

Appendix 1: Correcting the food intake to rectify the MARI family's starvation diet

1. What is the MARI diet as modelled by AWN?

According to Appendix 6.3, Attachment C, the diet of MARI (adult) consists of only the following:

Leafy Vegetables = 0.118 kg/day
 Tuberous vegetables = 0.225 kg/day
 Meat = 0.179 kg/day
 Milk = 0.243 kg/day

Attachment C informs us that the child's diet is considered to be exactly half of the adult's in each category.

These food intakes are derived from a national food intake survey¹, and it is easy to reconstruct the food groups that have been used (the complete table is shown in at the end of this Appendix). From this we can reconstruct the calorie intake of the MARI adult, as follows. I will use the adult values for the moment, because these were used in the IUNA survey. Food weights are from Attachment C of Appendix 6.3 as listed above.

Table (i): Leafy vegetables – 118 g per day, made up of the following IUNA groups:

Food item & IUNA code	Mean intake (g/day)	kcal per 100 g	Total kcal
28 - Vegetable & pulse dishes	17	155 (based on baked beans)	26
29 - Peas, beans & lentils	23	98 (average of peas & lentils)	23
30 - Green vegetables	14	15 (based on lettuce)	2
31 - Carrots	15	41	6
32 - Salad vegetables	24	15 (based on lettuce)	4
33 - Other vegetables	25	41 (based on carrots)	10
Total	118 g per day		71 kcal per day

Table (ii): Tuberous vegetables – 225 g per day, made up of the following IUNA groups:

Food item & IUNA code	Mean intake (g/day)	kcal per 100 g	Total kcal
25 - Potatoes	158	77	122
26 - Processed and homemade potato products	7	77 (as potato)	5
27 - Chipped, fried and roasted potatoes	59	77 (only the potato, because fat for frying has to come from milk or meat)	45
Total	224 g per day		172 kcal per day

¹ IUNA North/South Ireland Food Consumption Survey: Food and Nutrient Intakes, Anthropometry, Attitudinal Data and Physical Activity Patterns, published by the Irish Universities Nutrition Alliance and The Food Safety Promotion Board, Abbey Court, Lower Abbey St, Dublin, 2001; <http://www.iuna.net/docs/NSIFCSummary.pdf>

Table (iii): Meat (food items 43-55 in the IUNA table) – 179 g per day:

Food item & IUNA code	Mean intake (g/day)	kcal per 100 g	Total kcal
43-55 - Meat	179 g/day	250 (as beef, which is the only meat source for MARI)	448 kcal/day

Table (iv): Milk (food items 10-12 in the IUNA table) – 243 g/day:

Food item & IUNA code	Mean intake (g/day)	kcal per 100 g	Total kcal
10-12 - Milk	243 g/day	64.2 (full cream milk)	156 kcal/day

The total energy intake based on the above categories is thus:

	kcal/day
Leafy vegetables	71
Tuberous vegetabes	172
Meat	448
Milk	156
Total for adult	847
Total for child	424

The first point to be made about the table above is that this low calorie intake is not consistent with long term survival and health. The second is that, since nearly all human dioxin intake is from food, this starvation diet lowers the modelled MARI dioxin intake, and with a realistic food intake, the dioxin intake would be much higher. The remainder of this Appendix will explore how much of the dioxin intake has been removed by the MARI's starvation diet.

2. What is missing from the MARI diet?

A glance at the IUNA table reveals that it contains 67 food groups. But adding the food groups in the tables above tells us that the MARI adult diet contains only 25 of them, which explains why the calorie intake above is so low – most food groups in the average Irish diet are simply not there. I have not missed out any part of the MARI diet, as can be verified from the totals in the tables above: the weight in grams of each category agrees with Attachment C of Appendix 6.3. The MARI diet really does consist of only 25 of the 67 food groups in the source cited in the Appendix.

Food groups omitted include some of the biggest sources of dioxins and similar compounds in the average Irish diet, notably butter, cheese and other dairy items. This means that, although at first sight Attachment C seems to say that MARI has a normal Irish diet, in fact the MARI family are consuming a small fraction of the dairy fat that a normal Irish family would, and thus getting only a fraction of the dioxins from that source.

It is also notable that all grains are missing, so MARI does not eat bread or cereals. The MARI family's carbohydrate intake would be seriously deficient. Although plant-based carbohydrates do not contain high concentrations of dioxins, the amount we eat makes them a substantial source nevertheless.

I will consider below the implications of adding each of these food groups on dioxin intake. It should be noted at the outset that I will not be adding *all* the missing food groups, only dairy fat and carbohydrate, and thus the intake will still be underestimated; I will return to that point at the end of this Appendix.

3. Adding back (some of) the missing foods form the MARI diet

(i) Dairy products apart from milk (food groups 13-22 except 19)

Consumption of these for MARI can be based on the IUNA data (footnote 10). The missing items in this group are relevant because of their milk fat content, because almost all dioxins in foods are contained in fats. The table below thus assesses the amount of milk fat that has to be added to the MARI diet.

Food item & IUNA code	Mean intake (g/day)	kcal per 100 g	Total kcal	Fat %	Fat (g)
13 - Creams	2	350	7	10	0.2
14 - Cheeses	12	400	48	32	3.8
15 - Yogurts	16	62	10	4	0.64
16 - Ice creams	7	200	14	13	0.91
17 - Puddings/ desserts	16	100	16	2.8	0.45
18 - Milk puddings	6	100	6	2.5	0.15
20 - Butter	6	720	43	80	4.8
21 - Low fat spreads	4	720 (assume MARI would eat butter)	29	80	3.2
22 - Other spreading fats	12	720 (butter)	86	80	9.6
Total	81 g/day		259 kcal/day		23.75 g/day

In the MARI modelling done by AWN, the only dairy product allowed was 243 g of milk per day. Full fat milk contains about 4 % fat, i.e. the MARI adult has an intake of 9.72 g milk fat. As the table above shows, 23.75 g of milk fat has been omitted from the MARI's diet. We can add back the missing fraction by adding $(23.75/9.72)$ of the current dairy-based dioxin and furan intake of the MARI adult.

(ii) Carbohydrate food group (food types 1-9)

The MARI diet in the EIS contains no grain-based carbohydrates (rice, breads, cereals, biscuits). These provide a large fraction of the calories in the Irish diet. Since MARI is constrained to eat only home-produced food, the most likely replacement would be potatoes (growing grains would need more land than MARI has). We can therefore increase the intake of potatoes to replace the calories not obtained from these grains.

Considering these 9 food items in the IUNA survey:

Food item & IUNA code	Mean intake (g/day)	kcal per 100 g	Total kcal
1 - Rice/pasta/flours/grains/starches	20	131	26
2 - Savouries	24	470	113
3 - White breads	78	265	207
4 - Wholemeal breads	45	247	111
5 - Other breads	15	265	40
6 - Ready to eat breakfast cereals	19	379	72
7 - Other breakfast cereals	16	379	61
8 - Biscuits	14	474	66
9 - Cakes/pastries/buns	17	436	74
Total	248 g/day		770 kcal/day

To replace these 770 calories with potatoes (77 kcal/100 g), MARI would need to eat 1 kg of potatoes per day. The intake of tuberous vegetables thus increases from 224 g/day to 1224 g/day, and of total vegetables from 342 g/day to 1342 g/day. We are not given a separate analysis of the dioxin content of leafy vs tuberous vegetables, so all we can do is to increase the vegetable fraction of the dioxin-like toxicity intake by (1000/342).

Once we have added the missing dairy fats and carbohydrate, the calorie intake for the MARI adult is increased by 259 kcal/day (non-milk dairy) and 770 kcal/day (carbohydrate) to a total of 1876 kcal/day for the MARI adult. and I will return to this later.

To determine the effect these corrections would have on total uptake, we can simplify by extrapolating from one congener to the others, so I will consider 2,3,7,8-TCDD as an example. The following uptake table is drawn from Attachment D of Appendix 6.3 (I have included only the adult and lifelong values, as we will consider the child in my Appendix B).

Exposure per route (mg/(kg.d))

Exposure route	Adult	Lifelong
inhalation indoor air	2.39E-17	3.02E-17
inhalation outdoor air	3.81E-17	3.58E-17
ingestion soil	5.08E-14	9.88E-14
dermal contact soil	7.78E-14	7.33E-14
inhalation soil	5.67E-16	6.01E-16
ingestion milk	4.84E-12	6.25E-12
ingestion meat	1.82E-11	1.98E-11
ingestion vegetables	6.37E-12	6.92E-12
Total exposure	2.95E-11	3.31E-11

To this total exposure we should add the missing dairy fat (23.75 / 9.72 x current dairy fat intake), and the missing vegetable intake (1000 / 342 x current vegetable intake):

Missing dairy fat	1.18E-11	1.53E-11
Missing vegetable	1.86E-11	2.02E-11
Revised total exposure	5.99E-11	6.86E-11
Revised exposure relative to original value	203 %	207 %

As expected, because the lifelong value is dominated by the adult, the results for ‘adult’ and ‘lifelong’ are similar: adding back the missing dairy fat and carbohydrate consumption increases the total dioxin and furan intake to just over double the value given by AWN. We can now return to the tables in the main body of Appendix 6.3 and correct the dioxin and furan intake given there. Since the only total intake we are given in Tables 5.1 and 7.1 in that Appendix is the lifelong one, we should base our corrections on that. The baseline lifelong intake of 2.0826 pg/kg/week should be increased to 207 % of that value, to correct for the omission of dairy fat and carbohydrate; it would then become **4.31 pg/kg/week**, just over twice the EU TWI.

4. The food groups that are still missing

As already mentioned, the MARI diet with these corrections is still inadequate, at only 1,876 calories – just over 80 % of an adult’s nutritional needs. This is because, for simplicity and to save time, the analysis above still omits important food groups. We have added 18 food groups (the 9 missing sources of dairy fat, and the 9 carbohydrate items) to the 25 that were included in the MARI model, to make 43 food groups out of the 67 in the IUNA list.

The missing food groups include some very important sources of dioxin-like toxicity in the average Irish diet, such as fish, eggs, nuts, and vegetable oils. These are all high in fats or oils, and are therefore important sources of dioxins and related compounds, because dioxins in food are found in fats.

According to an analysis of dioxins and related compounds in the Irish diet², eggs, nuts and vegetable oils contribute about 11 % of total dioxin-like toxicity in the average Irish diet. Fish is another matter: according to the same study, fish consumption contributes 39 % of total intake of dioxin-like toxicity in the average Irish diet.

Our missing food groups thus contribute about 50 % of the dioxin-like toxicity in the average Irish diet. Even by adding the missing dairy fat and carbohydrate groups in the analysis above, we are still seriously underestimating the MARI intake. How should we deal with this? Should these foods be included in the MARI model at all?

This is perhaps best answered with reference to the last paragraph of my explanation of the model, at the beginning of this report. The MARI model is not trying to reproduce a real subsistence farmer, but to test whether food grown locally is safe to send into the human food chain. If sent into the food chain, it would be bought in a supermarket along with fish, eggs, nuts and oils. So these items should simply be added to the MARI diet, and they would bring the food intake up to the 2300 kcal/day adult requirement. So their dioxin-like toxicity should simply be added to the intake that results from the MARI model. Since they contribute half of the dioxin-like toxicity in the Irish diet, then the intake obtained from the MARI model, already doubled by correcting the amounts of dairy fat and vegetables, would double again.

I do not intend to press this point, because I have not had time to quantify it in view of the short period of public consultation. But it is important to realise that the correction of the MARI food intake for dairy fat and vegetables still leaves us with a very serious underestimate of the total toxicity from dioxins and related compounds, and the MARI still has only 1876 of the necessary 2300 kcal per day.

The following two pages show the complete IUNA list of foods in the average Irish diet.

² Tlustos et al “Exposure of the adult population resident in Ireland to dioxins and PCBs from the diet” Food Additives and Contaminants Part A 31(6):1100-1113 (2014)

Food Consumption

Foods and Beverages

During the course of the survey, respondents recorded 3,060 individual food items into the 7-day food diary. Each of these foods was allocated to one of 68 food groups. **Table 3**

summarises some of the data from the report on average food group intakes in the total population and in consumers only.

TABLE 3

MEAN AND SD OF FOOD GROUP INTAKES (g/DAY) IN THE TOTAL SAMPLE, PERCENTAGE CONSUMERS OF FOOD GROUPS, AND MEAN AND SD OF FOOD GROUP INTAKES (g/DAY) IN CONSUMERS ONLY

	Population (n=1379)		% consumers	Consumers only	
	Mean	SD		Mean	SD
1 Rice & Pasta, Flours, Grains & Starches	20	32	44	46	33
2 Savouries	24	40	56	43	46
3 White Breads & Rolls	78	59	94	83	57
4 Wholemeal & Brown Breads & Rolls	45	58	73	61	60
5 Other Breads	15	25	52	30	29
6 "Ready To Eat" Breakfast Cereals	19	23	67	29	23
7 Other Breakfast Cereals	16	52	15	105	92
8 Biscuits	14	18	76	19	18
9 Cakes, Pastries & Buns	17	25	60	29	26
10 Wholemilk	150	188	73	205	192
11 Low Fat, Skimmed & Fortified Milks	88	140	45	194	152
12 Other Milks	5	32	6	88	101
13 Creams	2	5	23	7	9
14 Cheeses	12	15	74	17	16
15 Yoghurts	16	33	32	49	41
16 Icecreams	7	13	37	20	14
17 Puddings & Chilled Desserts	16	27	50	32	31
18 Milk Puddings	6	16	16	34	26
19 Eggs & Egg Dishes	17	21	68	25	22
20 Butter	6	12	47	12	15
21 Low Fat Spreads	4	11	28	16	15
22 Other Spreading Fats	12	14	68	17	15
23 Oils*	0	1	14	2	2
24 Hard Cooking Fats	0	1	1	3	4
25 Potatoes	158	165	95	167	165
26 Processed & Homemade Potato Products	7	17	28	25	26
27 Chipped, Fried & Roasted Potatoes	59	59	82	72	58
28 Vegetable & Pulse Dishes	17	43	50	34	56
29 Peas, Beans & Lentils	23	27	75	30	27

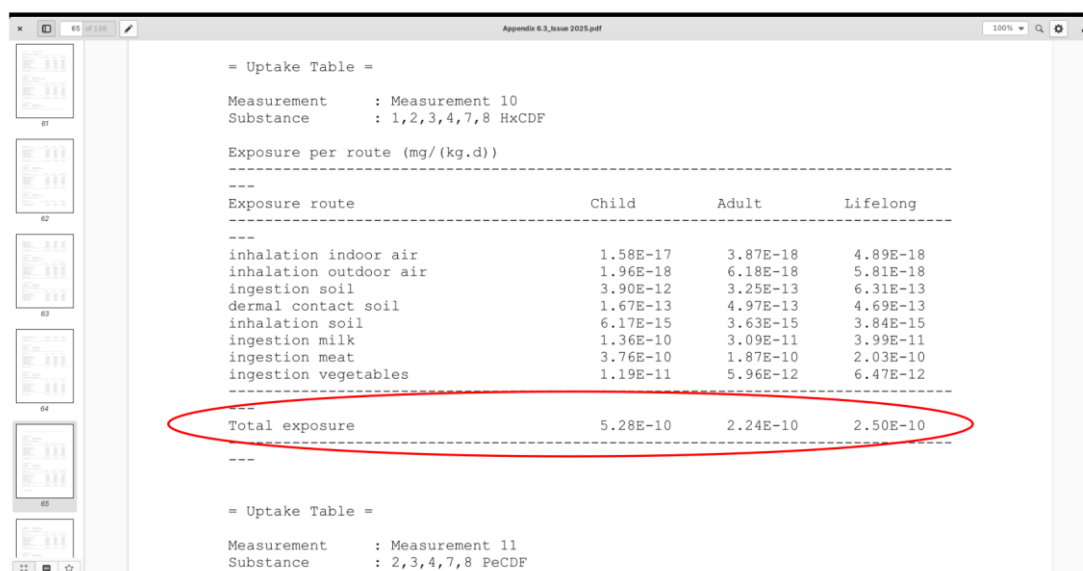
	Population (n=1379)		Consumers only		
	Mean	SD	% consumers	Mean	SD
30 Green Vegetables	14	18	63	22	18
31 Carrots	15	20	66	22	22
32 Salad Vegetables	24	28	76	32	28
33 Other Vegetables	25	27	85	30	27
34 Tinned or Jarred Vegetables	3	8	23	12	14
35 Fruit Juices	33	60	41	81	70
36 Bananas	27	44	49	56	49
37 Other fruits	45	65	62	72	69
38 Citrus Fruit	22	50	31	71	68
39 Tinned Fruit	3	9	14	18	18
40 Nuts & Seeds, Herbs & Spices	1	5	18	7	11
41 Fish & Fish Products	23	27	66	35	26
42 Fish Dishes	3	13	80	27	27
43 Bacon & Ham	22	25	66	22	25
44 Beef & Veal	17	25	55	31	26
45 Lamb	7	16	26	27	21
46 Pork	10	19	35	29	20
47 Chicken, Turkey & Game	22	25	71	31	25
48 Offal & Offal Dishes	1	5	4	19	15
49 Beef & Veal Dishes	31	46	47	65	47
50 Lamb, Pork & Bacon Dishes	7	22	14	50	37
51 Poultry & Game Dishes	21	37	35	60	40
52 Burgers (Beef & Pork)	7	15	28	25	20
53 Sausages	10	13	59	16	14
54 Meat Pies & Pastries	5	16	19	29	24
55 Meat Products	19	24	70	27	24
56 Alcoholic Beverages	333	587	65	513	662
57 Sugars, Syrups, Preserves & Sweeteners	18	23	80	23	24
58 Chocolate Confectionery	12	20	63	19	23
59 Non-chocolate Confectionery	2	5	23	8	8
60 Savoury Snacks	6	11	48	12	13
61 Soups, Sauces & Miscellaneous Foods	46	52	93	50	52
62 Teas	561	409	91	619	385
63 Coffees	153	259	55	279	295
64 Other Beverages	258	386	77	335	410
65 Carbonated Beverages	86	152	54	158	177
66 Diet Carbonated Beverages	35	121	21	170	218
67 Squashes, Cordials & Fruit Juice Drinks	20	67	21	96	118

* Does not include oils consumed in recipes

Appendix 2: Comparison of adult and child MARI dioxin intakes

1. Adult and child dioxin intakes in the AWN modelling

The table below shows the child, adult and lifelong dioxin intakes for one of the congeners, 1,2,3,4,7,8 hexachlorodibenzofuran (1,2,3,4,7,8 HxCDF), taken from the 2025 EIS, Appendix 6.3, Attachment D.



Exposure route	Child	Adult	Lifelong
inhalation indoor air	1.58E-17	3.87E-18	4.89E-18
inhalation outdoor air	1.96E-18	6.18E-18	5.81E-18
ingestion soil	3.90E-12	3.25E-13	6.31E-13
dermal contact soil	1.67E-13	4.97E-13	4.69E-13
inhalation soil	6.17E-15	3.63E-15	3.84E-15
ingestion milk	1.36E-10	3.09E-11	3.99E-11
ingestion meat	3.76E-10	1.87E-11	2.03E-10
ingestion vegetables	1.19E-11	5.96E-12	6.47E-12
Total exposure	5.28E-10	2.24E-10	2.50E-10

When one looks at the 'Total exposure' row, it is immediately obvious to the reader, and the modeller, that the child's intake is well over twice that of the adult in the modelling by AWN; also that the adult and lifelong intakes are very similar. Reporting only the lifelong intake in the main body of Appendix 6.3, as AWN does in Tables 5.1 and 7.1 as well as the text of the Appendix, biases the reporting towards the adult intake, and obscures the much higher child intake; but that child intake should also be reported, according to the HHRAP methodology that AWN states is being followed.

2. What should the child's intake actually be, relative to the adult?

The AWN intake in the table above demonstrates the obvious difference between child and adult intakes, but the AWN modelling is based on impossibly restricted and unrepresentative diets for both child and adult, and the assumption that the child eats half of the adult's diet. In reality, a six-year-old child's calorie intake is more like two-thirds of the adult's intake.

In calculating the real dioxin intake for a child relative to an adult, we can ignore intake from the air, which, as can be seen in the table above, is extremely small, comprising one millionth or less of the total dioxin intake. This accurately reflects the real world situation, where intake from inhaled air is negligible. Similarly, intake from eating soil is very small relative to food intake, less than 1%. We can thus concentrate exclusively on intake from food.

If, as an approximation, the MARI child eats a similar mix of food groups (meat, milk and vegetables) as the adult MARI, all we need to consider is body weight and calorie intake, since the proportion of calories from each food group will not differ between adult and child.

According to US Government guidance³, a healthy food intake for a 6-year-old child (the MARI child is 6 years old) is 1400 calories (girls) or 1600 calories (boys); since we do not know which the MARI child is, we can assume a mean of 1500. For adults in their 30s, the healthy food intake is 2000 calories

³ https://www.dietaryguidelines.gov/sites/default/files/2019-05/2015-2020_Dietary_Guidelines.pdf, pages 77-78

(women) or 2600 calories (men); since we do not know which the MARI is, we can assume a mean of 2300.

With regard to body weight, this is apparent in the AWN model as 60 kg for the adult, and, according to the HHRAP methodology that we are told is being followed in the modelling, 15 kg is used for the child⁴.

This allows us to easily calculate a ratio of calorie intake (and therefore food-related intake of dioxins and related compounds) between adult and child.

	Adult:	Child:
Intake	2300 calories/day	1500 calories/day
Body weight	60 kg	15 kg
Intake relative to weight	38.3 calories/kg/day	100 calories/kg/day

The MARI child's dioxin intake from food, per kilogram of body weight, will thus be $100/38.3 = 2.61$ times that of the adult, if the MARI family is given an adequate diet in calorie terms. This reflects the fact that a child's calorie intake is just under two thirds of the adult's, while the MARI child's body weight is a quarter of the adult's.

If we use the same assumptions as AWN with regard to the lifelong intake, 64 years as an adult and 6 as a child, then the average lifelong calorie intake per kg per day will be:

$$(38.3 \times 64 + 100 \times 6) / 70 = 43.6 \text{ calories/kg/day}$$

This means that we can convert from lifetime intake to the child's intake; the child's intake will be $100/43.6 = 2.29$ times lifelong intake.

In Appendix 1, section 3, we calculated the corrected lifelong intake, including the missing dairy fat and carbohydrate, to be **4.31 pg/kg/week**. Using the conversion factor just worked out, the child's corrected intake will be $4.31 \times 2.29 = \mathbf{9.87 \text{ pg/kg/week}}$. This is nearly 5 times the EU TWI.

⁴ 'Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities' US EPA, 2005, page 6-5. Available from <https://nepis.epa.gov/Exe/ZyPDF.cgi/P10067PR.PDF?Dockey=P10067PR.PDF>

Appendix 3: Correcting for the exclusion of dioxin-like PCBs from the AWN modelling

The samples at Ringaskiddy and in its surroundings contain highly variable levels of DL-PCBs. The actual upper bound measurements can be found in the lab reports appended to Appendix 6.2 of the EIS. In upper bound measurements, compounds that are below the detection threshold are treated as being present at the detection threshold; the upper bound is the one that is more normally used. Lower bound measurements, in contrast, treat those compounds below the detection threshold as zero values, i.e. as being absent. This of course leads to the likelihood of underestimation. It is unfortunate, therefore, that in the tables in Appendix 6.2 (e.g. Insert 4.1), it is the lower bound values that are presented, making DL-PCB concentrations appear very low. This is why it is necessary to go to the raw lab reports to find more reliable values.

The mean upper bound concentration of dioxins and furans is 0.492 ng/kg soil, and that of DL-PCBs is 0.227 ng/kg, meaning that DL-PCBs contribute a mean of 46.1 % of the toxicity of dioxins and furans combined.

It is also possible to estimate the contributions of DL-PCBs based on the EPA's milk sampling programme. At Ringaskiddy, annual samples are taken from farms in the district.

Year	Dioxin + Furan pg/g milk fat TEQ	DL-PCB pg/g milk fat TEQ
2012	0.21	0.22
2013	0.17	0.12
2014	0.19	0.13
2015	0.22	0.11
2016	0.17	0.09
2017	0.16	0.07
2018	0.17	0.11
2019	0.16	0.06
2020	0.16	0.07
2021	0.17	0.1
2022	0.17	0.06
2023	0.16	0.07
Mean	0.162	0.0930
Ratio of DL-PCB to dioxins + furans		57.3 %

As an approximation between the milk samples and soil samples, we could consider that DL-PCBs contribute approximately 50 % of the toxicity of dioxins and furans combined.

From Appendices 1 and 2, we had calculated the corrected lifetime intake of dioxins and furans to be 4.31 pg/kg/week and the child's intake to be 9.87 pg/kg/week. These values should be increased by 50 % to approximate the contribution that would come from DL-PCBs. The lifetime intake would be $4.31 \times 1.5 = 6.46$ **pg/kg/week**, and the child's intake would be $9.87 \times 1.5 = 14.8$ **pg/kg/week**. These values are over 3 times and over 7 times the EU TWI respectively. It is noteworthy that the child's intake is now above even the old EU TWI.

Appendix 4: Choice of sample site for the modelling

1. Variability in the point of maximum modelled deposition or concentration

As stated in the main body of this report, the choice of sample site to use for the modelling has a weak logical foundation. The site is stated as being the site closest to the point of maximum deposition of dioxins and furans from the proposed incinerator. However, this may not be the point where total soil concentration, i.e. baseline plus the contribution from the modelled incinerator, is maximal. It is of course total soil concentration that determines total intake in the model, and it is that total that must be compared against the EU TWI.

Furthermore, the site of maximum deposition moves around widely from year to year, especially when the cumulative output from existing facilities plus the proposed incinerator is considered.

Finally, the sample site actually chosen for the modelling has always been the same one, since 2002, even though it is often not near to the point of maximum deposition, and, if its coordinates are correctly stated in the EIS, it is never the closest site to the maximum. The following aerial photographs show the sample sites in the Ringaskiddy area, and the points of maximum dioxin/furan deposition and maximum NO₂ concentration, as determined by air dispersion modelling.



Figure 1. Sample points and points of maximum modelled dioxin/furan deposition and NO₂ concentration from the proposed incinerator, from 2008 to 2025.

It is clear that the point of maximum deposition from the proposed incinerator is variable, and seldom close to a sampling site (except in 2008, although the very close sample site 2A/F was not used then, and instead site 4A/E was chosen, for reasons that are not clear). In the 2019 modelling in the present EIS, the maximum is to the south-east of the proposed incinerator, and two sites are almost equidistant from it: 3A/A and 4A/E. Site 4A/E was chosen, although according to its coordinates, site 3A/A was slightly closer to the point of maximum deposition. The dioxin and furan concentration at site 4A (which was used for modelling) was reported in Appendix 6.2 to be a little less than half of the slightly nearer sample site 3A/A, which was not used. I can see no rational reason to choose the more distant site, with lower concentration, over the closer one, with higher concentration, except to lower the calculated MARI dioxin intake.

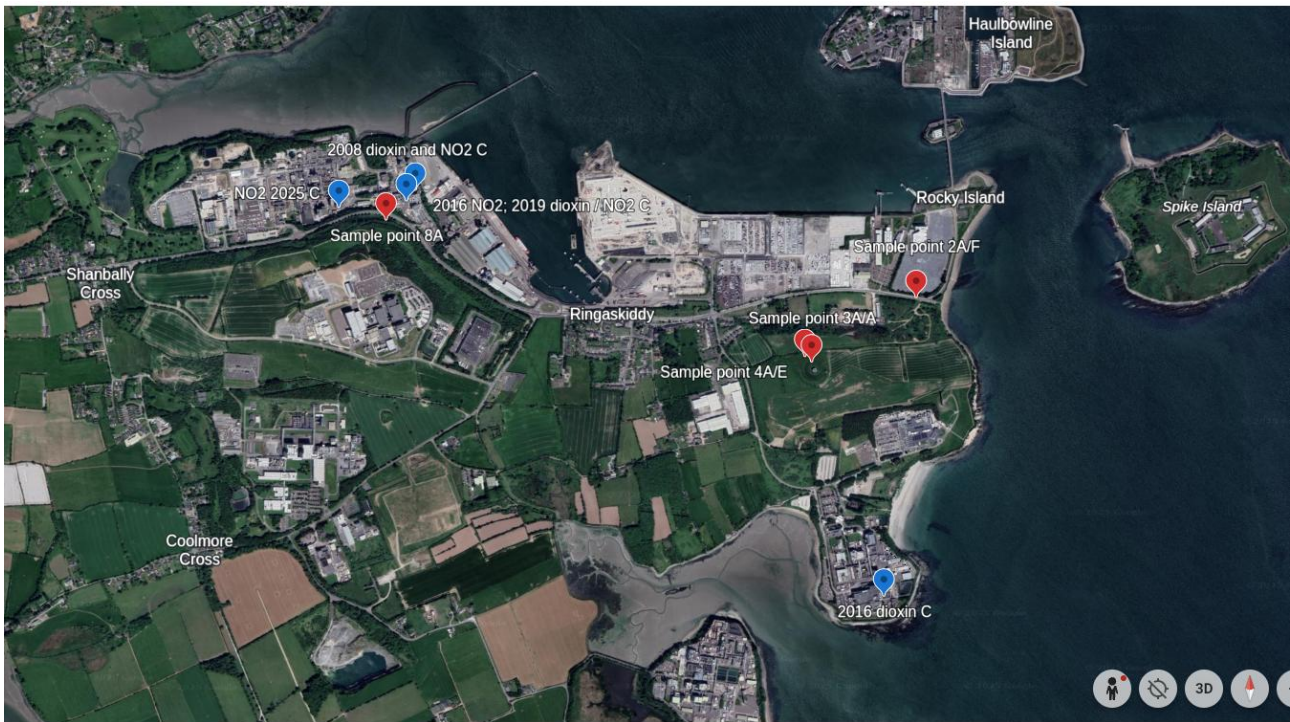


Figure 2. Points of maximum cumulative dioxin/furan deposition and NO₂ concentration, from 2008 to 2019.

The cumulative output of the proposed incinerator plus existing sources of dioxins and NO₂ in the area was modelled, and the points of maximum dioxin/furan deposition and NO₂ concentration are shown. The variability of the maxima from year to year is very clear here, making the approach of choosing a single sampling site close to any one of these points rather tenuously justified. In truth, depending on annual winds, the maxima could be anywhere in a wide area, not always in the same direction.

Based on this, it would seem more sensible and conservative to choose one of these four sample sites that would have the largest sum of baseline concentration plus maximum deposition, even if it is not at the point of maximum deposition in a given year.

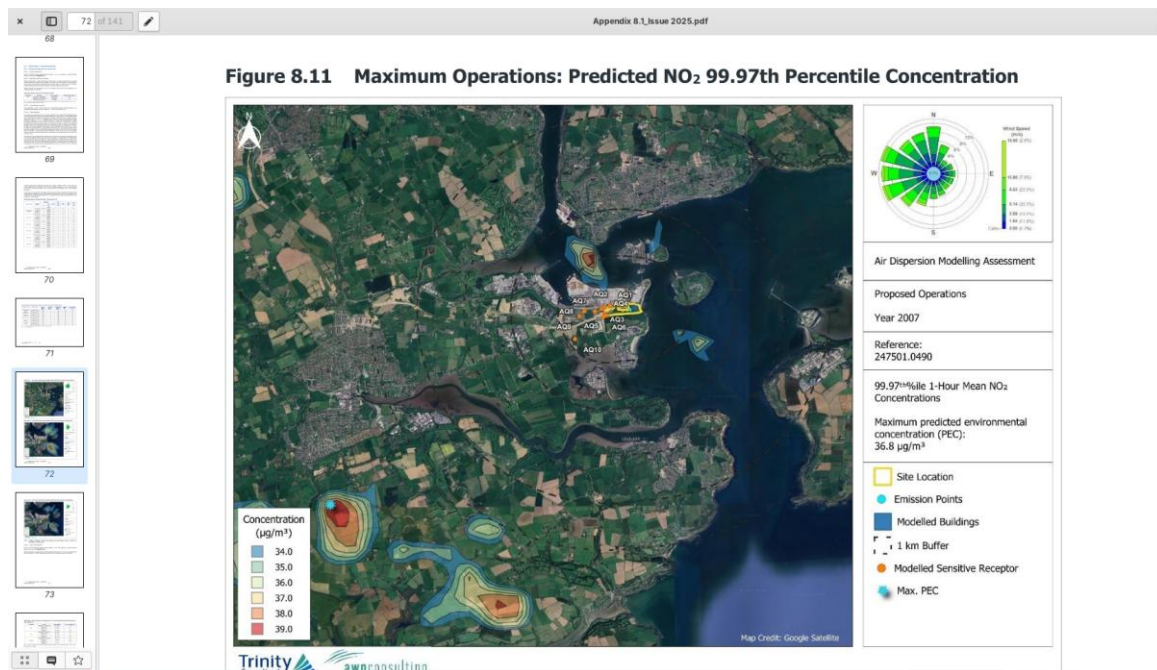


Figure 3. NO₂ 99.97th percentile concentration in 2007, making clear that emissions from the incinerator may spread over a very wide area.

This also suggests that using a specific sample site within a much smaller area around the incinerator makes little sense, when the point of maximum concentration is so variable in both direction and distance. In most years, under most conditions, the maximum is within the area of the four Ringaskiddy sample points shown in Figures 1 and 2, suggesting that the wise and conservative approach would be to choose the one of these that has the highest baseline plus incinerator concentration.

2. The effect of sample site choice

As mentioned above, the sample site always chosen for the modelling is site 4A (previously labelled E). The reason for that choice is unclear, as (if the coordinates given in Appendix 6.2 are correct) it has never been the sample site closest to the maximum deposition or concentration, which is the stated criterion for choosing the sample site for the modelling. According to the coordinates in Appendix 6.2, another site very nearby, 3A, is closer in 2016 and 2019.

Of the two sample sites, the one chosen each time is the one with the lower dioxin and furan concentration. It is hard to see any other reason for the choice.

As I have suggested, a more cautious and conservative approach would be to choose the site with the greatest total concentration, baseline plus modelled incinerator. Of the four sites in the Ringaskiddy area, the highest baseline concentration is at site 3A. Since it is almost indistinguishable from site 4A in distance from the recent maxima, and probably slightly closer, it is hard not to conclude that site 3A is the more appropriate one to use for the modelling, both from a precautionary point of view, and because of proximity to the recent maxima.

Concentrations are given for these two sites in Insert 4.1 of Appendix 6.2, but these are lower bound concentrations, and thus very likely underestimated. The modelling itself has used upper bound concentrations, as is evidence from Attachment D of Appendix 6.2, so it is these upper bound concentrations that must be compared.

Site 4A, which was used in the modelling, has an upper bound concentration of 0.48 ng/kg soil. Site 3A, the one that was not used, has an upper bound concentration of 0.75 ng/kg soil. The ratio is $0.75/0.48 = 1.56$. So site 3A would have given a concentration around 56 % higher than site 4A in the modelling.

In Appendix 3, we reached an intake of dioxin-like toxicity of 6.46 pg/kg/week as a lifelong intake, and 14.8 pg/kg/week for the MARI child. If these had been based on sample site 3A instead of sample site 4A, the resulting intake would have been $6.46 \times 1.56 = \mathbf{10.1 \text{ pg/kg/week}}$ as a lifelong intake, and $14.8 \times 1.56 = \mathbf{23.1 \text{ pg/kg/week}}$ for the child. These are baseline intakes, without considering the effect of the proposed incinerator on intake. The lifelong intake is just over 5 times the EU TWI, and the child's intake is over 11 times the EU TWI, as well as being well over the old EU TWI.

Appendix 5: The contribution of the incinerator to intake of dioxin-like toxicity for MARI

The contribution of the incinerator, in TEQ terms, to MARI intake of dioxin-like toxicity fell to one-sixth between 2008 and 2019, despite the incinerator output of dioxins and furans only falling by about 12 % (from 6.7 to 5.9 ng/sec). This seemed to require some explanation, so the mathematics underlying it was investigated to determine what had changed.

To understand the changes in MARI intake from the incinerator, we must first look to soil concentration, because MARI intake is proportional to soil concentration (similar to the situation at baseline).

The following table shows soil concentration in 2008 and 2019, and the ratio between the years.

	2008 Sc mg/kg	2019 Sc mg/kg	Ratio 2008/2019 Sc
PCDD Congeners			
2,3,7,8-TCDD	5.51E-09	9.86E-12	558.5999
1,2,3,7,8-PeCDD	1.01E-08	5.29E-09	1.9084
1,2,3,6,7,8-HxCDD	1.31E-07	1.12E-08	11.6449
1,2,3,4,7,8-HxCDD	8.68E-08	9.55E-09	9.0902
1,2,3,7,8,9-HxCDD	1.11E-07	2.09E-08	5.3167
1,2,3,4,6,7,8-HpCDD	6.02E-07	1.02E-07	5.9048
OCDD	2.23E-05	1.73E-07	129.3203
PCDF Congeners			
2,3,7,8-TCDF	4.28E-08	2.67E-09	16.0532
1,2,3,7,8-PeCDF	5.68E-07	8.15E-09	69.6984
2,3,4,7,8-PeCDF	9.25E-08	1.81E-08	5.0984
1,2,3,4,7,8-HxCDF	1.42E-07	6.43E-08	2.2036
1,2,3,6,7,8-HxCDF	4.55E-08	2.86E-08	1.5887
2,3,4,6,7,8-HxCDF	1.43E-07	4.69E-08	3.0452
1,2,3,7,8,9-HxCDF	1.30E-07	2.89E-08	4.5018
1,2,3,4,6,7,8-HpCDF	2.58E-07	1.61E-07	1.6083
1,2,3,4,7,8,9-HpCDF	8.72E-08	1.85E-08	4.7196
OCDF	9.95E-07	1.04E-07	9.5492

The first thing that is clear is that the ratio 2008/2019 is above 1 in every case, i.e. soil concentration of every congener has fallen; and all of them by more than 12 %. Some are particularly noticeable, e.g. 1,2,3,7,8-PeCDF at 69.7 and OCDD at 129.3, but the most striking is 2,3,7,8-TCDD whose concentration has fallen by 558-fold.

The equation describing soil concentration is as follows:

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

where Sc is soil concentration, Ds is deposition, and ks is a 'soil loss constant'. T is time.

Clearly, soil concentration is proportional to deposition and will be reduced by a high value for soil loss. This makes sense, in that soil concentration is determined by the balance between deposition and soil loss. So we should next look at deposition and soil loss.

The table below shows deposition of each congener in 2008 and 2019.

	2008 Ds mg/kg/yr	2019 Ds mg/kg/yr	Ratio 2008/2019 Ds	
PCDD Congeners				
2,3,7,8-TCDD		4.68E-10	3.36E-11	13.9317
1,2,3,7,8-PeCDD		5.27E-10	3.73E-10	1.4106
1,2,3,6,7,8-HxCDD		6.12E-09	7.91E-10	7.7329
1,2,3,4,7,8-HxCDD		4.15E-09	6.48E-10	6.4131
1,2,3,7,8,9-HxCDD		5.79E-09	1.48E-09	3.9229
1,2,3,4,6,7,8-HpCDD		2.82E-08	6.83E-09	4.1322
OCDD		1.05E-06	1.15E-08	90.8294
PCDF Congeners				
2,3,7,8-TCDF		3.11E-09	2.34E-10	13.2547
1,2,3,7,8-PeCDF		3.19E-08	6.08E-10	52.5033
2,3,4,7,8-PeCDF		4.96E-09	1.31E-09	3.7751
1,2,3,4,7,8-HxCDF		7.53E-09	4.66E-09	1.6163
1,2,3,6,7,8-HxCDF		2.25E-09	1.98E-09	1.1369
2,3,4,6,7,8-HxCDF		7.33E-09	3.32E-09	2.2053
1,2,3,7,8,9-HxCDF		6.67E-09	2.05E-09	3.2602
1,2,3,4,6,7,8-HpCDF		1.35E-08	1.14E-08	1.1856
1,2,3,4,7,8,9-HpCDF		4.57E-09	1.31E-09	3.4776
OCDF		4.67E-08	6.95E-09	6.7110
Sum		1.2205E-06	5.5534E-08	
Ratio of sum 2008/2019				21.9776

Again, deposition of every congener has fallen in 2019 compared to 2008; TCDD shows a 14-fold fall, and the other two that showed marked falls in soil concentration also show similar falls in deposition. In mass terms, there is an approximately 22-fold fall in deposition, resulting from a 12% reduction, in mass terms, in output from the incinerator. If this reflects genuine year-to-year variability, it would seem we can have little confidence in the deposition in any given year, and it would be very unwise to assume that a year with a low rate of deposition is representative.

The variable that links deposition and soil concentration is soil loss *ks*, and this is the next place we should look. Soil loss is described as the outcome of several physical processes, such as washout, but since the soil and the rain do not change much from year to year, we could begin by looking at the ratio between deposition and soil concentration. The next table shows this.

The table below shows the ratio between deposition and soil concentration, corresponding to soil loss (note that this is not the value of k_s , but only an approximation to aid our investigation).

PCDD Congeners	2008 Ds mg/kg/yr	2008 Sc mg/kg	2008 Ratio Ds/Sc Corresponding to soil loss	
2,3,7,8-TCDD		4.68E-10	5.51E-09	0.0850
1,2,3,7,8-PeCDD		5.27E-10	1.01E-08	0.0522
1,2,3,6,7,8-HxCDD		6.12E-09	1.31E-07	0.0469
1,2,3,4,7,8-HxCDD		4.15E-09	8.68E-08	0.0478
1,2,3,7,8,9-HxCDD		5.79E-09	1.11E-07	0.0521
1,2,3,4,6,7,8-HpCDD		2.82E-08	6.02E-07	0.0468
OCDD		1.05E-06	2.23E-05	0.0469
PCDF Congeners				
2,3,7,8-TCDF		3.11E-09	4.28E-08	0.0725
1,2,3,7,8-PeCDF		3.19E-08	5.68E-07	0.0561
2,3,4,7,8-PeCDF		4.96E-09	9.25E-08	0.0537
1,2,3,4,7,8-HxCDF		7.53E-09	1.42E-07	0.0531
1,2,3,6,7,8-HxCDF		2.25E-09	4.55E-08	0.0495
2,3,4,6,7,8-HxCDF		7.33E-09	1.43E-07	0.0513
1,2,3,7,8,9-HxCDF		6.67E-09	1.30E-07	0.0513
1,2,3,4,6,7,8-HpCDF		1.35E-08	2.58E-07	0.0524
1,2,3,4,7,8,9-HpCDF		4.57E-09	8.72E-08	0.0524
OCDF		4.67E-08	9.95E-07	0.0469

In 2008, the rate of soil loss for all congeners was broadly similar, varying only by a factor of 2 or so between the largest and smallest ratio.

Next we look at 2019.

The table below shows the ratio of deposition to soil concentration, corresponding approximately to soil loss, in 2019.

PCDD Congeners	2019 Ds mg/kg/yr	2019 Sc	2019 Ratio Ds/Sc Corresponding to soil loss
2,3,7,8-TCDD		3.36E-11	9.86E-12
1,2,3,7,8-PeCDD		3.73E-10	5.29E-09
1,2,3,6,7,8-HxCDD		7.91E-10	1.12E-08
1,2,3,4,7,8-HxCDD		6.48E-10	9.55E-09
1,2,3,7,8,9-HxCDD		1.48E-09	2.09E-08
1,2,3,4,6,7,8-HpCDD		6.83E-09	1.02E-07
OCDD		1.15E-08	1.73E-07
PCDF Congeners			
2,3,7,8-TCDF		2.34E-10	2.67E-09
1,2,3,7,8-PeCDF		6.08E-10	8.15E-09
2,3,4,7,8-PeCDF		1.31E-09	1.81E-08
1,2,3,4,7,8-HxCDF		4.66E-09	6.43E-08
1,2,3,6,7,8-HxCDF		1.98E-09	2.86E-08
2,3,4,6,7,8-HxCDF		3.32E-09	4.69E-08
1,2,3,7,8,9-HxCDF		2.05E-09	2.89E-08
1,2,3,4,6,7,8-HpCDF		1.14E-08	1.61E-07
1,2,3,4,7,8,9-HpCDF		1.31E-09	1.85E-08
OCDF		6.95E-09	1.04E-07

It is immediately obvious that the value for 2,3,7,8-TCDD stands out from the rest. The others are broadly similar to the 2008 values, but TCDD has a much larger ratio. In order to see how much it has changed, we need to find the ratio between the 2008 and 2019 soil loss approximations. This is in the next table.

The following table shows the ratio between the soil loss approximations in 2008 and 2019.

	2008 Ratio Ds/Sc	2019 Ratio Ds/Sc	Ratio 2019/2008 of soil loss
PCDD Congeners			
2,3,7,8-TCDD	0.0850	3.4099	40.0956
1,2,3,7,8-PeCDD	0.0522	0.0706	1.3530
1,2,3,6,7,8-HxCDD	0.0469	0.0706	1.5059
1,2,3,4,7,8-HxCDD	0.0478	0.0678	1.4174
1,2,3,7,8,9-HxCDD	0.0521	0.0706	1.3553
1,2,3,4,6,7,8-HpCDD	0.0468	0.0669	1.4290
OCDD	0.0469	0.0667	1.4238
PCDF Congeners			
2,3,7,8-TCDF	0.0725	0.0878	1.2111
1,2,3,7,8-PeCDF	0.0561	0.0745	1.3275
2,3,4,7,8-PeCDF	0.0537	0.0725	1.3505
1,2,3,4,7,8-HxCDF	0.0531	0.0725	1.3633
1,2,3,6,7,8-HxCDF	0.0495	0.0692	1.3974
2,3,4,6,7,8-HxCDF	0.0513	0.0708	1.3808
1,2,3,7,8,9-HxCDF	0.0513	0.0708	1.3808
1,2,3,4,6,7,8-HpCDF	0.0524	0.0711	1.3566
1,2,3,4,7,8,9-HpCDF	0.0524	0.0711	1.3571
OCDF	0.0469	0.0667	1.4229

Apart from 2,3,7,8-TCDD, all the soil loss values show more or less uniform behaviour. They have all become greater, by around one third, with the extreme values being 21 % - 51 %. But TCDD has become over 40 times greater – a 40 times faster rate of soil loss. Nothing in the text of the Appendix prepares us for such a dramatic change, there is no citation to a research article that reports the discovery that TCDD, alone among the congeners, disappears from soil 40 time faster than was thought a few years ago. It goes without saying that such a drastic change needs clarification.

In understanding the marked change in the contribution of the proposed incinerator to MARI intake of dioxins and furans, we have seen two phenomena: the drastic change in soil loss in the table above, and a very substantial fall in deposition for some congeners. The latter is probably the main contributor to the reduction in soil concentration and thus in MARI intake. Although some congeners show extreme changes, such as the 90-fold reduction in deposition of OCDD, for others the change is less marked. It may well be a genuine and very dramatic year-to-year change in deposition resulting from the behaviour of the air dispersion model. A 22-fold reduction in deposition at the point of maximum deposition, resulting from a 12 % fall in incinerator output, is indicative of a rather extreme year-to-year variation in how pollutants move around the Ringaskiddy area. It suggests that we would be very unwise to place any reliance on a deposition value that happens to be low in any particular year, and that a precautionary approach requires that we base our analysis on the 2008 behaviour until proven otherwise. As detailed in the main text, the 2008 contribution from the incinerator (reduced by 12 % to reflect the reduced output), superimposed on the baseline reported in Appendix 6.3, would lead to a 40 % increase in dioxins and furans over a baseline that is already well over the EU tolerable weekly intake.