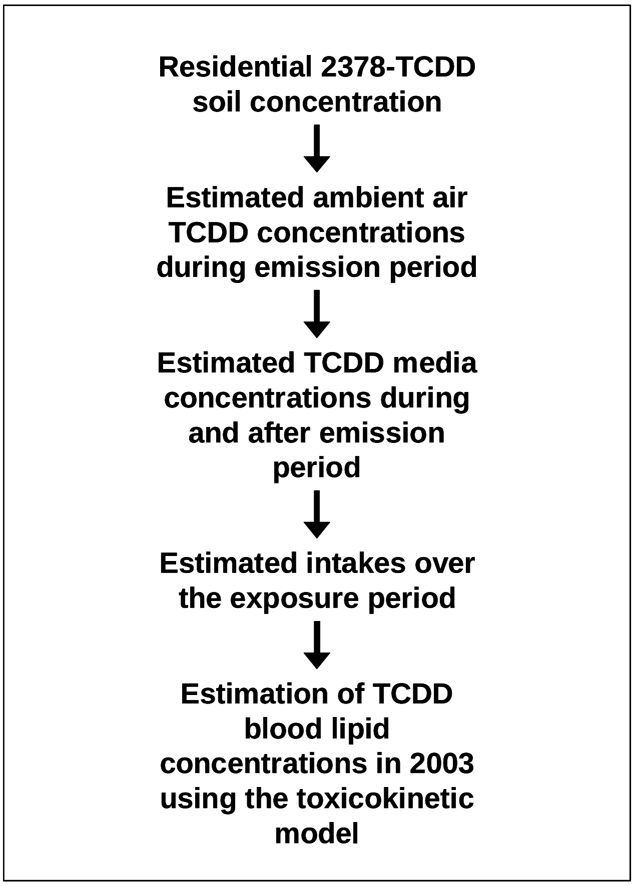
Summary Description of Candidate Selection Model

The candidate selection model was developed to estimate the incremental increase in 2378-TCDD blood lipid concentrations above background levels for individuals who lived in the vicinity of the former IWD agrochemical plant. The model is intended to provide a tool to assist the selection of candidates to participate in the blood serum sampling programme. The model initially predicted individual 2378-TCDD blood lipid concentrations up to the year 2000 but was later extended to estimate concentrations to 2003.

The model assumes that present 2378-TCDD soil concentrations in the area surrounding the plant result primarily from emissions of the contaminant to air between the years of 1962 and 1975. For each potential candidate, multipathway exposure modelling is used to estimate historical exposure to 2378-TCDD, both during and after the assumed emission period, from the soil concentration (measured or interpolated from measured results) at their current or former residence location near the plant and their consumption of home grown produce. The multipathway modelling includes exposures via inhalation, soil ingestion and consumption of home grown fruit and vegetables, and eggs and meat from home-raised free-range poultry, to the extent that these apply to the individual. The residual 2378-TCDD concentration still remaining in blood lipid in the year 2004 is then estimated using a toxicokinetic model. An overview of the calculation procedure is shown in Figure 1.

Figure 1. Overview of model calculation procedure



Overview of modelling procedure

For each individual, the following information is entered in the model:
- age
- gender
- the period when they resided near the plant
- the 2378-TCDD soil concentration recorded (or estimated) at their residential location
- the typical proportion of their fruit and vegetable consumption obtained from their home garden
- the typical proportion of their egg and poultry meat consumption obtained from free range poultry kept at their home

These details are then used by the model to estimate age-dependent and gender-dependent intake rates of 2378-TCDD, the elimination of 2378-TCDD in the body between 1962 and 2003, and the 2378-TCDD fat body concentration in 2003. Each candidate's body weight and body fat is assumed to vary with age in accordance with estimated typical New Zealand male and female body profiles.

Previous analyses suggest that emissions of 2378-TCDD from the waste incinerators at the plant are unlikely to be a significant contributor to the observed soil concentrations. The model therefore assumes that 2378-TCDD soil concentrations in the area surrounding the plant are most likely to be associated with emissions during the early operational period of the plant between the years of 1962 and 1975. Emissions over this period have been assumed to vary in proportion to the annual production of 2,4,5-T herbicide at the IWD plant (see Table 1). Two emission scenarios are considered in the model; an emission period between 1962 and 1975 and a shorter emission period between 1962 and 1972, corresponding to the enforcement of the Clean Air Act in 1974.

Table 1. Recorded annual production (tonnes) of 2,4,5-T at IWD Annual

Year	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Annual Production	103	111	196	127	124	167	167	343	310	265	377	453	563	525

At each candidate's residential location the average annual ambient air concentration of 2378-TCDD over the two emission periods has been estimated based upon the observed (and interpolated) 2378-TCDD soil concentration recorded in 2000. The model estimates what the concentration in the soil would be at the end of the emission period assuming a 2378-TCDD half-life of approximately 25 years. Based on the back-calculated soil concentrations, ambient air levels over the emission period are estimated assuming a deposition velocity of 2378-TCDD. As there is a degree of uncertainty associated with 2378-TCDD deposition rates, three values are used in the model as a mean of assessing the sensitivity of the parameter. Deposition velocities were derived from the USEPA (1998) HHRAP (≈0.74cm/s), McLachlan (1997) scavenging model (≈0.029cm/s), and a deposition velocity of 0.20cm/s based on experimental observed values.

The choice of deposition velocities has a significant influence over the estimated ambient air concentration required over the period of significant emissions to account for the measured levels of 2378-TCDD in soil and consequently 2378-TCDD intakes through inhalation and the consumption of exposed produce over the emission period. As inhalation was shown to be the most significant 2378-TCDD intake pathway for residents living near the plant between

1962 and 1975, the different deposition velocity has a significant influence on the predicted blood lipid concentration in the year 2003.

Based upon the predicted ambient air concentrations over the assumed period of significant emissions (1962-1975), 2378-TCDD concentrations in soil, exposed above ground produce, protected above ground produce, root vegetables and poultry were estimated for each residential location, using the USEPA (1998) Human Health Risk Assessment Protocol for waste incinerators. For the years between 1975 and 2003 when emissions were assumed to be zero, ambient air concentrations were also assumed to be zero and 2378-TCDD intakes via inhalation also zero. Also, over this period exposed fruit was assumed to be contaminated only through the root uptake of 2378-TCDD that deposited to the soil over the emission period.

The soil samples taken in 2002 indicated that 2378-TCDD was relatively evenly mixed over approximately the first 12.5cm of topsoil. In the model it has been assumed that 2378-TCDD was deposited in the first 2cm of topsoil during the emission period, but becomes mixed evenly through the first 12.5cm of soil over the years between 1975 and 2000. However, in garden soils 2378-TCDD was assumed to be mixed in the top 20cm throughout the modelling period. The model assumes that 2378-TCDD has a typical half-life of 25 years in soil.

Once media concentration of 2378-TCDD were estimated, the typical daily 2378-TCDD intake for each candidate was calculated between 1962 and 2000 on a year-by-year basis. Intakes were based on the estimated proportions of vegetables, fruit and poultry in the candidate's diet that was home grown and the proportions of their typical daily inhalation and soil consumption that was likely to be contaminated by emissions from the plant.

The model assumes that an individual's typical total daily intake of air, soil, fruit, vegetables and poultry varies in proportion to their body weight, assuming that weight provides an approximate indicator of calorific intake and lung capacity. The average daily intakes per kilogram of body weight are shown in Table 2.

Table 2. Daily average intakes

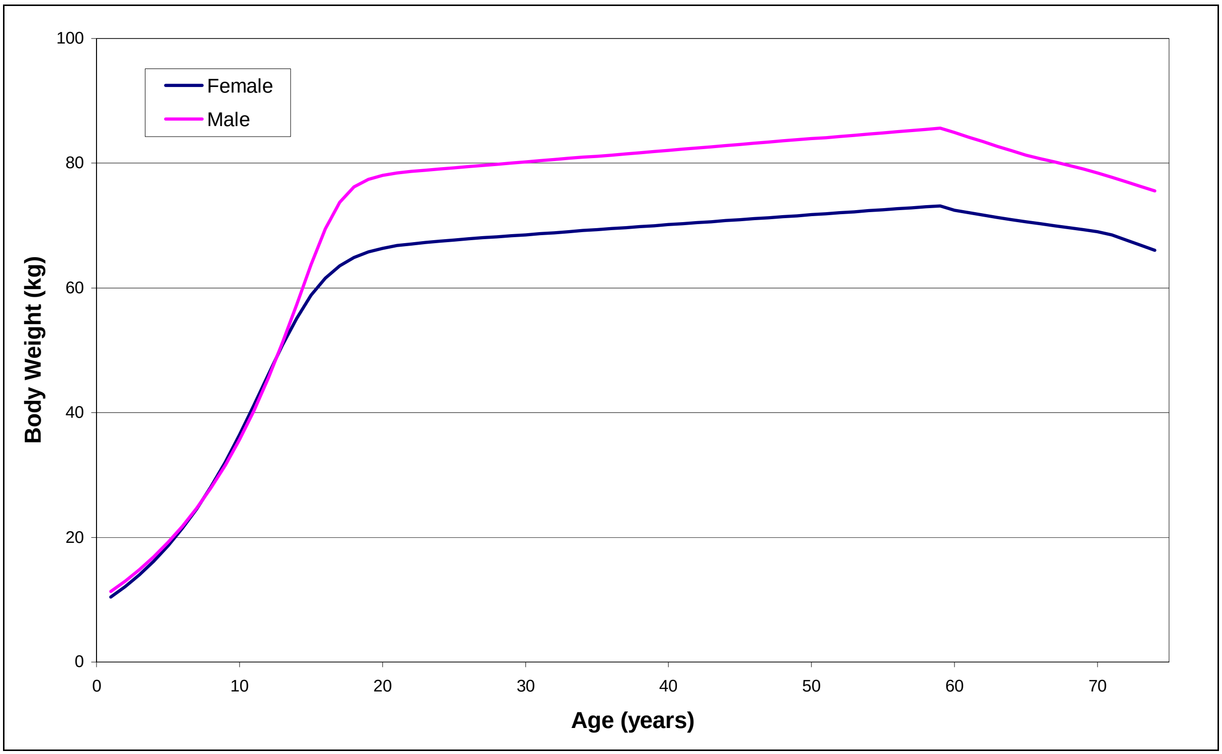
Media		Intake
Air	(m^3/kg-day)	0.26
Soil	(kg/kg BW-day)	0.00032
Produce, exposed above-ground	(g DW/kg BW-day)	0.29
Produce, protected above-ground	(g DW/kg BW-day)	0.55
Produce, below-ground	(g DW/kg BW-day)	0.22
Chicken	(g FW/kg BW-day)	0.58
Eggs	(g FW/kg BW-day)	0.43

FW = fresh weight, DW = dry weight, BW = body weight

The calculation of total intakes in proportion to body weight were intended to provide a simple method for estimating the varying intakes of growing children and distinguished between the typically higher dietary intakes of men compared to those of women. Age dependent body weight profiles for New Zealand men and women were developed principally from the from the Ministry of Health (1999) National Nutrition Survey for adults aged over 15 year (see

Figure 2). Younger age groups were estimated using data derived from the USEPA exposure handbook for 6 to 14 year olds and the body weight data were obtained from the Ministry of Health for 1 to 5 year olds. To ensure relatively smooth transitions between ages, linear interpolation functions were used to estimate year-by-year changes in body weight. The functions were defined so that the average body weight of each age group was maintained. The New Zealand body weight profiles varied slightly from the profiles previously constructed for the *NZ Toxicokinetic model* (AES, 2003).

Figure 2. Estimated average age dependent body weights profiles for New Zealand mean and women



The methodology used to assess intake rates does not take into consideration varying food preferences over the time period or with age, or an individual's consumption rates. It is likely to underestimate soil and food intake rate for children and adolescents. However, since the model indicates that inhalation is the dominant contributor to total incremental increases in 2378-TCDD body burden, small differences between actual and modelled food and soil consumption rates are unlikely to influence the predicted 2003 2378-TCDD blood lipid concentrations significantly.

The residual 2378-TCDD remaining in the candidate's body fat in the year 2003 is estimated using a toxicokinetic model. A methodology and algorithm structure similar to that used to estimate 2378-TCDD elimination rates in the *NZ Toxicokinetic model* was used here (AES, 2003). The most important features of the model are:

- 2378-TCDD elimination rates, defined in term of a half-life, are a function of the total percentage lipid content in the body and vary with respect to age and gender
- the 2378-TCDD is assumed to be evenly distributed throughout the individual's body fat
- the percentage body fat of each candidate (and hence 2378-TCDD elimination rate and dilution) is equivalent to the typical NZ male and female age-dependent profiles

The toxicokinetic method used in the candidate selection model varies from that used in the *NZ Toxicokinetic model*. The revised estimates of the typical percentages body fat for male and female New Zealanders in the candidate selection model are slightly lower than in the *NZ Toxicokinetic model*. This results in faster predicted 2378-TCDD elimination rates. However, although the total body burden will be lower over time due to the higher elimination rates, using the revised profiles it also means that the remaining lipid-distributed TCDD is more concentrated due to the lower total body fat.

The candidate selection model also does not incorporate a general 'background intake' function that had been used in the *NZ Toxicokinetic model* to estimate the average historical intakes of 2378-TCDD in New Zealand. The background intake function in the candidate selection model is replaced by the year-by-year estimates of TCDD intakes due to the consumption of air, soil, produce and poultry contaminated by emissions from the plant. The candidate selection model is designed to predict only the incremental increase in TCDD level resulting from these exposures to plant emissions as opposed to predicting 2378-TCDD levels associated with all intakes.

In the candidate selection model 2378-TCDD elimination rates (k(t)) were defined using two different body fat-dependent elimination functions (F(t)): the Pinsky and Lorber (1998) expression

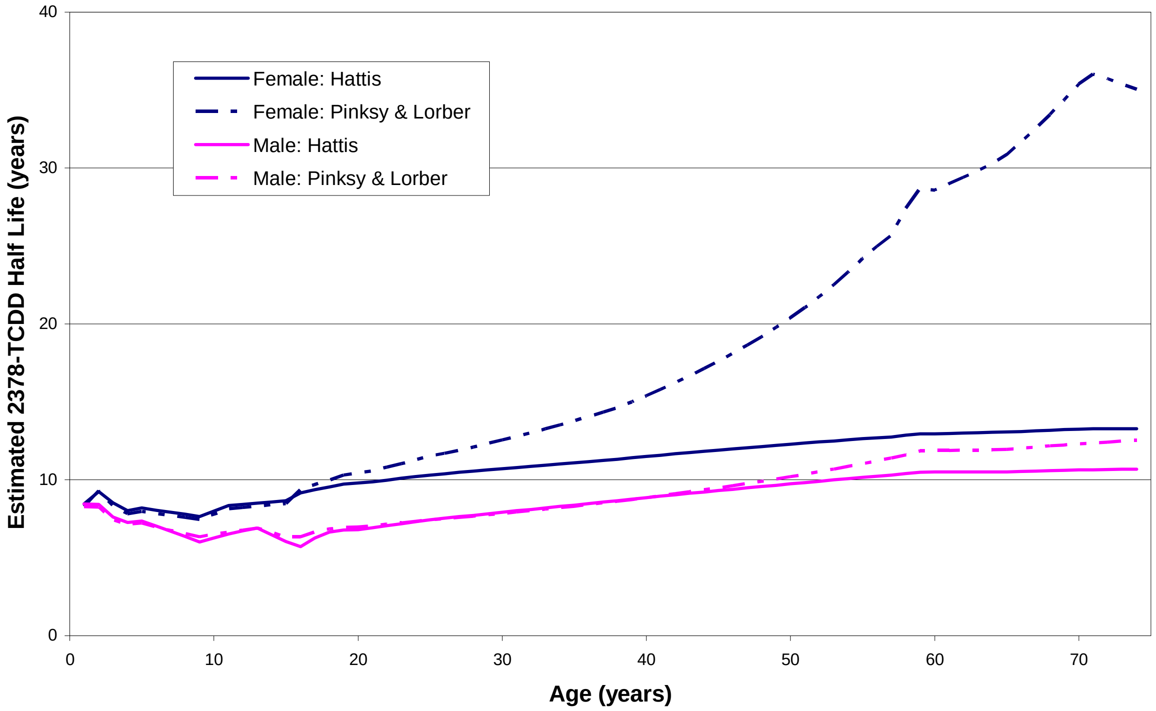
$$k(t)\ (\text{years}^{-1}) = 0.0775 - 0.00313*(F(t) - 25)$$

and the expression derived by Professor Dale Hattis (Clark University, USA), using available empirical data

$$k(t)\ (\text{years}^{-1}) = 0.0209 + 0.0140*[1/(.01* F(t))]$$

The estimated age-dependent elimination rates for both Pinsky and Lorber (1998) and Hattis expressions are shown in Figure 3 for typical New Zealand males and female. As indicated in the figure both elimination rate functions predict similar elimination rates for men. However, due to the higher body fat content significant differences in elimination rates are predicted for older women.

Figure 3. Estimated 2378-TCDD half lives



It should be noted that all losses of 2378-TCDD from the body are modelled using the body fat dependent elimination rate. For instance, the potentially significant loss of 2378-TCDD from women through breast feeding is not considered in the model.

Uncertainties of the model

As noted above the model is based on a number of assumptions. Each of these assumptions introduces a degree of uncertainty in the 2004 estimated 2378-TCDD blood lipid concentrations. Some of these uncertainties have been previously discussed in the NZ Toxicoknetic model report (AES, 2003).

However, these uncertainties should be considered in light of the purposes of the models, which were:

- to assess the likelihood of finding statistically detectable increases in 2378-TCDD levels in blood of candidates compared with those of the New Zealand population in general
- to provide a relative ranking of candidates in terms of likely increases in 2378-TCDD levels in blood, taking account of the concentrations of 2378-TCDD in soil at their homes and the periods over which they lived there.

In spite of the necessary assumptions and uncertainties in the models, they successfully predicted that statistically detectable increases in 2378-TCDD levels in blood lipid concentration in the year 2004 in comparison to the New Zealand population were likely to be found and gave a reasonable basis for selection of candidates.

References

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