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2. A GUIDED TOUR THROUGH THE LEAD MODEL

2.1 THE LEAD MODEL IS DRIVEN BY MENUS

Environmental Protection Agency's Integrated Exposure, Uptake, and Biokinetic Model for Lead in Children (IEUBK Model) is a microcomputer program that performs many different functions related to estimating blood lead levels in children. The overall model functions are sketched in Figure 2-1.

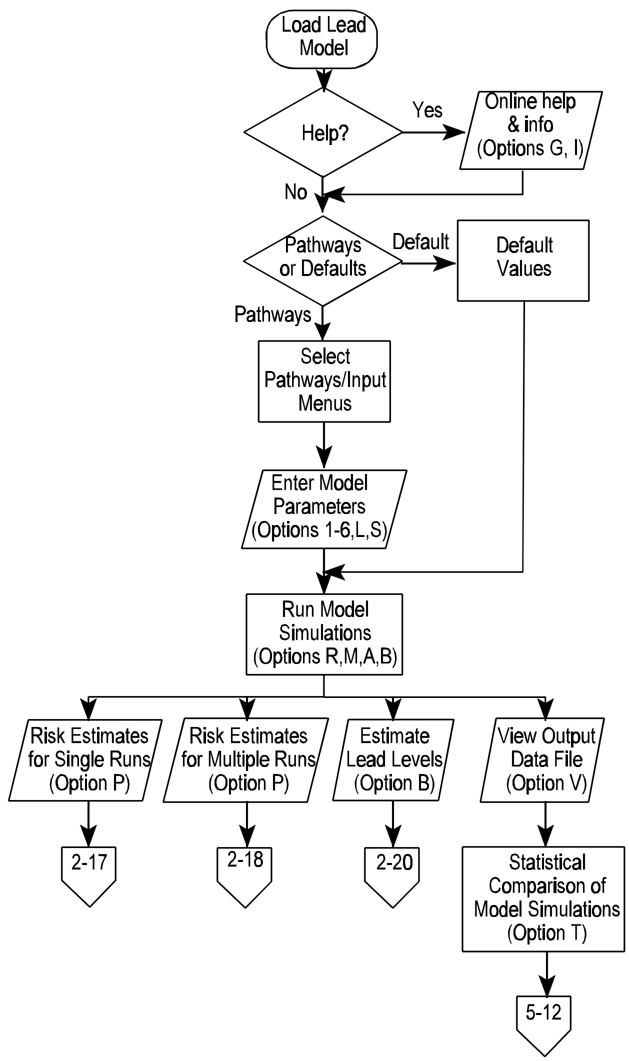


Figure 2-1. Schematic diagram of the overall functions of the lead model. Numbers in pentagons indicate sections in this document containing more detailed information.

The oval shapes are terminal steps (i.e., the beginning or end of a function or option). Rectangles show internal processes and rhomboids show user data entry operations or functions. Diamond-shaped figures are decision points where the user must choose one of the model options on a list. The "NO" branch usually follows the model's baseline or "default" parameters and functions. Horizontal and vertical arrows refer the user to another figure or page.

The IEUBK model is menu-driven, with on-line help available in almost any menu. The main menu, where any use of the IEUBK model begins, is shown in Screen 2-1. There are five numbered options:

1. Parameter Input Menu
   1: Air lead menu
   2: Dietary lead menu
   3: Drinking water lead menu
   4: Soil/Dust lead menu
   5: Alternative lead source menu
   6: Maternal lead menu
   L: Load pre-saved parameter input menu
   R: Return to Main Menu

2. Computation Menu
   1: Run a single model simulation
   2: Multiple simulation runs with a range of values
   3: Blood lead versus media with a range of values
   4: Multiple simulation runs with batch input (input data file for each child or household)
   R: Return to Main Menu

3. Output Processing Menu
   1: Save program parameters to file
   2: Plot graphs of blood lead distributions
   R: Return to Main Menu

4. Help Menu
   1: General information
   2: Information about menus plus help in other menus
   R: Return to Main Menu

5. Quit
   Q: Return to DOS prompt.

Screen 2-1. The main menu.

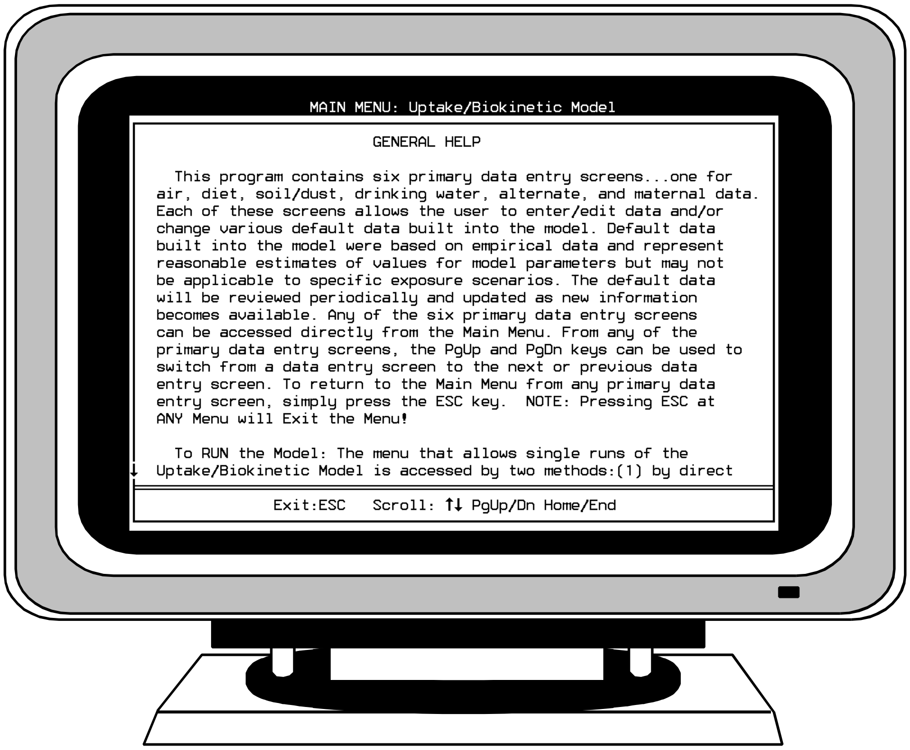
We will briefly discuss the options in each of the input menus. Scientific justifications for the options and guidance values are provided in Section 2.3.

2.2 DETAILED DESCRIPTION OF MENUS

2.2.1 Help Menu (4)

2.2.1.1 General Help (1)

The General Help menu provides on-line information on the data or parameter entry menus, menu selections for running single or multiple model simulations, and use of keyboard keys. This information is shown in Screen 2-2.



Screen 2-2. The general help menu.

2.2.1.2 Information Menu (2)

The Information Menu provides on-line information on the parameter save and load file options, on multiple-run and output processing menus. The information is presented here in Screen 2-3.

2.2.1.3 Other On-Line Help Menus

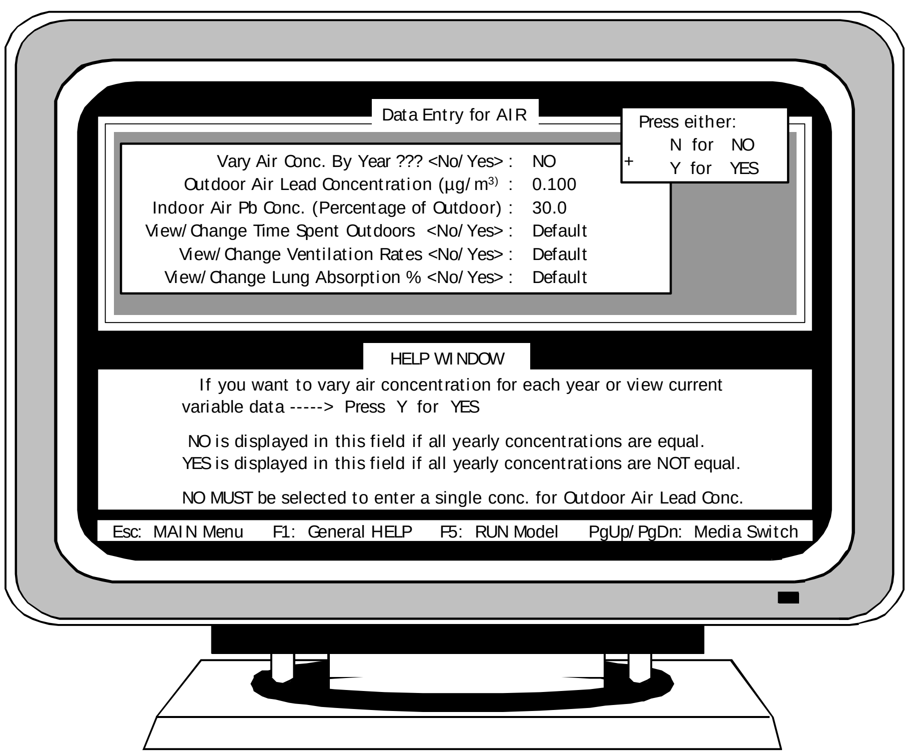
Most menu screens contain additional information on the lower part of the screen. Additional information screens are available on specific menu options.

2.2.2 Parameter Input Menus

2.2.2.1 Air Lead (1)

The Air Lead input parameter menu is shown in Screen 2-4 and schematically in Figure 2-2. The air lead concentration is set initially to a typical 1993 urban value of 0.1 $\mu g/m^3$ (U.S. Environmental Protection Agency, 1991c). It is assumed that the indoor air

Screen 2-3. The information menu.



Screen 2-4. The air lead menu.

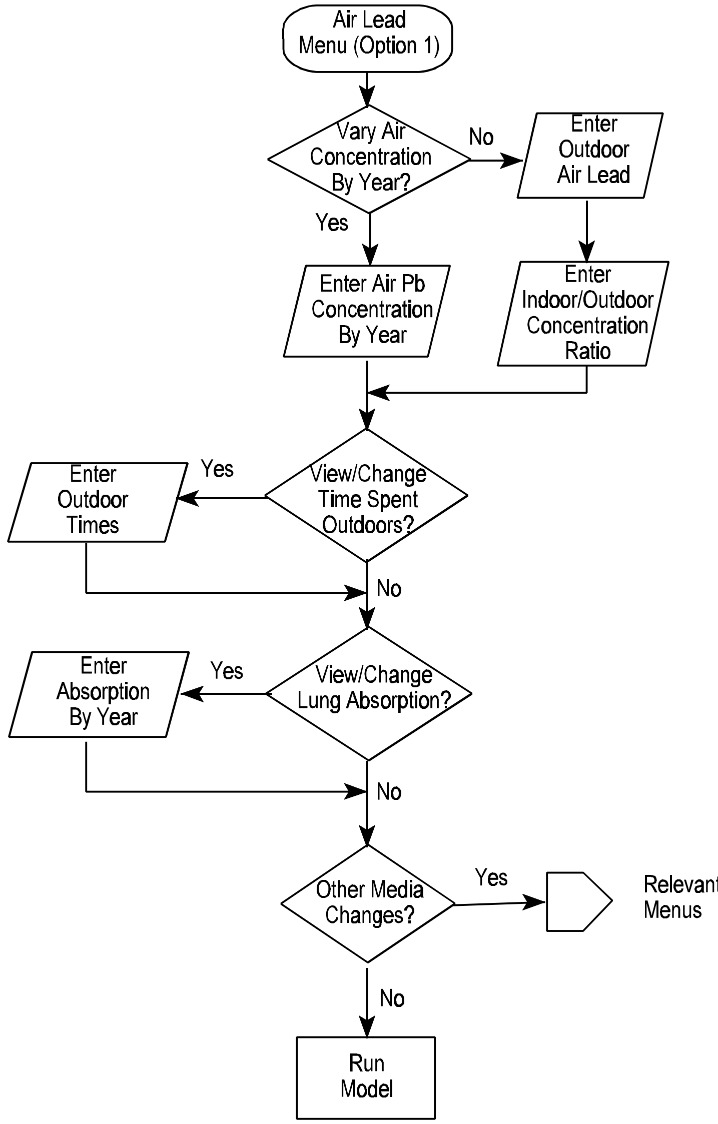
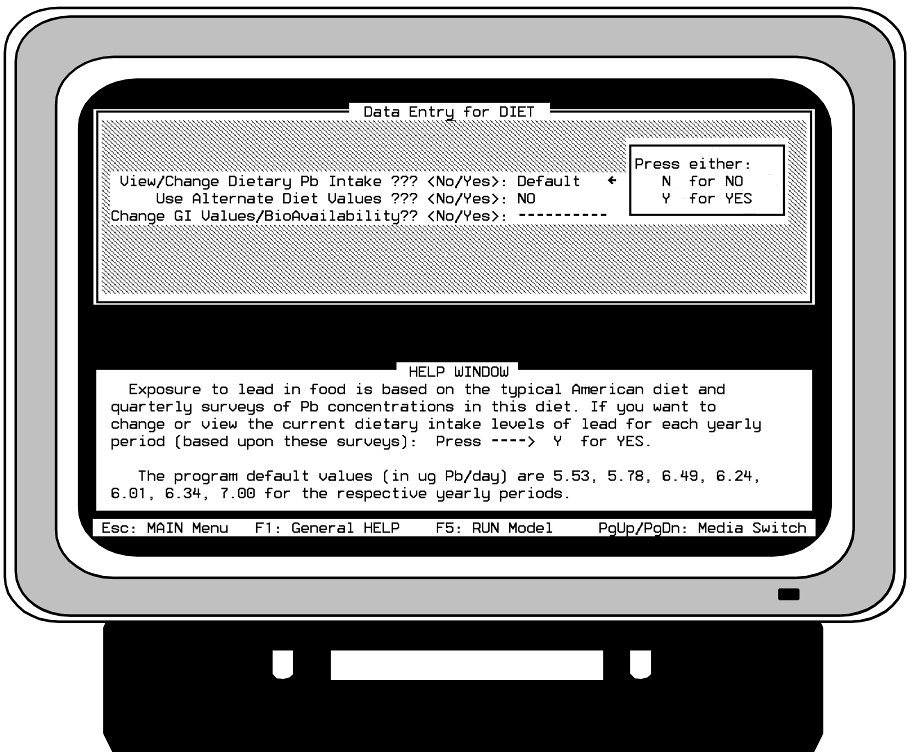


Figure 2-2. Decision diagram for the air lead menu options.

lead concentration is 30% of the outdoor concentration (i.e., 0.03 μg/m^3) initially. The time spent outdoors and ventilation rate are assumed to depend on the child's age. These parameters allow a time-weighted air lead intake to be calculated; 32% of that intake is absorbed through the lungs into the child's blood. All parameters except the indoor/outdoor air lead concentration ratio may be changed by entering YES in the first line. Some are age-specific values.

2.2.2.2 Dietary Lead (2)

The Dietary Lead input parameter menu is shown in Screen 2-5 and schematically in Figure 2-3. The daily dietary lead intake values for each age apply to a typical U.S. child in a typical setting in the United States after 1990. These dietary lead values may be altered by entering YES to the query "View/Change Dietary Pb Intake?" During the period 1982-1989 there was a distinct reduction in food lead generally attributed to the replacement of lead-soldered cans and the removal of lead from gasoline. Since 1990, food lead in U.S. supermarket food has remained relatively constant. Dietary lead ingestion for years prior to 1990 are given in Section 2.3.2.



Screen 2-5. The dietary lead main menu.

If the dietary lead sources are non-standard, usually because of suspected contamination of fruits, vegetables, fish and meat raised locally or otherwise lead-contaminated, the user can enter specific values by responding YES to the query, "Use Alternate Diet values?" This invokes the alternative menu shown in Screen 2-6.

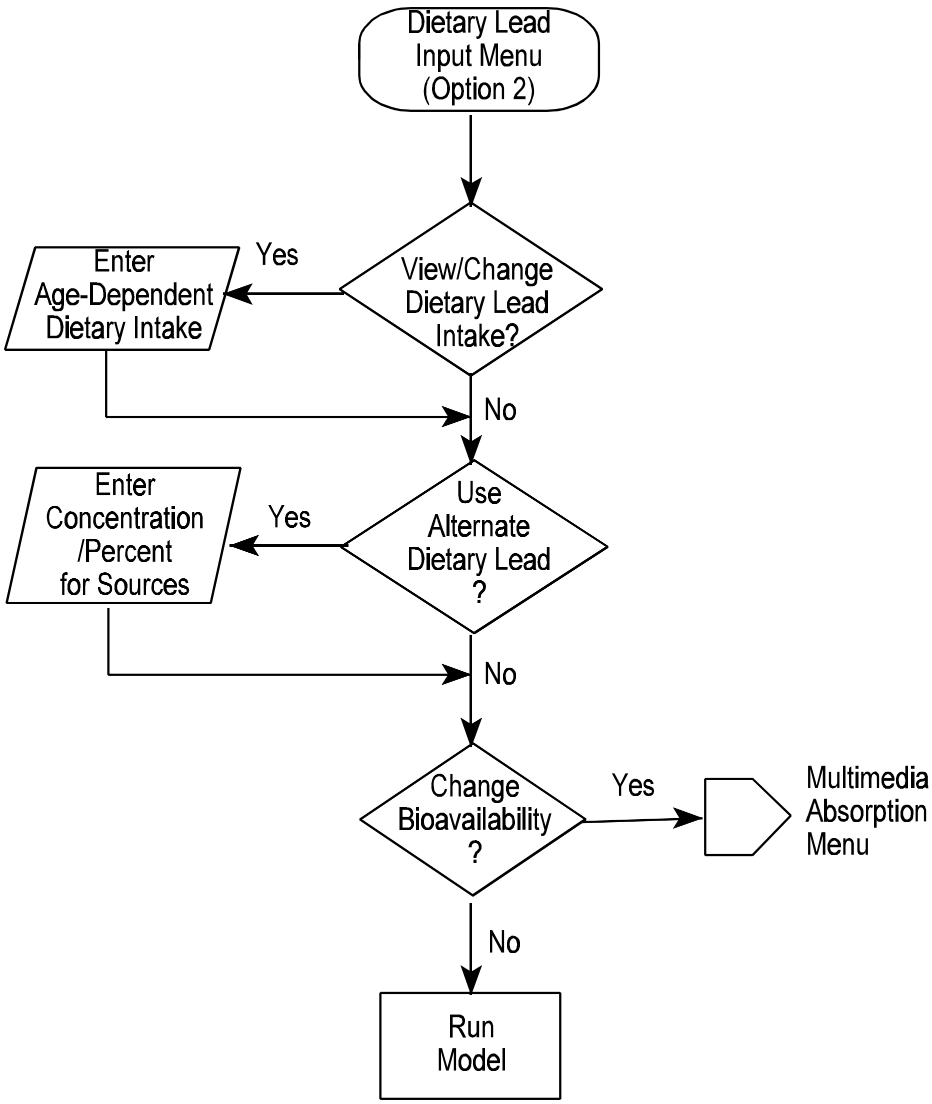
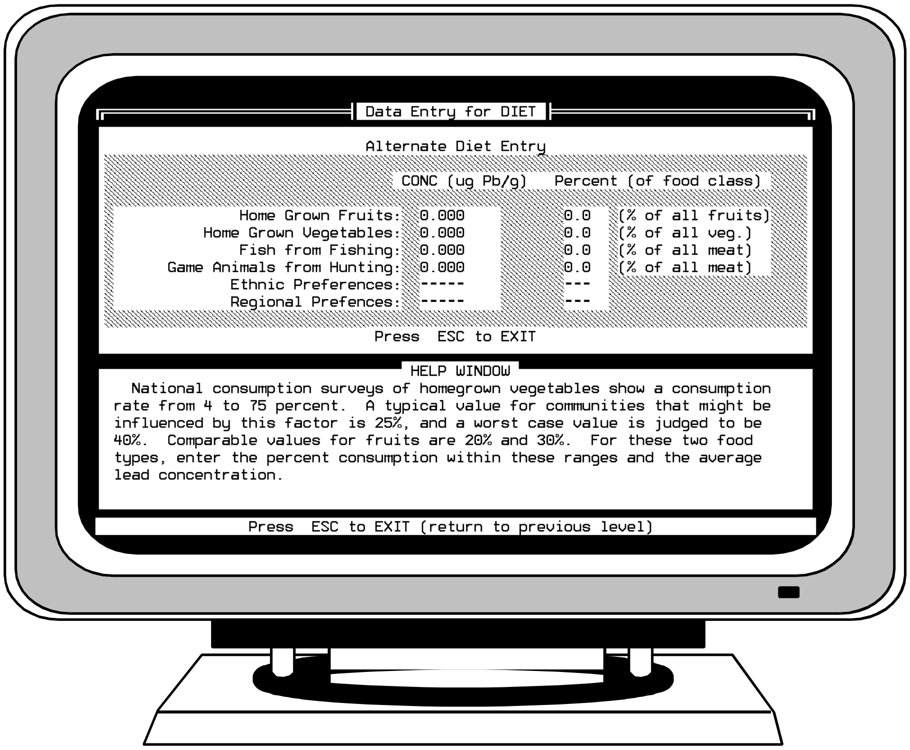


Figure 2-3. Decision diagram for the dietary lead menu options.

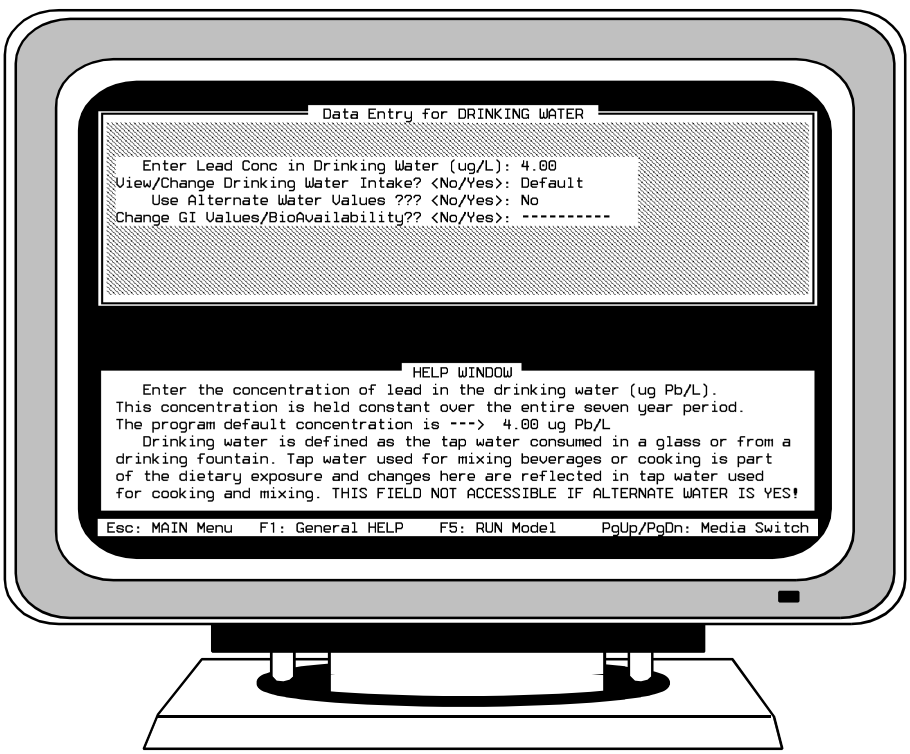
2.2.2.3 Drinking Water Lead (3)

The Water Lead input parameter menu is shown in Screen 2-7 and schematically in Figure 2-4. The water lead concentration is set initially to a typical 1990 urban value of 4 μg/L (Marcus and Holtzman, 1990). The age-specific ingestion of tap water is described in Section 2.3.3.2. Consumption may be modified by responding YES to "View/Change Drinking Water Intake?" and entering new values, as shown on Screen 2-8.

Alternative information may be available in the form of measured lead concentration and percentage of tap water intake from water fountains or other outside sources, and water



Screen 2-6. The alternative dietary source menu.



Screen 2-7. The drinking water lead main menu.

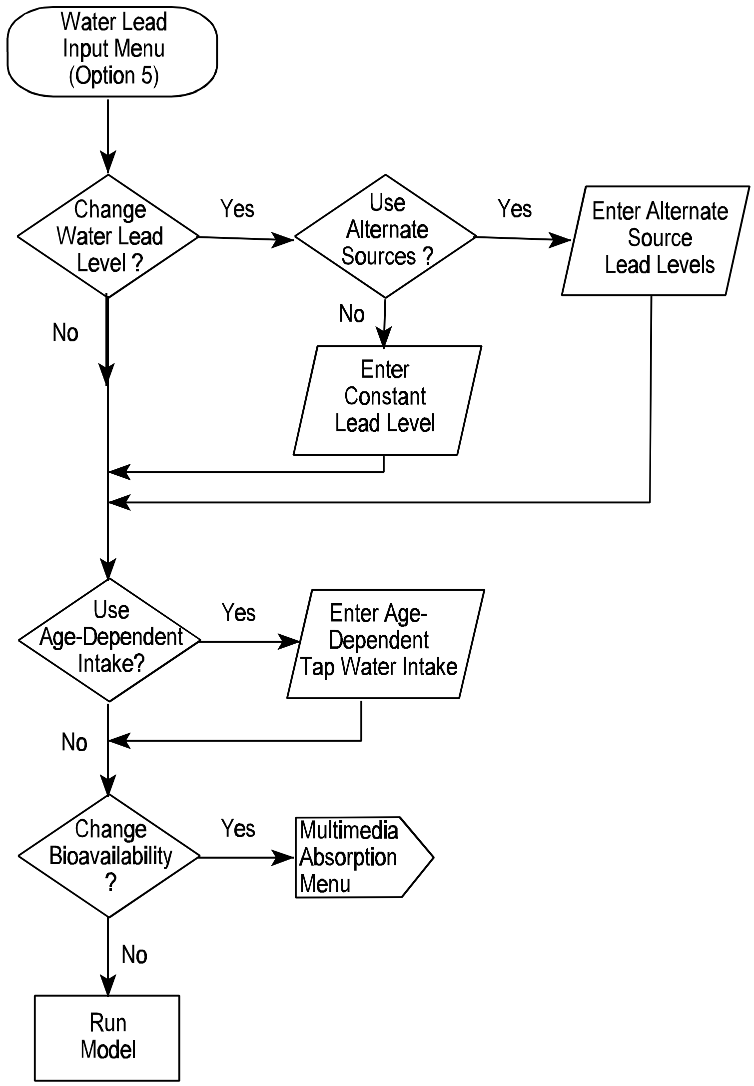
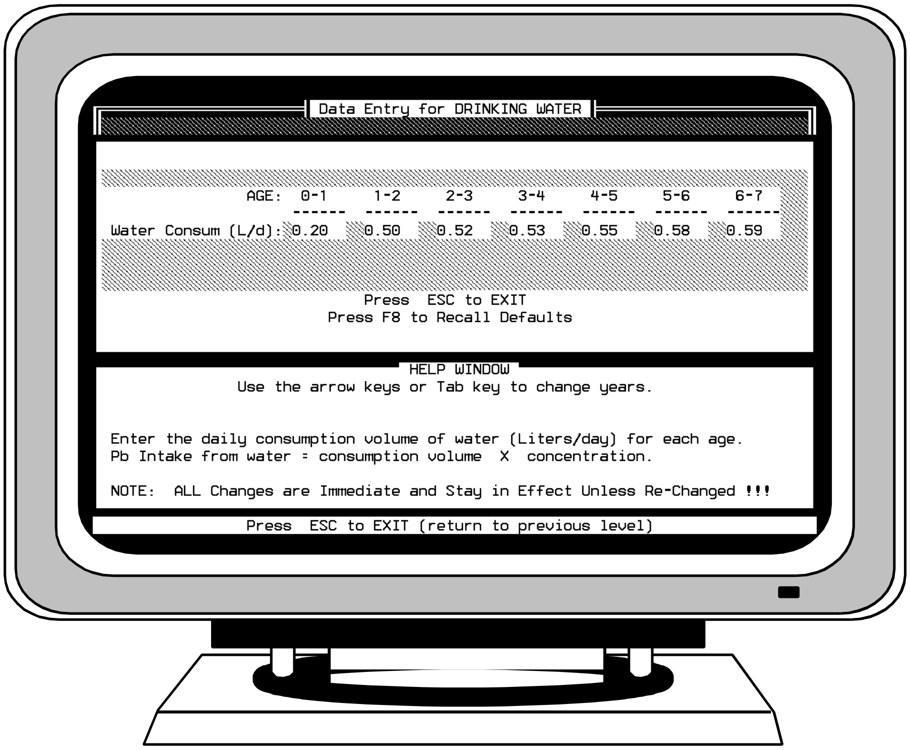


Figure 2-4. Decision diagram for the drinking water lead menu options.

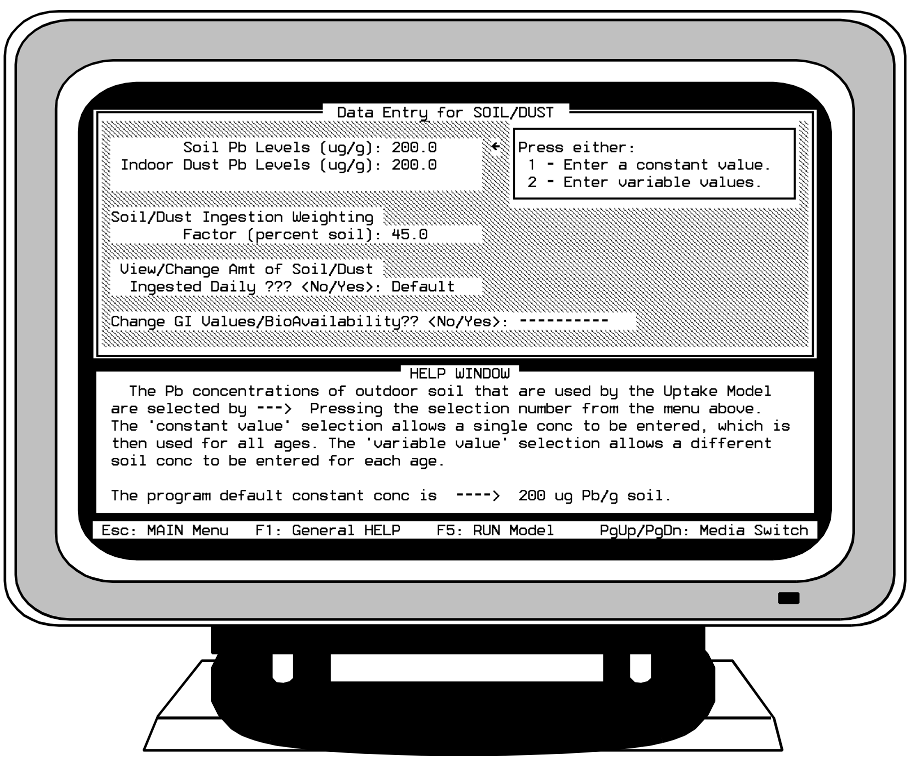
consumed at home in first-draw or flushed modes. This may be entered by responding YES to "Use Alternate Water Values?"

2.2.2.4 Soil and Dust Lead (4)

The Soil and Dust Lead input parameter menu is shown in Screen 2-9 and schematically in Figure 2-5. The soil and dust lead concentrations are set initially to a value of 200 μg/g. The age-specific ingestion intake of soil and dust combined was estimated from the EPA/OAQPS staff paper on Exposure Assessment Methodology and Validation for the first



Screen 2-8. The age-specific drinking water consumption menu.



Screen 2-9. The soil and dust main menu.

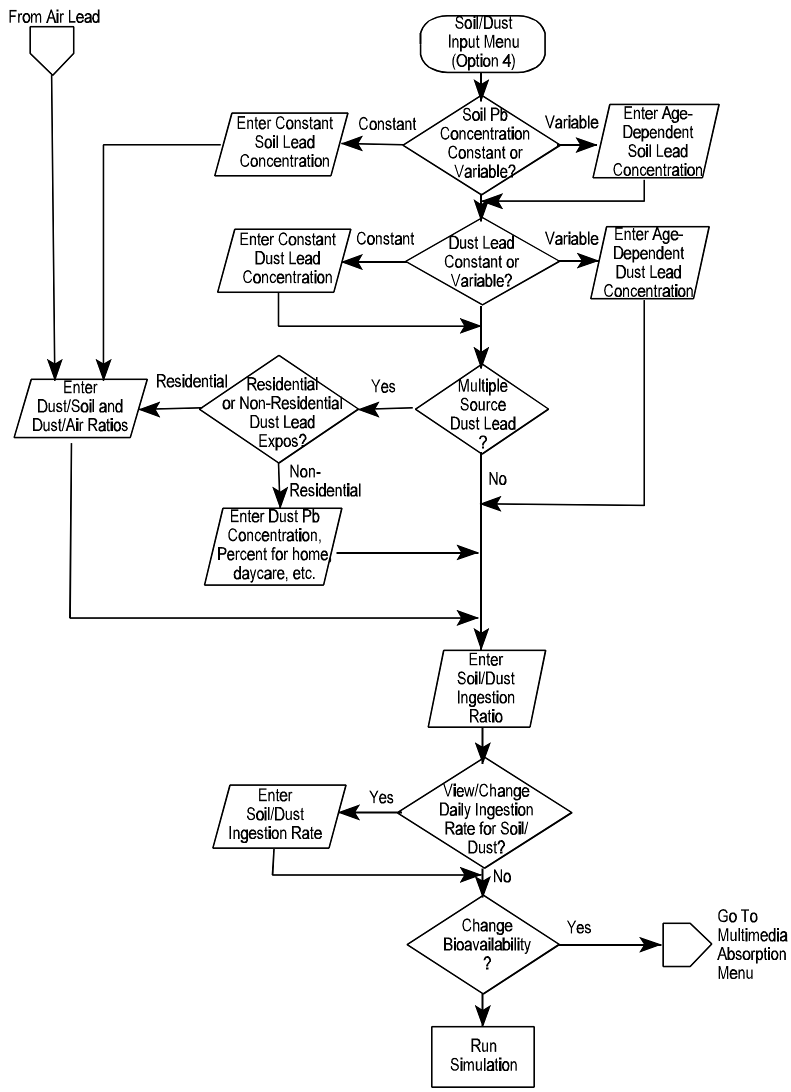
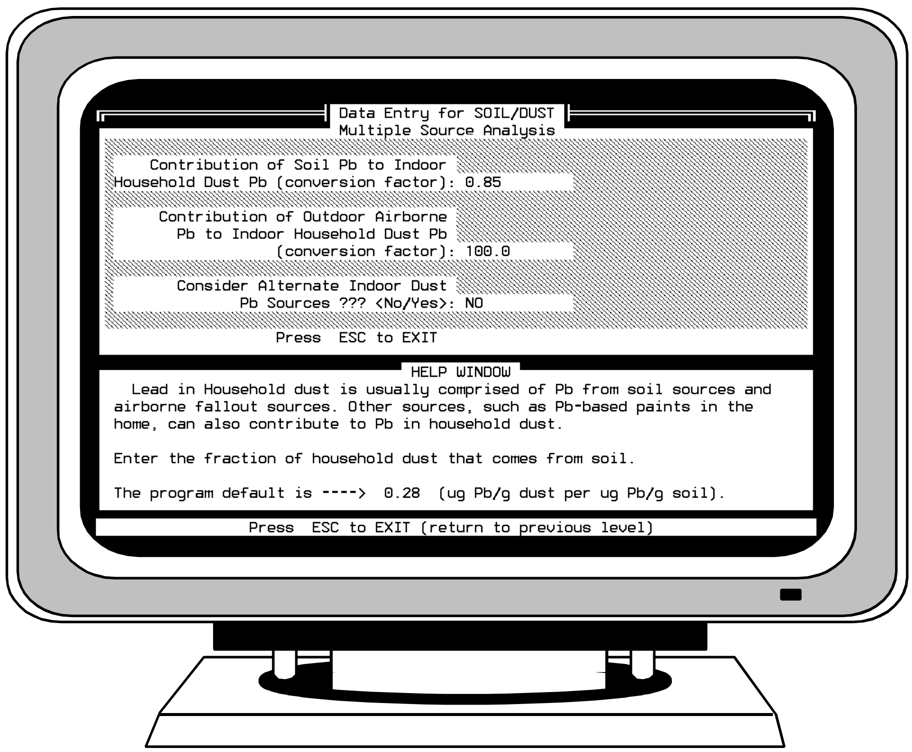


Figure 2-5. Decision diagram for the soil/dust lead menu options.

version of the UBK model (U.S. Environmental Protection Agency, 1989a). Both concentration and intake may be modified by the user.

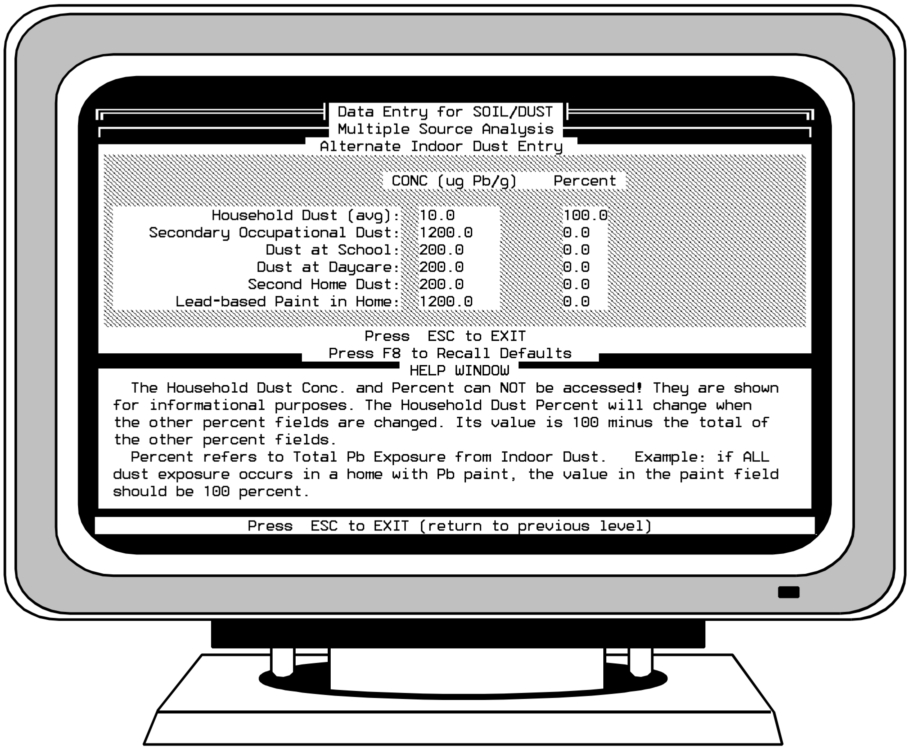
As shown in Screen 2-9, both soil lead and dust lead concentrations may be changed on a yearly basis by user selection "2", allowing the user to construct reasonable site-specific scenarios.

The multiple-source option ("3") on the dust entry line allows the user to use information about the contribution of soil lead, air lead, and other sources to household dust lead. The Data Entry Screen for the Multiple Source Analysis (Screen 2-10) has three data entry lines. The first line is the *fraction of the soil lead concentration* that contributes to the *concentration of lead in household dust*. If there were no other sources, this would be the ratio of the dust lead concentration to the soil lead concentration. The current default value of 0.70 is appropriate to neighborhoods or residences in which loose particles of surface soil are readily transported into the house. The second data entry line is the contribution to household dust from the deposition of airborne lead, over and above the soil lead contribution. The current default value is an additive increment of 100 μg/g lead in house dust for each μg Pb/m^3 air.



Screen 2-10. The multiple dust source menu.

The third line asks whether the user wants to add other sources. If "Yes", then the Multiple Source Analysis Screen is replaced by the Alternative Indoor Dust Entry screen (Screen 2-11). The user may assign both the concentration and percentage of dust intake to baseline household dust, secondary occupational dust, dust at school, daycare, or second home, and the exposure to lead in dust from household paint measured as a percentage of total dust ingestion and its concentration. The default dust lead concentration in the



Screen 2-11. The alternative indoor dust menu.

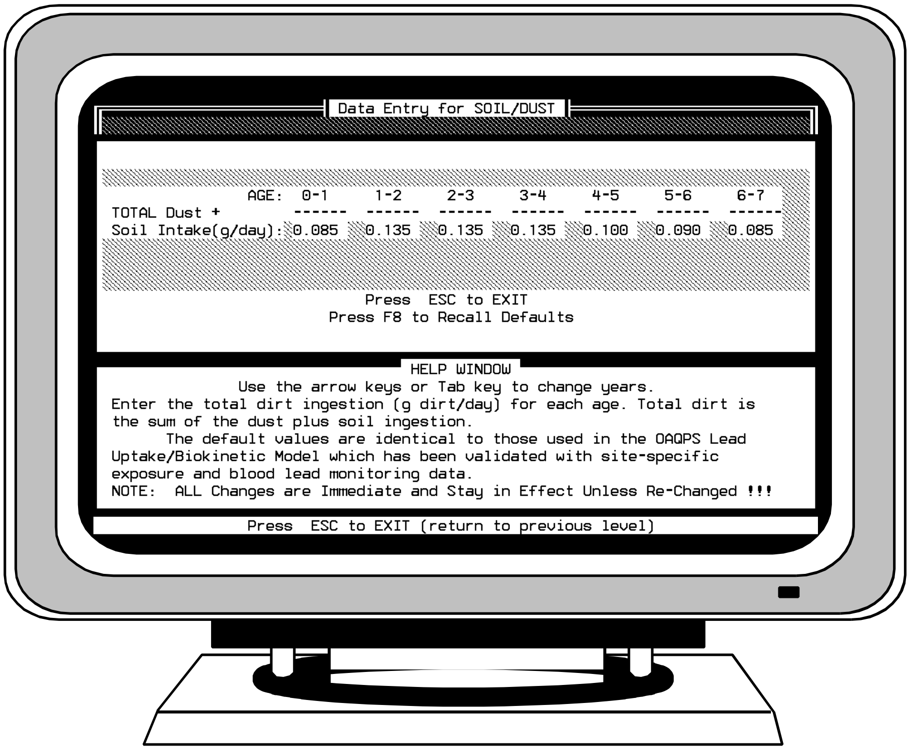
Alternative Indoor Dust Entry screen is 100% of household dust at 150 μg/g. If the Alternative Source Analysis is not used, then the default dust contribution consists of 70% of the soil concentration plus 100 times the air lead concentration. For default conditions, the total dust lead concentration equals 150 μg/g.

If non-residential exposures to soil/dust are important, the user may access the multiple non-residential source menu.

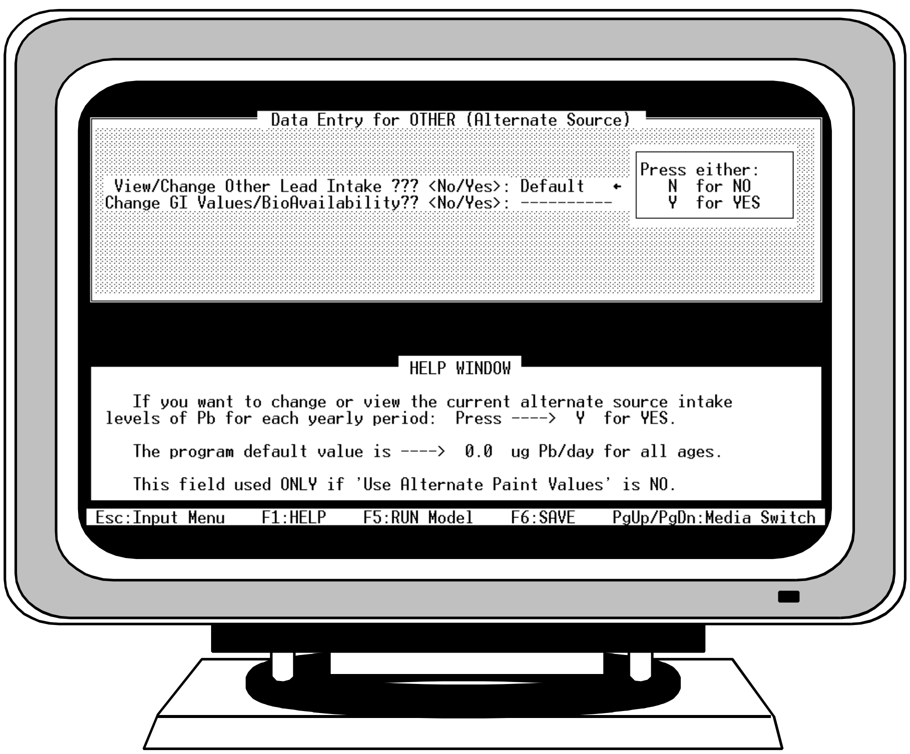
The combined soil/dust ingestion rate (grams total soil + dust per day) can be changed from the current default values in Screen 2-12.

2.2.2.5 Alternate Source (5)

The alternate exposure source menu is shown in Screen 2-13 and schematically in Figure 2-6. The default daily lead intake value for each age is set to 0 μg Pb/day. The user has the option to input any source not otherwise covered by other menus. Examples might be the direct ingestion of lead-based paint, cosmetics or home remedies. In this case, the amount of lead per day needs to be calculated from the information available. If the



Screen 2-12. The soil/dust ingestion rate menu.



Screen 2-13. The alternate lead source menu.

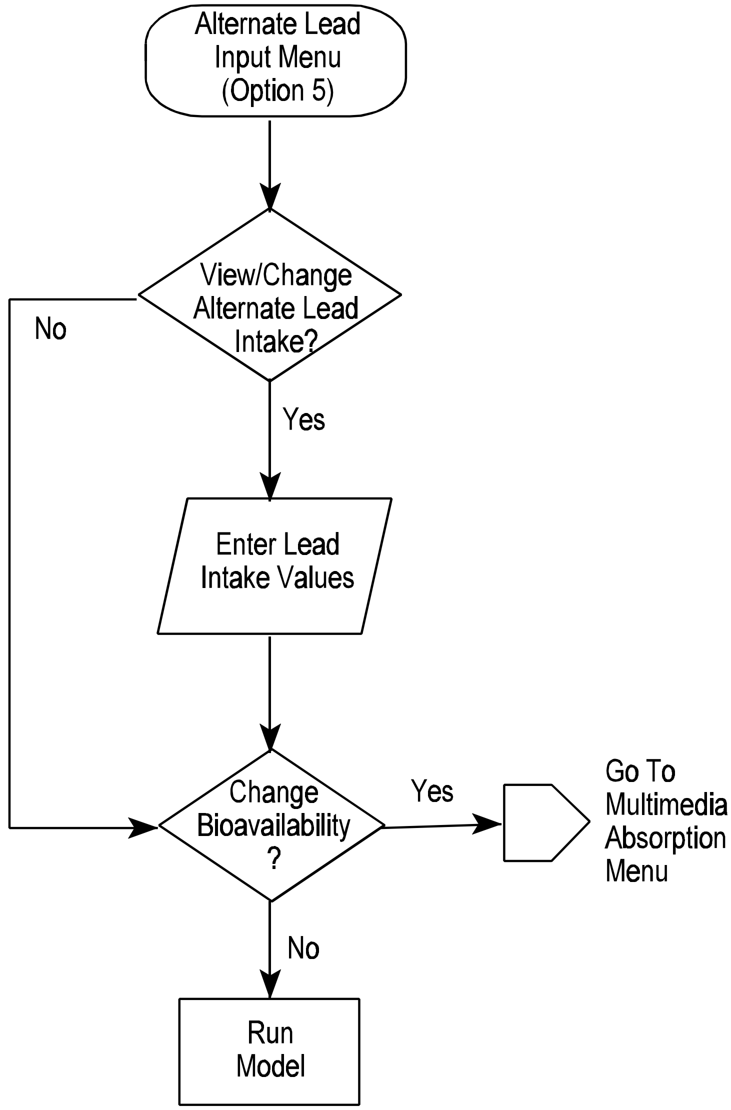


Figure 2-6. Decision diagram for the alternate lead source menu options.

alternative source is lead-based paint (LBP), this exposure would be in addition to exposure to lead-based paint in house dust, which is Option 4 in the multiple source menu of soil and dust. See Section 4.7.1 for a discussion on issues in the use of the model for paint chips.

Building an exposure scenario using this option should be done with care. The model assumes all entries represent chronic exposure. In the example above, the child would require immediate medical attention. Remember that the model output represents only those children defined by the exposure scenario.

2.2.2.6 Bioavailability of Lead in Food, Drinking Water, Soil, and Dust

Bioavailability or absorption of intake from the gut or lung into the blood is a key element in relating external exposure to body burden. Lead intake from media with low bioavailability poses much less of a hazard than does the same intake from media with high bioavailability. The bioavailability of lead from normal infant diet is known to be very high (Alexander et al., 1974a,b; Ziegler et al., 1978; Ryu et al., 1983), with at least 40 to 50% of the dietary lead intake passing into the child's blood. See Section 4.1 for a discussion of bioavailability.

The main functions of the bioavailability menu are shown in Figure 2-7. The model calculates lead absorption from the gut as a function of two components. The *passive* component does not depend on lead concentration in the gut and is not saturable. The *facilitated or active* component may become saturated when the total concentration of lead in the gut from total gut intake by all media is sufficiently large, which is a kinetically *non-linear* absorption mechanism. The data entry Screen 2-14 allows the user to specify the parameters for intake from soil, dust, drinking water, diet, and alternate sources. The total absorption percentage is the sum of the passive and facilitated absorption components. The default value of absorption for alternate sources is 0%, which requires that the user must enter the bioavailibilty of any specific alternative source, such as lead-based paint.

The total absorption from any medium is then divided into two components, and the user specifies a small fraction of the total absorption percent for the passive or non-saturable (i.e., high-dose) component. The default is 20% of the total available for absorption. The percentage absorption in the larger saturable component is the remainder of the total available for absorption. For example, with a dietary lead intake of 50%, the absorption fraction for the passive component is 20% of 50%, or 10% of dietary lead intake, and the saturable component is 80% of 50%, or 40% of dietary lead intake.

2.2.2.7 Maternal-Fetal Lead Exposure (6)

The maternal lead exposure input parameter menu is shown in Screen 2-15. The lead is transferred from the mother to the fetus *in utero*. The lead that is stored in the tissues of the newborn child is calculated by entering the maternal blood lead value at birth (default = 2.5 μg/dL). The IEUBK model assumes that the infant's blood lead at birth is a fraction of the maternal blood lead level, and the amounts of lead in the blood and other tissues in the newborn infant are calculated so as to be consistent with concentration ratios observed in autopsies of newborn infants (Barry, 1981).

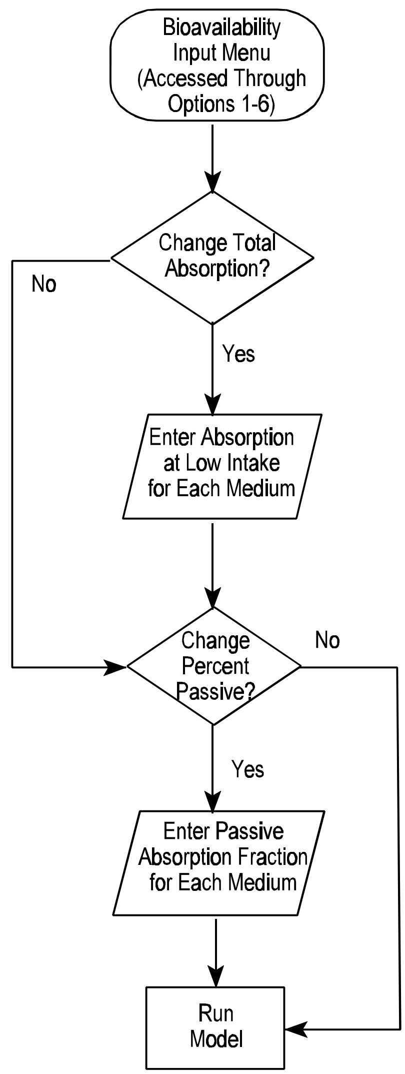
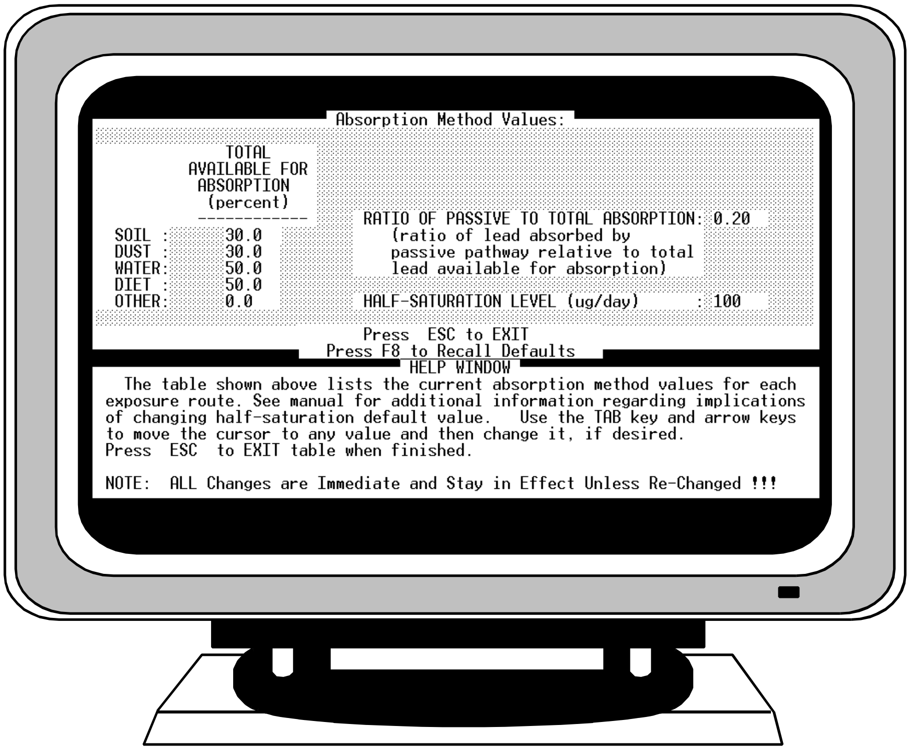


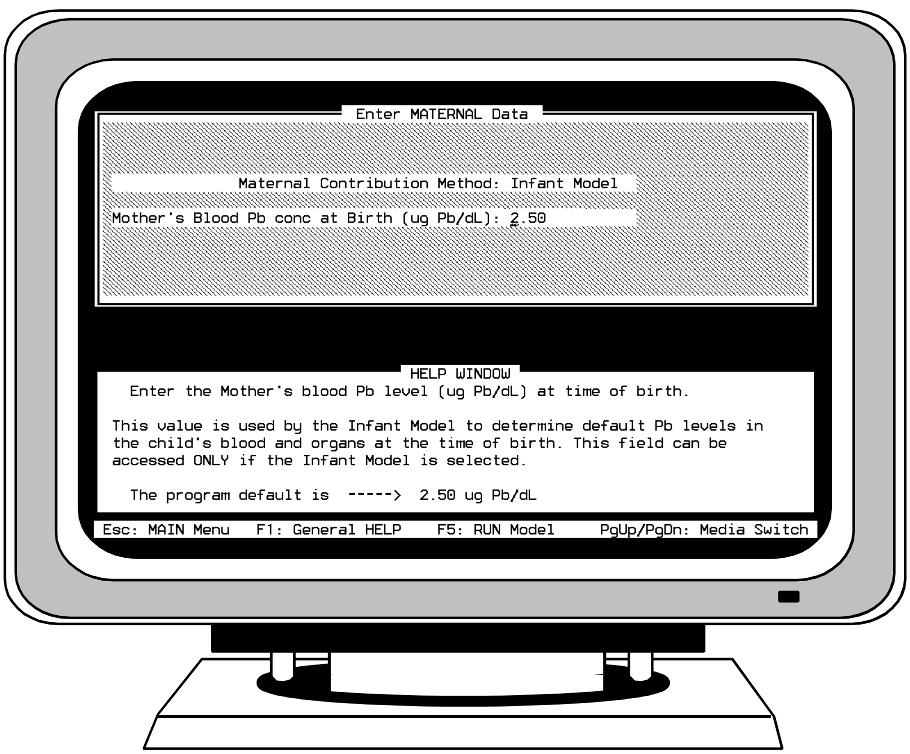
Figure 2-7. Decision diagram for the absorption/bioavailability menu options.

2.2.2.8 Save and Load Options

If the user wishes to use a certain set of model parameters as the starting point for another analysis, the parameter set created from use of Options 1 through 6 should be *saved* using the "S" option on the output menu accessed from the main menu, or the F6 option on any of the parameter input menus. The user may create an 8-character or shorter name for the file, which will be stored in the form [NAME].SV3. If a saved parameter set is needed later, it may be loaded from the "L" option on the Parameter Input Menu.



Screen 2-14. The absorption/bioavailability menu.



Screen 2-15. The maternal/fetal lead exposure menu.

2.2.3 Computation Menu

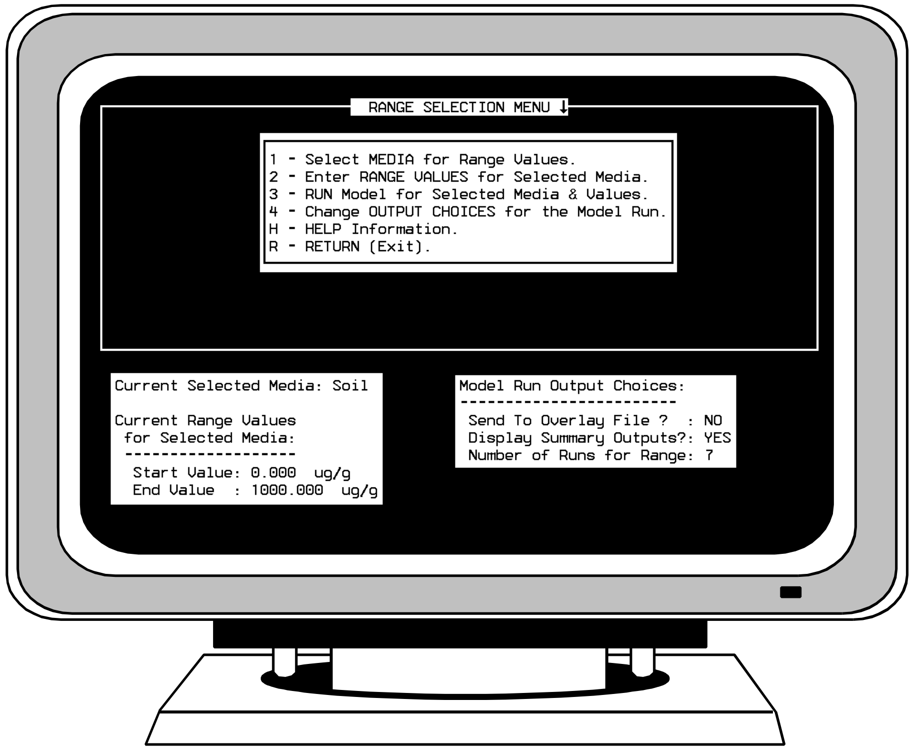
2.2.3.1 Run a Single Simulation of the Model (1)

The menus for the Run command are shown in Screen 2-16. This option uses only the currently loaded parameter set. The user may view or change the time step for the numerical iteration. The default is four hours. We recommend setting the iteration time to the lowest convenient selection, and verifying all "important" solutions by rerunning the model with the shortest possible time step (currently 15 min). An output option (Option 2) allows plotting of results and calculation of probability of elevated blood lead.

Screen 2-16. Single simulation using the program processing menu.

2.2.3.2 Run Multiple Simulations of the Model for a Range of Media Lead (2)

The menus for the Multiple Run command are shown in Screen 2-17 and schematically in Figure 2-8. More detailed menus for range selection and output are shown in Screens 2-18 and 2-19. This option uses only the currently loaded parameter set, except that it repeats the run for each new value of a medium concentration (e.g., soil lead concentration) or intake (dietary lead as μg Pb per day). The user may view or change the



Screen 2-17. Multiple simulation using the program processing menu.

time step for the numerical iteration during the run step. We recommend verifying all of the "important" solutions by rerunning the model with the shortest possible time step (currently 15 min). Since only one medium can be changed in each use of the "2" option, the user who wants to look at a range of soil lead values should use the Multiple Source Dust option "3" and a user-specified dust lead to soil lead concentration ratio. Output data for plotting, with overlays of results at each concentration in the range, may be saved when the user creates RANGE#.LAY files.

2.2.3.3 Multiple Simulation Runs of a Medium To Find Concentration of Lead in the Medium That Produces a Specified Blood Lead (3)

This option is similar to Option 2. The menus for the Multiple Run command are shown in Screen 2-20 and schematically in Figure 2-8. This option uses only the currently loaded parameter set, except that it repeats the run for each new value of a medium concentration (e.g., soil lead concentration) or intake (dietary lead as μg Pb per day) until the specified age-dependent geometric mean blood lead level is achieved *exactly* by that concentration.

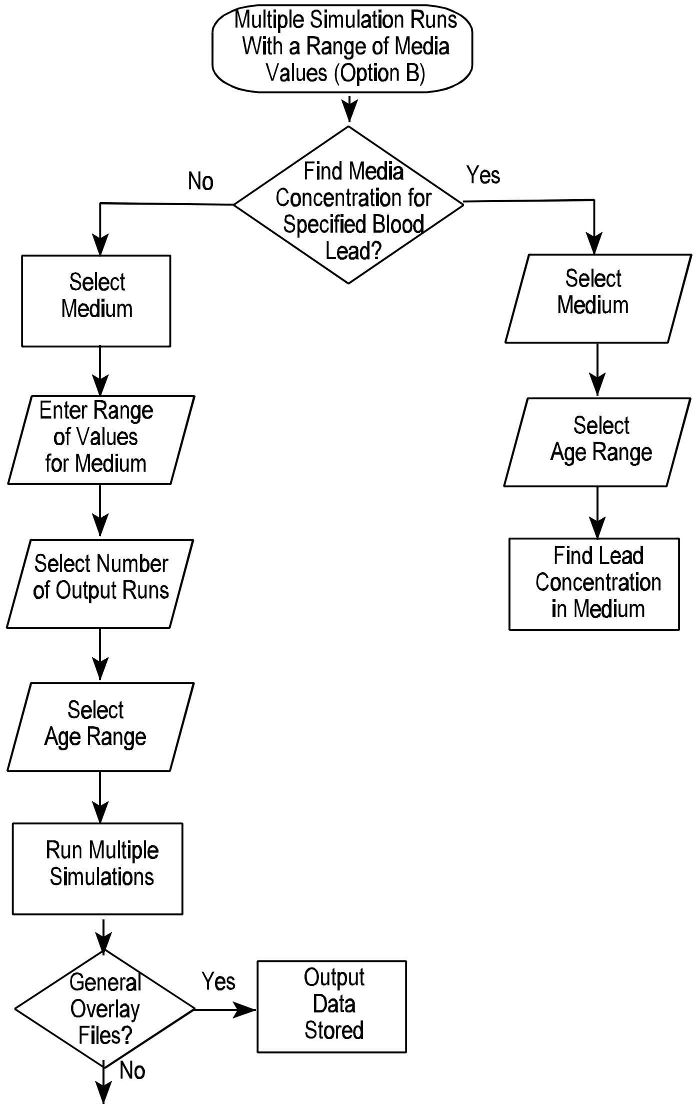
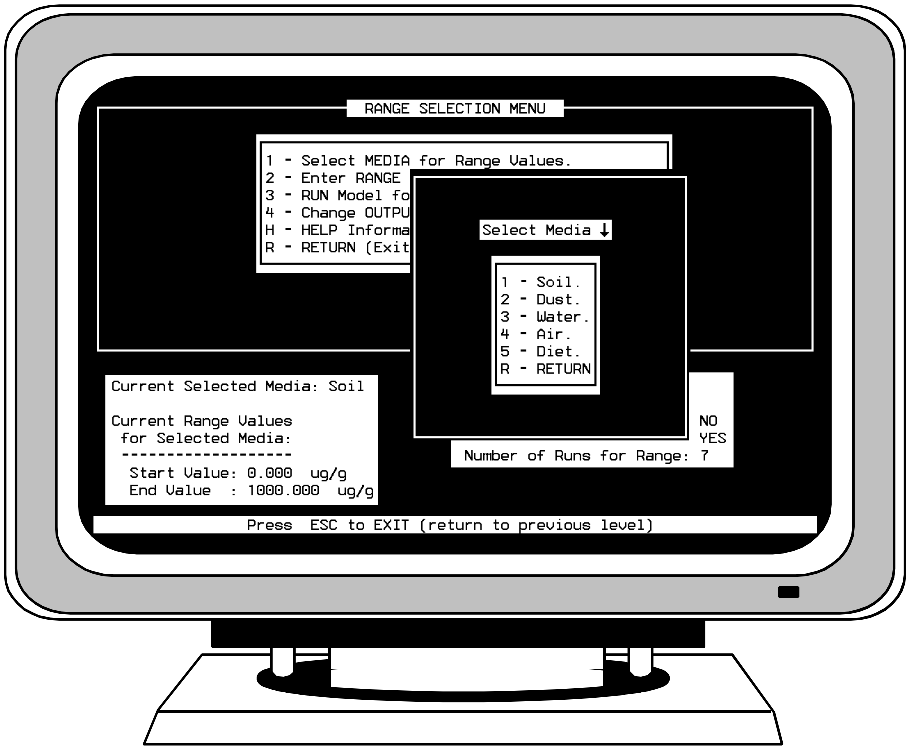


Figure 2-8. Decision diagram for the multiple simulation menu options.

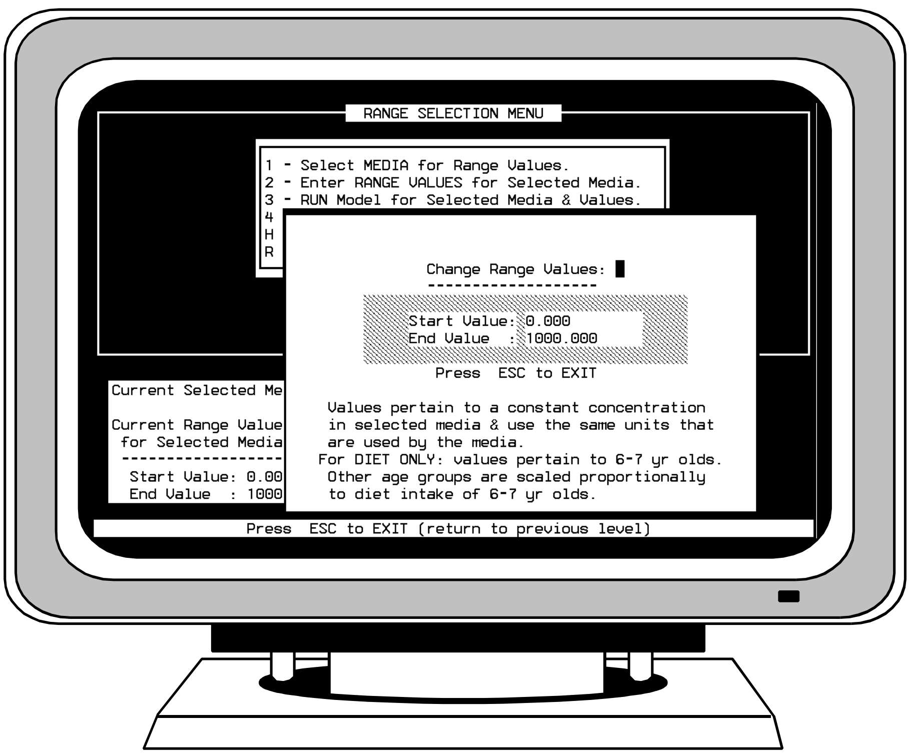
Since only one medium can be changed in each use of the Multiple Simulation Run "3" option, the user who wants to look at a range of soil lead values should use the Multiple Source Dust option "3" and a user-specified dust lead to soil lead concentration ratio. Output data for plotting may be saved when the user creates *.PBM files.

2.2.3.4 Batch Mode Multiple Simulation Runs Using Input Data Files (4)

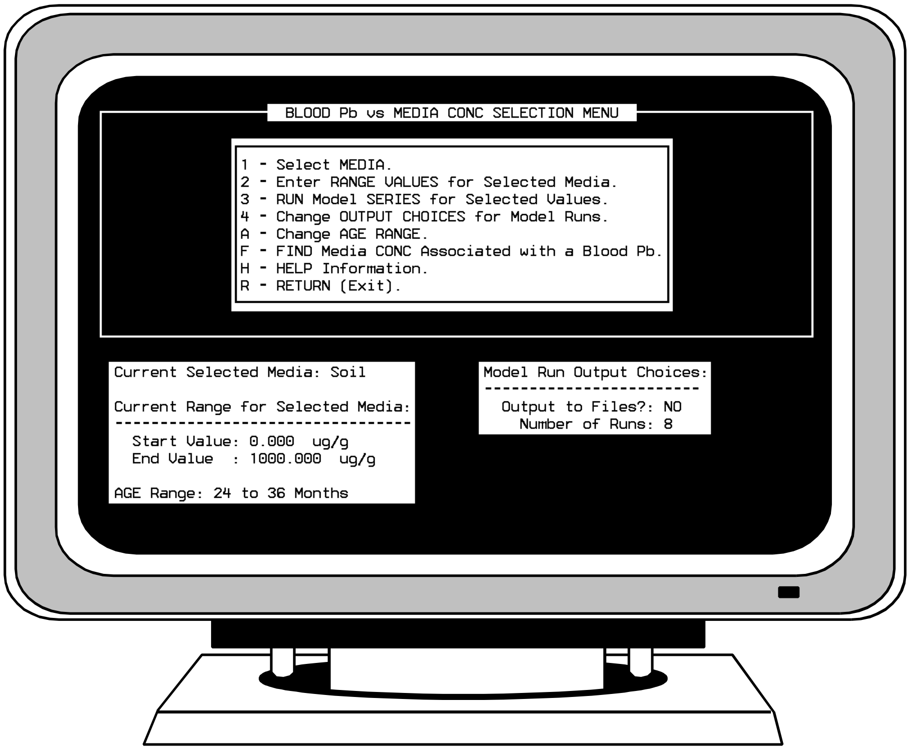
This option is similar to Option 2. The menus for the Batch Mode Run command are shown in Screen 2-21 and schematically in Figure 2-9. This option uses the currently loaded default parameter set, but repeats the run for using the new values for the five exposure



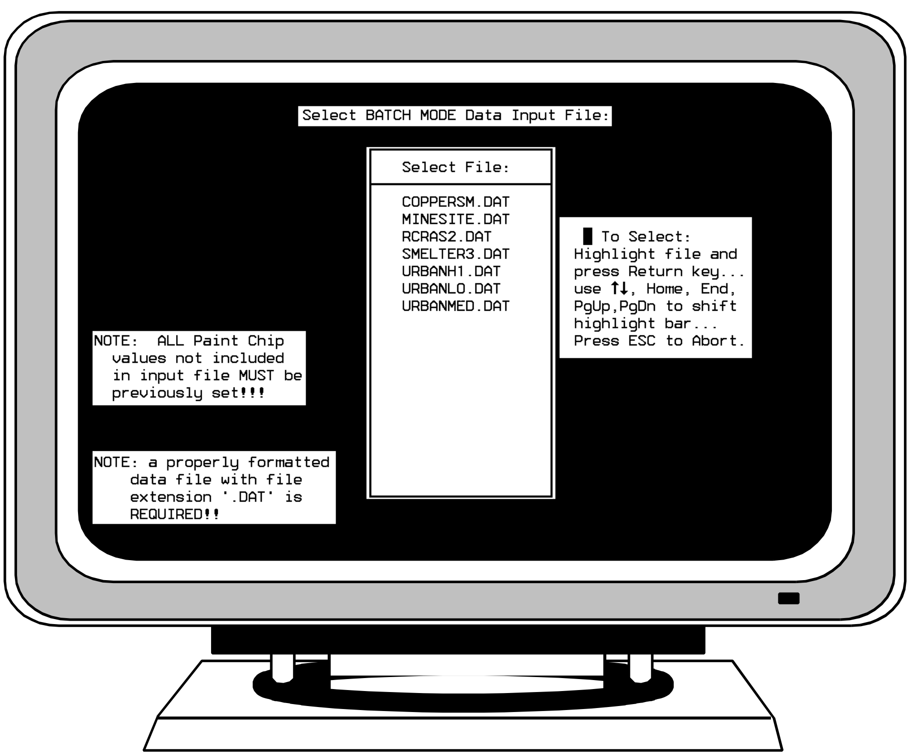
Screen 2-18. Selection of media for multiple range run.



Screen 2-19. Range selection during multiple processing.



Screen 2-20. Using multiple simulation to find acceptable media concentrations for a predetermined blood lead concentration.



Screen 2-21. Running the model in batch mode.

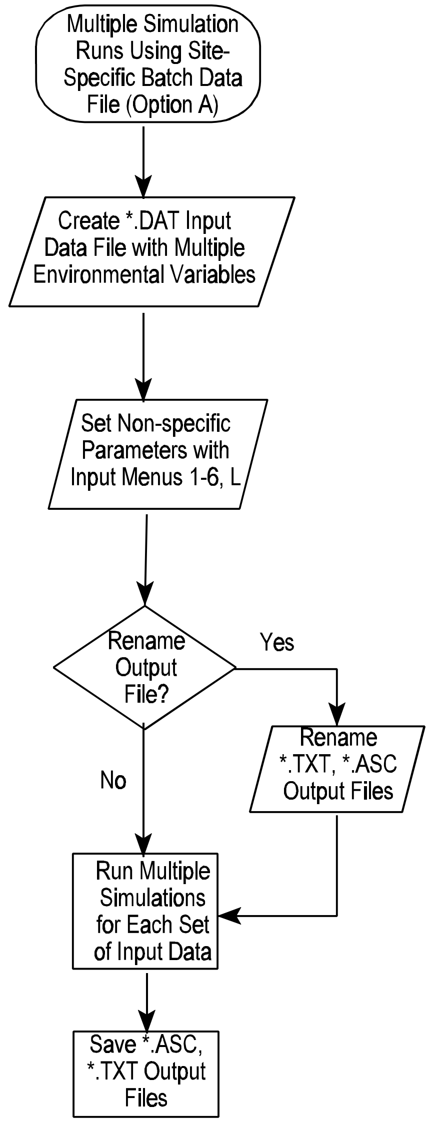


Figure 2-9. Decision diagram for the batch mode menu options.

parameters (soil concentration, dust concentration, drinking water concentration, air concentration and alternate source consumption) for each child in the data set. The input data are entered one line at a time from a data set with a specified list of input variables. These must be created by the user in a special *.DAT file in the Lead Model directory.

Each line of data *may* include:

The child code or case;

The "family" identifier for individuals at the same living unit;

An area, block, or neighborhood identifier;

Each line of data *must* include:

The child's age, in months, as of the end of the data collection period;

The soil lead concentration, in μg/g;

The house dust lead concentration, in μg/g;

The drinking water lead concentration, in μg/L;

The air lead concentration, in $\mu g/m^3$;

The alternate source intake rate, in μg/day;

The child's blood lead level at specified age, in μg/dL.

The child's age must be entered. Either a soil lead or a dust lead value is needed for the simulation, along with a stand-in value (imputation rule) if one of them is missing (for example, if the user does not fill in missing dust lead values, the current default is to replace a missing dust lead concentration by the soil lead concentration). The user may prefer to create an input data file with missing dust lead concentrations replaced by some fraction of the soil lead concentration. Missing values of air, water, and alternate lead are replaced by default values. If there is no actual child blood lead data, then Option 1 produces output data sets with *.ASC and *.TXT extensions that contain all of the input data, including imputed values, and predicted blood lead levels for each line of data.

The batch mode option can be used to perform statistical analyses of simulated community blood lead distributions, even without observed blood lead levels (for example, if an investigator has carried out a multimedia environmental lead study at a site, without blood lead data being collected). However, this option will be even more useful if blood lead data from a well-conducted study are available for model comparisons using statistical tests in Option 5. Output data files may be reviewed using Option 2, as demonstrated in later sections.

2.2.3.5 Statistical Analyses of Batch Mode Data Sets (4)

A set of statistical procedures for analyzing batch mode data sets exists as a separate module in the IEUBK Lead Model. Although the Option 1 data sets can be edited and used in any other statistical programs the user may have available, we have included in Option 5 some of the most commonly used statistics, statistical hypothesis tests, and graphical data displays for comparing observed and modelled blood lead levels. We recommend using a variety of graphical and statistical techniques in evaluating the output of Batch Mode model runs. This will also be demonstrated in Section 5.

2.3 BUILDING AN EXPOSURE SCENARIO

2.3.1 Air Lead Menu

2.3.1.1 Default Air Lead Exposure Parameters

The default air lead concentration is 0.1 $\mu g/m^3$, which is approximately the average 1990 urban air lead concentration (U.S. Environmental Protection Agency, 1991b). During the period 1970-90, ambient air lead concentrations dropped drastically in the United States due to the phasedown of lead in gasoline (Figure 2-10). When adequate monitoring data exist to define concentrations higher or lower than the default outdoor lead concentrations, these should be used. Current air lead levels are low in most places in the United States, and do not require year-to-year specification. Elevated air lead levels have been reported around some point sources in the United States and Europe (Davis and Jamall, 1991) and lead modeling for changes in these sources requires year-by-year input data.

A constant air lead value larger than 0.1 $\mu g/m^3$ may be appropriate for assessment at locations in the vicinity of active point sources of lead emissions such as lead smelters or battery plants. In such cases, an appropriate estimate of annual average air lead concentration must be available.

An example of a striking increase over time was the air lead levels in Kellogg/Silver Valley, Idaho, following a September 1973 baghouse fire. These levels remained elevated for a sufficiently long time such that the use of these values in predicting blood lead concentrations for 1974-1975 from the Lead Model was justified (Agency for Toxic Substances and Disease Registry, 1988).

2.3.1.2 Ventilation Rate

The intake of air increases from infancy to adulthood. The range of values for child ventilation rates was established by EPA (U.S. Environmental Protection Agency, 1989a) as

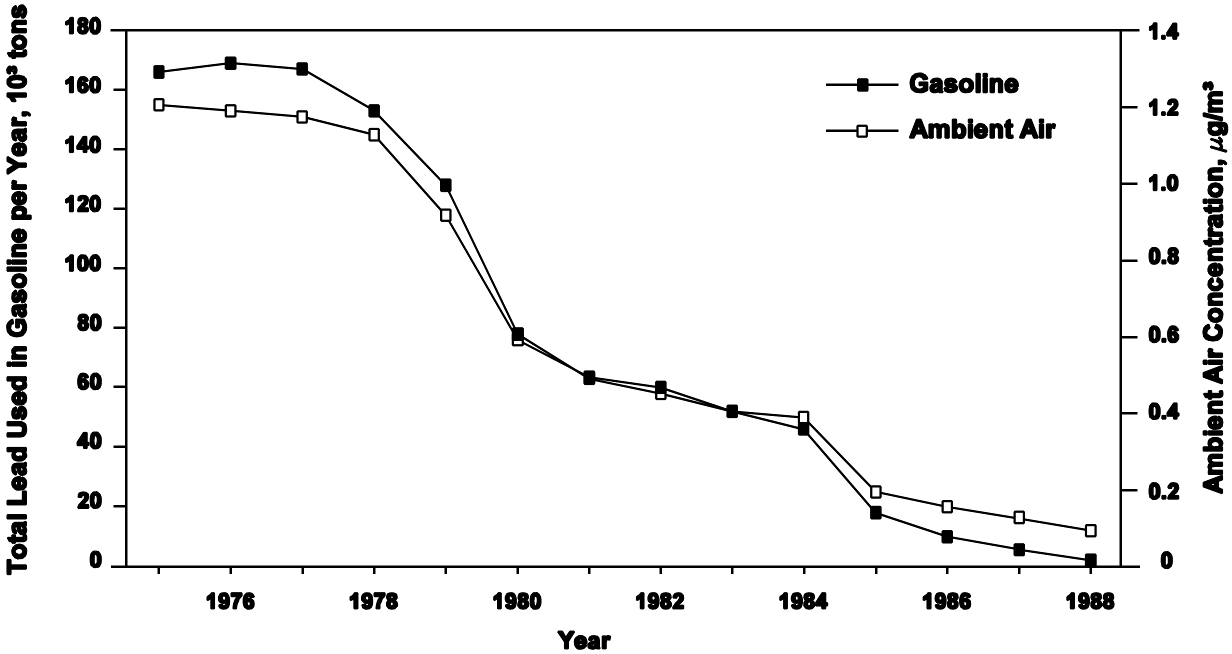


Figure 2-10. Historical relationship between lead in gasoline and lead in air in the United States.

Source: U.S. Environmental Protection Agency (1986), with updating.

2 to 3 m^3/day at age 0 to 1 years, 3 to 5 m^3/day at age 1, 4 to 5 m^3/day at ages 2 and 3, 5 to 7 m^3/day at ages 4 and 5, and 6 to 8 m^3/day at age 6. The Lead Model uses midrange values of 2, 3, 5, and 7 m^3/day at ages 0+, 1, 2 to 4, and 5 to 7 respectively. Children who exercise more than average will have a correspondingly greater intake, and those who are very inactive will have a lower ventilation rate. The higher intakes may be useful in modeling children who spend time at playgrounds or outdoor play areas near an air lead source. Changes in activity pattern can change ventilation rate in a child or in a neighborhood.

2.3.1.3 Indoor/Outdoor Activity Patterns

The range of values for outdoor time was established by EPA (U.S. Environmental Protection Agency, 1989a) as 1 to 2 h/day in the first year of life, 1 to 3 h at age 1, 2 to 4 h at age 2, and 2 to 5 h/day from ages 3 to 7. The default values in the Lead Model are 1, 2, 3, and 4 h/day at ages 0+, 1, 2, and 3+, respectively, roughly at the middle of these ranges. The outdoor air lead concentration provides a large part of the total air lead exposure, because the indoor air lead concentration is typically only about 30% of the outdoor concentration (U.S. Environmental Protection Agency, 1986). Site-to-site differences may exist due to natural ventilation, climate, season, family activity, and community access to outdoor play activities.

2.3.1.4 Lung Absorption

The range of values for child lung absorption was established by EPA (U.S. Environmntal Protection Agency, 1989a) as 25 to 45% for young children living in non-point source areas, and 42% for those living near point sources. The default value used in the Lead Model is 32%. Changes in the source of airborne particulates may also affect lung absorption. No quantitative recommendations can be made.

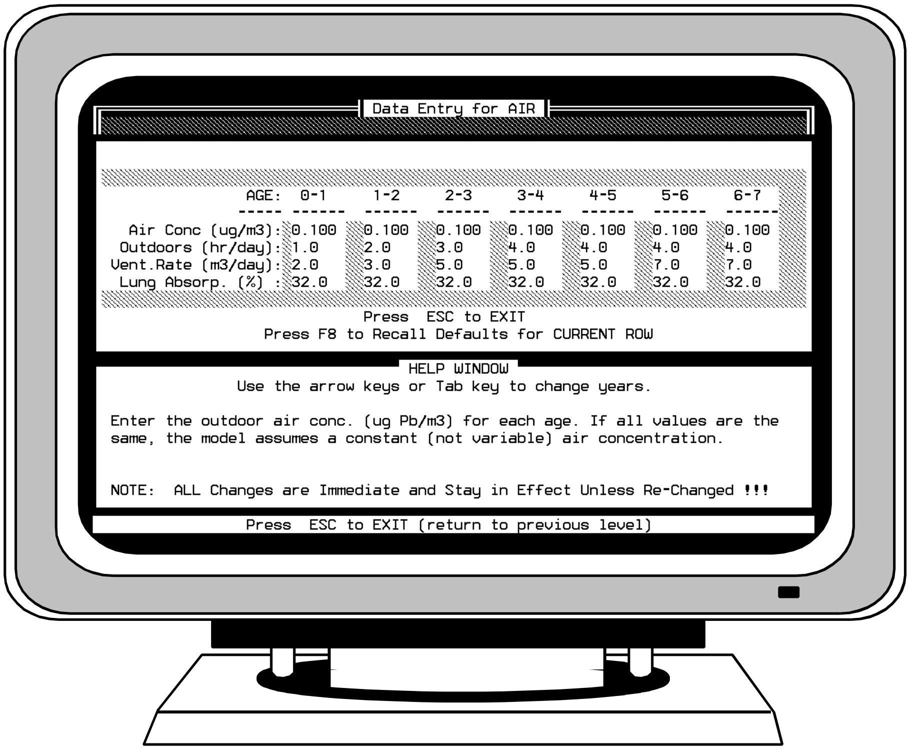
EXAMPLE 2-1: Characterizing Effects of Air Lead Phasedown on Inhalation Intake

If the Lead Model were to be used to estimate blood levels of children living in an urban area in previous decades, when the predominant sources of lead exposure for many U.S. children were air lead from combustion of leaded gasoline and dietary lead from lead-soldered food cans, it would necessary to use community air lead levels during that period of time. Representative values of air lead concentrations were presented in the EPA Air Quality Criteria Document for Lead (U.S. Environmental Protection Agency, 1986, Chapter 7, Table 7-2) for urban center or suburban locations in nine metropolitan areas for 1970 through 1984. The reductions in air lead from 1977 through 1988 attributable to the phasedown of leaded gasoline are quite evident in both urban centers and suburban areas. For example, for a retrospective estimate of blood lead levels in children in 1981, one would need to start with 1975 air lead levels to include prenatal exposure of children up to age 7 in 1981. Figure 2-10 shows that air lead exposure in 1981 would be at 0.48 µg/m^3, and so on. For a 5-year old child in 1981, air lead exposure, at age 0+ in 1975 is 1.2 µg/m^3, and so on. This adjustment in air lead concentration does not estimate the indirect effects of air lead changes on blood lead through gradual changes in soil and dust lead. This example is generic, not site-specific, however. The air lead data entry screen for children born in 1975 is shown in Screen 2-22.

2.3.2 Dietary Lead Menu

2.3.2.1 Total Dietary Lead Exposure

Data assembled from a variety of sources, including Market Basket Surveys (Pennington, 1983) and representing changes in consumer behavior over time, were used to construct dietary lead intake estimates as described in Chapter 7 of the EPA Air Quality Criteria Document for Lead (U.S. Environmental Protection Agency, 1986). The method is



Screen 2-22. Data entry for air. The user may input data from historical records of air lead concentrations on this screen.

based on U.S. FDA Market Basket samples in 231 food categories and has been updated to 1988 (U.S. Environmental Protection Agency, 1989a). Because two major sources of lead in food (lead-soldered cans and air deposition on food crops) have been greatly reduced or eliminated, dietary lead is believed to be relatively constant since 1990, especially for children under seven years.

Table 2-1 shows how estimated mean dietary lead intake depends on the child's age, and that this intake has changed very drastically with the near-elimination of lead solder from food cans and other food packaging in the United States since the 1970s. Where site-specific dietary levels are not available, it is recommended that the values from Table 2-1 be used for the appropriate years and ages, and that the most recent values (1988) be assumed for all future years. Seasonal effects are omitted here since the Lead Model uses annual values for dietary exposure parameters. For alternate exposure scenarios with seasonal intakes, the user may need to calculate time-weighted annual averages from seasonal data.

If the Lead Model is used in connection with historical exposures, for such purposes as model validation or retrospective dose reconstruction, the dietary intake data should be

TABLE 2-1. DIETARY LEAD INTAKE (μg/day) FOR U.S. CHILDREN BY AGE, FOR EACH YEAR FROM 1978 TO PRESENT

	Age						
	6-11 Mo	1 Year	2 Years	3 Years	4 Years	5 Years	6 Years
1978[1]	NE	45.8	52.9	52.7	52.7	55.6	NE
1979[1]	NE	41.2	48.0	47.8	47.8	50.3	NE
1980[1]	NE	31.4	36.9	36.9	36.9	38.7	NE
1981[1]	NE	28.3	33.8	33.7	36.8	35.8	NE
1982[2]	19.2	25.0	27.5	27.4	27.2	28.6	31.6
1983[2]	14.4	18.3	21.9	21.4	21.1	22.3	24.8
1984[2]	19.0	22.7	26.4	26.0	25.7	27.1	29.9
1985[2]	10.2	10.6	12.3	11.9	11.8	12.4	13.6
1986[*]	7.9	8.2	9.4	9.1	8.9	9.4	10.3
1987-Present[3]	5.5	5.8	6.5	6.2	6.0	6.3	7.0

NOTES: NE = Not estimated.
1 = Estimated by J. Cohen and D. Sledge, Table A-2 (U.S. Environmental Protection Agency, 1989a).
2 = U.S. Environmental Protection Agency (1986), updated with data from the FDA Market Basket Survey.
3 = Average of 1986 Q4 through 1988 Q3. Further decreases in food lead concentrations since 1987 are believed to be negligible.
* = Linear extrapolation between 1985 and 1987.

adjusted to the year when the data were collected. For prediction in future years, the most recent default value for each age may be used.

2.3.2.2 Dietary Lead Exposure by Additional Pathways

For some children, there are important dietary lead sources that are not characterized by the FDA Market Basket Survey data summarized in Table 2-1. Child-specific or site specific data will be needed to verify these alternative dietary lead sources. Local sources of fruit and vegetables are used in many small towns and in rural areas. Some individuals obtain much of their produce from their own gardens. If the local or home-grown produce is grown in soils with high concentrations of lead, or if the edible leafy portions are contaminated by airborne lead particles, then some fraction of the environmental lead may be added to the child's diet. The additional intake of lead in diet may become important if the environmental lead concentrations are sufficiently high. This was important in evaluating the Bunker Hill Superfund site in Kellogg ID and was included in the Risk Assessment Data Evaluation Report (the "RADER") prepared by EPA (U.S. Environmental Protection Agency, 1990c). Additional pathways of dietary lead exposure are discussed in Example 2-2.

Dietary lead exposure is the product of the amount of food consumed in each category and the concentration of lead in the food item. Normal intakes are reported by Pennington (1983). To adjust for home gardens, a fraction of this intake may be allocated by the Alternate Diet Entry Menu to local produce, and the rest to Market Basket produce that is not grown locally.

Local game animals feeding on plants contaminated by lead in soil may also have elevated lead concentrations. Lead contamination of rivers and lakes by deposition and by erosion of leaded soils may also increase lead concentrations in local fish. Some rural families may use hunting and fishing as a significant supplement or even as their primary source of animal protein. See Baes et al. (1984) for a comprehensive approach to estimating pathways of trace elements in the food chain. A fraction of the meat and fish intake may be allocated by the Alternate Diet Entry Menu to local game and fish.

Other consumer products may have nontrivial potential for dietary lead exposure. These include lead-glazed or soldered cooking and food preparation utensils, ethnic or regional preferences for food products with high lead content, and the use of oral ethnic medicines such as "empacho" or "azarcon" that have high concentrations of lead and are known to have caused cases of acute lead poisoning in children (Trotter, 1990; Sawyer et al., 1985). No general recommendations about parameter values for these sources of lead can be made at this time. Approximate intake for oral medicines may be estimated from recommended or customary doses for young children.

EXAMPLE 2-2: Characterizing Indirect Dietary Lead Intakes for an Old Lead Smelter Community

Some data from the Human Health Risk Assessment (Jacobs Engineering, 1989) and the RADER for Kellogg ID may be useful (U.S. Environmental Protection Agency, 1990c). Table 2-2 shows that a large percentage of the population uses local produce, that the use of local produce increases toward the more rural Pinehurst area but the lead concentration decreases, and that the lead levels in local produce in 1983 were enormously higher than in

TABLE 2-2. ESTIMATES OF LEAD INTAKE FROM CONSUMPTION OF LOCAL PRODUCE BY CHILDREN, AGES 2 TO 6 YEARS, IN KELLOGG, IDAHO

			Consumption (g/day)		Concentration (μg/g wet wt.)		Intake (μg/day)
Area	Percent Using Local Produce	Number of Gardens	Leafy*	Root*	Leafy	Root	In Summer**
Smelterville	16%	2	25	15	6.1	4.5	220
Kellogg	36%	17	25	15	6.1+	4.5+	220+
Pinehurst	46%	20	25	15	3.5	2.2	121
National Market Basket	--	--	25	15	0.017	0.041	1

NOTES: *Leafy vegetables are lettuce and spinach. Root vegetables are carrots and beets.
+Average of Kellogg and Smelterville.
**Annual average is 1/4 of this.

Source: RADER Tables 5-8 and 5-4 (U.S. Environmental Protection Agency, 1990).
Jacobs Engineering (1988) Table 7-16.

the National Market Basket samples for the same period (1982 to 1984). The calculated increment of daily dietary lead intake during the summer months was 220 µg/day in the report. However, for the purposes of this example, we will assume that this total consumption occurs over the course of the year and includes fresh as well as frozen or canned produce to give an annual average increment of 55 µg/day.

Table 2-3 shows that the lead concentration in fish in nearby Lake Coeur d'Alene in 1985 was much higher than in the Columbia River and higher than fish at the average National Pesticide Monitoring Station lead concentration for 1976/1977. A moderate rate of consumption is two 2-oz fish portions per week, or 114 g/week = 16 g/day on average. The incremental intake from local fish is equal to the concentration difference, 0.80 to 0.34 = 0.46 μg/g times 16 g/day = 7.5 µg/day.

Screen 2-23 shows dietary lead intakes for a typical child born in 1983, and Screen 2-24 shows the extra exposure for intake from contaminated fish.

2.3.3 Drinking Water Lead Exposure Menu

2.3.3.1 Drinking Water Lead Default Exposure Parameters

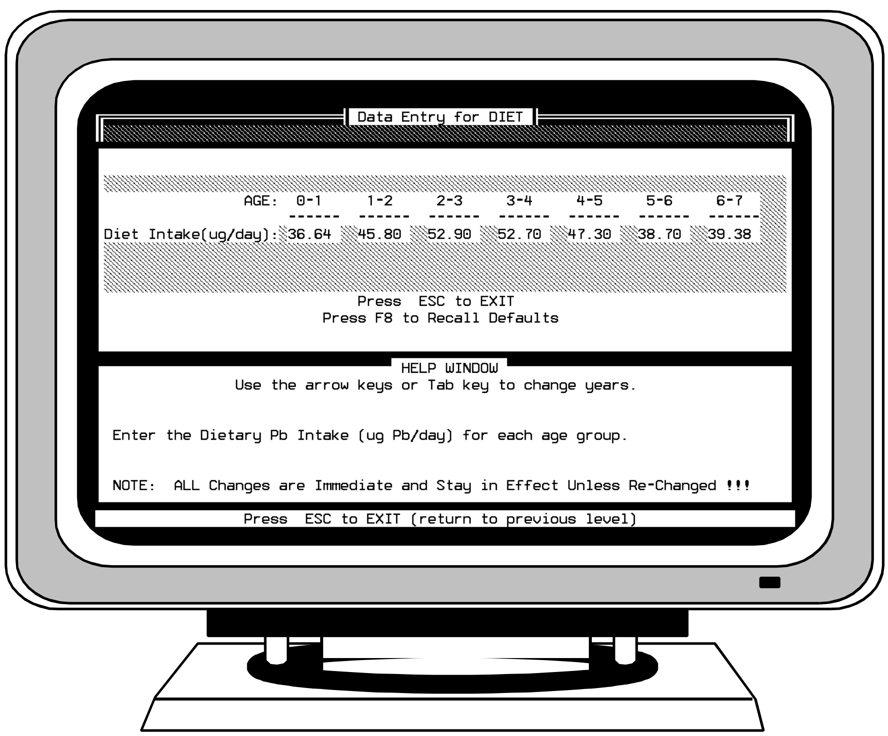
Water sampling methods may be as first draw standing samples, partially flushed samples, or fully flushed samples. The highest lead concentrations at the tap are usually obtained for lead pipes, lead-alloy solder on copper pipes, or lead-alloy brass faucets and

TABLE 2-3. ESTIMATES OF LEAD INTAKE FROM CONSUMPTION OF LOCAL FISH BY CHILDREN, AGES 2 TO 6 YEARS, IN KELLOGG, IDAHO

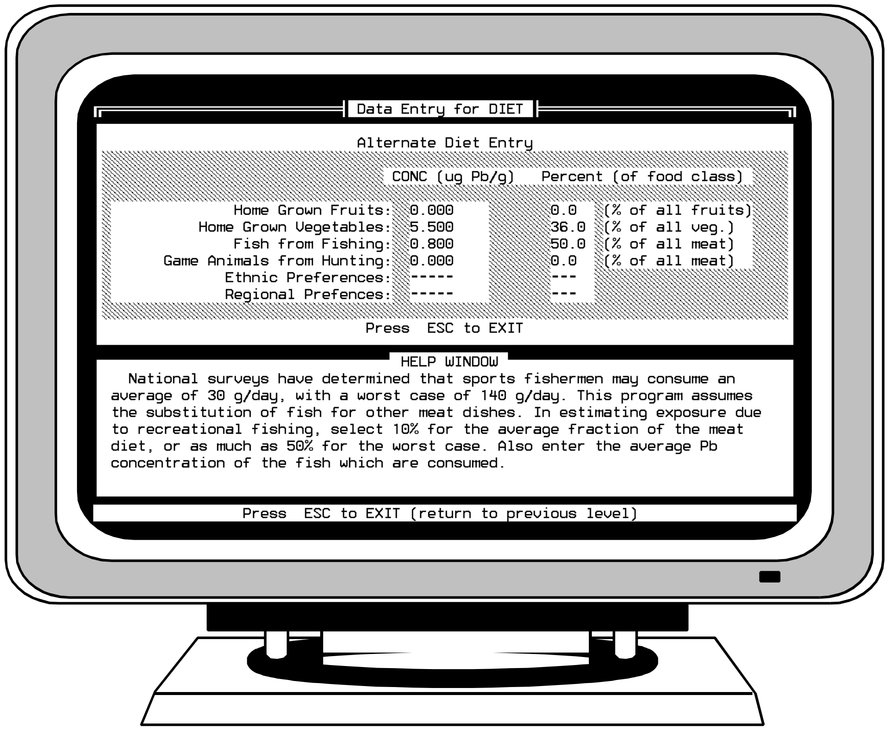
Source	Concentration (μg/g wet wt.)	Fish Consumption* (g/day)	Lead Intake** (μg/day)
Lake Coeur d'Alene (1985)	0.80	16	13.0
Columbia River (1986)	0.34	16	5.5
National Pesticide Monitoring Stations (1976-1977 August)	0.34	16	5.5

NOTES: *Two-ounce portions, twice a week.
**For annual average, multiply by fraction of year when local fish are consumed.

Source: RADER Tables 5-8 and 5-4 (U.S. Environmental Protection Agency, 1990).
Jacobs Engineering (1989) Table 7-16.



Screen 23. Using dietary lead intake for a child born in 1983 (see Example 2-2).



Screen 24. Using dietary intake from local vegetables and fish in Kellogg (see Example 2-2).

fittings in contact with corrosive water for several hours. The new EPA National Primary Drinking Water Regulation for Lead (NPDWR) requires public water systems to collect first draw samples, standing a minimum of 6 h, from a sample of homes targeted as potentially at risk. Water lead concentrations can be significantly different for different sampling protocols, depending on the sources of lead in water drawn through the tap. First draw samples generally have higher lead concentrations than flushed samples. The typical effects of different water sampling procedures are discussed in the Sampling Manual that is to accompany this model.

Drinking water lead concentrations in the Lead Model are held constant during the entire seven years of the child's exposure. In the Case Studies below, household-specific water lead concentrations are used. If no household-specific or relevant community water lead data are available, we recommend using the default value of 4 µg/L.

If a substantial fraction of the child's activity is spent outside the home, it may be useful to separate drinking water exposure into primary residence and secondary residence or daycare. A large number of U.S. children spend time during the weekday at daycare centers or secondary residences. If adults and older children in the household are either at work or at school during the day, there may be two stagnation periods for drinking water during the day —overnight, and midday. In this case, a larger fraction of the child's water lead exposure can occur at the higher "first-draw" concentrations. Some exposure scenarios are discussed by Marcus (1991) in evaluating the risk from lead leached out of newly installed brass faucets. The default scenario is defined by setting 50% of the child's water intake to household first-draw consumption. The remaining intake consists of partially flushed intake inside the home (35%) and water consumed outside the home (15%). The total intake of lead in drinking water would then be:

$$PbW = 0.5 \times PbW\text{ (first draw)} + 0.35 \times PbW\text{ (flushed)} + 0.15 \times PbW\text{ (fountain)}.$$

There is no general rule for estimating the amount of water ingested from water coolers in day care centers or other non-home locations. Since the child's activities outside the home are likely to be different than inside the home, it is unlikely that the ratio of non-home to home water intake is proportional to the amount of time spent away from the home versus at home. Two drinks per day, each about 60 mL (2 oz) or 120 mL, is a reasonable upper limit for day care intake. The default is 15% of the daily tap water intake, which ranges from 75 mL at age 1 year to 90 mL at age 6 years.

2.3.3.2 Alternate Drinking Water Exposure by Age

The default values in the IEUBK model (Table 2-4) are taken from the U.S. EPA Exposure Factors Handbook (U.S. Environmental Protection Agency, 1989c). A survey of drinking water consumption in U.S. children was reported by Ershow and Cantor (1989) in a study for the National Cancer Institute. These values have been smoothed and disaggregated into yearly values shown in Table 2-4. The range of values from the Ershow-Cantor data in Table 2-5 show that the default values for the IEUBK model are similar to but somewhat lower than the median values, but also contain information about the percentiles of the distribution of tap water intake, about gender differences in intake and other factors that you may find useful. A plausible scenario for elevated exposure to lead in drinking water would be to use larger tap water intakes, such as the 90th percentile values in Table 2-5. Note that for children receiving formula reconstituted with tap water, consumption of tap water would be much higher, perhaps closer to one liter per day. In an assessment addressing risks from lead in drinking water, the exposure to infants consuming reconstituted formula requires specific attention.

TABLE 2-4. AVERAGE DAILY WATER INTAKE IN U.S. CHILDREN

	Ershow-Cantor Study*				IEUBK Model**	
	Total (L/day)		Tap (L/day)			
Age (Months)	M	F	M	F	Age (Mo)	Tap Water Intake (L/day)
0-5	0.992	1.035	0.250	0.293	0-5	0.20
6-11	1.277	1.238	0.322	0.333	6-11	0.20
					12-23	0.50
					24-35	0.52
12-47	1.409	1.300	0.683	0.606	36-47	0.53
					48-59	0.55
					60-71	0.58
48-84	1.551	1.488	0.773	0.709	72-84	0.59

*Ershow and Cantor (1989).
**U.S. Environmental Protection Agency Exposure Factors Handbook (1989c).

TABLE 2-5. TAP WATER INTAKE (L/day) BY AGE CATEGORY

Age Category		Percentiles		
(Months)	Mean	10	50 (Median)	90
0 - 5	0.27	0	0.24	0.64
6 - 11	0.33	0	0.27	0.69
12 - 47	0.65	0.24	0.57	1.16
48 - 84	0.74	0.30	0.66	1.30

Source: Table 2-5, Ershow and Cantor (1989).

2.3.4 Soil/Dust Lead Exposure Menu

One of the most important uses of the IEUBK model is to compare risks among alternative soil lead and dust lead exposure scenarios. Many of these scenarios arise in assessing exposure reduction strategies. For example, in evaluating soil lead abatement at a particular residential yard, we might be interested in the following sequence of comparisons:

(1) Calculate the risk of an elevated blood lead level for the present soil and dust lead levels;

(2) Calculate the risk of an elevated blood lead level for the replacement of soil lead with soil having a lower lead concentration, along with cleaning up household dust;

The first scenario describes risk to occupants with present exposure levels. The second scenario describes risk to occupants in the distant future after lower new lead levels have been achieved by abatement. The IEUBK model can accept input data describing both of these exposure scenarios.

2.3.4.1 Soil and Dust Lead Default Exposure Parameters

The natural concentration of lead in soil, from weathering of crustal materials, is estimated as about 10 to 25 µg/g. A plausible urban background is 75 to 200 µg/g (U.S. Environmental Protection Agency, 1989a; HUD, 1990).

It is expected that lead concentrations in undisturbed soils may persist for many thousands of years. However, urban areas are hardly undisturbed environments and available data (von Lindern, 1991; Jacobs Engineering, 1990) suggest that near-surface soil lead concentrations may decrease by a few percent over a decade or so. It is usually adequate to assume a constant soil lead concentration unless soil abatement is included in the exposure scenario.

It is also possible that the soil becomes recontaminated over time, for example if surface soil is abated and then is recontaminated by ongoing atmospheric lead deposition from non-abated sites near by or by contamination from deteriorating exterior lead-based paint. Changes in soil concentration can be incorporated on an annual basis in developing the exposure scenario. This is done with the Option "2" on the Soil/Dust Data Entry Menu.

2.3.4.2 Exposure to Soil and Dust

The default value for total intake of soil and dust depends on age, and ranges from 85 to 135 mg/day. These values are within the ranges identified in the OAQPS staff paper that supported the first UBK model and have been reviewed by the EPA Clean Air Science Advisory Committee. Recent investigations by Binder et al. (1986), Clausing et al. (1987), Calabrese et al. (1989, 1991b), van Wijnen et al. (1990), and Davis et al. (1990) apply the trace element approach to quantify ingestion rate. These investigations currently constitute the most appropriate basis for estimating the quantity of soil ingested. The results are summarized in Table 2-6. The van Wijnen et al. data are discussed in Section 2.3.4.4. It is likely that the intake rate depends on the child's age, activity pattern, and the total

TABLE 2-6. DAILY INTAKE OF SOIL AND DUST ESTIMATED FROM ELEMENTAL ABUNDANCES

		Soil/Dust Intake, mg/day		
Study	Element	Median	Mean	Maximum
Davis et al. (1991)	Al	25	39	904
Ages 2-7 years	Si	59	82	535
	Ti	81	246	6,182
Calabrese et al. (1989)	Al	30	154	4,929
Ages 1-4 years	Ti	30	170	3,597
	Y	11	65	5,269
	Zr	11	23	838
Binder et al. (1986)	Al	121	181	1,324
Ages 1-3 years	Si	136	184	799
	Ti	618	1,834	17,076
Clausing et al. (1987)	Al	92	232	979
Ages 2-4 years	Ti	269	1,431	11,620
	AIR	106	124	302

AIR = Acid Insoluble Residue.

accessible dust and soil in the environment. It is *recommended* that soil and dust intake be defined by an age-dependent scenario shown in Table 2-7, as reviewed by the Clean Air Science Advisory Committee (U.S. Environmental Protection Agency, 1990b).

Two of the studies, Davis et al. (1991) and Calabrese (1989), measured the dietary (including medication) intake of the trace elements and subtracted this quantity in estimating soil ingestion. These studies therefore provide the most complete quantitation of ingestion. Because Binder et al. (1986) did not measure dietary intake, the results for this study are likely to provide an upper bound on ingestion among those subjects. Van Wijnen et al. (1990) did not measure dietary intake but attempted to compensate for this approach by using the lowest observed tracer result for each child and subtracted out a value obtained for hospitalized children who were assumed not to ingest soil or dust. The combination of these two techniques may lead to a downward bias in ingestion estimates.

TABLE 2-7. AGE-SPECIFIC SOIL AND DUST INTAKE

Age (Years)	Intake (g/day)	Adopted for Guidance Manual
0 - < 1	0 - 0.085	0.085
1 - < 2	0.080 - 0.135	0.135
2 - < 3	0.080 - 0.135	0.135
3 - < 4	0.080 - 0.135	0.135
4 - < 5	0.070 - 0.100	0.100
5 - < 6	0.060 - 0.090	0.090
6 - < 7	0.055 - 0.085	0.085

Source: U.S. EPA (1989a).

The reader should also note that there are statistical problems in interpreting an observed median value from these studies. For example, in a population of children who all ingested very small amounts of soil on most days but occasionally ingested larger quantities, the median from a short term measurement study will be below the average daily quantity ingested by any of the children. The mean value is not subject to this bias, and therefore is judged to be a more meaningful measure of ingestion.

It should be noted that the 200 mg/d ingestion value presented in Superfund guidance can be supported as, roughly, an upper bound on mean ingestion considering the values seen in different ingestion studies. The values recommended for use in the model (85 to 135 mg/d) represent a more central value within the range of values seen in different studies.

The smaller study of Clausing et al. (1987) used methods similar to the later study of van Wijnen et al. The values shown for soil ingestion in Table 2-7 are uncorrected for dietary intake. The paper presents additional estimates using acid insoluble residue and tracer excretion by hospitalized children.

2.3.4.3 Sources of Dust Exposure

Contribution from Atmospheric Deposition and Soil

We recommend collecting household dust data. If that has not been done, then Option 3 may be used to estimate dust lead concentrations. The OAQPS Exposure Analysis and Methodology Validation (U.S. Environmental Protection Agency, 1989a), used for the earlier version of the model on which the current IEUBK Model is based, calculates the contribution of atmospheric deposition and soil to house dust by linear regression models between dust lead, soil lead, and air lead. There is a relationship between dust lead concentration in µg/g (denoted as PbD), soil lead concentration in µg/g (denoted as PbS), and air lead concentration in µg/m^3 (denoted as PbA). In a number of studies, statistically significant relationship of the form:

$$PbD = \beta_O + \beta_S \, PbS + \beta_A \, PbA$$

This equation suggests that house dust lead concentration consists of three components: a soil component, which is the fraction β_S of the soil concentration, an air component, consisting of a coefficient β_A relating μg/g lead in dust to μg/m^3 of lead in air, and a third component of β_O coming from unidentified sources.

As a default value in the model, we used $\beta_A = 100$ µg/g per µg/m^3 based on several analyses. We recommend a default soil-to-dust coefficient of 0.70, which represents some real sites where soil is a major contribution to household dust. The reader should be aware that other values have been identified for other site-specific exposure scenarios.

Dust Lead Increment from School Dust

Dust ingestion while at school may be significant, depending on the amount of exposure on the floor or playground. While the IEUBK model deals primarily with preschool children, some children may be in school and subject to a more structured regimen of hygiene and reduced dust exposure. The amount of dust ingested and its implicit fraction of total dust ingestion is not necessarily proportional to length of time at the facility. Hygiene and dust loading are additional predictive factors. Playground geometric mean dust lead levels of 170 - 3,700 µg/g were reported by Duggan et al. (1985) in a sample of 11 British schools.

Dust Lead Increment from Day Care

Dust ingestion while at daycare (including nursery school and kindergarten) may be significant, depending on the amount of exposure on the floor or outside play area. Dutch children who spent a considerable amount of time at a daycare center were known to ingest a large quantity of dust and soil, although apparently much less in rainy weather than in good weather (van Wijnen et al., 1990).

Dust Lead Increment from Second Home

Children often spend several hours per day in the home of a relative or in an informal daycare setting. Dust exposure information can often be collected and used in the same manner as for the primary home.

Dust Lead Increment Remaining from Primary Residence

When the Multiple Source Analysis option is selected on the Soil/Dust Data Entry Menu, the IEUBK model offers the opportunity to change the soil and air parameters of the regression equation set at 0.70 and 100, respectively as default values. The selection of a default value for the soil-to-dust coefficient was based on empirical data. In sites where soil-to-dust coefficients have been measured and where paint does not contribute greatly to dust, the range was from 0.09 to 0.85. Among the sites where soil-to-dust coefficients have been measured are the following: East Helena, 0.85 (0.81 and 0.89); Midvale, 0.70 (0.68, 0.72); Butte, 0.26; and Kellogg, 0.09. Recent data suggest the coefficient decreases over time at some sites where major sources of soil lead deposition are no longer active. The user is cautioned, however, that the contribution of soil to dust concentration varies greatly from site to site, and site-specific soil and dust data should be collected for use in the model. The user may choose to enter values for alternate sources of dust, including both an estimate of concentration (μg/g) and relative contribution (%) for each source. Of the five alternate sources, two (secondary occupational dust and lead-based paint in home) represent contributions to house dust lead within the home, and three (dust at school, dust at daycare, and second home dust) represent exposure outside the primary home. If no selection is made from any of these five, the house dust concentration remains as calculated from the linear equation. If any of the five options are selected, this percentage is subtracted from the house dust component, the contribution from all sources is calculated, and the average is shown on the Multiple Source Average line of the Soil/Dust Data Entry Menu. This line appears only if the Multiple Source Option is selected.

2.3.4.4 Fraction of Exposure as Soil or Dust

We recommend using the default assumption that 45% of the total dust intake is derived from soil. The ratio of soil intake to dust intake is not simply proportional to the ratio of the number of waking hours that the child spends outdoors versus indoors. Children spend only 15 to 30% of their waking hours playing outside but are more likely to be in contact with bare soil areas, in locations with large amounts of accessible loose particles, and are likely to wash their hands less often than when they are indoors. The default 45/55 ratio in the model represents our best judgement of a properly weighted ratio for this parameter.

The issue of intake of soil and dust has not been properly resolved in the scientific literature. The distinction is important because there is some indication that even if soil lead is the principal source of dust lead, there may be chemical or physical differences between soil and dust that may affect bioavailability. Calabrese (1992) has found that most of the soil and dust intake in a soil pica child was in the soil component, but this is hardly representative of a larger population that may have large differences in relative exposure to soil and dust.

Section 2.3.4.4 discusses the option to select the amount of dust and soil consumed by the child each day. The default values are age weighted from 85 to 135 mg/day, and this dust is ingested either during kitchen preparation of food or by hand-to-mouth activity during indoor and outdoor play activity. This section discusses the option to allocate a portion of the ingested dust to dust derived from soil that is ingested during outdoor play activity. This distinction is important when there are differences between the bioavailability of dust derived from soil and dust in the home, and when there are large differences in the concentration of dust from the two sources. When house dust is thought to be mostly of soil origin and each are expected to have similar bioavailability, the designation of this fraction is a moot point. It is in cases where house dust differs significantly from soil derived dust that the soil/dust ratio becomes important. One example might be the presence of interior lead-based paint. In this case the parameter can be effective in separating soil derived dust and paint derived dust into two components where both the amount ingested and percent absorbed can be correctly input into the model.

There is some evidence that the soil intake is very responsive to exogenous factors, such as weather and location. Data reported by van Wijnen et al. (1990), summarized in Table 2-8, show the lowest soil and dust intakes at daycare centers occurred in rainy weather, when the children had the least amount of outdoor activity.

There is an implicit assumption that the exterior dust that a child ingests during outside play activity is derived completely from soil, and we use soil as a surrogate for exterior dust exposure. These intakes were measured during a 3 to 5 day sampling period, when soil and dust intake estimates ranged from 33 to 88 mg/day for children aged 1 to 2 years and from 12 to 62 mg/day for children older than 3 years. The intake of soil and dust is describe in detail in Section 2.3.4.2.

In the absence of any better data, we have reanalyzed and reinterpreted the van Wijnen et al. data based on the assumption that the rainy-weather intake is only interior dust, and

TABLE 2-8. MINIMUM PERCENTAGE SOIL INTAKE AS A FUNCTION OF AGE IN DUTCH CHILDREN IN DAYCARE CENTERS[a]

	Estimated Geometric Mean LTM, mg/day		
Age (years)	Good	Rainy	Difference (mg/d)
< 1	102 (4)	94 (3)	8
1 - < 2	229 (42)	103 (18)	126
2 - < 3	166 (65)	109 (33)	57
4 - < 5	132 (10)	124 (5)	8

[a]Minimum daily ingestion of acid insoluble residue or other tracers, denoted LTM (Limiting Tracer Method) from Table 4 in Van Wijnen et al. (1990). Number of children shown in parenthesis.

that the good-weather intake is both interior and exterior dust although probably with a smaller amount of interior dust than in rainy weather. The authors also made the distinction between soil and dust in their discussion of the study. For our reanalysis, we took the rainy-weather intake by age as dust and the good-weather intake as soil plus dust, to estimate an age-related difference of 8 to 126 mg/day soil (Table 2-8). The difference between LTM during good weather and LTM during mostly rainy weather is believed to be a lower bound on the soil intake. The combined intakes of soil and dust estimated by other authors are of a similar order of magnitude, such as the median soil and dust intake of 25 to 81 mg/day found by Davis et al. (1991) for children of ages 2 to 7 years in Richland-Pasco-Kennewick, Washington. We therefore assume that a substantial fraction of the combined soil and dust intake in U.S. children is in the form of soil, as suggested by the large difference in Table 2-8 between good and rainy weather intakes, and a substantial fraction is in dust, as suggested by the large intake during rainy weather, in Table 2-8. The minimum intake, denoted LTM for Limiting Tracer Method, has not been corrected for food intake. However, it is likely that the differences between LTM intakes do not depend on food intake.

2.3.4.5 Bioavailability of Lead in Soil and Dust

The current assumption in the Lead Model is that 30% of dust and soil lead intake is absorbed into the blood. This is assumed to be partitioned into a nonsaturable component of 6% and a saturable component of 24%. Some investigators (Steele et al., 1990) argue that the bioavailability of lead in soil from some old lead mining sites is much less than that of dissolved lead salts for several reasons: (1) large lead particles may not be completely dissolved in the GI tract; (2) the solubility of chemical species commonly found in mine wastes, particularly lead sulfide, is much lower than that of other lead salts. These hypotheses are based on studies in small laboratory animals such as rats (Barltrop and Khoo, 1975; Barltrop and Meek, 1979), and while the results may be qualitatively relevant to humans, it is not clear how they should be extrapolated to humans or to other large animals with similar physiological properties such as baboons or swine.

2.3.5 Alternate Source Exposure Menu

One possible use of the Alternative Source Exposure Menu is the direct ingestion of chips of lead-based paint (LBP). The user might assume that a child with pica for paint ingests one paint chip per day. If this chip weighs 0.3 grams and contains lead at 10% (100,000 µg/g), then the calculated ingestion is 100,000 µg/g × 0.3 g/day, or 30,000 µg/day each day for a year. Note that this exposure would be in addition to exposure to lead-based paint in housedust, which is Option 4 in the Multiple Source Menu of Soil and Dust. The limited information available on the bioavailability of lead in paint chips suggests that at doses this high, absorption mechanisms may be largely saturated (Mallon, 1983), which would indicate appropriate adjustments in bioavailability. The user is referred to Section 4.7, and is encouraged to review the literature on this topic prior to making a risk assessment decision. Similar calculations can be made for the ingestion of soil or other non-food items.

2.4 STARTING AND RUNNING THE MODEL

2.4.1 Loading and Starting the Model

The IEUBK Model is a stand alone software package that requires only an IBM compatible PC with DOS. The diskette accompanying this manual contains the following files:

LEAD99d.EXE (the main program file)
PBHELP99.HLP (a help file)

PBSTAT.EXE (the statistical package)

Several *.BGI files (for graphic output)

One or more EXAMPLE*.DAT (sample data sets)

Copy all files into a directory of your choice, then type LEAD99d at the DOS prompt to start the program. The initial screen gives the model name and version number. Several information screens with recent developments and other news items then follow. The Main Menu gives the user access to all of the menus described in this chapter.

While the LEAD99d.EXE file occupies only about 160 KB on the hard drive, it will expand to a much larger size when loaded into RAM. Normally, a PC with 640 KB has enough RAM to run the program, but there may be some conflicts with TSR (Terminate and Stay Resident) programs. It may be necessary for the user to remove some TSR programs in order to run the IEUBK Model.

The Model does not require a math co-processor, but calculations may take up to 20 times longer without a co-processor.

2.4.2 Running the Model

The user should fill in the worksheet in Figure 2-11, which defines the exposure scenario, before proceeding with the parameter entries and the computations.

2.4.2.1 Computation Options

The computation menus present the user with a set of computation choices. One choice is the iteration time step, Selection "2". These choices range from 15 minutes to 30 days. The default of 4 hours is adequate for most purposes. Setting this option on the RUN Menu also sets the iteration time for other computation modes, including the Batch Mode.

2.4.2.2 Output Options

At any time during the session, the program may be saved to a designated file. This gives the user the option of retrieving a set of parameters at some future session without reentering the parameters individually. After each model run, the user can select one of several plot options, which can be viewed on the screen, printed to file or sent to a printer. Most plots generated by the model can be printed by using the F10 key on the keyboard. The program presently interfaces with nine standard printer types or orientations. The Graphics Menu selection "7" allows user-specified scaling of the X-axis variable. Future versions of the model may have additional output options.

IEUBK MODEL WORKSHEET			
SITE OR PROJECT:	Model Version:	Date:	
Model Run Control Number:	Site Description:		
PARAMETER	DEFAULT VALUE	USER SELECTED OPTION	UNITS
AIR (constant)			
Outdoor air lead concentration	0.10		$\mu g/m^3$
Ratio of indoor to outdoor air lead concentration	30		%
AIR (by year)			
Air concentration Age = 0-1 year (0-11 mo), 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 .10 .10 .10 .10 .10 .10 .10		 $\mu g/m^3$
Time outdoors Age = 0-1 year (0-11 mo), 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-7 years (36-83 mo)	 1 2 3 4		h/day
Ventilation rate Age = 0-1 year (0-11 mo), 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 2 3 5 5 5 7 7		m^2/day
Lung absorption	32		%
DATA ENTRY FOR DIET (by year)			
Dietary lead intake Age = 0-1 year (0-11 mo), 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 5.53 5.78 6.49 6.24 6.01 6.34 7.00		μg Pb /day

Figure 2-11. Integrated exposure uptake biokinetic model sample worksheet.

DATA ENTRY FOR ALTERNATE DIET SOURCES (by food class)			
Concentration: home-grown fruits home-grown vegetables fish from fishing game animals from hunting	 0 0 0 0		μg Pb/g
Percent of food class: home-grown fruits home-grown vegetables fish from fishing game animals from hunting	 0 0 0 0		%
DATA ENTRY FOR DRINKING WATER			
Lead concentration in drinking water	4		μg/L
Ingestion rate Age = 0-1 year (0-11 mo), 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 0.20 0.50 0.52 0.53 0.55 0.58 0.59		liters/day
DATA ENTRY FOR ALTERNATE DRINKING WATER SOURCES			
Concentration first-draw water flushed water fountain water	 4 1 10		μg/L
Percentage of total intake first-draw water flushed water (not a user entry; calculated based on entries for first-draw and fountain percentages) fountain water	 50 100 minus first draw and fountain 15		%
DATA ENTRY FOR SOIL/DUST (constant)			
Concentration Soil Dust	 200 200		μg/g
Soil ingestion as percent of total soil and dust ingestion	45		%

Figure 2-11 (cont'd). Integrated exposure uptake biokinetic model sample worksheet.

DATA ENTRY FOR SOIL/DUST INGESTION (by year)			
Soil/dust ingestion			
Age = 0-1 year (0-11 mo),	0.085		g/day
1-2 years (12-23 mo)	0.135		
2-3 years (24-35 mo)	0.135		
3-4 years (36-47 mo)	0.135		
4-5 years (48-59 mo)	0.100		
5-6 years (60-71 mo)	0.090		
6-7 years (72-84 mo)	0.085		
DATA ENTRY FOR SOIL (by year)			
Soil lead concentration			μg/g
Age = 0-1 year (0-11 mo)	0		
1-2 years (12-23 mo)	0		
2-3 years (24-35 mo)	0		
3-4 years (36-47 mo)	0		
4-5 years (48-59 mo)	0		
5-6 years (60-71 mo)	0		
6-7 years (72-84 mo)	0		
DATA ENTRY FOR DUST (by year)			
Dust lead concentration			μg/g
Age = 0-1 year (0-11 mo)	0		
1-2 years (12-23 mo)	0		
2-3 years (24-35 mo)	0		
3-4 years (36-47 mo)	0		
4-5 years (48-59 mo)	0		
5-6 years (60-71 mo)	0		
6-7 years (72-84 mo)	0		
DATA ENTRY FOR SOIL/DUST MULTIPLE SOURCE ANALYSIS (constant)			
Ratio of dust lead concentration to soil lead concentration	0.70		unitless
Ratio of dust lead concentration to outdoor air lead concentration	100		μg Pb/g dust per μg Pb/m^3 air
DATA ENTRY FOR SOIL/DUST MULTIPLE SOURCE ANALYSIS WITH ALTERNATIVE HOUSEHOLD DUST LEAD SOURCES (constant)			
Concentration			μg/g
household dust (calculated)	150		
secondary occupational dust	1,200		
school dust	200		
daycare center dust	200		
second home	200		
interior lead-based paint	1,200		

Figure 2-11 (cont'd). Integrated exposure uptake biokinetic model sample worksheet.

Percentage household dust (calculated) secondary occupational dust school dust daycare center dust second home interior lead-based paint	 100 minus all other 0 0 0 0 0		%
BIOAVAILABILITY DATA ENTRY FOR ALL GUT ABSORPTION PATHWAYS			
Total lead absorption (at low intake) diet drinking water soil dust alternate source	 50 50 30 30 0		%
Fraction of lead absorbed passively at high intake diet drinking water soil dust alternate source	 0.2 0.2 0.2 0.2 0.2		unitless
DATA ENTRY FOR ALTERNATE SOURCES (by year)			
Total lead intake Age = 0-1 year (0-11 mo), 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 0 0 0 0 0 0 0		μg/day
DATA ENTRY MENU FOR MATERNAL-TO-NEWBORN LEAD EXPOSURE			
Mother's blood lead level at time of birth	2.5		μg/dL
DATA ENTRY MENU FOR PLOTTING AND RISK ESTIMATION			
Geometric standard deviation for blood lead, GSD	1.6		unitless
Blood lead level of concern, or cutoff	10		μg/dL
COMPUTATION OPTIONS			
Iteration time step for numerical integration	4		h

Figure 2-11 (cont'd). Integrated exposure uptake biokinetic model sample worksheet.