10 | ~~1.99~~2.18E-01 | 0.1 | 0.1 | ~~1.99~~2.18E-02 | ~~1.99~~2.18E-02 |
| 1,2,3,7,8,9-HxCDF | 7.~~48~~83E-11 | 7.~~48~~83E-02 | 0.1 | 0.1 | 7.~~48~~83E-03 | 7~~48~~.83E-03 |
| 2,3,4,6,7,8-HxCDF | 3.~~51~~68E-10 | 3.~~51~~68E-01 | 0.1 | 0.1 | 3.~~51~~68E-02 | 3~~51~~.68E-02 |
| 1,2,3,4,6,7,8-HpCDF | 1.~~48~~55E-09 | 1.~~48~~55E+00 | 0.01 | 0.01 | 1.~~48~~55E-02 | 1~~48~~.55E-02 |
| 1,2,3,4,7,8,9-HpCDF | ~~1.99~~2.09E-10 | ~~1.99~~2.09E-01 | 0.01 | 0.01 | ~~1.99~~2.09E-03 | ~~1.99~~2.09E-03 |
| OCDF | 1.6~~9~~8E-09 | 1.6~~9~~8E+00 | 0.001 | 0.0003 | 1.6~~9~~8E-03 | ~~4.81~~5.04E-04 |
| | | | | | | |
| pg/kg bw/day | | | | | 0.~~304314~~296870 | 0.32 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| Base air + Predicted | | | | | | 0.0003535 |
| | | | | | | |
| Total | | | | | | 0.32 |
| | | | | | | |
| pg/kg bw/wk | | | | | | ~~2.26~~2.24 |

***Table 7.1*** Modelled WTE + baseline PCDD/F intake for MARI

The predicted dioxin and furan dose (for all exposure routes) was therefore estimated to increase by 0.22~~4~~ pg WHO-TEQ/kg body weight/wk, to 2.2~~6~~4 WHO-TEQ/kg body weight/wk, an increase of ~~1.7%~~ 1.5% of the EC TWI limit value of 14 pg WHO-TEQ /kg body weight. The predicted dose is therefore well below applicable limit values for PCDD/F intake.

The TWI was set by the EU in order to protect human health and was based on applying a safety factor to the LOAEL (Lowest Observed Abnormal Effect Levels) for dioxin and furans.

## 8.0 CONCLUSIONS

It was concluded that the predicted impact of the emissions from the waste-to-energy facility, even assuming both municipal solid waste and hazardous waste facilities operating at maximum capacity, maximum permitted exhaust flow rates and maximum permitted dioxin and furan concentrations, in terms of dioxin and furan dose to a theoretical MARI, is not significant, with the dioxin and furan dose to the MARI predicted to increase by only ~~1.7%~~ 1.5 % of the limit value.

Based on a worst case scenario, the predicted dioxin and furan intake for the MARI was predicted to be well within the EU 14 pg WHO-TEQ /kg bw/wk value, a limit set for the protection of human health.

It can therefore be concluded that the proposed municipal solid waste and hazardous waste-to-energy facilities will have no significant impact on dioxin and furan intake for even the theoretical MARI and that, with respect to dioxin and furan intake, the facility will have no impact on human health.

## 9.0 REFERENCES

1. Human Health And Ecological Risk Assessment Support To The Development Of Technical Standards For Emissions From Combustion Units Burning Hazardous Waste, EPA Contract No. 68 - W6 – 0053, US EPA, Washington, July 1999.

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3. Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Volume II, Polynuclear Aromatic Hydrocarbons, Polychlorinated Dioxins and Dibenzofurans, Mackay, D., Ying Shiu, W. and Chimg Ma, K., Lewis Publishers, Ann Arbor, Tokyo and London, 1995.

## ***ATTACHMENTS A - J***

**END OF REPORT**