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Health Impact Assessment for a Proposed Plastic Pyrolysis Plant Near Chelveston

Dallol Energy Limited

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Executive Summary

A health impact assessment has been undertaken to assess the risk to the health of people living in the vicinity of a proposed plastic pyrolysis plant to be developed by Dallol Energy Limited near Chelveston in East Northamptonshire. Detailed atmospheric dispersion modelling of emissions from the 35 metre high chimney was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors where people may congregate for significant periods of time. The assessment involved a comparison of model-predicted process contributions against health-based air quality standards and relevant environmental assessment levels.

Short term acute effects were for NO_2, SO_2 and PM_{10} were assessed in line with COMEAP procedures and showed that increases in background pollutant concentrations at nearby residential properties were low and would not have a significant impact on the health of people living and working nearby. Similar conclusions were drawn for other pollutants with short term, acute effects (HCl, HF and CO). Process contributions for pollutants such as VOCs and Heavy Metals were very low and their potential health effects screened out as insignificant in relation to health-based air quality standards and relevant EALs recommended by the Environment Agency.

The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities used to assess the potential risk to health of people living and working in the locality of the plastic pyrolysis plant due to emissions of Dioxins and Furans, and Dioxin-like PCBs. The assessment considered the potential health risks associated with the intake of Dioxins due to the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the chimney of the facility. The assumptions used within the assessment are conservative and therefore the study was undertaken on a conservative worst-case basis.

The assessment indicates that the risk to health of the local population due to exposure to dioxins in emissions from the plastic pyrolysis plant is likely to be low, and generally less than 1 % of the Tolerable Daily Intake (TDI) of 2 pg/kg. The inclusion of dioxin-like PCBs into the assessment resulted in a small increase in the resulting process contributions, which remained a very small proportion of the 2 pg/kg TDI.

The assessment for health risks associated with exposure to emissions of PAH demonstrated that process contributions would be less than 0.2 % of the health-based air quality standard of 0.25 ng m^{-3}, and can be screened out as insignificant.

In conclusion, the results from the health impact assessment confirms that there is no significant health risk associated with emissions of pollutants from the proposed plastic pyrolysis plant to be developed by Dallol Energy Limited near Chelveston.

CONTENTS

1. Introduction

Environmental Visage Limited (Envisage) was commissioned to prepare a health impact assessment (HIA) for a proposed plastic pyrolysis plant to be located near Chelveston in East Northamptonshire. The assessment was undertaken using the Committee on the Medical Effects of Air Pollutants (COMEAP) procedures to assess the short-term effects of Nitrogen Dioxide, Sulphur Dioxide and fine particulate matter, and the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities to assess the potential risk to health of people living and working in the locality of the plastic pyrolysis plant, due to emissions of Dioxins and Furans.

As agreed between the development team and the Environment Agency, the air quality assessment which has informed this assessment(1), was based on the pollutant emission levels specified by the Industrial Emissions Directive (IED) for waste incineration processes, and includes consideration of NO_x, SO_2, CO, Particulates, VOCs, HCl, HF, Cadmium, Mercury, Heavy (Group 3) Metals, and Dioxins and Furans. Where available, the short-term transient, half-hourly IED emission limit values were applied, in order to present a worst-case assessment.

The site will receive non-recyclable plastic (including waste polystyrene, polyethylene and polypropylene) which will be heated in a reduced Oxygen environment and in the presence of a Bauxite catalyst in order to depolymerise the waste into hydrocarbon gases ranging from Liquid Petroleum Gas (LPG) to heavy wax. The majority of the gases produced are in the liquid fuel range (petrol and diesel), and are separated into their individual components in a fractionation column. Hot vapour ducts remove the gaseous hydrocarbons produced in the depolymerisation reaction to a scrubber, where they are cooled and washed free of particulates by the reflux diesel stream. Solid particles, dust (including any residual metal dust) and heavier oils and waxes are removed by the reflux diesel stream and fall back into the catalytic reactor to undergo further depolymerisation.

A number of individual process kilns will discharge to air from the proposed facility, and the cyclone combustor which heats the process will also include a release to atmosphere. However, these points will all discharge through a common chimney for emissions monitoring and control, with the incorporation of a blower fan to ensure that the exhaust velocity is constant no matter how many kilns are connected. Hence, the flow rate from the discharge will remain essentially constant, and as a worst-case scenario, the discharge is assumed to release at the emission limit concentrations specified in the Industrial Emissions Directive (IED). Where one or more kilns are not operational, the measured concentration in the flue will reduce, as the addition of fresh air to maintain the exhaust flow, will essentially reduce the concentration of the pollutants. There are not thought to be any other significant releases to atmosphere which may impact on the discharges from the process.

All of the activities associated with the plastic pyrolysis plant will take place within fully enclosed buildings, minimising the potential for fugitive release of pollutants from process areas. The principal sources of emissions to atmosphere are those from the pyrolysis process which will discharge to atmosphere via a 35-metre high chimney.

2. Principal Objectives and Scope of Work

The primary source of pollutant emissions from the plastic pyrolysis plant discharge through a single flue, 35-metre high chimney. Health effects associated with exposure to pollutants are generally associated with either acute effects (noticeable effects soon after exposure), or chronic effects (noticeable effects after prolonged exposure).

The pollutants considered in the health impact assessment fall into the following categories:

Acute Effects

- Oxides of Nitrogen (NO_x);
- Sulphur Dioxide (SO_2);
- Particulates;
- Carbon Monoxide (CO);
- Hydrogen Chloride (HCl);
- Hydrogen Fluoride (HF).

Chronic Effects

- Volatile Organic Compounds (VOCs);
- Heavy Metals;
- Dioxins and Furans;
- Polynuclear Hydrocarbons (PAH); and,
- Polychlorinated Biphenyls (PCBs).

The assessment considered the direct risks associated with the inhalation and consumption of substances released from the plastic pyrolysis plant. For most of the pollutants considered, the assessment is based upon the incremental increase in background concentration, the Process Contribution (PC), associated with emissions to atmosphere from the facility. Where data are available on current background concentrations then reference is made to the Predicted Environmental Concentration (PEC), which is the sum of the PC and the current background.

The HIA considers the potential impact of emissions of all of the pollutants on the health of local residents living in the vicinity of the proposed plastic pyrolysis plant, which is to be located in a relatively rural area of East Northamptonshire.

The assessment of the significance of these effects has been determined in relation to the following criteria:

- Comparison with the relevant Air Quality Standard or EAL;
- The ratio between the Process Contribution and the AQS or EAL; and,
- The incremental impact on health (in accordance with COMEAP procedures(2)); and,
- The US EPA Human Health Risk Assessment Protocol (HHRAP(3)) for Dioxins, Dioxin-like PCBs and PAH.

The COMEAP procedure involves the calculation of the potential number of members of the population that might be admitted to hospital as a result of exposure to pollutants. The following formula is used in the calculation procedure:

Incremental Impact = $Cavg\ x\ \left(\frac{DPollutant}{10}\right) xBHealth$

Where:

C_{avg} is the modelled concentration (annual average in µg m^{-3} derived from atmospheric dispersion modelling);
$D_{Pollutant}$ is the COMEAP dose-response coefficient (% increase per 10 µg m^{-3});
B_{Health} is the baseline rate for the health effect (per annum).

The dose-risk coefficients specified in the COMEAP study are summarised below.

Table 1 COMEAP Dose-Risk Coefficients

Pollutant	Health Outcome	Dose-Response Coefficient
PM_{10}	Deaths brought forward (all causes)	+ 0.75% per 10 µg m^{-3} (24 hour mean)
	Respiratory hospital admissions	+ 0.80% per 10 µg m^{-3} (24 hour mean)
SO_2	Deaths brought forward (all causes)	+ 0.6% per 10 µg m^{-3} (24 hour mean)
	Respiratory hospital admissions	+ 0.5% per 10 µg m^{-3} (24 hour mean)
NO_2	See note below	See note below

Notes:
For NO_2 a dose-response coefficient of 0.5% per 10 µg m^{-3} was used to estimate the effect on respiratory hospital admissions in a sensitivity analysis.
Source: COMEAP (1998)

It should be noted that the preliminary assessment is based upon the maximum Process Contribution from all of the models run. This maximum value is predicted to occur approximately 83 metres to the west of the chimney of the plastic pyrolysis plant, which is a point within the small industrial area surrounding the site. The corresponding values at nearby residential receptors are likely to be significantly lower, as the magnitude of the PC decreases markedly with distance from the chimney.

It should also be noted that the assessment refers to potential hospital re-admissions for individuals with an existing respiratory complaint, and not members of the general public who are in reasonably good health.

3. Health Impact Assessment for Pollutants with Acute Effects

The following assessment relates to those pollutants identified in Section 2 that are associated with short-term acute health impacts.

3.1 Nitrogen Dioxide (NO_2)

The potential impact on human health of NO_2, arising from emissions of NO_x from the plastic pyrolysis plant, has been considered in relation to both the hourly peak and annual predictions.

Table 2 Relationship Between Model Predictions for NO_2 and AQS Values

Maximum PC	Existing Background Concentration	AQS	Ratio of AQS/EAL to PC (PEC)
176	-	200 µg m^{-3}	1.1
5.4	8.05	40 µg m^{-3}	7.4 (3)

There is a factor of approximately 1.1 for the ratio between the maximum (100 %) hourly average PC of approximately 176 µg m^{-3} (based upon the maximum hourly Process Contribution and the short-term IED ELV, and assuming that the half hourly average emissions occur for a full hour) and the hourly average AQS of 200 µg m^{-3}. The corresponding factor for the annual average is about 7, which reduces to approximately 3 when the PEC value is taken into account. Nevertheless, the predicted PEC is less than 35 % of the annual AQS for NO_2, which indicates that there is little risk of exceeding the health-based AQS for Nitrogen Dioxide.

When the COMEAP methodology is applied to the data for NO_2, the estimated increase in respiratory admissions to hospital per year could increase by 0.2 %, which is considered to be low. However, this is based upon the maximum Process Contribution, which occurs approximately 83 metres to the north of the plastic pyrolysis plant chimney, and is within the road network of the small industrial estate where very few people are likely to be exposed to emissions for extended periods. If this figure was applied across the whole population of the East Northamptonshire area (86,765) this might result in two additional hospital admissions per year due to respiratory complaints.

At Receptor number 2, the location of the nearest residential properties approximately 660 m to the north of the development site, the annual Process Contribution was predicted to be approximately 1.02 µg m^{-3}, with an associated 0.05 % increase in hospital admissions due to respiratory complaints.

Maximum hourly average NO_2 PEC values at this Receptor are likely to be about 130 µg m^{-3}, or about 65 % of the hourly average AQS. This corresponds to an air quality description in the "Low Band", with an Air Quality Index of 2, with the associated advice for health for at-risk individuals (Adults and children with heart or lung problems are at greater risk of symptoms.) "Enjoy your usual outdoor activities"[(4)].

3.2 Sulphur Dioxide (SO_2)

The potential impact on human health of SO_2, arising from emissions from the proposed plastic pyrolysis plant, has been considered in relation to both the hourly peak and annual predictions.

Table 3 Relationship Between Model Predictions for SO_2 and AQS Values

Maximum PC	Existing Background Concentration	AQS	Ratio of AQS/EAL to PC (PEC)
169	-	350 µg m^{-3}	2
1.26	< 2	20 µg m^{-3}	16 (6)

As can be seen, there is a significant factor of approximately 2 for the ratio between the maximum (100 %) hourly average PC of 169 µg m^{-3} (based upon the maximum hourly Process Contribution and the short-term IED ELV, and assuming that the half hourly average emissions occur for a full hour) and the hourly average AQS of 350 µg m^{-3}, and the corresponding factor for the annual average is approximately 16, which indicates that there is little risk of exceeding the health-based AQS for SO_2.

When the COMEAP methodology is applied to the data for SO_2, and based upon the worst-case maximum Process Contribution value, the estimated increase in respiratory admissions to hospital per year could increase by 0.06 %, and can probably be discounted as insignificant. As noted above, this relates to the location of maximum Process Contribution, which occurs approximately 83 metres to the north of the plastic pyrolysis plant chimney, within the road network of the small industrial estate. If this figure was applied across the whole population of the East Northamptonshire area (86,765) this might result in up to one additional hospital admission every two years due to respiratory complaints.

At Receptor number 2, the location of the nearest residential properties, the annual Process Contribution was predicted to be approximately 0.23 µg m^{-3}, with an associated 0.01 % increase in hospital admissions due to respiratory complaints, and unlikely to have a significant impact on the health of local residents.

Maximum hourly average SO_2 PEC values in the Chelveston Cresent area are likely to be about 14 µg m^{-3}, or approximately 4 % of the hourly average AQS. This corresponds to an air quality description in the "Low Band", with an Air Quality Index of 1, with the associated advice for health for at-risk individuals "Enjoy your usual outdoor activities".

The magnitude of the number of predicted additional admissions to hospital per year due to respiratory complains associated with increased background concentrations of SO_2 from the proposed plastic pyrolysis plant is very small, and can probably be discounted as insignificant.

3.3 Particulates (PM_{10})

The potential impact on human health of particulates, arising from emissions from the plastic pyrolysis process has been considered in relation to both the daily peak and annual predictions.

Table 4 Relationship Between Model Predictions for PM_{10} and AQS Values

Maximum PC	Existing Background Concentration	AQS	Ratio of AQS/EAL to PC (PEC)
6	-	50 µg m^{-3}	8
0.26	13.52	40 µg m^{-3}	152 (2.9)

As can be seen, there is a significant factor for the ratio of about 8 between the maximum (100%) daily average PC of approximately 6 µg m^{-3} and the daily average AQS of 50 µg m^{-3}, and the corresponding factor for the annual average is about 150, which falls to about 3 when the existing background concentration is taken into account, indicating that there is little risk of exceeding the health-based AQS for PM_{10}. It should be noted that the AQS applies to PM_{10} whereas the emission limit values specified in the IED and therefore applied as a worst-case to the modelling study are based upon total particulate emission. Therefore, the assessment may overestimate the significance of particulate emissions.

When the COMEAP methodology is applied to the data for particulates as PM_{10}, and based upon the worst-case maximum Process Contribution value, the estimated increase in respiratory admissions to hospital due to respiratory complaints could increase by 0.02 %. If this figure was applied across the population of the East Northamptonshire area, this might result in about one additional hospital admission every six years due to respiratory complaints.

At Receptor number 2, the location of the nearest residential properties, the annual Process Contribution was predicted to be approximately 0.05 µg m^{-3}, with an associated 0.004 % increase in hospital admissions due to respiratory complaints, which is small and can probably be discounted as insignificant.

3.4 Hydrogen Chloride (HCl)

The health effects associated with exposure to Hydrogen Chloride are primarily acute impacts on the respiratory system and accordingly, assessment is based upon the short-term modelling predictions. The maximum hourly PC for Hydrogen Chloride is approximately 50 µg m^{-3}, based upon the short-term IED ELV of 60 mg Nm^{-3}, which gives a factor of about 15 for the ratio of the PC to the short-term EAL of 750 µg m^{-3}. Consequently, no significant effects on the health of the nearby residents are expected as a result of the emission of HCl from the plastic pyrolysis plant.

3.5 Hydrogen Fluoride (HF)

The health effects associated with exposure to Hydrogen Fluoride are primarily acute impacts on the respiratory system and accordingly, assessment is based upon the short-term modelling predictions. The maximum hourly PC for Hydrogen Fluoride is approximately 3.5 µg m^{-3}, based upon the short-term IED ELV of 4 mg Nm^{-3}, which gives a factor of about 45 for the ratio of the PC to the short-term EAL of 160 µg m^{-3}. Consequently, no significant effects on the health of the local community are expected as a result of the emission of HF from the plastic pyrolysis plant.

4. Health Impact Assessment for Pollutants with Chronic Effects

The following assessment relates to those pollutants identified in Section 1.2.2 that are associated with long-term chronic health impacts.

4.1 Volatile Organic Compounds (VOCs)

There are no environmental assessment levels for VOCs as a combined pollutant. Therefore, to provide a worst-case assessment, the PC values for VOCs were compared against the AQS for Benzene, which is 5 µg m^{-3} expressed as an annual average. The health effects associated with exposure to Benzene in the ambient air are primarily chronic impacts and accordingly, assessment is based upon the long-term modelling predictions. It should also be noted that Benzene is likely to comprise only a small proportion (probably less than 5 %) of the total VOC emission, and therefore this assessment represents a gross overestimation of the true impact of VOC emissions.

The maximum annual average PC for VOCs was 0.26 µg m^{-3}, which gives a factor of about 19 for the ratio of the annual PC to the annual AQS of 5 µg m^{-3}, which indicates that there are unlikely to be any significant effects on the health of the community as a result of exposure to emissions of VOCs from the plastic pyrolysis plant.

4.2 Group 3 Metals

A detailed assessment for the significance of Group 3 metal emissions was undertaken in relation to Environment Agency guidance. The results are presented in Table 4 of the detailed atmospheric dispersion model prepared in conjunction with this health impact assessment, and demonstrated that emissions of heavy metals from the plastic pyrolysis plant could be screened out as insignificant in relation to relevant Air Quality Standards and Environmental Assessment Levels specified for the protection of human health.

4.3 Dioxins and Furans

The maximum annual PC for Dioxins associated with emissions from the plastic pyrolysis plant was approximately 2.7 fg m^{-3}, at the point of maximum Process Contribution, which is about 217 metres to the north, north east of the pyrolysis plant chimney. Emissions from the facility are not expected to significantly increase the airborne concentrations or deposition rate of Dioxins and Furans over what may be currently experienced in the local area.

The maximum daily average PC for Dioxins was predicted to be approximately 20.5 fg m^{-3}. It should be noted that the emissions profile was based on the long-term ELV prescribed for Dioxin emissions from incineration plant in the Industrial Emissions Directive (0.1 ng Nm^{-3} referenced to 11 % O_2, dry and STP). The plastic pyrolysis plant will operate in compliance with the IED, and Dioxin emissions are expected to be substantially below the limit value. The emissions profile is therefore considered to be overly pessimistic, and to result in higher predicted process contributions than are considered likely.

A dioxin health risk assessment was undertaken using the US EPA Human Health Risk Protocol (HHRAP) calculation procedures to estimate intake of dioxins via the dietary and inhalation routes in the vicinity of the proposed development site. The assessment was based upon the US EPA methodology outlined in the “Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities, EPA530-R-05-006, September 2005”, and the results are discussed in the following section.

5. Dioxin Health Risk Assessment

The basis for the Dioxin health risk assessment is predictive modelling using the ADMS atmospheric dispersion model to estimate likely ground level concentrations and deposition rates for Dioxins as a result of emissions to atmosphere from the plastic pyrolysis plant. The assessment is based upon the incremental increase in Dioxin concentrations due to emissions from the facility, and does not take account of any existing dioxin contamination at the location of the specific receptors. The assessment does, however, take account of ambient Dioxin concentrations in the atmosphere using measured data from the TOMPS network of monitoring stations operated by DEFRA[(4)].

The plastic pyrolysis plant is proposed to be located in a relatively rural area of East Northamptonshire, with some small industrial units in the immediate vicinity, and local village areas. Accordingly, the average Dioxin concentration for rural locations was used in the calculations.

The health risk assessment is based upon the US EPA calculation procedures outlined in the "Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities, EPA530-R-05-006, September 2005". There is currently no formal guidance in the UK on the assessment of health risks associated with exposure to emissions from waste management facilities, and in England the Environment Agency's Air Quality Management and Assessment Unit (AQMAU) approve the use of the US EPA methodology as an alternative.

5.1 Potential Pathways for Exposure

The following pathways were considered as part of the health risk assessment:

- Inhalation;
- Ingestion of soil;
- Consumption of fruit and vegetables;
- Consumption of milk
- Consumption of poultry and eggs; and
- Drinking water.

Members of the local population are only likely to be exposed to significant effects associated with emissions of Dioxins from the proposed facility if:

- They spend significant periods of time at locations where and when emissions from the facility increase the concentration of Dioxins above the existing background;
- They consume food grown at locations where emissions from the facility increase the concentration of Dioxins above the concentration normally present in food from those locations;
- They undertake activities likely to lead to ingestion of soil at locations where emissions from the facility have increased the concentration of Dioxins in the soil above those normally present; and
- They drink water from sources exposed to increased concentrations of Dioxins above the levels normally present.

The extent of exposure that any person may experience will depend directly on the degree to which they engage in any or all of the above activities, and by how much existing background concentrations of Dioxins increase as a result of the operation of the plastic pyrolysis plant. The drinking water route is considered to be highly unlikely as very few people are likely to collect and drink rainwater in the vicinity of the development site.

5.2 Pathways Relevant to the Proposed Plastic Pyrolysis Plant

5.2.1 Inhalation

People living in the vicinity of the development site may be exposed to marginally higher levels of Dioxins as a result of the operation of the plastic pyrolysis plant for the proportion of the time that they spend there. Accordingly, this pathway is considered relevant to the current assessment, and the default values recommended by the US EPA were used as the basis for assessment. Reference was also made to the average rural background concentration for Dioxins and Furans of 7.1 fg m^{-3} in 2010, based upon measured data for Auchencorth, Hazlerigg, High Muffles and Weybourne(5).

5.2.2 Ingestion of Soil

People working on the land in close proximity to the development site may be exposed to marginally higher levels of Dioxins as a result of the operation of the plastic pyrolysis plant for the proportion of the time that they work there. The potential for exposure by soil ingestion is likely to affect only a few local residents who may tend allotments or plots in their home gardens, and then for only limited periods of the year. Dioxin intake via the ingestion of soil is included in the assessment.

5.2.3 Consumption of Fruit and Vegetables

The majority of the general population purchase their fruit and vegetables from commercial outlets that are likely to source their produce from outside the locality. Unless a substantial proportion of fruit and vegetables sold are produced locally, the overwhelming majority of the local population's exposure to Dioxins due to consumption of fruit and vegetables will not be affected significantly by the operation of the plastic pyrolysis plant.

People who consume fruit and vegetables grown within the vicinity of the proposed facility may be exposed to marginally higher levels of Dioxins as a result of the operation of the process, although any increase is likely to be small. The likelihood of individuals obtaining almost all of their fruit and vegetable consumption from gardens or allotments in the vicinity of the development site is likely to be low. Nevertheless, Dioxin intake via the consumption of fruit and vegetables is included in the assessment as the situation could change in future.

5.2.4 Consumption of Local Dairy Produce

The development site is situated within an area with a high proportion of the land dedicated to agricultural activities, where grazing animals may forage on pasture land in the vicinity of the development site that could be contaminated by deposition of Dioxins from the proposed plastic pyrolysis plant. Accordingly, the consumption of locally produced dairy produce has been considered in this assessment.

5.4.5 Consumption of Poultry and Eggs

Free-range poultry may be exposed to dioxins through soil ingested with food picked up from the ground. It is not known if the rearing of free-range poultry occurs to a significant level in the vicinity of the development site. However, a future scenario might see a change in land use that could be used for rearing chickens. Under this scenario, the consumption of chickens and eggs could be a realistic exposure pathway in future, and has therefore been considered further in this assessment.

5.4.6 Consumption of Beef and Pork

Consumption of beef and pork reared on land in the vicinity of the development site is highly unlikely. As the assessment for the consumption of chicken meat revealed that this dietary pathway represented less than 1 % of the total potential Dioxin intake, and that beef and pork consumption was similar to that of chicken, similar conclusions were drawn for beef and pork and no further assessment was carried out.

5.4.7 Breast Milk

The consumption of breast milk by infants may be a potentially significant pathway for the dietary intake of Dioxins due to absorption from contaminated foodstuffs by the mother's lactate system. However, the Dioxin intake via the consumption of cow's milk has been considered and Dioxin levels in both milks are likely to be of a similar level. Where an infant is consuming breast milk it is unlikely that it will also be consuming cow's milk, and vice versa, therefore the assessment for cow's milk is considered to be representative of the situation for the consumption of breast milk, and no further assessment has been carried out.

5.4.8 Drinking Water

The likelihood of contamination of groundwater aquifers occurring due to the deposition of Dioxins associated with emissions from the proposed plastic pyrolysis plant is considered highly unlikely given the very low solubility of dioxins in water. Furthermore, the likelihood of local residents collecting rain water for drinking purposes is also thought to be low, and has been discounted. Accordingly, no further consideration has been given to drinking water as a potential pathway.

5.3 Exposure Scenarios

For all of the exposure scenarios, being at the location of exposure for less than 100 % of the time, and obtaining less than 100 % of the total consumption of relevant food, would reduce proportionately any exposure to potential emissions of Dioxins from the facility. Accordingly, the estimates of exposure resulting from this assessment are likely to overestimate considerably, those likely to be experienced by local residents when the plastic pyrolysis plant is operational.

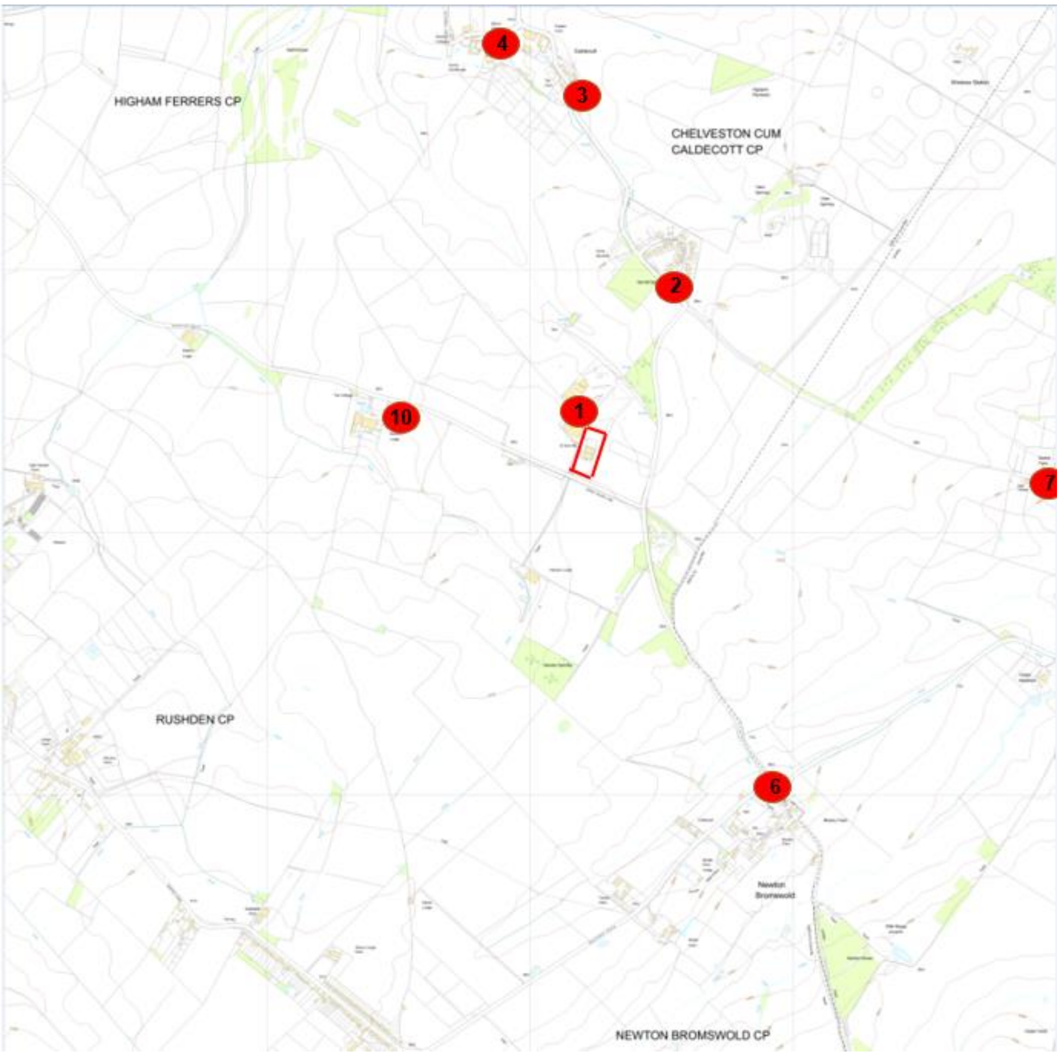
The following exposure scenarios have been considered as relevant to the exposure sites selected:

5.3.1 General Population Exposure

The area in the immediate vicinity of the development site is predominantly rural with some local industrial units and villages. Eleven specific receptors were included in the assessment representing the nearest locations where members of the general public may be present for significant periods of time. People living and working in the vicinity of the development site may be exposed to emissions of Dioxins from the proposed facility via the inhalation route, although the facility may not be the only source of airborne dioxins in the wider area.

The area covered by the modelling assessment is shown in Figure 1, with the human health receptors shown.

Figure 1 Plan Depicting Some of the Modelled Human Health Receptors



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5.3.2 Exposure by the Consumption of Poultry

This scenario could apply to those individuals who derive their total consumption of eggs and poultry meat produced within the potential zone of exposure of the emissions from the proposed facility.

5.3.3 Exposure via the Consumption of Fruit and Vegetables

This scenario is only likely to apply to a small proportion of the local population who grow fruit and vegetables for their own consumption either in their gardens or on allotments in the vicinity of the proposed development site.

5.3.4 Exposure via the Consumption of Milk

This scenario is likely to apply to those people whose milk supply is produced by dairy herds grazing on pasture land that could potentially become contaminated in the vicinity of the proposed development site.

5.3.5 Ingestion of Soil

This scenario could apply to workers on nearby agricultural land and local residents working in their gardens or allotments, who may be exposed to soil that could be contaminated by Dioxins deposited from the emissions from the plastic pyrolysis plant.

5.4 Exposure Factors

Exposure factors were obtained from literature sources for rates of breathing and ingestion of soil and foodstuffs.

5.4.1 Inhalation Rates

For a 70 kg adult the daily respiration volume was taken as approximately 20 m^3 day^{-1} which is in line with US EPA recommendations. This corresponds to an average value of approximately 0.012 m^3 kg^{-1} hr^{-1}. The corresponding value for an infant weighing about 14.5 kg was 5.1 m^3 day^{-1}, or about 0.015 m^3 kg^{-1} hr^{-1}.

5.4.2 Consumption of Eggs and Poultry Meat

Information on the intake of eggs and poultry meat was obtained from the Food Standards Agency website(6), and is summarised in the following table.

Table 5 UK Official Figures for the Consumption of Poultry Products (g/kg/day)

Food Category	UK Adult Mean (g/kg BW/day)	UK Infant Mean (g/kg BW/day)
Poultry Meat	0.81	1.90
Eggs	0.26	0.69

The above figures are based upon the average values for men and women to give an overall average for an adult member of the population. The values relate to the average daily consumption of eggs and chicken meat in terms of g/kg body weight/day, and the values are derived from the "National Diet and Nutrition Survey, Year 1 Report", published in 2010(7), and co-authored by Beverley Bates, Alison Lennox and Gillian Swan of the Food Standards Agency.

The values in Table 5 are the average values for consumption of eggs and chicken by males and females (Table 5.1 of the above report), normalised for daily consumption on the basis of an average adult weighing 70kg, and an average child weighing 14.5kg, in line with the US EPA HHRAP approach. The National Nutrition and Diet Survey covers adults between the ages of 19 and 64, and values for infants were based upon the data for children aged between 4 and 10 years.

For home-reared or allotment-reared eggs and poultry meat, it is unlikely that meat consumption rates would be as high as those for eggs, as the birds are the source of the eggs. Accordingly, the majority of poultry meat consumed is likely to have come from sources outside the area, and the assessment is likely to overestimate considerably the potential impact of poultry meat consumption.

5.4.3 Consumption of Fruit and Vegetables

Values for the consumption of fruit and vegetables are provided in the US EPA HHRAP methodology as follows:

Table 6 US EPA HHRAP Estimates for the Consumption of Fruit and Vegetables

Category	Ingestion Rate (kg/kg-day DW)			
	Farmer	Farmer Child	Resident	Resident Child
Exposed above ground fruit and vegetables	0.00047	0.00113	0.00032	0.00077
Protected above ground fruit and vegetables	0.00064	0.00157	0.00061	0.00150
Below ground Produce	0.00017	0.00028	0.00014	0.00023

As can be seen the values for the case of the "Farmer" indicate a higher level of consumption due to the increased likelihood of consuming home-produced fruit and vegetables. To provide a worst-case assessment for potential dietary intake of Dioxins, the consumption figures for the "Farmer" were used in the assessment.

5.4.4 Consumption of Milk

Information on the intake of milk was obtained from the Food Standards Agency website and is summarised in the following table.

Table 7 UK Official Figures for the Consumption of Milk (g/kg/day)

Food Category	UK Adult Mean	UK Infant Mean
Whole Milk	0.42	5.24

The above figures are based upon the average values for men and women, including non-consumers, to give an overall average for an adult member of the population. The values relate to the average daily consumption of whole milk in terms of g/kg body weight/day, and the values are derived from the "National Diet and Nutrition Survey, Year 1 Report", published in 2010. Whole milk has a higher fat content than semi-skimmed or skimmed milk, and therefore provides a worst-case basis for assessment.

It has been assumed that all of the milk consumed has been produced on pastures in the vicinity of the development site. This will overestimate considerably the potential impact of milk consumption.

5.4.5 Ingestion of Soil

Values for the ingestion of soil are provided in the US EPA HHRAP methodology as follows:

Table 8 US EPA HHRAP Estimates for Soil Ingestion

Category	Adult	Infant
Soil Intake Rate (kg day^{-1})	0.0001	0.0002

The higher value for a child reflects the greater likelihood of soil ingestion by children playing outdoors.

5.5 Emissions Scenario

The proposed plastic pyrolysis plant will be subject to regulation by the Environment Agency in line with the emission limit values (ELVs) for Dioxins and Furans for incineration plant as defined by the EU Industrial Emissions Directive (IED). Atmospheric dispersion modelling was undertaken on the basis of Normal Operation with emissions of dioxins at the 0.1 ng Nm^{-3} ELV specified by the IED, which is the design point and performance guarantee for the proposed technology.

It is expected that when the facility becomes operational, actual Dioxin emissions will be significantly lower than the IED limit, and therefore the results from this assessment are likely to overestimate significantly the situation that might be expected during normal operation.

Exposure via the dietary route was assessed by modelling Dioxin deposition in both the gaseous and particulate phases. The results from deposition modelling were then taken in conjunction with the US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion for calculating the intake of Dioxins into the soil, fruit and vegetables, dairy products and poultry products to provide an estimate of dietary intake of Dioxins as a result of the operation of the new plant. Partitioning of Dioxins between the vapour phase and the particulate phase was assumed to be in the proportions 66.4:33.6 as provided by HHRAP guidance(9), and the modelling results were adjusted accordingly. The results were compared against the Tolerable Daily Intake (TDI) value of 2 pg kg-1 day-1 recommended by the UK Committee on Toxicity(10).

The values predicted by modelling represent Process Contributions, but in certain instances also take into account estimated background levels for rural areas in the UK. Where necessary, estimated background values for atmospheric Dioxin concentrations have been used as input values for some of the equations in the HHRAP methodology.

5.6 Area Covered and Specific Receptors Included in the Assessment

Atmospheric dispersion modelling using ADMS Version 5.2 was undertaken to estimate likely ground level concentrations of Dioxins at nearby sensitive receptors arising from emissions from the proposed plastic pyrolysis plant. Meteorological data from the Bedford meteorological station for the years 2006 to 2010 were used in the modelling and the results reported are based upon the maximum values over the five-year period. The model was also run in dry deposition mode to estimate likely Dioxin deposition rates in the vicinity of the development site.

The location of some of the specific sensitive receptors included in the modelling study are shown in Figure 1.

5.7 Results from Detailed Modelling - Concentration Mode

The results from modelling emissions of Dioxins from the proposed plastic pyrolysis plant, based upon the IED emission limit value of 0.1 ng Nm^{-3} gave a maximum Process Contribution of approximately 20.5 fg m^{-3} (2.05×10^{-18} g m^{-3}) expressed as a daily average value, and located approximately 220 metres to the north, north east of the facility discharge point. The maximum annual average Process Contribution was approximately 2.7 fg m^{-3}.

5.8 Deposition Mode

Wet deposition is usually considered to be the most significant mode of deposition close to the point of release of buoyant plumes from waste incineration processes, as a result of "wash out" by rain droplets falling through the plume. At greater distances, plume expansion and the associated pollutant dilution, brings particulates and vapours in the plume into contact with the surface vegetation, and the "dry deposition" mechanism assumes greater importance. It is important therefore that both aspects of pollutant deposition from the plume are considered within the assessment.

The ADMS model was run in deposition mode but due to the absence of rainfall data in the meteorological data file only a value for dry deposition was obtained. Guidance from the Environment Agency in Horizontal Guidance Note H1 Annex F recommends multiplying the dry deposition value by a factor of 3 to provide an estimate of total deposition, i.e., the combination of both dry and wet deposition(11). The value of 3 is a nominal factor to convert dry deposition to total deposition.

The results from deposition modelling of emissions from the plastic pyrolysis plant, assuming emissions at the maximum IED ELV of 0.1 ng Nm^{-3}, gave a maximum value for total Dioxin deposition of approximately 4×10^{-12} µg m^{-2} s^{-1} for Dioxins in the gaseous and particulate phases. The results showed deposition rates for dioxins decreasing markedly with distance from the point of release.

5.9 Specific Receptor Locations and Exposure Pathways

Exposure is potentially possible at any location to a greater or lesser degree, and the locations shown in Figure 1 were included in the modelling study as specific receptors, including residential areas, schools and nearby places of employment.

Eleven specific receptors were modelled in terms of Dioxin deposition, and included potentially sensitive locations where members of the local population may be present for significant periods of the day. The locations of the specific receptors included in the dioxin deposition modelling study are detailed below.

Table 9 Specific Receptors Included in Dioxin Deposition Modelling

Receptor Number	Receptor Name	Grid Reference		
		X (m)	Y (m)	Direction from Stack
1	Industrial unit to the north	499213	267439	N
2	Houses to the north - Chelveston Crescent	499536	267965	N
3	Houses Caldecott	499126	268715	N
4	Manor Farm	498834	268856	N
5	Chelveston Village	499143	269491	N
6	Newton Bromswold	499954	265953	SSE
7	Yelden Village	500951	267232	E
8	Lodge Farm	502411	269631	NE
9	High Barn Farm	501654	268415	NE
10	Farm to the west	498429	267386	W
11	Hargrave Lodge Farm	501557	270752	NNE

5.10 Results and Discussion

Health risk estimates are directly affected by several factors, including:

- Location of the receptor with regard to exposure to emissions from the facility;
- Proportion of time spent by the receptor at locations where Dioxin concentrations may increase as a result of emissions from the facility;
- Proportions of the types of food consumed that are produced at locations where Dioxin concentrations may increase as a result of emissions from the facility; and
- The emissions scenario.

The results from the Dioxin health risk assessment reported here represent the maximum potential incremental increase as a result of emissions from the proposed plastic pyrolysis plant for each of the pathways included, based upon emissions of dioxins at the ELV of 0.1 ng Nm^{-3} specified by the IED, which is the design point and performance guarantee for the proposed technology. When operational, emissions of Dioxins from the facility are expected to be significantly lower than the ELV, and therefore the results represent a worst-case assessment.

Intake of Dioxins was estimated on the basis of the maximum daily intake due to inhalation as well as dietary consumption. The combined results were then compared against the 2 pg kg^{-1} Tolerable Daily Intake (TDI) reference value to determine whether there is likely to be a significant risk to health as a result of potential exposure to dioxins released from the proposed plastic pyrolysis plant.

5.11 Exposure via Inhalation

The following equation was used in the calculation of the Maximum Daily Intake due to inhalation of dioxins as a result of exposure to emissions from the proposed facility. The equation is taken from HMIP Report, "Risk Assessment of Dioxin Releases from Municipal Waste Incineration Processes", 1996:

Equation 1 Maximum Daily Intake Due to Inhalation

Maximum Daily Intake Due to Inhalation = $\frac{((C+B)x\ IR)}{BW}$

Where:
C = Maximum daily average Dioxin concentration (pg m^{-3})
B = Estimated background concentration (pg m^{-3})
IR = Inhalation rate (m^3 day^{-1})
BW = Body weight (kg).

The following input data were assumed:

- The estimated background dioxin concentration (B) was taken to be 0.007 pg m^{-3}. This is the average of the 2010 annual average values for the rural measurement stations (Auchencorth, Hazlerigg, High Muffles and Weybourne) in the TOMPS (Toxic Organic Micropollutants) monitoring stations within the UK network. It is assumed that the data are representative of the situation in the vicinity of the proposed development site;
- The inhalation rate (IR) was 19.92 m^3 day^{-1} for an adult and 5.1 m^3 day^{-1} for an infant (US EPA recommended value);
- Body weight (BW) was taken as 70 kg for an adult and 14.5 kg for an infant (US EPA recommended value).

Using these data, the maximum daily intake of Dioxins due to inhalation by adults was calculated at 0.008 pg kg^{-1} day^{-1}. For infants the corresponding figure was 0.01 pg kg^{-1} day^{-1}. The Tolerable Daily Intake (TDI) for Dioxins is 2 pg kg^{-1} day^{-1}. Accordingly, the estimated exposure via inhalation for adults represents approximately 0.4 % of the TDI, while the estimated value for infants is approximately 0.5 % of the TDI.

5.12 Potential Increase in Concentration of Dioxins in Soil Due To Emissions from the Proposed Plastic Pyrolysis Plant

Any increase in Dioxin concentration in the soil has the potential to transfer into the food chain and to add to the daily intake via the dietary pathway. An assessment was made of the potential increase in Dioxin concentration in the soil as a result of deposition due to emissions from the proposed facility.

Deposition modelling of Dioxins, in the particulate and gaseous phases, was carried out using ADMS Version 5.2. The likelihood is that the majority of Dioxins released from the plastic pyrolysis plant would be associated with the particulates in the emission to atmosphere. Accordingly, the model predictions for Dioxin deposition associated with the particulates with a diameter of 1 µm represents an appropriate worst case value for assessment of dioxin deposition to soils in the vicinity of the facility. The following deposition rates were predicted at the eleven specific receptor locations in the vicinity of the development site.

Table 10 Deposition Modelling of Dioxins in the Gaseous and Particulate Phases Based Upon Normal Operating Conditions at the IED ELV of 0.1ng Nm^{-3}

Receptor Number	Total Deposition Rate* (Gaseous & Particulate) (µg m^{-2} s^{-1})	Annual Deposition Rate (ng m^{-2} $annum^{-1}$)
1	3.79E-13	0.012
2	8.44E-13	0.027
3	1.66E-13	0.005
4	1.32E-13	0.004
5	9.51E-14	0.003
6	1.39E-13	0.004
7	1.70E-13	0.005
8	1.15E-13	0.004
9	1.84E-13	0.006
10	1.38E-13	0.004
11	8.12E-14	0.003

* Total deposition rate = 3 x dry deposition rate.

The above values represent a worst case based upon the ELV of 0.1 ng Nm^{-3} specified by the IED, however, when operational, emissions of dioxins from the plastic pyrolysis plant are expected to be significantly lower than the ELV.

Little of the Deposited dioxins are likely to penetrate far into the ground due to the low solubility of Dioxins in water. Absorption of Dioxins by the soil is also likely to decrease mobility. The US EPA HHRAP database quotes a value of 0.19 ng $litre^{-1}$ for the solubility of Dioxins in water.

The following assessment is based upon the maximum deposition rate at the location of the maximum Process Contribution, approximately 217 metres to the north, north east of the plastic pyrolysis plant chimney.

The increase in Dioxin loading of soils as a result of deposition was estimated using the equations in Table B-3-1 in Appendix B of the US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities.

Equation 2 The Increase in Dioxin Concentration in the Soil Due to Deposition

$$Cs = \frac{\left(\frac{Ds \cdot tD - Cs_{tD}}{ks}\right) + \left(\frac{Cs_{tD}}{ks} \cdot \left[1 - exp\left(-ks \cdot \left(T_2 - tD\right)\right)\right]\right)}{\left(T_2 - T_1\right)};$$

$$Cs_{tD} = \frac{Ds \cdot \left[1 - \exp\left(-ks \cdot tD\right)\right]}{ks}; and$$

$$Ds = \frac{100 \cdot Q}{Z_s \cdot BD} \cdot \left[F_v \cdot \left(Dydv + Dywv\right) + \left(Dydp + Dywp\right) \cdot \left(1 - F_v\right)\right]$$

Where:

- Cs = Maximum average incremental increase in soil concentration over exposure duration;
- CstD = Soil concentration at time tD - calculated;
- Ds = Deposition Term – mg/kg soil/yr;
- tD = Time period over which deposition occurs – 30 years;
- ks = Dioxin soil loss constant due to all mechanisms – calculated;
- T2 = Length of exposure duration – 30 years;
- T1 = Time period at the beginning of combustion – 0;
- 100 = Conversion Factor;
- Q = Dioxin emission rate (g s^{-1});
- Zs = Soil Mixing Zone depth – 2 cm;
- BD = Soil Bulk Density – 1.5 kg m^3;
- Fv = Fraction of dioxin air concentration in the vapour phase – 0.664 (US EPA HHRAP value);
- Dydv = Unitised annual average dry deposition from vapour phase – derived from ADMS output;
- Dywv = Unitised annual average wet deposition from vapour phase – derived from ADMS output;
- Dydp = Unitised annual average dry deposition from particulate phase – derived from ADMS output; and
- Dywp = Unitised annual average dry deposition from particulate phase – derived from ADMS output.

Using the above equations and input parameters, gave a value for the increase in soil Dioxin concentration due to deposition of approximately 0.0012 ng kg^{-1}. This value represents the case at the location of the maximum Process Contribution based upon Normal Operating Conditions at the IED emissions limit value, and is approximately 0.03 % of the maximum concentration of dioxin in soils in rural locations (about 4.7 ng kg^{-1}) reported by the Environment Agency(12). As discussed earlier, the urban land classification is considered to be appropriate for the area surrounding the proposed development.

The value reported above is based upon the maximum deposition rate at the location of the maximum Process Contribution which occurs approximately 217 metres to the north, north east of the plastic pyrolysis plant chimney, while deposition at specific receptors farther afield is predicted to occur at significantly lower rates as indicated in Table 10.

5.13 Exposure from Dietary Intake of Poultry and Eggs

The potential link between human receptors and the consumption of locally reared poultry meat or eggs is not known, and it is unclear to what extent chickens are reared locally. Nevertheless, the consumption of chickens and eggs could be a potential exposure pathway, either currently or in the future. This is a foreseeable scenario since there is no requirement for a householder or allotment holder to seek permission to keep chickens or other livestock and to notify the owners of a nearby industrial process if they did. As such, this could be a key pathway for Dioxin exposure and it is appropriate that it should be investigated.

Accordingly, an assessment for exposure to Dioxins has been undertaken for the intake of Dioxins via the consumption of eggs and chicken in order to represent a possible future scenario where the rearing of free-range eggs and poultry became significant.

The US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities methodology was used to assess the potential exposure to Dioxins arsing from emissions from the new plastic pyrolysis plant. The equation in Table B-3-13 in Appendix B of the HHRAP was used to determine the concentration of dioxins in eggs at locations in the in the vicinity of the proposed development, and the equation in Table B-3-14 was used to determine the corresponding concentration of dioxins in poultry meat.

The results presented in the following section relate to the deposition rate at the location of the maximum Process Contribution, approximately 217 metres to the north, north east of the chimney of the proposed plastic pyrolysis plant.

5.13 1 Dioxin Concentration in Eggs

The following formula was used to estimate the potential dioxin concentration in eggs due to ingestion of soil and grain by free-range chickens reared in the locality:

Equation 3 The Intake of Dioxin in Eggs Due to Foraging on Contaminated Soil

$$A_{egg} = \left(\sum \left(F_i \cdot Qp_i \cdot P_i \right) + Q_s \cdot C_s \cdot B_s \right) \cdot Ba_{egg}$$

Where:

- Aegg = Concentration of dioxin in egg
- Fi = Fraction of grain grown on contaminated soil and ingested by chickens – assumed to be 1.0
- Qpi = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP)
- Pi = Concentration of dioxin in grain – derived from separate equation below
- Qs = Quantity of soil ingested by chicken – assumed to be 0.022 kg day^{-1} (US EPA HHRAP)
- Cs = Maximum annual average incremental increase in dioxin concentration in soil – estimated by modelling to be 0.0012 ng kg^{-1};
- Bs = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP)
- Baegg = Biotransfer factor for chicken eggs – assumed to be 1.09984 (US EPA HHRAP Database)

The value of Pi was derived using the equation in Table B-3-9 of Appendix B of the HHRAP:

Equation 4 The Intake of Dioxin in Grain Due to Increase in Soil Concentration

$$P_i = C_s \cdot Br_{forage}$$

Where:

- Pi = Concentration of dioxin in grain;
- Cs = Annual average increase in dioxin concentration in soil – estimated by modelling to be 0.0012 ng kg^{-1};
- Brforage = Plant-soil bioconcentration factor for grain – assumed to be 0.00455 (US EPA HHRAP Database);

Using the above equations, a value of approximately 3 x 10^{-11} mg kg^{-1} Fresh Weight (FW) basis (about 0.03 pg kg-1) was derived for the Dioxin concentration in eggs due to the foraging of chickens on soil with an incremental annual average increase in Dioxin concentration in the soil of 0.0012 ng kg^{-1}, due to the operation of the proposed facility.

5.13.2 Dioxin Concentration in Chicken Meat

The following formula was used to estimate the potential Dioxin concentration in chicken meat due to ingestion of soil and grain by free-range chickens reared in the locality:

Equation 5 The Intake of Dioxin in Chicken Meat Due to Foraging on Contaminated Soil

$$A_{Chicken} = \left(\sum \left(F_i \cdot Qp_i \cdot P_i \right) + Q_s \cdot C_s \cdot B_s \right) \cdot Ba_{Chicken}$$

Where:

- AChicken = Concentration of dioxin in chicken meat
- Fi = Fraction of grain grown on contaminated soil and ingested by chickens – assumed to be 1.0
- Qpi = Quantity of grain ingested by chickens – assumed to be 0.2 (US EPA HHRAP)
- Pi = Concentration of dioxin in grain – derived from the equation in Section 4.14.7 above
- Qs = Quantity of soil ingested by chickens – assumed to be 0.022 kg day^{-1} (US EPA HHRAP)
- Cs = Maximum annual average incremental increase in Dioxin concentration in soil – estimated by modelling to be 0.0012 ng kg^{-1};
- Bs = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP)
- Baegg = Biotransfer factor for chicken carcase – assumed to be 1.09984 (US EPA HHRAP Database)

Using the above equations, a value of approximately 5.3×10^{-11} mg kg^{-1} (about 0.053 pg kg^{-1}) of fresh meat was derived for the Dioxin concentration in chicken meat due to the foraging for food on soil with an incremental annual average increase in dioxin concentration, due to the operation of the proposed facility, of 0.0012 ng kg^{-1}.

5.13.3 Dietary Intake Due to the Combined Consumption of Chicken Meat and Eggs

Data published by the Food Standards Agency gave the following dietary intakes of eggs and chicken for adults and infants in the UK:

Table 11 UK Data on the Consumption of Eggs and Chicken

Food Category	UK Adult Mean (g/kg BW/day)	UK Infant Mean (g/kg BW/day)
Poultry Meat	0.81	1.90
Eggs	0.26	0.69
Poultry Meat	0.81	1.90
Eggs	0.26	0.69

The above figures are based upon the average values for men and women, and boys and girls, to give an overall average for an adult or infant member of the population. The values relate to the average daily consumption of eggs and chicken meat in terms of g/kg body weight/day, and the values are derived from the "National Diet and Nutrition Survey", published in 2010.

The values in Table 11 are the average values for consumption of eggs and chicken by males and females (Table 5.1 of the above report), normalised for daily consumption on the basis of an average adult weighing 70 kg, and an average child weighing 14.5 kg, in line with the US EPA HHRAP approach. The National Nutrition and Diet Survey covers adults between the ages of 19 and 64, and the data for infants relate to children aged between 4 years and 10 years.

For home-reared or allotment-reared eggs and poultry meat, it is unlikely that meat consumption rates would be as high as those for eggs, as the birds are the source of the eggs. Accordingly, the majority of poultry meat consumed is likely to have come from sources outside the area, and the assessment is likely to overestimate considerably the potential impact of poultry meat consumption.

When the dietary intake data are combined with the estimated Dioxin concentration data for eggs and chicken meat calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and infants with a body weight of 14.5 kg:

Table 12 Dietary Intake of Dioxins via the Consumption of Eggs and Chicken Reared at the Location of the Maximum Process Contribution

Food Category	UK Adult mean	UK Infant mean
	pg day^{-1}	
Chicken	0.003	0.0015
Eggs	0.0006	0.0003
	Percentage of Tolerable Daily Intake (2 pg kg^{-1})	
Chicken	0.151 %	0.073 %
Eggs	0.028 %	0.015 %

As can be seen in the above table, the estimated daily intake of Dioxins due to the consumption of chicken meat, arising from the maximum incremental annual average increase in Dioxin concentration in the soil of 0.0012 ng kg^{-1}, represent values that are approximately 0.15 % or less of the Tolerable Daily Intake value of 2 pg kg^{-1} day^{-1}. The values for egg consumption are generally about five times lower than those for the consumption of chicken meat.

As stated earlier, it is likely that the consumption of chicken meat would be significantly lower under this scenario as the chickens would be required to supply the eggs, and therefore a significant proportion of the chicken meat consumed would very likely be sourced from outside of the area. Furthermore, the assessment is based upon worst case scenario with emissions at the IED ELV of 0.1 ng Nm^{-3}. However, when operational, emissions of Dioxins from the proposed plastic pyrolysis plant are expected to be significantly lower than the IED ELV.

5.14 Exposure from Dietary Intake of Milk

The potential link between human receptors and the consumption of locally produced milk is not known. Nevertheless, to provide a worst-case basis for assessment, exposure to Dioxins via the consumption of milk has been assumed.

The US EPA Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities methodology was used to assess the potential exposure to Dioxins arising from emissions from the proposed plastic pyrolysis plant. The equation in Table B-3-11 in Appendix B of the HHRAP was used to determine the concentration of dioxins in milk at locations in the in the vicinity of the proposed facility.

The results presented in the following section relate to the deposition rate at location of the maximum process contribution, approximately 217 metres to the north, north east of the development site.

5.14.1 Dioxin Concentration in Milk

The following formula was used to estimate the potential Dioxin concentration in milk due to ingestion of soil and grain by cows reared in the locality:

Equation 6 The Intake of Dioxin in Milk Due to Grazing on Contaminated Soil

$$A_{milk} = \left(\sum \left(F_i \cdot Qp_i \cdot P_i \right) + Q_s \cdot C_s \cdot B_s \right) \cdot Ba_{milk} \cdot MF$$

Where:

- Amilk = Concentration of dioxin in milk
- Fi = Fraction of forage grown on contaminated soil and ingested by cows – assumed to be 1.0
- Qpi = Quantity of forage ingested by cows – assumed to be 13.2 (US EPA HHRAP)
- Pi = Concentration of dioxin in forage – derived from separate equation below
- Qs = Quantity of soil ingested by cows – assumed to be 0.04 kg day^{-1} (US EPA HHRAP)

- Cs = Maximum annual average incremental increase in dioxin concentration in soil – estimated by modelling to be 0.0012 ng kg^{-1};
- Bs = Soil bioavailability factor – assumed to be 1.0 (US EPA HHRAP)
- Bamilk = Biotransfer factor for milk – assumed to be 5.499 (US EPA HHRAP Database)

The value of Pi was derived using the equation in Table B-3-9 of Appendix B of the HHRAP:

Equation 7 The Intake of Dioxin in Forage Due to Increase in Soil Concentration

$$P_i = C_s \times Br_{forage}$$

Where:

- Pi = Concentration of dioxin in forage;
- Cs = Annual average increase in dioxin concentration in soil – estimated by modelling to be 0.0012 ng kg^{-1};
- Brforage = Plant-soil bioconcentration factor for forage – assumed to be 0.00455 (US EPA HHRAP Database);

Using the above equations, a value of approximately 3 x 10^{-9} mg kg^{-1} Fresh Weight (FW) basis (approximately 3 pg kg^{-1}) was derived for the Dioxin concentration in milk due to the grazing of cows on soil with an incremental annual average increase in Dioxin concentration in the soil of 0.0012 ng kg^{-1}, due to the operation of the proposed facility.

5.14.2 Dietary Intake Due to the Consumption of Milk

Data published by the Food Standards Agency gave the following dietary intake of whole milk for adults and infants in the UK:

Table 13 UK Data on the Consumption of Milk

Food Category	UK Adult Mean (g/kg BW/day)	UK Infant Mean (g/kg BW/day)
Whole Milk	0.42	5.24

The above figures are based upon the average values for men and women, and boys and girls between the ages of 4 and 10, to give an overall average for an adult or infant member of the population. The values relate to the average daily consumption of whole milk in terms of g/kg body weight/day, and the values are derived from the “National Diet and Nutrition Survey, Year 1 Report”, published in 2010. The value for whole milk was selected because Dioxins tend to collect in fats and fatty tissue, and therefore are likely to be more concentrated in whole milk than in semi-skimmed milk. The application of whole milk figures into the assessment therefore represents a worst-case assessment for Dioxin intake via milk consumption. Furthermore, the assessment assumes that the milk is produced by cows grazing at a location approximately 220 metres to the north, north east of the chimney of the proposed plastic pyrolysis plant for the whole of the year, which is unrealistic, and highlights further the fact that the assessment represents a worst-case scenario.

The values in Table 13 are the average values for consumption of milk by males and females, and boys and girls between the ages of 4 and 10 (Table 5.1 of the FSA report), normalised for daily consumption on the basis of an average adult weighing 70 kg, and an average child weighing 14.5 kg, in line with the US EPA HHRAP approach.

When the dietary intake data are combined with the estimated Dioxin concentration data for milk calculated above, the following daily intake values were derived for adults with a body weight of 70 kg, and infants with a body weight of 14.5 kg:

Table 14 Dietary Intake of Dioxins via the Consumption of Milk Produced at the Location of the Maximum Process Contribution

Food Category	UK Adult mean	UK Infant mean
	pg day^{-1}	
Whole Milk	0.089	0.23
	Percentage of Tolerable Daily Intake (2 pg kg^{-1})	
Whole Milk	4.5 %	11.5 %

As can be seen in Table 11, the estimated daily intake of Dioxins due to the consumption of potentially contaminated milk, arising from the maximum incremental annual average increase in Dioxin concentration in the soil of 0.0012 ng kg^{-1}, represent values that are less than 5 % of the Tolerable Daily Intake for adults and less than 12 % for infants. These values are considerably higher than those for eggs and chicken meat and reflect the fact that Dioxins tend to concentrate in fats and fatty tissues, which includes an animal's lactate system. The above assessment is based upon the consumption of whole milk, and as such the results probably overestimate considerably the significance of Dioxin intake via the consumption of milk.

It should also be noted that this assessment is based upon potential Dioxin deposition at a location approximately 220 metres to the north, north east of the chimney of the proposed facility, based upon emissions at the IED ELV for dioxins (0.1 ng Nm^{-3}) for the whole of the year, and for individuals who source all of their milk from animals grazing at this location for the whole of the year. Accordingly, this represents an absolute worst-case assessment for the potential impact of emissions of Dioxins from the plastic pyrolysis plant on Dioxin intake via the consumption of locally produced milk. As stated earlier, when operational, emissions of Dioxins from the facility are expected to be significantly lower than the IED ELV.

5.15 Exposure from Dietary Intake Due to Ingestion of Soil

The formula in Table C-1-1 in Appendix C of the US EPA HHRAP was used to estimate the potential intake of dioxins due to ingestion of soil in the locality of the plastic pyrolysis plant:

Equation 8 The Intake of Dioxin Due to Ingestion of Soil

$$I_{Soil} = \frac{Cs \times CR_{Soil} \times F_{Soil}}{BW}$$

Where:

- ISoil = Daily intake of dioxin via soil ingestion;
- Cs = Maximum incremental increase in dioxin concentration in the soil due to deposition - estimated by modelling to be 0.0012 ng kg^{-1};
- CRSoil = Consumption rate of soil (US EPA HHRAP Values)
- FSoil = Fraction of soil contaminated by dioxins – US EPA HHRAP recommends the use of 1.0; and,
- BW = Body weight

Using the above equation, a Dioxin intake of 0.0000017 pg kg^{-1} day^{-1} was calculated for adults and 0.000016 pg kg^{-1} day^{-1} for infants as a result of soil ingestion, and due to the operation of the plastic pyrolysis plant. These values represent approximately 0.000086 % and 0.0008 % respectively of the TDI of 2 pg day^{-1} and are considered to be negligible.

5.16 Exposure from Dioxin Intake Due to the Consumption of Fruit and Vegetables

An assessment for exposure to Dioxins has been undertaken for the consumption of fruit and vegetables in order to represent a scenario where local residents are obtaining their dietary intake of fruit and vegetables from plants grown in soil that could potentially be contaminated by Dioxins in the emissions from the plastic pyrolysis plant.

The equation in Table C-1-2 in Appendix C of the HHRAP methodology was used to estimate the daily intake of dioxins via the consumption of fruit and vegetables:

Equation 9 The Intake of Dioxin in Produce Due to Increase in Concentration in the Soil

$$I_{ag} = \left[\left(\left(Pd \times Pv \times \mathrm{Pr}_{ag}\right) \times CR_{ag}\right) + \left(\mathrm{Pr} \times CR_{pp}\right) + \left(\mathrm{Pr}_{bg} \times CR_{bg}\right)\right] \times F_{ag}$$

Where:

- Iag = Daily intake of Dioxins from the consumption of fruit and vegetables;
- Pd = Above ground exposed fruit and vegetables concentration due to direct deposition onto plant surfaces – calculated using Equation B-2-7 in Appendix B of HHRAP methodology;
- Pv = Above ground exposed fruit and vegetables concentration due to air-to-plant transfer – calculated using Equation B-2-8 in Appendix B of HHRAP methodology;
- Prag = Above ground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-9 in Appendix B of HHRAP methodology;
- Prbg = Below ground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-10 in Appendix B of HHRAP methodology;
- CRag = Consumption rate of above ground fruit and vegetables (US EPA HHRAP Value);
- CRpp = Consumption rate of protected above ground fruit and vegetables (US EPA HHRAP Value);
- CRbg = Consumption rate of below ground fruit and vegetables (US EPA HHRAP Value);
- Fag = Fraction of fruit and vegetables that is contaminated – assumed to be 1.0

5.16.1 Calculation of Pd

Equation B-2-7 in Appendix B of the US EPA HHRAP methodology was used for the calculation of Pd and is as follows:

Equation 10 The Increase in Dioxin Concentration in Aboveground Produce Due to Deposition

$$Pd = \frac{1000 \times Q \times \left(1 - F_v\right) \times \left[Dydp + \left(Fw \times Dywp\right)\right] \times Rp \times \left[1.0 - e^{(kp \times Tp)}\right]}{Yp \times kp}$$

Where:

- Pd = Concentration of Dioxins in aboveground fruit and vegetables due to direct deposition;
- Q = Dioxin emission rate;
- Fv =Fraction of dioxin in the vapour phase – US EPA HHRAP value for dioxins = 0.664;
- Dydp = Unitised yearly average dry deposition from particulate phase – ADMS modelling;
- Fw = Fraction of dioxin that adheres to plant surfaces – US EPA HHRAP value = 0.6 for organics;

- Dywp = Unitised yearly average wet deposition from particulate phase – ADMS modelling;
- Rp = Interception fraction of the edible portion of the plant – US EPA HHRAP value = 0.39;
- Kp = Plant surface loss coefficient – US EPA HHRAP value = 18;
- To = Length of plant exposure to deposition per harvest of edible portion of plant – US EPA HHRAP value = 0.16;
- Yield of standing crop biomass of the edible portion of the plant (productivity) – US EPA HHRAP value = 2.24.

Using the above equation, a value of approximately 8.5 x 10^{-11} mg Dioxin per kg Dry Weight was obtained for Pd.

5.16.2 Calculation of Pv

Equation B-2-8 in Appendix B of the US EPA HHRAP methodology was used for the calculation of Pv and is as follows:

Equation 11 The Increase in Dioxin Concentration in Above Ground Produce Due to Air-Plant Transfer

$$Pv = Q \times F_v \times \frac{Cyv \times Bv_{ag} \times Vg_{ag}}{\rho_a}$$

Where:

- Pv = Concentration of dioxins in aboveground fruit and vegetables due to air-to-plant transfer;
- Q = Dioxin emission rate;
- Fv =Fraction of Dioxin in the vapour phase – US EPA HHRAP value for Dioxins = 0.664;
- Cyv = Unitised annual average atmospheric concentration – ADMS modelling;
- Bvag = Dioxin air-to-plant Biotransfer factor for above ground fruit and vegetables – US EPA HHRAP value = 6.55 x 10^{-4};
- Vgag = Empirical correction factor for above ground fruit and vegetables – US EPA HHRAP value = 0.01;
- Pa = Density of air (1,200 g m^{-3}).

Using the above equation, a value of approximately 9.2 x 10^{-10} mg Dioxin per kg Dry Weight was obtained for Pv.

5.16.3 Calculation of Pr_{ag}

Equation B-2-9 in Appendix B of the US EPA HHRAP methodology was used for the calculation of Pr_{ag} and is as follows:

Equation 12 The Increase in Dioxin Concentration in Above Ground Produce Due to Root Intake

$$\mathrm{Pr}_{ag} = Cs \times Br_{ag}$$

Where:

- Pr_{ag} = Concentration of Dioxins in above ground fruit and vegetables due to root intake;
- Cs = Incremental increase in Dioxin concentration in the soil over exposure period;
- Brag = Plant-soil bioconcentration factor for above ground fruit and vegetables – US EPA HHRAP value for dioxins = 0.00455.

Using the above equation, a value of approximately 5.5 x 10^{-12} mg Dioxin per kg Dry Weight was obtained for Pr_{ag}.

5.16.4 Calculation of Pr_{bg}

Equation B-2-10 in Appendix B of the US EPA HHRAP methodology was used for the calculation of Pr_{bg} and is as follows:

Equation 13 The Increase in Dioxin Concentration in Below Ground Produce Due to Deposition

$$\mathrm{Pr}_{bg} = Cs \times Br_{rootveg} \times Vg_{rootveg}$$

Where:
- Pr_{bg} = Concentration of dioxins in below ground fruit and vegetables due to root intake;
- Cs = Incremental increase in Dioxin concentration in the soil over exposure period;
- $Br_{rootveg}$ = Plant-soil bioconcentration factor for belowground fruit and vegetables – US EPA HHRAP value for Dioxins = 1.03;
- $Vg_{rootveg}$ = Empirical correction factor for belowground fruit and vegetables – US EPA HHRAP value = 0.01.

Using the above equation, a value of approximately 1.23 x 10^{-11} mg Dioxin per kg Dry Weight was obtained for Pr_{bg}.

5.16.5 Calculation of Dioxin Intake from the Consumption of Fruit and Vegetables

Equation C-1-2 in Appendix C of the US EPA HHRAP methodology was used to calculate the overall intake of dioxins due to the consumption of fruit and vegetables:

Equation 14 The Daily Intake of Dioxins Due to the Consumption of Fruit & Vegetables

$$I_{ag} = \left[\left((Pd \times Pv \times \mathrm{Pr}_{ag}) \times CR_{ag}\right) + \left(\mathrm{Pr} \times CR_{pp}\right) + \left(\mathrm{Pr}_{bg} \times CR_{bg}\right)\right] \times F_{ag}$$

Where:
- Iag = Daily intake of Dioxins from the consumption of fruit and vegetables;
- Pd = Above ground exposed fruit and vegetables concentration due to direct deposition onto plant surfaces – calculated using Equation B-2-7 in Appendix B of HHRAP methodology = 3.8 x 10-12 mg/kg-day DW;
- Pv = Above ground exposed fruit and vegetables concentration due to air-to-plant transfer – calculated using Equation B-2-8 in Appendix B of HHRAP methodology = 3.8 x 10-10 mg/kg day DW;
- Prag = Above ground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-9 in Appendix B of HHRAP methodology = 1.0 x 10-12 mg/kg-day DW;
- Prbg = Below ground exposed and protected fruit and vegetables concentration due to root intake – calculated using Equation B-2-10 in Appendix B of HHRAP methodology = 2.4 x 10-12 mg/kg day DW;
- CRag = Consumption rate of above ground fruit and vegetables (US EPA HHRAP Value) = 0.00047 kg/kg-day DW for adults and 0.00113 kg/kg-day DW for children;
- CRpp = Consumption rate of protected above ground fruit and vegetables (US EPA HHRAP Value) = 0.00064 kg/kg-day DW for adults and 0.00157 kg/kg-day DW for children;
- CRbg = Consumption rate of below ground fruit and vegetables (US EPA HHRAP Value) = 0.00017 kg/kg day DW for adults and 0.00028 kg/kg-day DW for children;
- Fag = Fraction of fruit and vegetables that is contaminated – assumed to be 1.0

Using the above equation, a value of 0.0005 pg kg^{-1} Dioxin per kg Dry Weight for adults was obtained for Iag, the dietary intake via the consumption of fruit and vegetables, and a value of 0.0011 pg kg^{-1} Dioxin per kg Dry Weight for children.

5.17 Combined Dietary Intake via the Consumption of Chicken and Eggs, Milk, Fruit & Vegetables and the Ingestion of Soil

When the results from the above calculation procedures for dietary intake of Dioxins are added together with the estimated intake via inhalation, the following results are obtained:

Table 15 Intake of Dioxins at the Location of Maximum Process Contribution

Food Category	UK Adult Mean (pg kg^{-1})	UK Infant Mean (pg kg-1)
Chicken	0.0030	0.0015
Eggs	0.0006	0.00030
Milk	0.089	0.230
Soil	0.0000017	0.000016
Produce	0.0005	0.0011
Inhalation	0.008	0.010
Total	**0.10**	**0.24**

Table 16 Intake of Dioxins at the Location of Maximum Process Contribution as an Approximate Percentage of the Tolerable Daily Intake

Food Category	UK Adult Mean	UK Infant Mean
Chicken	0.151 %	0.073 %
Eggs	0.028 %	0.015 %
Milk	4.5 %	11.5 %
Soil	0.000086 %	0.00080 %
Produce	0.024 %	0.057 %
Inhalation	0.39 %	0.49 %
Total	**5.1 %**	**12.2 %**

The results presented in Tables 15 and 16 represent a worst case estimate, based upon Dioxin deposition rates due to emissions at the IED ELV (0.1 ng Nm^{-3}), at the location of the maximum Process Contribution which is approximately 220 metres to the north, north east of the chimney of the proposed plastic pyrolysis plant. It is also assumed that total dietary intake of eggs, chicken meat, milk, and fruit and vegetables is derived from produce grown at that specific location. Emissions of Dioxins when operational are expected to be significantly lower than the IED ELV.

Nevertheless, the results show that the potential impact of Dioxin release from the facility on Dioxin concentrations in the soil, and on the associated increase in dietary intake through the consumption of eggs, chicken meat, fruit and vegetables, as well as via the ingestion of soil through the working of the land, is likely to be considerably below the recommended Tolerable Daily Intake of 2 pg kg^{-1} day^{-1}.

It should be noted that the in defining a TDI of 2 pg kg^{-1} for Dioxins, the Committee on Toxicity acknowledged the uncertainties associated with the approach:

We concluded that the available human data did not provide a sufficiently rigorous basis for establishment of a tolerable intake. This was because:

- *the epidemiological studies do not reflect the most sensitive population identified by animal studies,*
- *there are considerable uncertainties in the exposure assessments and inadequate allowance for confounding factors;*
- *the patterns of exposure did not reflect exposures experienced in the general UK population, which are mainly from diet.*

We therefore found it necessary to base our evaluation on the data from studies conducted in experimental animals.

Accordingly, the results from this assessment, which are based upon a series of overly pessimistic assumptions relating to emissions of Dioxins and the associated deposition, should be viewed within the context that they are low relative to an inexact assessment level. This is particularly the case with regard to the predictions for the consumption of milk. These values reflect the fact that Dioxins tend to concentrate in fats and fatty tissues, and pass through into an animal's lactate system.

It should also be noted that this assessment is based upon a series of pessimistic assumptions, including the fact that potential Dioxin deposition is based upon the location of the maximum Process Contribution, approximately 220 metres from the site; that the cows graze only on grass or forage grown at this location; that emissions of Dioxins from the facility are discharged at the IED ELV of 0.1 ng Nm^{-3} for the whole of the year; and that individuals source all of their milk from animals grazing at this location for the whole of the year.

The corresponding values, based upon the maximum process contributions for nearby specific receptors, were lower due to their distance from the site, as shown in Table 17.

Table 17 Exposure to Dioxins at Specific Receptors in the Vicinity of the Plastic Pyrolysis Plant

Receptor Number	Percentage of Tolerable Intake* (Adult)	Percentage of Tolerable Daily Intake* (Infant)
1	0.7 %	1.3 %
2	1.0 %	2.4 %
3	0.3 %	0.6 %
4	0.3 %	0.5 %
5	0.2 %	0.4 %
6	0.3 %	0.5 %
7	0.3 %	0.6 %
8	0.2 %	0.4 %
9	0.3 %	0.6 %
10	0.3 %	0.5 %
11	0.2 %	0.3 %

* Total deposition rate = 3 x dry deposition rate.

The assessment indicates that the risk to the health of the local population due to exposure to dioxins in emissions from the proposed plastic pyrolysis plant is likely to be very low in comparison to the recommended Tolerable Daily Intake of 2 pg/kg/yr.

It should also be remembered that the above results are based upon emissions at the ELV of 0.1 ng Nm^{-3} specified by the IED, and that when operational, emissions of Dioxins are likely to be significantly lower, with proportionate benefits for lower exposure levels for individuals living in the vicinity of the site.

When the above exposure data are translated into the associated cancer risk data, the following values were obtained.

Table 18 Approximate Cancer Risk Due to Exposure to Dioxins at Specific Receptors in the Vicinity of the Proposed Plastic Pyrolysis Plant

Receptor Number	Cancer Risk (Adult)		Cancer Risk (Infant)	
1	8.57E-07	1 in 1,167,482	1.70E-06	1 in 586,871
2	1.33E-06	1 in 754,340	3.08E-06	1 in 324,929
3	3.76E-07	1 in 2,661,610	7.47E-07	1 in 1,339,032
4	3.34E-07	1 in 2,994,666	6.37E-07	1 in 1,570,941
5	2.76E-07	1 in 3,620,985	5.03E-07	1 in 1,987,455
6	3.47E-07	1 in 2,881,947	6.66E-07	1 in 1,502,040
7	4.09E-07	1 in 2,447,792	7.93E-07	1 in 1,260,429
8	3.09E-07	1 in 3,235,318	5.77E-07	1 in 1,732,636
9	4.00E-07	1 in 2,502,523	8.06E-07	1 in 1,240,341
10	3.71E-07	1 in 2,695,575	6.94E-07	1 in 1,440,397
11	2.49E-07	1 in 4,019,429	4.46E-07	1 in 2,243,213

The above Cancer Risk estimates represent the incremental probability that an individual, living at a particular receptor location, will develop cancer over that person's lifetime as a result of a specific exposure to Dioxins emitted from the chimney of the proposed plastic pyrolysis plant. The position in the UK at present is that a risk level of $1E^{-05}$ is considered to be appropriate for use as the basis for assessment for carcinogenic contaminants such as Dioxins. As all of the results reported in table 18 remain within this figure, they can be screened as insignificant.

It should be noted that the above results are based upon a series of worst case, conservative assumptions as follows:

1. Emissions of Dioxins are at the IED ELV of 0.1 ng Nm^{-3} for waste incineration plants, which is unlikely as emissions are expected to be significantly lower than the IED ELV when the plastic pyrolysis plant is operational.
2. The HHRAP calculation procedure requires estimates of both dry deposition and wet deposition of Dioxins in both the particulate and vapour phases. In the absence of measured data on rainfall, it was assumed that total deposition (wet plus dry) was three times the figure for dry deposition. Accordingly, deposition assessments for Dioxins in the particulate phase are likely to significantly overestimate the situation in the vicinity of the development site.
3. It is assumed that all of the food consumed by individuals is grown at that location, which is highly unlikely given the likelihood that for the majority of the population food is purchased from supermarkets, or other outlets, and is grown outside of the area; and,
4. All of the milk consumed is produced by cows grazing at the specific receptor location for the entire year, which is highly unlikely. Furthermore, the consumption of milk accounts for about 20 % to 30 % of the estimated dietary intake due to the propensity for Dioxins to accumulate in fatty body tissue and pass through into the cows' lactate system.

Accordingly, the above results are considered to provide an overly conservative assessment of the potential exposure to Dioxins in the vicinity of the proposed plastic pyrolysis plant, and it is expected that values will be significantly lower when the facility is operational.

To put the Cancer Risk data into perspective, information is presented below relating to risk of death from a range of causes(13).

Table 19 Risk of an Individual Dying in Any One Year

Activity	Risk
Smoking 10 cigarettes a day	1 in 200
All natural causes, age 40	1 in 850
All violence and poisoning	1 in 3,300
Influenza	1 in 5,000
Accident on the road	1 in 8,000
Leukaemia	1 in 12,000
Accident at home	1 in 26,000
Accident at work	1 in 43,000
Murder	1 in 100,000
Accident on railway	1 in 500,000
Hit by lightning	1 in 10,000,000
Radiation from nuclear reactor	1 in 10,000,000

These values are not absolute, but indicative, and enable the Cancer Risk estimates to be viewed in perspective with other activities that individuals may be associated with. As can be seen, when compared to the Cancer Risk scores for Receptor number 2, the nearest residential receptor, (approximately 1 in 754,340), the risk of dying in a road traffic accident is about ninety-four times higher than the risk of developing cancer due to exposure to Dioxins released from the proposed plastic pyrolysis plant.

6. The Impact of Emissions of PAH and Dioxin-like PCBs

PAH (Polynuclear Aromatic Hydrocarbons) is a term that describes a group of organic compounds, made up of Carbon and Hydrogen, and comprised of fused multiple aromatic rings, and include substances such as Naphthalene, Chrysene and Benzo[a]Pyrene (B[a]P), the latter being one of the more toxic of the group of compounds. PAH can be formed by the inefficient combustion of Carbon-containing fuels such as coal, diesel and biomass.

Reference has been made to the scientific literature to identify an appropriate emission concentration to use as the basis for assessment of emissions of PAH from the plastic pyrolysis plant. Two studies of health impacts associated with emissions from energy from waste facilities(14 and 15), refer to DEFRA Research Report WR0608(16), which presents information on emissions from waste management facilities. To provide a worst-case basis for assessment it has been assumed that all of the PAH emission will be as B[a]P, which will overestimate the significance of the actual situation by a considerable margin. The DEFRA research report provides a median value for B[a]P emission concentrations of 9.0×10^{-5} mg Nm^{-3} (90 ng Nm^{-3}) as an appropriate value to use for the assessment of PAHs. There is an air quality objective value of 0.25 ng m^{-3} specified for B[a]P, and this was used as the basis for assessment.

PCBs (Poly Chlorinated Biphenyls) are synthetic organic compounds made up of Carbon, Hydrogen and Chlorine. There are 209 different PCB compounds with up to 10 Chlorine atoms attached to a two ring, Biphenyl group. They are sometimes referred to as Aroclor compounds with different numbering configurations. For example, Aroclor 1254 refers to a 12-Carbon atom compound containing 45 % Chlorine by mass. Reference to the DEFRA Research Report suggested that an emission concentration of 3.6×10^{-8} mg Nm^{-3} (3.6×10^{-2} ng Nm^{-3}) was appropriate for the assessment of PCBs. An Inhalation Reference Concentration for Aroclor 1254 of (7×10^{-5} mg m^{-3}) 70 ng m^{-3} was used as the basis for assessment.

6.1 Results and Discussion

Detailed atmospheric dispersion modelling of emissions of PAH and PCBs from the proposed plastic pyrolysis plant was undertaken at the eleven specific receptor locations listed in Table 9. The results from detailed modelling are based upon the maximum annual average Process Contribution for the years 2006 to 2008 at the various receptor locations and are presented in the following table.

Table 20 Maximum Exposure to PAH and PCBs at Specific Receptors in the Vicinity of the Plastic Pyrolysis Plant

Receptor Number	Annual Average PAH Concentration (ng m^{-3})	Percent AQS	Annual Average PCB Concentration (µg m^{-3})	Percent EAL
1	1.15E-04	0.05 %	4.62E-11	0.000000023%
2	4.03E-04	0.16 %	1.61E-10	0.000000081%
3	6.79E-05	0.03 %	2.71E-11	0.000000014%
4	4.47E-05	0.02 %	1.79E-11	0.000000009%
5	3.95E-05	0.02 %	1.58E-11	0.000000008%
6	3.32E-05	0.01 %	1.33E-11	0.000000007%
7	6.26E-05	0.03 %	2.50E-11	0.000000013%
8	5.69E-05	0.02 %	2.27E-11	0.000000011%
9	7.99E-05	0.03 %	3.20E-11	0.000000016%
10	6.65E-05	0.03 %	2.66E-11	0.000000013%
11	4.00E-05	0.02 %	1.60E-11	0.000000008%

As can be seen, the maximum annual average PAH and PCB process contributions are all considerably below their respective AQS objective values and Inhalation Reference Concentrations, and can probably be screened out as insignificant at all of the specific receptor locations.

The emission concentration for PCBs used in the assessment represents a value that is equivalent to 36 % of those associated with Dioxins and Furans. The annual average Process Contributions of PCBs reported at each of the sensitive receptors suggest increases of up to 33 % on the Dioxin baseline if the potential impact of the combined emissions of Dioxins and Dioxin-like PCBs are to be considered. In order to provide a worst-case assessment, a 33 % increase has been applied to the results of the estimated uptake at each receptor in the table below. The Dioxin Tolerable Daily Intake value of 2 pg/kg BW used as the basis for assessment for Dioxins, was also applied to the process contribution of the PCBs.

The results for the estimated daily average intake of Dioxins have been updated in Table 21 to take account of the increase due to the incorporation of the PCBs into the calculation.

Table 21 Exposure to Dioxins and PCBs at Specific Receptors in the Vicinity of the Plastic Pyrolysis Plant

Receptor Number	Dioxins Alone		Dioxins and PCBs	
	Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Infant)	Percentage of Tolerable Daily Intake (Adult)	Percentage of Tolerable Daily Intake (Infant)
1	0.7 %	1.3 %	0.9 %	1.7 %
2	1.0 %	2.4 %	1.3 %	3.2 %
3	0.3 %	0.6 %	0.4 %	0.8 %
4	0.3 %	0.5 %	0.4 %	0.7 %
5	0.2 %	0.4 %	0.3 %	0.5 %
6	0.3 %	0.5 %	0.4 %	0.7 %
7	0.3 %	0.6 %	0.4 %	0.8 %
8	0.2 %	0.4 %	0.3 %	0.5 %
9	0.3 %	0.6 %	0.4 %	0.8 %
10	0.3 %	0.5 %	0.4 %	0.7 %
11	0.2 %	0.3 %	0.3 %	0.4 %

As can be seen, the combined intake of Dioxins & Furans and Dioxin-like PCBs, due to emissions from the proposed plastic pyrolysis plant, represent a small percentage of the Tolerable Daily Intake of 2 pg/kg BW at all nearby specific receptor locations, with values of less than 3.5 % (for infants), and generally less than 1 % of the TDI assessment level for the combined pollutants. Accordingly, inclusion of PCBs into the Dioxin HRA results in a small increase in the predicted impact, which can be screened out as insignificant.

7. Conclusions

A health impact assessment has been undertaken to assess the risk to the health of people living in the vicinity of a proposed plastic pyrolysis plant to be developed by Dallol Energy Limited near Chelveston in East Northamptonshire. Detailed atmospheric dispersion modelling of emissions from the 35 metre high chimney was undertaken using the ADMS Version 5.2 model to predict increases in pollutant concentrations at nearby sensitive receptors where people may congregate for significant periods of time. The assessment involved a comparison of model-predicted process contributions against health-based air quality standards and relevant environmental assessment levels.

Short term acute effects were for NO_2, SO_2 and PM_{10} were assessed in line with COMEAP procedures and showed that increases in background pollutant concentrations at nearby residential properties were low and would not have a significant impact on the health of people living and working nearby. Similar conclusions were drawn for other pollutants with short term, acute effects (HCl, HF and CO). Process contributions for pollutants such as VOCs and Heavy Metals were very low and their potential health effects screened out as insignificant in relation to health-based air quality standards and relevant EALs recommended by the Environment Agency.

The US EPA Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities used to assess the potential risk to health of people living and working in the locality of the plastic pyrolysis plant due to emissions of Dioxins and Furans, and Dioxin-like PCBs. The assessment considered the potential health risks associated with the intake of Dioxins due to the consumption of potentially contaminated foodstuffs due to emissions to atmosphere from the chimney of the facility. The assumptions used within the assessment are conservative and therefore the study was undertaken on a conservative worst-case basis.

The assessment indicates that the risk to health of the local population due to exposure to dioxins in emissions from the plastic pyrolysis plant is likely to be low, and generally less than 1 % of the Tolerable Daily Intake (TDI) of 2 pg/kg. The inclusion of dioxin-like PCBs into the assessment resulted in a small increase in the resulting process contributions, which remained a very small proportion of the 2 pg/kg TDI.

The assessment for health risks associated with exposure to emissions of PAH demonstrated that process contributions would be less than 0.2 % of the health-based air quality standard of 0.25 ng m^{-3}, and can be screened out as insignificant.

In conclusion, the results from the health impact assessment confirms that there is no significant health risk associated with emissions of pollutants from the proposed plastic pyrolysis plant to be developed by Dallol Energy Limited near Chelveston.

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