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APPENDIX A

EQUATIONS AND PARAMETERS IN THE IEUBKwin MODEL

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The parameters and equations presented here are not a line by line documentation of the IEUBKwin model source code. Although most of the symbols and notations are identical to the model source code, some notations may differ but are mathematically equivalent. The equations and parameters presented in this document have been simplified for clarity. All the equations, with the exception of those listed below, were taken from the *Technical Support Document (TSD)*: *Parameters and Equations Used in the Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children* (v 0.99d) [December 1994]. The TSD (December 1994) is an update of the TSD (July 1994) and was prepared and reviewed by the Technical Review Workgroup for Metals and Asbestos (TRW).

Appendix A consists of three tables which contain the equations used in the IEUBKwin model. Exposure equations are listed in Table A-1. Tables A-2 and A-3 contain the equations for the uptake and biokinetic components, respectively. Within each table, similar equations or equations which combine to achieve a common purpose are grouped together. For example, in Table A-1, the equation groups are defined by the different environmental media.

TABLE A-1. EQUATIONS OF THE EXPOSURE MODEL COMPONENT

GROUP	NUMBER	EQUATION
Air Lead	E-1	IndoorConc[AGE] = 0.01 * indoorpercent * air_concentration[AGE]
	E-2	$TWA[AGE] \; \frac{[time\_out[AGE] * air\_concentration[AGE]] + [(24 - time\_out[AGE]) * IndoorConc[AGE]]}{24}$
	E-3	INAIR[AGE] = TWA[AGE] * vent_rate[AGE]
Dietary Lead	E-4a *or* E-4b	INDIET[AGE] = diet_intake[AGE] *or* INDIET[AGE] = DietTotal[AGE] = InOtherDiet[AGE]+ InMeat[AGE] + InGame[AGE] + InFish[AGE] + InCanVeg[AGE] + InFrVeg[AGE] + InHomeVeg[AGE] + InCanFruit[AGE] + InFrFruit[AGE] + InHomeFruit[AGE]
	E-4c	InOtherDiet[AGE] = InDairy[AGE] + InJuice[AGE] + InNuts[AGE] + InBread[AGE] + InPasta[AGE] + InBeverage[AGE] + InCandy[AGE] + InSauce[AGE] + InFormula[AGE] + InInfant[AGE]

<u>Note</u>: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-1. EQUATIONS OF THE EXPOSURE MODEL COMPONENT

GROUP	NUMBER	EQUATION
Dietary Lead (continued)	E-4d	beverage[AGE] = beverageConc * beverage_Consump[AGE]
	E-4e	bread[AGE] = breadConc * bread_Consump[AGE]
	E-4f	can_fruit[AGE] = canFruitConc * canFruit_Consump[AGE]
	E-4g	can_veg[AGE] = canVegConc * CanVeg_Consump[AGE]
	E-4h	candy[AGE] = candyConc * candy_Consump[AGE]
	E-4i	dairy[AGE] = dairyConc * dairy_Consump[AGE]
	E-4j	f_fruit[AGE] = fFruitConc * fFruit_Consump[AGE]
	E-4k	f_veg[AGE] = fVegConc * fVeg_Consump[AGE]
	E-4l	formula[AGE] = formulaConc * formula_Consump[AGE]
	E-4m	infant[AGE] = infantConc * infant_Consump[AGE]
	E-4n	juices[AGE] = juiceConc * juice_Consump[AGE]
	E-4o	meat[AGE] = meatConc * meat_consump[AGE] or meat_Consump[AGE]
	E-4p	nuts[AGE] = nutsConc * nuts_Consump[AGE]
	E-4q	pasta[AGE] = pastaConc * pasta_Consump[AGE]
	E-4r	sauce[AGE] = sauceConc * sauce_Consump[AGE]
	E-5a	meatFraction = 1 – userFishFraction – userGameFraction
	E-5b	vegFraction = 1 – userVegFraction
	E-5c	fruitFraction = 1 – userFruitFraction

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TABLE A-1. EQUATIONS OF THE EXPOSURE MODEL COMPONENT

GROUP	NUMBER	EQUATION
Dietary Lead (continued)	E-5d	InMeat[AGE] = meatFraction * meat[AGE]
	E-5e	InCanVeg[AGE] = vegFraction/2 * can_veg[AGE]
	E-5f	InFrVeg[AGE] = vegFraction/2 * f_veg[AGE]
	E-5g	InCanFruit[AGE] = fruitFraction/2 * can_fruit[AGE]
	E-5h	InFrFruit[AGE] = fruitFraction/2 * f_fruit[AGE]
	E-5i	InHomeFruit[AGE] = userFruitFraction * (canFruit_Consump[AGE] + fFruit_Consump [AGE]) * UserFruitConc
	E-5j	InHomeVeg[AGE] = userVegFraction * (canVeg_Consump[AGE] + fVeg_Consump[AGE]) * UserVegConc
	E-5k	InFish[AGE] = userFishFraction * meat_consump[AGE] * UserFishConc
	E-5l	InGame[AGE] = userGameFraction * meat_consump[AGE] * UserGameConc
	E-5m	InDairy[AGE] = Dairy[AGE]
	E-5n	InJuice[AGE] = Juices[AGE]
	E-5o	InNuts[AGE] = Nuts[AGE]
	E-5p	InBread[AGE] = Bread[AGE]
	E-5q	InPasta[AGE] = Pasta[AGE]
	E-5r	InBeverage[AGE] = Beverage[AGE]
	E-5s	InCandy[AGE] = Candy[AGE]
	E-5t	InSauce[AGE] = Sauce[AGE]
	E-5u	InFormula[AGE] = Formula[AGE]
	E-5v	InInfant[AGE] = Infant[AGE]

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TABLE A-1. EQUATIONS OF THE EXPOSURE MODEL COMPONENT

GROUP	NUMBER	EQUATION
Water Lead	E-6a	INWATER[AGE] = water_consumption[AGE] * constant_water_conc
	or	
	E-6b	*or*
		INWATER[AGE] = water_consumption[AGE] * (HomeFlushedConc * HomeFlushedFraction + FirstDrawConc * FirstDrawFraction + FountainConc * FountainFraction)
	E-7	*HomeFlushedFraction = 1 - FirstDrawFraction - FountainFraction*
Soil Lead	E-8a	INSOIL[AGE] = constant_soil_conc[AGE] * soil_ingested[AGE] * (0.01 * weight_soil)
	or	*or*
	E-8b	INSOIL[AGE] =soil_content[AGE]* soil_ingested[AGE] * (0.01 * weight_soil)
Dust Lead	E-9a	INDUST[AGE] = constant_dust_conc[AGE] * soil_ingested[AGE] * (0.01 * (100 - weight_soil))
	E-9b	INDUST[AGE] = DustTotal[AGE] * soil_indoor[AGE] * HouseFraction
	E-9c	INDUSTA[AGE] = OCCUP[AGE] + SCHOOL[AGE] + DAYCARE[AGE] + SECHOME[AGE] + OTHER[AGE]
	E-9d	INDUST[AGE] = soil_indoor[AGE] * soil_ingested[AGE] * (0.01 * (100 - weight_soil))
	E-9e	INDUST[AGE] = dust_indoor[AGE] * soil_ingested[AGE] * (0.01 * (100 - weight_soil))
	E-9.5	*HouseFraction = 1 – (OccupFraction - SchoolFraction - DaycareFraction - SecHomeFraction – OtherFraction)*
	E-10	DustTotal[AGE] = soil_ingested[AGE] * (0.01 * (100 - weight_soil))
	E-11a	soil_indoor[AGE] = (contrib_percent *soil_content[AGE]) + (multiply_factor * air_concentration[AGE])
	E-11b	soil_indoor[AGE] = (contrib_percent * constant_soil_conc[AGE]) + (multiply_factor * air_concentration[AGE])
	E-11c	soil_indoor[AGE] = dust_indoor[AGE]
	E-11d	soil_indoor[AGE] = constant_dust_conc[AGE]

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[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-1. EQUATIONS OF THE EXPOSURE MODEL COMPONENT

GROUP	NUMBER	EQUATION
Dust Lead	E-12a	OCCUP[AGE] = DustTotal[AGE] * OccupFraction * OccupConc
	E-12b	SCHOOL[AGE] = DustTotal[AGE] * SchoolFraction * SchoolConc
	E-12c	DAYCARE[AGE] = DustTotal[AGE] * DaycareFraction * DaycareConc
	E-12d	SECHOME[AGE] = DustTotal[AGE] * SecHomeFraction * SecHomeConc
	E-12e	OTHER[AGE] = DustTotal[AGE] * OtherFraction *OtherConc

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TABLE A-2. EQUATIONS OF THE UPTAKE MODEL COMPONENT

GROUP	NUMBER	EQUATION
Absorption Coefficients, Passive Uptakes		
		Note: In calculating uptake, first, medium-specific passive uptakes are calculated using equations U1a-U1f, then, the medium-specific passive uptake values are updated with the inclusion of the active uptake contribution using equations U1g-U1l.
Dust Lead (continued)	U-1a	UPDIET[MONTH]=PAFF*ABSF*AVF*INDIET[AGE]
	U-1b	UPWATER[MONTH]=PAFW*ABSW*AVW*INWATER[AGE]
	U-1c	UPDUST[MONTH]=PAFD*ABSD*AVD*INDUST[AGE]
	U-1d	UPDUSTA[MONTH]=PAFD*ABSD*AVD*INDUSTA[AGE]
	U-1e	UPSOIL[MONTH]=PAFS*ABSS*AVS*INSOIL[AGE]
Absorption Coefficients, Active Uptakes		
Dust Lead (continued)	U-1g	$UPDIET[MONTH] = UPDIET[MONTH] + \left[\frac{(1 - PAFF) * ABSF * AVF * INDIET[AGE]}{1 + \frac{AVINTAKE[MONTH]}{SATUPTAKE[MONTH]}} \right]$
	U-1h	$UPWATER[MONTH] = UPWATER[MONTH] + \left[\frac{(1 - PAFW) * ABSW * AVW * INWATER[AGE]}{1 + \frac{AVINTAKE[MONTH]}{SATUPTAKE[MONTH]}} \right]$

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[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-2. EQUATIONS OF THE UPTAKE MODEL COMPONENT

GROUP	NUMBER	EQUATION
	U-1i	$\mathrm{UPDUST[MONTH]} \quad \mathrm{UPDUST[MONTH]} + \left[\frac{(1 - \mathrm{PAFD}) * \mathrm{ABSD} * \mathrm{AVD} * \mathrm{INDUST[AGE]}}{1 + \frac{\mathrm{AVINTAKE[MONTH]}}{\mathrm{SATUPTAKE[MONTH]}}} \right]$
	U-1j	$\mathrm{UPDUSTA[MONTH]} \quad \mathrm{UPDUSTA[MONTH]} + \left[\frac{(1 - \mathrm{PAFD}) * \mathrm{ABSD} * \mathrm{AVD} * \mathrm{INDUSTA[AGE]}}{1 + \frac{\mathrm{AVINTAKE[MONTH]}}{\mathrm{SATUPTAKE[MONTH]}}} \right]$
	U-1k	$\mathrm{UPSOIL[MONTH]} \quad \mathrm{UPSOIL[MONTH]} + \left[\frac{(1 - \mathrm{PAFS}) * \mathrm{ABSS} * \mathrm{AVS} * \mathrm{INSOIL[AGE]}}{1 + \frac{\mathrm{AVINTAKE[MONTH]}}{\mathrm{SATUPTAKE[MONTH]}}} \right]$
	U-2	AVINTAKE = ABSD * INDUST[AGE] + ABSD * INDUSTA[AGE] + ABSS * INSOIL[AGE] + ABSF * INDIET[AGE] + ABSO * INOTHER[AGE] + ABSW * INWATER[AGE]
	U-3	$\mathrm{SATUPTAKE[MONTH]} \quad \mathrm{SATUPTAKE2} * \left[\frac{\mathrm{WTBODY[MONTH]}}{\mathrm{WTBODY[24]}} \right]$
Total Lead Uptake	U-4	UPAIR[MONTH] = air_absorp[AGE] * 0.01 * INAIR[AGE]
	U-5	
UPTAKE[MONTH] = 30 * {(UPDIET[MONTH] + UPWATER[MONTH] + UPDUST[MONTH] + UPSOIL[MONTH] + UPDUSTA[MONTH] + UPOTHER[MONTH] + UPAIR[MONTH]}		

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT		
GROUP	**NUMBER**	**EQUATION**
Compartmental Lead Transfer Times		
	B-1a	$TBLUR[MONTH] = TBLUR[24] * \left(\frac{WTBODY[MONTH]}{WTBODY[24]} \right)^{0.333}$
	B-1b	$TBLLIV[MONTH] = TBLLIV[24] * \left(\frac{WTBODY[MONTH]}{WTBODY[24]} \right)^{0.333}$
	B-1c	$TBLOTH[MONTH] = TBLOTH[24] * \left(\frac{WTBODY[MONTH]}{WTBODY[24]} \right)^{0.333}$
	B-1d	$TBLKID[MONTH] = TBLKID[24] * \left(\frac{WTBODY[MONTH]}{WTBODY[24]} \right)^{0.333}$
	B-1e	$TBLBONE[MONTH] = TBLBONE[24] * \left(\frac{WTBODY[MONTH]}{WTBODY[24]} \right)^{0.333}$
	B-1f	TBLFEC[MONTH] = RATFECUR * TBLUR[MONTH]
	B-1g	TBLOUT[MONTH] = RATOUTFEC * TBLFEC[MONTH]

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT		
GROUP	**NUMBER**	**EQUATION**
Compartmental Lead Transfer Times (*continued*)	B-1h	$TBONEBL[MONTH] \quad CRBONEBL[MONTH] * TBLBONE[MONTH] * \left[\frac{\{WTTRAB[MONTH] + WTCORT[MONTH]\}}{\left(\frac{VOLBLOOD[MONTH]}{10}\right)} \right]$
	B-2a	TPLRBC = 0.1
	B-2b	$TRBCPL \quad TPLRBC * \left[RATBLPL - \frac{0.55}{(0.55 + 0.73)} \right]$
	B-2c	$TPLUR[MONTH] \quad \frac{TBLUR[MONTH]}{RATBLPL}$
	B-2d	$TPLLIV[MONTH] \quad \frac{TBLLIV[MONTH]}{RATBLPL}$
	B-2e	$TLIVPL[MONTH] \quad CRLIVBL[MONTH] * \left[\frac{TBLLIV[MONTH]}{1 - \frac{TBLLIV[MONTH]}{TBLFEC[MONTH]}} \right] * \left[\frac{WTLIVER[MONTH]}{\left(\frac{VOLBLOOD[MONTH]}{10}\right)} \right]$
	B-2f	$TLIVFEC[MONTH] \quad CRLIVBL[MONTH] * TBLFEC[MONTH] * \left[\frac{WTLIVER[MONTH]}{\left(\frac{VOLBLOOD[MONTH]}{10}\right)} \right]$

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
Compartmental Lead Transfer Times (*continued*)	B-2g	$TPLKID[MONTH] = \frac{TBLKID[MONTH]}{RATBLPL}$
	B-2h	$TKIDPL[MONTH] = CRKIDBL[MONTH] * TBLKID[MONTH] * \left[\frac{WTKIDNEY[MONTH]}{\left(\frac{VOLBLOOD[MONTH]}{10}\right)}\right]$
	B-2i	$TPLTRAB[MONTH] = \frac{TBLBONE[MONTH]}{(0.2 * RATBLPL)}$
	B-2j	TTRABPL[MONTH] = TBONEBL[MONTH]
	B-2k	$TPLCORT[MONTH] = \frac{TBLBONE[MONTH]}{(0.8 * RATBLPL)}$
	B-2l	TCORTPL[MONTH] = TBONEBL[MONTH]
	B-2m	$TPLOTH[MONTH] = \frac{TBLOTH[MONTH]}{RATBLPL}$

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
Compartmental Lead Transfer Times (*continued*)	B-2n	$TOTHPL[MONTH] = CROTHBL[MONTH] * \left[\frac{TBLOTH[MONTH]}{\left(1 - \frac{TBLOTH[MONTH]}{TBLOUT[MONTH]}\right)}\right] * \left[\frac{WTOTHER[MONTH]}{\left(\frac{VOLBLOOD[MONTH]}{10}\right)}\right]$
	B-2o	$TOTHOUT[MONTH] = CROTHBL[MONTH] * TBLOUT[MONTH] - \left[\frac{WTOTHER[MONTH]}{\left(\frac{VOLBLOOD[MONTH]}{10}\right)}\right]$
	B-2.5	$TPLRBC2[STEPS] = \frac{TPLRBC}{\left[1 - \frac{MRBC[STEPS]}{\left(VOLRBC([MONTH]-1) / CONRBC\right)}\right]}$
Blood to Plasma-ECF Lead Mass Ratio	B-3	RATBLPL = 100
Fluid Volumes and Organ Weights	B-4a	CRKIDBL[MONTH] = 0.777 + [2.35 * {1 - exp(-0.0468*[MONTH])}]
	B-4b	CRLIVBL[MONTH] = 1.1 + [3.5 * {1 - exp(-0.0462*[MONTH])}]
	B-4c	CRBONEBL[MONTH] = 6.0 + [215.0 * {1 - exp(-0.000942*[MONTH])}]
	B-4d	CROTHBL[MONTH] = 0.931 + [0.437 * {1 - exp(-0.00749*[MONTH])}]

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT		
GROUP	**NUMBER**	**EQUATION**
Fluid Volumes and Organ Weights (*continued*)	B-5a	$VOLBLOOD[MONTH] = \left[\frac{10.67}{1+\exp\left\{-\frac{([MONTH]-6.87)}{7.09}\right\}}\right] + \left[\frac{21.86}{1+\exp\left\{-\frac{([MONTH]-88.15)}{26.73}\right\}}\right]$
	B-5b	$VOLRBC[MONTH] = \left[\frac{4.31}{1+\exp\left\{-\frac{([MONTH]-6.45)}{10.0}\right\}}\right] + \left[\frac{26.47}{1+\exp\left\{-\frac{([MONTH]-129.61)}{25.98}\right\}}\right]$
	B-5c	$VOLPLASM[MONTH] = \left[\frac{6.46}{1+\exp\left\{-\frac{([MONTH]-6.81)}{5.74}\right\}}\right] + \left[\frac{8.83}{1+\exp\left\{-\frac{([MONTH]-65.66)}{23.62}\right\}}\right]$
	B-5d	VOLECF[MONTH] = 0.73 * VOLBLOOD[MONTH]
	B-5e	$WTECF[MONTH] = 0.73 * \frac{VOLBLOOD[MONTH]}{10}$
	B-5f	$WTBODY[MONTH] = \left[\frac{8.375}{1+\exp\left\{-\frac{([MONTH]-3.80)}{3.60}\right\}}\right] + \left[\frac{17.261}{1+\exp\left\{-\frac{([MONTH]-48.76)}{20.63}\right\}}\right]$

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
Fluid Volumes and Organ Weights (*continued*)	B-5g	WTBONE[MONTH] = 0.111 * WTBODY[MONTH] [MONTH] ≤12 months = 0.838 + 0.02 * [MONTH] [MONTH] >12 months
	B-5h	WTCORT = 0.8*WTBONE[MONTH]
	B-5i	WTTRAB = 0.2*WTBONE[MONTH]
	B-5j	$\mathrm{WTKIDNEY}[\mathrm{MONTH}] = \left[\frac{0.050}{1+\exp\left\{-\frac{([\mathrm{MONTH}]-5.24)}{4.24}\right\}}\right] + \left[\frac{0.106}{1+\exp\left\{-\frac{([\mathrm{MONTH}]-65.37)}{34.11}\right\}}\right]$
	B-5k	$\mathrm{WTLIVER}[\mathrm{MONTH}] = \left[\frac{0.261}{1+\exp\left\{-\frac{([\mathrm{MONTH}]-9.82)}{3.67}\right\}}\right] + \left[\frac{0.584}{1+\exp\left\{-\frac{([\mathrm{MONTH}]-55.65)}{37.64}\right\}}\right]$
	B-5l	
WTOTHER[MONTH] = WTBODY[MONTH] - WTKIDNEY[MONTH] - WTLIVER[MONTH] - WTTRAB[MONTH] - WTCORT[MONTH] - WTBLOOD[MONTH] - WTECF[MONTH]		
	B-5m	$\mathrm{WTBLOOD}[\mathrm{MONTH}] = 1.056 * \frac{\mathrm{VOLBLOOD}[\mathrm{MONTH}]}{10}$
		NOTE: The following equations (B-6a to B-6i) represent the correct mathematical specification. These differential equations are translated into difference equations employing the backward Euler solution in the series B-6.5a to B-6.5i (an algebraic rearrangement presented for ease of interpretation). The calculations are shown in B-9a–B9i.
Compartmental Lead Masses (Differential Equations)		

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
	B-6a	dMPLECF(STEPS)/dt = UPTAKE(STEPS) + *INFLOW(STEPS) - OUTFLOW(STEPS)*
Compartmental Lead Masses (Differential Equations) (*continued*)	B-6b	$INFLOW(STEPS) = \frac{MLIVER[STEPS]}{TLIVPL[MONTH]} + \frac{MKIDNEY[STEPS]}{TKIDPL[MONTH]} + \frac{MOTHER(STEPS)}{TOTHPL[MONTH]} + \frac{MTRAB(STEPS)}{TTRABPL[MONTH]} + \frac{MCORT[STEPS]}{TCORTPL[MONTH]} + \frac{MRBC[STEPS]}{TRBCPL}$
	B-6c	$OUTFLOW[STEPS] = MPLECF[STEPS] * \left[\frac{1}{TPLUR[MONTH]} + \frac{1}{TPLLIV[MONTH]} + \frac{1}{TPLKID[MONTH]} + \frac{1}{TPLOTH[MONTH]} + \frac{1}{TPLTRAB[MONTH]} + \frac{1}{TPLCORT[MONTH]} + \frac{1}{TPLRBC2}\right]$
	B-6d	$\frac{dMRBC[STEPS]}{dt} = \left(MRBC[STEPS] + \frac{MPLECF[STEPS]*ns}{TPLRBC2}\right) / \left(1 + \frac{ns}{TRBCPL}\right)$
	B-6e	$\frac{dMLIVER[STEPS]}{dt} = \frac{MPLECF[STEPS]}{TPLLIV[MONTH]} - MLIVER[STEPS] * \left[\frac{1}{TLIVPL[MONTH]} + \frac{1}{TLIVFEC[MONTH]}\right]$
	B-6f	$\frac{dMKIDNEY[STEPS]}{dt} = \frac{MPLECF[STEPS]}{TPLKID[MONTH]} - \frac{MKIDNEY[STEPS]}{TKIDPL[MONTH]}$

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TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
	B-6g	$\frac{dMOTHER[STEPS]}{dt} = \frac{MPLECF[STEPS]}{TPLOTH[MONTH]} - MOTHER[STEPS] \times \left[1 / \frac{1}{TOTHPL[MONTH]} + \frac{1}{TOTHOUT[MONTH]} \right]$
Compartmental Lead Masses (Differential Equations) (*continued*)	B-6h	$\frac{dMTRAB[STEPS]}{dt} = \frac{MPLECF[STEPS]}{TPLTRAB[MONTH]} - \frac{MTRAB[STEPS]}{TTRABPL[MONTH]}$
	B-6i	$\frac{dMCORT[STEPS]}{dt} = \frac{MPLECF[STEPS]}{TPLCORT[MONTH]} - \frac{MCORT[STEPS]}{TCORTPL[MONTH]}$
	B-6.5a	$\frac{MPLECF[STEPS] - (MPLECF[STEPS] - NS)}{NS} = UPTAKE[MONTH] + INFLOW[STEPS] - OUTFLOW[STEPS]$
	B-6.5b	
	$INFLOW[STEPS] = \frac{MLIVER[STEPS]}{TLIVPL[MONTH]} + \frac{MKIDNEY[STEPS]}{TKIDPL[MONTH]} + \frac{MOTHER[STEPS]}{TOTHPL[MONTH]} + \frac{MTRAB[STEPS]}{TTRABPL[MONTH]} + \frac{MCORT[STEPS]}{TCORTPL[MONTH]} + \frac{MRBC[STEPS]}{TRBCPL}$	
	B-6.5c	
$OUTFLOW[STEPS] = MPLECF[STEPS] \times \left[\frac{1}{TPLUR[MONTH]} + \frac{1}{TPLLIV[MONTH]} + \frac{1}{TPLKID[MONTH]} + \frac{1}{TPLOTH[MONTH]} + \frac{1}{TPLTRAB[MONTH]} + \frac{1}{TPLCORT[MONTH]} + \frac{1}{TPLRBC2} \right]$		

Note: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
	B-6.5d	$\frac{MRBC[STEPS] = (MRBC[STEPS] - NS)}{NS} = \frac{MPLECF[STEPS]}{TPLRBC2} - \frac{MRBC[STEPS]}{TRBCPL}$
Compartmental Lead Masses (Differential Equations) (*continued*)	B-6.5e	$\frac{MLIVER[STEPS] = (MLIVER[STEPS] - NS)}{NS} = \frac{MPLECF[STEPS]}{TPLLIV[MONTH]} - MLIVER[STEPS] \times \left[\frac{1}{TLIVPL[MONTH]} + \frac{1}{TLIVFEC[MONTH]}\right]$
	B-6.5f	$\frac{MKIDNEY[STEPS] = (MKIDNEY[STEPS] - NS)}{NS} = \frac{MPLECF[STEPS]}{TPLKID[MONTH]} - \frac{MKIDNEY[STEPS]}{TKIDPL[MONTH]}$
	B-6.5g	$\frac{MOTHER[STEPS] = (MOTHER[STEPS] - NS)}{NS} = \frac{MPLECF[STEPS]}{TPLOTH[MONTH]} - MOTHER[STEPS] \times \left[\frac{1}{TOTHPL[MONTH]} + \frac{1}{TOTHOUT[MONTH]}\right]$
	B-6.5h	$\frac{MTRAB[STEPS] = (MTRAB[STEPS] - NS)}{NS} = \frac{MPLECF[STEPS]}{TPLTRAB[MONTH]} - \frac{MTRAB[STEPS]}{TTRABPL[MONTH]}$
	B-6.5i	$\frac{MCORT[STEPS] = (MCORT[STEPS] - NS)}{NS} = \frac{MPLECF[STEPS]}{TPLCORT[MONTH]} - \frac{MCORT[STEPS]}{TCORTPL[MONTH]}$

<u>Note</u>: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT		
GROUP	**NUMBER**	**EQUATION**
		NOTE: Equations B-7b, B-7c, and B-7d represent the distribution of fetal blood lead, derived from the mother's blood lead, at birth. In this simplified form, these equations are numerically equivalent to the following equations that more precisely represent the distribution of lead at birth. The difference in these two sets of equations is insignificant after 2-3 iteration steps.
Tissue Lead Masses and Blood Lead Concentration at Birth		$MPLECF(0) = \dfrac{PBBLD0 * (VOLPLASM(0) + VOLRBC(0)) * \left(\dfrac{TPLRBC}{NS}\right)}{\left(\dfrac{TRBCPL(0)}{NS}\right)}$
		$MRBC(0) = PBBLD0 * (VOLPLASM(0) + VOLRBC(0)) * \left[1 - 0.416\left(\dfrac{TPLRBC(0)}{TRBCPL(0)}\right)\right]$
		$MPLASM(0) = \dfrac{MPLECF(0)}{0.416}$
	B-7a	PBBLD0 = 0.85 * PBBLDMAT
	B-7b	$MPLECF(0) = \dfrac{PBBLD0 * (VOLPLASM(0) + VOLRBC(0)) * \left(\dfrac{TPLRBC}{NS}\right) * (1.7 - HCT0)}{\left(\dfrac{TRBCPL(0)}{NS} + \dfrac{TPLRBC}{NS}\right)}$
	B-7c	$MRBC(0) = \dfrac{PBBLD0 * (VOLPLASM(0) + VOLRBC(0)) * \left(\dfrac{TRBCPL(0)}{NS}\right)}{\left(\dfrac{TRBCPL(0)}{NS} + \dfrac{TPLRBC}{NS}\right)}$

Note: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
Tissue Lead Masses and Blood Lead Concentration at Birth (*continued*	B-7d	$MPLASM(0) = \frac{MPLECF(0)}{(1.7 - HCT0)} =$
	B-7e	MCORT(0) = 78.9 * PBBLD0 * WTCORT(0)
	B-7f	MKIDNEY(0) = 10.6 * PBBLD0 * WTKIDNEY(0)
	B-7g	MLIVER(0) = 13.0 * PBBLD0 * WTLIVER(0)
	B-7h	MOTHER(0) = 16.0 * PBBLD0 * WTOTHER(0)
	B-7i	MTRAB(0) = 51.2 * PBBLD0 * WTTRAB(0)
	B-8a	$MPLECF[STEPS] = \frac{\lvert MPLECF[STEPS - NS] + (UPTAKE[MONTH]/STEPS) + SUM3 \rvert}{[1 + (NS * SUM1) + (NS * SUM2)]}$
	B-8b	

$$SUM1[STEPS] = \frac{1}{TPLUR[MONTH]} + \frac{1}{TPLRBC2} + \frac{1}{TPLLIV[MONTH]} + \frac{1}{TPLKID[MONTH]} + \frac{1}{TPLOTH[MONTH]} + \frac{1}{TPLTRAB[MONTH]} + \frac{1}{TPLCORT[MONTH]}$$

Note: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
Compartmental Lead Masses (Solution Algorithm)	B-8c	$SUM2[STEPS] = \frac{1}{TPLRBC2 * \left(\frac{TRBCPL}{NS} + 1\right)} + \frac{1}{TPLLIV[MONTH] * \left(\frac{TLIVPL[MONTH]}{NS} + \frac{TLIVPL[MONTH]}{TLIVALL[MONTH]} + 1\right)} + \frac{1}{TPLKID[MONTH] * \left(\frac{TKIDPL[MONTH]}{NS} + 1\right)} + \frac{1}{\left(\frac{TOTHPL[MONTH]}{NS} + \frac{TOTHPL[MONTH]}{TOTHALL} + 1\right)} + \frac{1}{TPLTRAB[MONTH] * \left(\frac{TTRABPL[MONTH]}{NS} + 1\right)} + \frac{1}{TPLCORT[MONTH] * \left(\frac{TCORTPL[MONTH]}{NS} + 1\right)}$
	B-8d	$SUM3[STEPS] \; \frac{MRBC([STEPS] - NS)}{\left(\frac{TRBCPL}{NS} + 1\right)} + \frac{MLIVER([STEPS] - NS)}{\left(\frac{TLIVPL[MONTH]}{NS} + \frac{TLIVPL[MONTH]}{TLIVALL[MONTH]} + 1\right)} + \frac{MKIDNEY([STEPS] - NS)}{\left(\frac{TKIDPL[MONTH]}{NS} + 1\right)} + \frac{MOTHER([STEPS] - NS)}{\left(\frac{TOTHPL[MONTH]}{NS} + \frac{TOTHPL[MONTH]}{TOTHALL} + 1\right)} + \frac{MTRAB([STEPS] - NS)}{\left(\frac{TTRABPL[MONTH]}{NS} + 1\right)} + \frac{MCORT([STEPS] - NS)}{\left(\frac{TCORTPL([MONTH])}{NS} + 1\right)}$

Note: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT

GROUP	NUMBER	EQUATION
Compartmental Lead Masses (Solution Algorithm) (*continued*)	B-9a	$\mathrm{MRBC}[\mathrm{STEPS}] = \dfrac{\mathrm{MRBC}([\mathrm{STEPS}]-\mathrm{NS}) + \left[\mathrm{MPLECF}[\mathrm{STEPS}] * \left(\dfrac{\mathrm{NS}}{\mathrm{TPLRBC2}}\right)\right]}{\left[1 + \dfrac{\mathrm{NS}}{\mathrm{TRBCPL}}\right]}$
	B-9b	$\mathrm{MLIVER}[\mathrm{STEPS}] = \dfrac{\mathrm{MLIVER}([\mathit{STEPS}]-\mathrm{NS}) + \left[\mathrm{MPLECF}([\mathit{STEPS}]) * \left(\dfrac{\mathrm{NS}}{\mathrm{TPLLIV}([\mathit{MONTH}])}\right)\right]}{\left[1 + \dfrac{\mathrm{NS}}{\mathrm{TLIVALL}([\mathit{MONTH}])}\right]}$
	B-9c	$\mathrm{MKIDNEY}[\mathrm{STEPS}] = \dfrac{\mathrm{MKIDNEY}\left([\mathrm{STEPS}]-\mathrm{NS} + \left[\mathrm{MPLECF}[\mathrm{STEPS}] * \left(\dfrac{\mathrm{NS}}{\mathrm{TPLKID}[\mathrm{MONTH}]}\right)\right]\right)}{\left[1 + \dfrac{\mathrm{NS}}{\mathrm{TKIDPL}[\mathrm{MONTH}]}\right]}$

<u>Note</u>: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT		
GROUP	**NUMBER**	**EQUATION**
Compartmental Lead Masses (Solution Algorithm) (*continued*)	B-9d	$MOTHER([STEPS]) = \frac{MOTHER([STEPS] - NS) + \left[MPLECF([STEPS]) * \left(\frac{NS}{TPLOTH([MONTH])} \right) \right]}{\left[1 + \frac{NS}{TOTHALL} \right]}$
	B-9e	$MCORT[STEPS] = \frac{MTRAB([STEPS] - NS) + \left[MPLECF[STEPS] * \left(\frac{NS}{TPLTRAB[MONTH]} \right) \right]}{1 + \frac{NS}{TTRABPL[MONTH]}}$
	B-9f	$MCORT[STEPS] = \frac{MCORT([STEPS] - NS) + \left[MPLECF[STEPS] * \left(\frac{NS}{TPLCORT[MONTH]} \right) \right]}{\left[1 + \frac{NS}{TCORTPL[MONTH]} \right]}$
	B-9g	$MPLASM[STEPS] = \frac{MPLECF[STEPS] * VOLPLASM[MONTH]}{VOLECF[MONTH] + VOLPLASM[MONTH]}$
	B-9h	$TOTHALL = \frac{1}{\left[\frac{1}{TOTHPL[MONTH]} + \frac{1}{TOTHOUT[MONTH]} \right]}$

Note: Italicized variables are not parameters in the model. These variables are only intermediate variables.

[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.

TABLE A-3. EQUATIONS OF THE BIOKINETIC MODEL COMPONENT		
GROUP	**NUMBER**	**EQUATION**
Compartmental Lead Masses (Solution Algorithm) (*continued*)	B-9i	$TLIVALL[STEPS] = \frac{1}{\left[\frac{1}{TLIVPL[MONTH]} + \frac{1}{TLIVFEC[MONTH]}\right]}$
Blood Lead Concentration	B-10a	**NOTE: Equation B-10a is computed by a cumulative loop** $BLOOD[STEPS] = \sum_{1}^{STEPS} \frac{MRBC[STEPS] + MPLASM[STEPS]}{VOLBLOOD([MONTH] - 1)}$
	B-10b	NS = 1/iterations per day STEPS = 30 / NS = iterations per month
	B-10c	PBBLOODEND([MONTH]) = BLOOD[STEPS]/STEPS

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[AGE] = 0–7 years; [MONTH] = 0–84; [NS] = iteration period expressed as a fraction of one day; [STEPS] = The time step is selected by the user. It is used in the biokinetic component of the model in combination with compartmental transfer times to calculate the distribution of lead among bodily tissues.