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Lead Benchmarks for Soil with Human Health Model in a Region

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Abstract

To derive the reference value of contaminated soil lead in Wenling region on optimal model (IEUBK、ALM) parameters, which made the predicting results more scientific and accurate and a theoretical basis was provided for the latter part of the reference value of contaminated soil lead formulation. The pregnant woman and child in Wenling of Zhejiang Province were selected as objects in this study. The Integrated Exposure Uptake Biokinetic Model (IEUBK) and the Adult Lead Model (ALM) combined with the methods of laboratory tests, questionnaires, and documents were used to determine environment references of Pb in soil based on health risk by the study on the pregnant woman and child in study area. Two kinds of model parameters were analyzed by Monte Carlo to discuss changes in one factor model predictions impact. The reference values of Wenling region were 180 mg/kg and 555.6 mg/kg. The sensitivity of the air and drinking water media of IEUBK model parameters exposure to lead concentrations were 50.8%. The probability values of geometric standard deviation of women blood lead concentration of child bearing age (GSD) and protecting the population according the setting target blood lead concentration (n) in ALM model were negatively sensitive and the values of sensitivity were -39.6% and -19.5%. The reference values of Wenling region bellowed the values of Britain and other developed countries. The exposure way of respiratory was the most significant and widespread and its impact on result of model was higher than oral exposure ways according to sensitivity analysis results. However, there were higher levels of digestion and absorption due to oral exposure accumulated which also caused a certain extent to the model prediction.

Keywords: IEUBK; ALM; Soil Lead; Environmental benchmark.

1. Introduction

Lead and its compounds are the non-degradable environmental pollutants. They are stable and long-term enrichment. People will be absorbed in lead from atmosphere, soil, water, food and other media. The damage of the people from lead is systematic and multi-organ resistance. It can cause a lot of chronic injury, such as hematopoietic system, urinary system, reproductive system, cardiovascular system, digestive system, nervous system and so on. It is reported that children and women can be lead poisoning easily when they are in the lead environment. It can cause memory, intelligence and neurobehavioral disorder. Soil lead is an important source of population. With the increasing of contaminated sites in the recent years, soil lead has become an important factor of affecting human health. Soil lead standard in China now is “The Quality Standards of Soil Environment” in 2008. It is established on the basis of the protection of soil resources background values and the standard value of soil agricultural production functions and environmental functions [1], but many countries in the world think of human health as the

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lead benchmarks for soil in the region according to migration and transformation of pollutants and human exposure mode.

A series of derivation guidelines of soil benchmarks and the corresponding soil reference value of contaminants based on health risk have been reported from Canada, American and England since American published "The Super Law of Fund" in 1980. There are some important reference value models in the world, such as RAGS Model of "Superfund Site-specific Risk Assessment Guidelines" in American, RBCA Model of American Society for Testing and Materials, CSOIL 2000 Model in Netherlands and CLEA Model in England. Estimation methods of soil reference values have been established by Chinese Ministry of Environmental Protection based on RAGS and RBCA in the recent years. Besides, Chinese Ministry of Environmental Protection published "Site Environmental Assessment Guidelines" [2] and "Contaminated Sites Guidelines for Risk Assessment Techniques" (for approval) (Environment Ministry of Environmental Protection) one after another. "Contaminated Site Guidelines for Risk Assessment Techniques"(for approval)[3] announced soil benchmarks of 100 pollutants for residential land and industrial land, but derivation of the reference value and lead benchmarks for soil are the same as American's.

Generally speaking, environmental baseline means that the maximum dose (no effect measurement) or concentration[4] of pollutants in the environment does not have bad effect on some specific objects (human or other organisms). Due to the difference from receptors, benchmark is not the single measured value, but multi-objective function and the range of value based on different protected objects.[5] Now, a lot of scientists in China infer lead benchmarks for environment from different objectives when they consider environmental baselines in the water and soil media[6]. Besides, some published baselines adopt American's reference value parameters rather than environmental baselines from the point of view of human health. The research will adopt human blood lead model widely recognized around the world. What's more, the research will optimize the model parameters and infer lead benchmarks for soil in the region according to human health risk assessment and Chinese geographical features and laboratory test simulates. It will be the foundation of the research of Chinese lead-contaminated site risk assessment and environmental baselines.

2. Research Methods

2.1 The Introduction of IEBUK, ALM

Adults and children should be considered when the study of human health risk. It is widely considered that children have many soil exposure approaches when people study human health risk of the soil media. Environmental Protection Agency of US established exposure absorption biodynamic models in vitro of a large amount of children's blood lead and environmental lead exposure results. The model is widely used in the world[7]. Besides, the model will be used in values of lead-contaminated soil restoration and environmental lead pollution that will affect children's blood lead in China[8]. The model has four modules (exposure, absorption, metabolic power, probability distribution) and simulates the relations between absorption efficiency of lead and lead content of various organs in the human body especially changes in blood lead. The model is composed with figure 1, and the study will conduct research on lead benchmarks for soil in a region with IEUBKwin v1.1 build 11 modeling software.

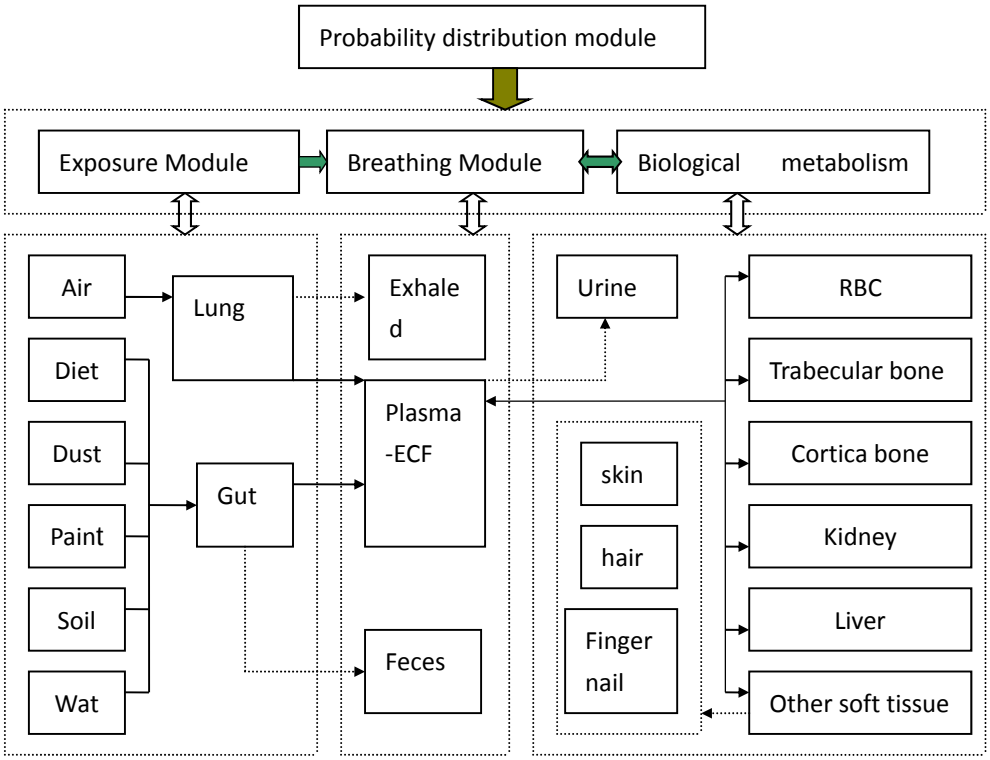

Figure 1. The IEUBK Model Constitute of Lead Exposure, Absorption, Metabolism, and Blood Lead Levels Estimates

Adult blood lead model (ALM)[9]is proposed by EPA. The method represents the relationship between environmental lead exposure and adults (pregnant women) blood lead levels according to biodynamic slope coefficient (BKSF), and adopt geometric standard deviation to descript inter-individual differences in blood lead levels on the lead exposure. It has two modules, the one is exposure module and the other is probability module. According to the blood lead level of proportion coefficient of the fetus and mother, it can evaluate probability of occurrence of an event about fetal blood lead levels over 10 μg/dL when adults (pregnant women) are stressed by lead contamination of soil. In the recent years, a lot of countries have adopted ecological risk assessment of soil lead because it is simple and practical. The formulas (1) and (2) are the calculation method of ALM model.

$$PbS = \frac{(PbB_{adult,central,goal} - PbB_{adult,0}) \cdot AT}{BKSF \cdot IR_s \cdot AF_s \cdot EF_s} \tag{1}$$

$$PbBadult, central, goal = \frac{PbB_{fetal,0.95,goal}}{GSD_{i,adult}^{n} \cdot R_{fetal/maternal}} \tag{2}$$

In the formulas: PbS means environmental baseline soil lead that is based on the human health risk. $PbB_{adult,cental,goal}$ means goal for central estimate of blood lead concentration in Pregnant woman that have site exposures. $PbB_{adult,0}$ means the background blood lead levels of the Pregnant women

without lead exposure. AT means long exposure time. $BKSF$ means the slope coefficient of blood lead and daily intake of lead content in the human body. IR_s means daily intake rate of soil. AF_s means absolute gastrointestinal absorption fraction for ingested lead in soil or in dust derived from soil. EF_s means The number of days of annual average exposure to lead-contaminated scene. $PbB_{fetal,0.95}$ means goal for the 95% percentile blood lead concentration among fetuses of women having exposures to the specified site soil concentration. GSD_i means geometric standard deviation of blood lead levels for women of childbearing age. $R_{fetal/maternal}$ means constant of proportionality between fetal PbB concentration at birth and maternal PbB concentration. n is based on the probability level of protection of the population.

2.2 Survey Methods

2.2.1 The study area of Introduction

Study area was Wenling of Zhejiang Province. The city was at the southeast coast of Zhejiang, the south wing of the Yangtze River Delta. Most people came from the Han nationality. There have been 1.1845 million people by the end of 2009. Besides, the rural population was 988500, the agricultural population was 98.85 million people. The people of this city almost ate grains and wheat and had the same lifestyle, so it was chosen these people (adults and children) as objects of study.

2.2.2 The object of study

165 pregnant women about 20-40 years old that has lived there for over 10 years and 282 children about 1-7 years old were chosen about 147 men and 135 women. We had household surveyed from July to November in 2011 aiming to get height, weight, diet and lifestyle of people. The survey would combine questionnaire with video recording.

2.3 Multi-media for sampling and testing on the environment

It was collected sixty farmland topsoil (0~20cm) and thirty-four groundwater samples (It was investigated that people usually drink mountain water or groundwater.) according to the different samples' technical specifications of collection, save and analysis. Besides, air samples was collected (24 hours all the time) of six different wind in the residential area. Nine dust samples were collected at fixed point for long time, so that it could improve dust samples representative. Fifty-two crop samples (cereals: rice, sweet potatoes et al; vegetables: celery, greens, spinach et al) should be collected at soil sampling point. Fourteen backyard and captive pork and chicken and feeding fish samples should be collected. What's more, five local productions for fruit samples (strawberry) should be collected.

2.4 Environmental sample pre-treatment and in vitro simulation test

Environmental sample pre-treatment: Firstly, the collecting crop samples were washed by pure water. Secondly, samples were minced by blender and freeze-dried to constant weight. Thirdly, they were

crushed into powder by a mortar through 100 mesh sleves. Lastly, they should preserve in the refrigerator. Fish and meat also should be washed by pure water and be cut piece to piece. Then these samples should be minced by blender and freeze-dried to constant weight. Besides, they should preserve in -20 ℃. The fruit samples pre-treatments were the same as crop samples pre-treatment.

Simulated gastric fluid in vitro digestion: the configuration of simulated gastric fluid was prepared (4.3875 g Nacl, 0.5 g Citric acid, 0.5 g Malic acid, 0.42 ml Lactate, 0.5 ml Glacial acetic acid), and then pH was 1.5 using concentrated hydrochloric acid, and 1.25 g pepsin was added. When in the intestinal condition, $NaHCO_3$ was added to the sterile water until pH was 7, and then 0.3 g trypsin and 1 g bile were mixed with water.

Stomach reaction stage: 0.4 g samples and 12 ml gastric juice were mixed in the reactor. The mixture was then incubated for 2 h at 37 ℃ using head-over-heel rotation. After incubation, the suspensions were centrifuged at 3000 g for 10 min, yielding supernatant and precipitate. The supernatant was filtered with a glass fiber membrane (0.45 mm). From the filtrate, amount of supernatant was removed and preserved at 4 ℃. Intestinal reaction stage: The mixture (pH=7) was further incubated for 6 h at 37 ℃, and then did as same as stomach reaction stage's. All of the samples were done under anaerobic conditions.

2.5 Sample testing and quality control

Environmental samples were tested by flame atomic absorption spectrometer (Z-2000 Hitachi Zeeman atomic absorption spectrophotometer made in Japan) and GB detection method (GB/T 160.10-2004, GB/T 22105.3-2008, GB/T 5750.6-2006, GB/T 5009.12-1996). Detection written by Lin[10] could be for reference to detect in vitro experimental samples. Standard substances and samples should be repeated analyzed in detection, and uncontaminated reagents and equipment also should be used. Determination of precision of standard deviation was all less than 3%. Methods of atomic absorption spectrophotometry test were good and precision.

3 Results and discussion

3.1 Research required parameters

IEBUK model and ALM model needed a large amount of parameters during the research of the affection of blood lead levels on population lead exposure. These parameters were divided into four categories: human exposure parameters, bioavailability, lead pollution levels in environmental media, special parameters. Most of researchers recommended model recommended values when they use IEBUK model and ALM model, but this study would optimize these research parameters, such as the basic parameters of regional population, lead pollution levels in environmental media, bioavailability of different media adopting laboratory testing and questionnaire because of the difference between American and Chinese, such as their own behavior, living habits, operation of different races in the human body's physiological-biochemical effects.

Human exposure parameters described the parameters of the amount of the human body's exposure to the outside world and rate through breath and mouth and human characteristics, such as weight and height. Evaluation of human exposure parameters was an important factor in foreign substance dose[11,12]. IEBUK model involved different routes of exposure parameters: dietary intake (cereal, vegetables, fruits, meat, fishes), drinking water intake, soil and dust intake, time outdoors, respiration rate. Besides, the type of food intake of such substances in accordance with production rate of local market statistics was more than 5%, and the average daily intake was higher than 0.1%. When calculating drinking water intake (direct

daily water intake and indirect water intake), it could measure water, tea and other direct water and rice, noodles, soup, porridge and other indirect water by way of inquiries and actual measurement. The parameters of soil and dusk intake of children were lack of the value of the actual investigation values[13], but most of people in the world believed that the parameters of soil and dusk intake for children at various stages generally had versatility. A total soil and dust intake of 0~1 years old children was 0.06 g/d and a total intake of 1~7 years old children was 0.11 g/d[14]. Time outdoors were counted up by way of inquiries and video recording. Estimation of respiration rate using the measured parameters of height, weight, et al adopted method of human energy metabolism [15]. These children's exposure parameters of IEUBK model were in Table 1.

Table 1. Children's Exposure Parameter Values in this Study Area

Exposure parameters		Ages		Data resources
		0~1years old	1~7years old	Measured
Dietary intake	Cereal	0 g/d	202 g/d	Measured
	Vegetable	0 g/d	74.5 g/d	Measured
	Fruit	0 g/d	107.2 g/d	Measured
	Meat	0 g/d	95.9 g/d	Measured
	Fish	0 g/d	6.05 g/d	Measured
Water intake		0.431 L/d	0.4895 L/d	Measured
Soil and dust intake		0.06 g/d	0.11 g/d	Literature
Time outdoors		1 h	3.5 h	Measured
Respiration rate		4.62 m^3/d	7.28 m^3/d	Calculated

The model set bioavailability of different media, such as soil, dust, water and food. This study using simulated human gastrointestinal status would measure bioavailability of lead from four kinds of media to predict children's blood lead concentrations, specific values in Table 2.

Table 2. Bioavailability of the Exposure Media

Exposure pathways	Parameter name	Exposure pathways	Range	Data resources	Value
Soil	Bioavailability	Gastrointestinal	3.16~36.84%	Measured	20%
Dust		Breath	5~67.2%	Measured	36.1%
Drinking		Gastrointestinal	31~89%	Measured	60%
Diet		Gastrointestinal	12.8~73.2%	Measured	43%

There needed to be input the parameters of specific values of lead pollution levels of four mediums including air, food, drinking water, soil and dust, as well as children's health threshold for blood lead and so on when soil lead environmental baselines on residential land using IEBUK model were reversed down.

ⅰ The lead levels of air: The air was collected in this study area , and lead levels was measured ranging from 0.13~0.46 μg/m^3. According to 《Ambient Air Quality Standard》(GB 3095-2012), maximum allowable concentration in ambient air of lead in season average was 1 μg/m^3, so soil lead environmental baselines were deduced from the mean 0.36 μg/m^3 that was measured with the area

selected by the model. Besides, region and the indoor air was measured ranging from 0.09~0.126 μg/m^3, so the mean was 0.108 μg/m^3, and lead concentration ratio of 30% indoor and outdoor was calculated.

ii Lead content of food: The human got lead through food, which would affect red blood cells, brain and nervous system[16], etc. According to lead content standards in food media in 《Contaminants in Foods》 (GB 2762-2005) combined with survey measured results, children aged from 0 to1 years old were a day intake of 0 g, and children aged from 1-7 years old were a day intake of 202 g、74.5 g、107.2 g、95.9 g、6.05 g. After testing, its average lead content was 0.092 mg/kg、0.056 mg/kg、0.085 mg/kg、0.125 mg/kg、0.159 mg/kg. It was added up total lead of total child feeding. By estimating, children's intake of lead every day through dietary aged 0-1 and 1-7 were 0 and 44.81 μg/d in the study area.

iii The Lead content of drinking water: The concentration rate of drinking water's risk was greater because the daily intake of drinking water and the bioavailability were relatively high. The regulation of lead content of groundwater was 0.01 mg/L in《Drinking Water Standards》 (GB 5749-2006). Drinkable groundwater in the study area was the main source of exposure of children, so local drinking water was collected and lead measured was ranging from 0.64 to 0.72. Lead content in drinking water defaults selected by model was 0.67 μg/L.

iv The lead levels of dust: The lead of dust could produce health hazards in the children's body from breath and hand-mouth. Lead of dust in surface was an important source of lead exposure in children's blood lead. Indoor dust of local residents was collected, and the average lead content of dust was 25.4 mg/kg. Therefore, this figure was soil environmental baseline derived from model parameter in residential land.

v Blood lead levels of children: A large amount of researches[17] showed that blood lead level of 10 μg/dL would have a significant impact on intelligence, physical development, learning and sensory function of children. The research was estimated by the model that the blood lead content of the geometric mean was 5.66 μg/dL. When the probability of blood lead content of children aged from 0 to 7 years old more than 10 μg/dL was 10.65%. The model chose geometric standard deviation 1.58 of blood lead concentration of children that was studied by Chinese scientists[18] to substitute into the model.

What's more, there was lack of the actual investigational values in China from children pulmonary absorption rate and soil weighting facto [19]. Therefore, default values used by model were 32% and 45%.

The model involved the average annual exposure to lead-contaminated scene number of days and the average exposure to lead-contaminated scene number of days when soil lead environmental baseline basing on blood lead levels of healthy adults was derived from ALM model. These parameters of two types through questionnaires were 365 and 220 days. It was noted that this research about the number of days of lead-contaminated scene was based on the days that the respondent was entirely in indoor or on outdoor less than 2 h and outdoor locations remote from lead-contaminated sites (such as roads). Intestines and stomach could absorb the efficiency of 20% from human body by experiment. Task force searched all published literature of Chinese Text from 2005 to 2013 and counted up that blood lead levels of Chinese pregnant women were 1.143[20]~7.217μg/d[21]. This study values geometric mean 3.86 μg/dL and geometric standard deviation 2.03. According to US EPA exposure parameters reference manual [22], adult daily soil ingestion rate was 0.05, probability of target value of fetal blood lead levels of 95% was 10 μg/dL, probability of level value of protective populations of target blood lead concentrations was 1.645. Other parameters were also more detailed from international public reports. Pocock[23]found that slope coefficient between blood lead and daily ingestion of lead content was 0.4 d/dL when he investigated the relationship between the change of blood lead concentration of male adults from 24

different towns in England with the intake of water content. Sherlock[24]also found the same conclusion when he studied the effect of the amount of drinking water on blood lead of female adult. Therefore, the slope coefficient of this model was 0.4 d/dL. The scientists[25,26] found that the correlation coefficient between maternal and fetal blood lead levels was 0.9 in Kosovo and Yugoslavia etc. Besides, A researcher[8] used the coefficient with ALM model. But in the recent years, Chinese scientist He[21] chose 600 cases of pregnant women staying in Huzhou city more than five years and determined blood lead of pregnant women and their newborns and got the correlative analysis by graphite furnace atomic absorption spectrometry. It was concluded that maternal blood lead levels and neonatal blood lead levels were positively relevant, the correlation coefficient was about 0.6. So in this study, correlation coefficient of fetal and maternal blood lead was 0.6. Parameters of ALM model were shown in Table 3.

Table 3. The Parameter Values of ALM Model in this Study

ALM model	Value	Unit	Data sources
Long exposure time	365	d	Questionnaire
The number of days of annual average exposure to lead-contaminated scene	220	d/a	Questionnaire
absolute gastrointestinal absorption fraction for ingested lead in soil or in dust derived from soil	20	%	Analog measured
the background blood lead levels of the Pregnant women without lead exposure	3.86	μg/dL	Calculation and literature
geometric standard deviation of blood lead levels for women of childbearing age	2.03	—	Calculation and literature
intake rate of soil	0.05	g/d	Manual exposure parameters
95% probability of target of fetal blood lead levels	10	μg/dL	Manual exposure parameters
Probability values to protect populations according to the blood lead concentration level of the set target	1.645	—	Manual exposure parameters
the slope coefficient of blood lead and daily intake of lead content in the human body	0.4	d/dL	Literature
constant of proportionality between fetal PbB concentration at birth and maternal PbB concentration	0.6	—	Literature

3.2 Derivation of the reference value of soil lead basing on human blood lead

Derivation results of IEBUK model showed that critical value of soil lead levels was 180 mg/kg when geometric mean of blood lead levels of children aged 0-7 was 5.66 μg/dL and probability of blood lead levels exceeding 10 μg/dL was 10.6%. Reference value of environmental soil lead predicted by adult blood lead model (ALM) was 555.6 mg/kg. Generally speaking, environmental baseline values were not the so-called largest single concentration or no effect dose. They didn't lead to adverse effects or harmful effects over the dose and concentration. In a word, they were a multi-objective function and range values basing on different objects of protection [27]. Blood lead levels of healthy human bodies (children, adults (pregnant women)) in this study were relatively values, and that healthy effects exceeding health

threshold were the relatively effects. Besides, there were also influence objects belonging to different effects, although receptors were susceptible. Therefore, the range of soil lead references based on human blood lead in this study was 180~555.6 mg/kg. Now, standard value of soil lead of our national residential land was 300 mg/kg, and standard value of soil lead of industrial/commercial land was 600 mg/kg (GB 15618-2008). Reference value of environmental lead basing on children health in this study was below the national environmental quality standards currently published of residential land, and reference value of soil lead of adult health was below standard value of residential, industrial and commercial land. It was showed by 《Technical Guidelines of Risk Assessment on Contaminated Site》 (draft for approval)[3] that soil start value of residential land was 400 mg/kg and industrial and the other land was 800 mg/kg. In conclusion, reference value of environmental soil deduced from study was below soil start value in "Technical Guidelines of Risk Assessment on Contaminated Site" currently published, and soil lead of adult health was far below soil start value of industrial and the other land.

In the recent years, with the deep of research on healthy effects of lead in the world, lead has been a likely carcinogenic pollutant and had more serious damage to children in EPA[28]. Many developed countries formulated soil environmental baseline based on children's health risks. U.S. Sixth District[29], Belgium[30] and England[31] adopted healthy risk model of children's blood lead to make reference value of soil environmental lead. Each of standard values of soil lead of residential land was 400 mg/kg、700 mg/kg、450 mg/kg, and each of industrial and commercial land was 800 mg/kg、2500 mg/kg 、750 mg/kg. Canada[32]and Switzerland[33] used the method of ecological risk assessment to derive. All of standard values of soil lead of residential land were 400 mg/kg, all of industrial and commercial land were 2000 mg/kg. The reference value in this study had difference with the other countries, presumably because it was related to exposure pathways, exposure dose and ingestion rates.

3.3 Sensitivity analysis

3.3.1 Sensitivity analysis of single factor in the model

The parameters of IEBUK and ALM model were Carlo analyzed by using Crystal ball 7.2.2, and the change of model's single factor having an impact on prediction was preliminary discussed. Sensitivity analysis of the parameter of IEUBK model's exposure module showed that the lead of soil concentration (c_{soil}), the lead of dust concentration (c_{dust}), the lead of air concentration (c_{air}), the drinking water of lead concentration (c_{water}) in the model's sensitivity were 32.7%、32.7%、50.8%、50.8%. Besides, total intake of soil and dust ($IR_{soil+dust}$), air volume of children daily intake (VR) and daily water intake (IR_{water}) in the model's sensitivity were 35.1%、32.2%、49.2%、49.2%. The proportion of direct ingestion of soil accounting for soil (WF_{soil}) and dust (1- WF_{soil}) were both 35.1%. Thus, these measured parameters of c_{dust}、c_{air}、c_{water}、IR_{water} in the model were positively sensitive, and the sensitivity of 32.2%-50.8% had a great effect on the model's exposure module in Figure 1. Absorption module was related to parameters of bioavailability and absorption rate of different exposure media of body. Absorption rate of air, food, soil, water, dust (ABS_{air}、 ABS_{diet} 、ABS_{soil}、 ABS_{water}、ABS_{dust}) in the model's sensitivity was ranging from 13% to 6.1%, and the bioavailability was ranging from 12.2% to 7.2%. Both of them were positively sensitive, and it would have a big impact on the results of derivation in Figure 2. The analysis of parameters of adult blood lead model (ALM) showed that 95% probability of target values of fetal blood lead levels and long exposure time were positively sensitive. Geometric standard deviation of blood lead levels of women of childbearing age ($GSD_{i,adult}$), probability level values of protective population according to the set target of blood lead concentration (n), the correlative coefficient of fetal and maternal

blood lead levels ($R_{fetal/maternal}$), pregnant women's blood lead levels without exposure lead ($PbB_{adult,0}$), the slope coefficient of blood lead and daily intake of lead content (BKSF), number of days of the average exposure to lead-contaminated scene (EF_s), absolute gastrointestinal absorption fraction for ingested lead in soil or in dust derived from soil(AF_s), daily intake rate of soil (IR_s) were negatively correlative. GSD、n were up to -39.6%、-19.5%, and the other parameters were ranging from -13.4 to -1.2%. AT、EF_s、、AF_s were the measured parameters in this model, and they would have an influence on calculations of model in Figure 3.

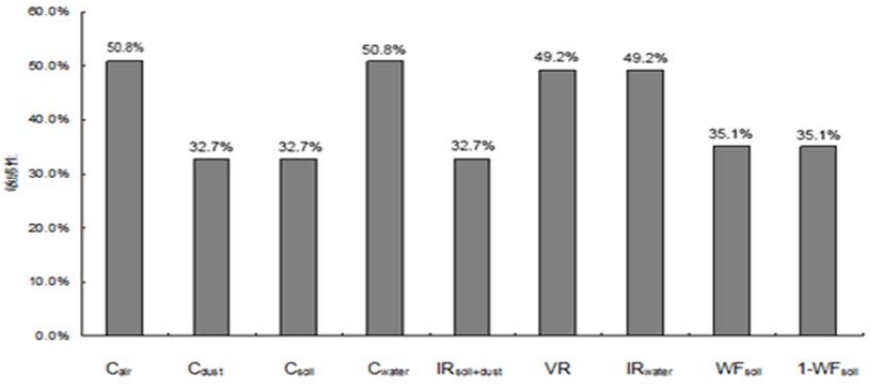

Figure2. Sensitivity of Exposure Parameters in the Media of Soil, Dust, Drinking Water, Air

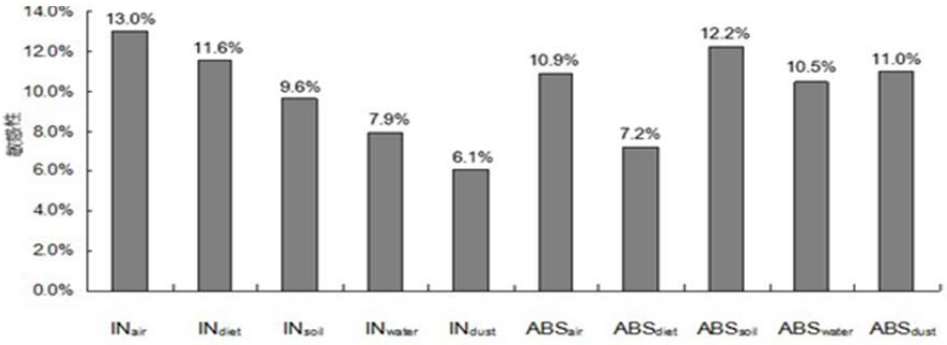

Figure 3. Sensitivity of each Risk Parameters of Children's Exposure in the Media

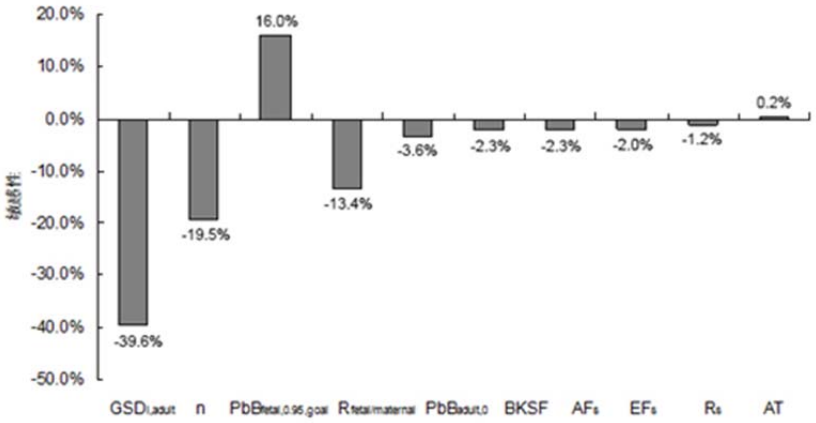

Figure 4. Sensitivity of Risk Parameters of Lead Exposure in the Adult Blood Lead Model

3.3.2 The analysis of exposure pathways model involved

From the comprehensive analysis results of single factor on IEUBK model (Figure 3), lead exposure intake and bioavailability of single factor from respiratory exposure pathways had a great influence on results of model. However, from the model, media of respiratory system involved atmosphere and dust, and media of digestive oral exposure involved soil, drinking water, food and so on. Although the single factors were not high, the amount of accumulating digestion and absorption would have a great effect on children health. There were a lot of similar conclusions in the world. American scientist Succop[34] investigated 1855 younger than 72 months of children's blood lead levels and exposure pathways and other relevant data for statistical analysis for 15 years on their 11 study area, and found that major sources of children's lead exposure were from indoor air and 0utdoor dust. Lanphear[35]studied lead concentration of indoor dust and soils of residential land having an effect on children's lead levels in 10 years in American, and found that lead pollution of indoor dust was a major source of children's lead exposure. Wang[36]studied Shenyang environmental lead pollution having an effect on children health, and found that the correlative coefficient of children's blood lead and pollution of air was 0.634. Therefore, it was concluded that lead pollution of air and local children's blood lead was significantly correlated. However, the oral contribution rate on the research of the health risks of lead exposure was greater. England scientist Davies [37] researched the related information of 72 urban children of 2 years old in Brimingham city. It was showed that 97% of ingested lead was from eating and drinking water, and children's blood lead concentrations were mainly from the oral route of exposure. Chen [38] researched blood lead levels of 404 pupils and their dietary conditions, and found that the average daily food intake of high blood lead students were higher than low blood lead students'. Therefore, children's blood lead levels were related with the oral exposure pathways. Li[39] collected soil in the surrounding area where is a lead-zinc zone in the Dongguanzhen of Shangyu city of Zhejiang province, and evaluated human health risks. It was showed that oral risk exposure of adults and children was highest.

ALM model was designed only a single exposure route, and most of countries used parameter of universal value. However, because of the difference of national and district race and lifestyle, and individual difference in the survey, especially the model for vulnerable populations of pregnant women and fetuses, it used to consider the measured parameters and selected parameters according to characteristics of Chinese populations and literature. The latest international findings found that effects of lead exposure on adult blood lead had diverse ways, mainly in the respiratory and oral route of exposure. Brazilian scientist Zentner[40]surveyed blood lead levels of 55 pregnant women living near lead smelter, and detected their blood lead levels were very higher than the control area. It was initially speculated that breathing exposure pathway led to the high blood lead levels of pregnant women. Lim[41]investigated blood lead levels of 123 pregnant women living in urban and rural area of Malaysia. The result showed that blood lead levels living in urban area were higher than pregnant women's in rural area, so it was concluded that environmental lead exposure had an impact on pregnant women. Chinese scientist Lu[42]investigated 505 cases of maternal blood lead levels in the Ningde city of Fujian province, and inquirer investigated family and environmental factors. It was found that maternal blood lead level had a significant correlation with air pollution and dietary factors, and maternal blood lead came from breathing and oral route of exposure. Xiang[43]researched 167 pregnant women near lead contaminated areas focusing lead battery enterprise in Zhejiang province, and investigated changes in blood lead concentrations during pregnancy and their influence factors. He found that blood lead concentrations during early pregnancy had an influence on eating rates of slight lead contaminated vegetables using univariate analysis.

Although a single exposure route on ALM model leaded derivation results to deviate, there had no other model beyond ALM model. Therefore, the development of this model in this study was one of the hotspots about health benchmarks in the future.

3.4 Some problem in this study

ⅰ When adopting two models (IEUBK, ALM), children's health risk model involved exposure pathways (absorption, dietary) and exposure media (soil, dust, air, drinking water, food), but adult health risk model only considered direct intake of soil and lead exposure pathways of indoor dust. Predictions of the two kinds of models were not the same. The conclusion of research still had a certain reference value because of prediction of main exposure pathways for different receptors. In addition, the two models didn't involve skin exposure pathway. The research team in previous studies found that strengthen organ protection to reduce skin exposure to lead in the procession of dismantling electronic waste and blood lead levels of occupational exposure showed a positive correlation[44]. It was preliminary thought that skin exposure to lead pathway had a negative effect on human body. The researchers needed to consider human health in the latter part of the study of environmental baseline.

ⅱ Derivation of this research and the predicted lead benchmarks for soil didn't lead into standards of residential land and standards of industrial/commercial land. Some regions of American made reference value of the soil environment on the people's health, and adopted IEUBK model, but this research was not considered. Besides, ALM model was not considered living land that characterizing body's risks through characterization of industrial/ commercial land. Therefore, result in vitro of this model only had a reference on the standards of industrial/commercial land.

ⅲ This study simulated gastrointestinal bioavailability of lead in the state in vitro of experiments. Two models were both considered the same kind of results, and didn't distinguish between adults and children. There were many kinds of in vitro models in the world currently, and the types of the model were diverse. This study used the physiologically based extraction test (PBET). This test was first proposed by Ruby[45]. The result of research might have some differences from other tests. At present, it was reported in the world that children's and adult's gastrointestinal absorption rate were quite different[46]. However, the simulated methods had not gotten uniform recognition, which was the main reason why it is not classified in this study.

ⅳ There were many kinds of media by mouth when researching oral exposure to the crowd. The research was selected main oral media of regional population through questionnaire. However, due to the limited number of respondents and dietary diversity and complexity, and no considering a variety of cooking for regional populations, it might cause certain bias on the results of derivation.

ⅴ Pollutant concentration and parameters of model intake were determined. The research was optimized parameters through questionnaire and laboratory tests, and the model combining various criteria was determined the relative parameter values. However, it was found in the actual study that the accuracy of test results were highly correlated with experimental precision instruments and laboratory personnel skills. Besides, the detection of environmental media should have many times.

It was important clarified that the developers of this model used in this study were all Americans. Although achieving wide recognition in the international area, the application of model in China had not carried out. Therefore, whether the model was applicable to Chinese people or not needed to be further verified. In addition, there needed to be determined the migration and transformation of pollutants and human exposure pathways and population exposure characteristics. And it was related to regional

environmental characteristics and population characteristics. In the latter part of research of derived model basing on environmental baseline of human health, it needed to be considered all above. When using other similar models, it needed to confirmed models and optimized appropriate parameters.

4. Conclusion

(1) It was derived environmental standard value of soil lead basing on IEUBK model of American. By laboratory tests, questionnaires and literature query, the result showed that environmental baseline of soil lead was 180 mg/kg when geometric mean value of children's blood lead aged 0-7 years old was 5.66 μg/dL, and probability of blood lead level was exceeding 10 μg/dL was 10.6%. The environmental baseline was lower than Britain's and other countries'.

(2) Lead benchmark for soil of industrial/commercial land basing on American's ALM model in this region was 555.6 mg/kg. Compared with the other developed countries, it was much lower than American's and Australia's.

(3) It was explored that predicting results had effect on change of single factors of model's parameters by Carlo analysis of IEUBK and ALM model's parameters. Various parameter of IEUBK model had an positive sensitivity to health risks. Maximum sensitivity of lead concentration on air and drinking water were 50.8%. 95% probability of target value for fetal blood lead level in ALM model ($PbB_{fetal,0.95,goal}$) and long exposure time (AT) had an positive sensitivity. Each of them was 16.0%、0.2%. The rest were negative sensitivity. Optimizing 14/29 parameters for the two kinds of models of this study, it improved scientificalness and accurancy of derived results, and reduced uncertainty.

(4) Lead in the body by IEUBK and ALM model was coming from breath exposure and the oral route of exposure. It was showed by sensitive analysis that breath exposure had a great impact on model's results, and was higher than the oral route of exposure. But due to digestion and absorption of the oral exposure, the influential results of model were not ignored.

References

[1] Xu M, Yan ZG, He MM, et al. Human Health Risk-Based Environmental Criteria for Soil: A Comparative Study Between Countries and Implication for China. Environmental Science, 2013; 34(5), 1667-1678.(In Chinese)

[2] DB11/T 656-2009. Site guidelines of environmental assessment. Beijing: Beijing quality technical superivision.2009. (In Chinese)

[3] Department of environmental protection. Guidelines of contaminated sites for risk assessment techniques (for approval). (In Chinese)

[4] US EPA. Ambient Water Quality Criteria (Series). Washington D C: Office of Regulation Standard, 1980.

[5] Meng W, Liu ZT, Zhang N, et al. The Study on Technique of Basin Water Quality Target Management N: Pollutant Total Amount Control Technique in Control Unit. Research of Environmental Science, 2008; 21(1): 1-8. (In Chinese)

[6] Shi J, Liu M. Investigation on health risk by environmental lead pollution in children. Chinese Journal of Industrial Medicine, 2009; 2(1), 31-34. (In Chinese)

[7] Deshommes E, Prevost M, Levallois P, et al. Application of lead monitoring results to predict 0–7 year old children's exposure at the tap. Water Research, 2013; 7(7), 2409-2420.

[8] Zhang HZ, Luo YM, Zhang HB, et al. Development of lead benchmarks for soil lead of human blood lead level in China. Environmental Science, 2009; (10), 3036-3042. (In Chinese)
[9] US EPA. Review of adult lead models evaluation of models for assessing human health risks associated with lead exposures at non-residential areas of superfund and other hazardous waste sites. http://www.epa.gov/superfund/lead/products/adultreview,pdf. 2001.
[10] Lin LX, Li SX, Zheng FY. Application of in vitro bionics models for speciation analysis and bioavailability assessment of trace metals in marine algal soup. Chinese Journal of Analytical Chemistry, 2010; (6), 823-827. (In Chinese)
[11] Yu YJ. Health risk assessment and management techniques of environmental pollution. Beijing: Chinese Environmental Science Press, 2010;5-271. (In Chinese)
[12] Duan XL. Research methods of exposure factors and its application in environmental health risk assessment. Beijing: Science Press, 2011; 1-14. (In Chinese)
[13] Sheng XY, Xu JD, Shen XM. Main parameters and estimation formula of normal weight and height for Chinese children under 7 years old. Chinese Journal of Contemporary Pediatrics, 2009; (8), 86-89. (In Chinese)
[14] Duan XL. Research methods of exposure factors and its application in environmental health risk assessment. Beijing: Science Press, 2011; 164. (In Chinese)
[15] Yang Y, Yu YJ, Li DL, et al. Study of Residents' Breath Exposure Parameter in Wenling Area. Journal of Environment and Health, 2011; 28(8), 698-701. (In Chinese)
[16] Ruan Y, Ji XQ. Wen M, et al. Research progress of lead contamination detection technology in food. Gui zhou Journal of Animal Husbandry & Veterinary Medicine, 2012; 36(5), 12-15. (In Chinese)
[17] Wang SQ, Zhang JL. Blood lead levels of children in China. Journal of Environmental and Health, 2004; 21 (6), 355-360. (In Chinese)
[18] Dong ZM, Wu SM, Hu JY. Health risk assessment for children duo to lead exposure in some region of China. China Environmental Science, 2011; 31(11), 1910-1916. (In Chinese)
[19] Duan XL. Research methods of exposure factors and its application in environmental health risk assessment. Beijing: Science Press, 2011; 161-164. (In Chinese)
[20] Ye Y, Shan QD. Lishui blood lead levels in all pregnant women cycle changes. Chinese Journal of Health Laboratory Technology, 2013; 23(3), 726-727. (In Chinese)
[21] He PY, Zhou Y, Zhang B. Correlated investigation of Huzhou maternity and neonatal umbilical cord blood lead. Modern Practical Medicine, 2005;17(8), 500-501. (In Chinese)
[22] US EPA. Review of adult lead models evaluation of models for assessing human health risks associated with lead exposures at non-residential areas of superfund and other hazardous waste sites. http://www.epa.gov/superfund/lead/products/adultreview.pdf. 2001.
[23] Pocock SJ, Shaper AG, Walker M, et al. Effects of tap water lead, water hardness, alcohol, and cigarettes on blood lead concentrations cigarettes on blood lead concentrations. Journal of Epidemiology and Community Health, 1983; 37, 1-7.
[24] Sherlock JC, Ashby D, Delves H T, et al. Reduction in Exposure to Lead from Drinking Water and its Effect on Blood Lead Concentrations. Human Toxicol, 1984; (3), 383-392.
[25] Goyer RA. Transplacental transport of lead. Environ. Environ Health Perspect, 1990; 89, 101-105.
[26] Graziano JH, Popovac D, Factor-Litvak P, et al. Determinants of elevated blood lead during pregnancy in a population surrounding a lead smelter in Kosovo, Yugoslavia. Environ Health Perspect, 1990; 89, 95-100.

[27] Gan S, Lau E V, Ng H K. Remediation of soils contaminated with polycyclic aromatic hydrocarbons （PAHs）. Journal of Hazardous Materials, 2009; 72(2-3), 532-549.

[28] US EPA. Lead and compounds(inorganic)(CASRN 7439-93-1). U.S. Environmental Protection Agency, http://www.epa.gov/iris/subst/0277.htm, 2011.

[29] US EPA. Region 6 Human Health Medium-Specific Screening Levels. http ://www.dep.state.ok.us/lpdnew/HW/02screentable.pdf. 2009.

[30] Provoost J, Cornelis C , Swartjes F. Comparison of Soil Clean-up Standards for Trace Elements Between Countries: Why do they differ?. J Soils Sediments, 2006; 6 (3), 173-181.

[31] DEFRA and Environment Agency. Contaminants in soil: Collation of toxicological data and intake values for humans. Swindon: The R&D Dissemination Centre, 2002.

[32] Csmwg. Compilation and Review of Canadian Remediation Guidelines, Standards and Regulations. Ottawa: Science Applications International Corporation (SAIC), Environmental Technologies Program, 2002.

[33] Carlon C. Derivation Methods of Soil Screening Values in Europe. A Review and Evaluation of National Procedures towards Harmonisation U: Ispra,uropean Commission , Directorate General , Joint Research Centre, 2007.

[34] Succop P, Bornschein R, Brown K, et al. An Empirical Comparison of Lead Exposure Pathway Models. Environmental Health Perspectives, 1998; 106(6), 1577-1583.

[35] Lanphear BP, Matte TD, Rogers J, et al. The Contribution of Lead-Contaminated House Dust and Residential Soil to Children's Blood Lead Levels. Environmental Research Section, 1998; 79, 51-68.

[36] Wang CM, Ou YH, Wang JD. Impact of Lead Pollution in Environment on Children's Health in Shenyang City. Environmental Science, 2003; 24(5), 17-22. (In Chinese)

[37] Davies DJA, Thornton I, Watt JM, et al. Lead intake and blood lead in two-year-old U.K. urban children. Science of the Total Environment, 1990; 90, 13-29.

[38] Cheng FJ, Zhou ZX, Mo BQ. et al. Research of the relationship between children's food intake of lead and blood lead levels[J]. Practical Preventive Medicine, 2006; 13(1), 21-22. (In Chinese)

[39] Li J, Yu TM, Zhou J. Assessment of Health Risk for Mined Soils Based on Critical Thresholds for Lead, Zinc, Cadmium and Copper. Environmental Science, 2008; 29(8), 2327-2330. (In Chinese)

[40] Zentner LEA, Rondo PHC. Lead contamination among pregnant Brazilian women living near a lead smelter. International Journal of Gynecology and Obstetrics, 2004; 87, 147-148.

[41] Lim HH, Ong CN, Domala Z, et al. Blood lead levels in Malaysian urban and rural pregnant women. Public Health, 1985; 99(1), 23-29.

[42] Lu SL, Xia QQ, Wei SZ. et al. Investigation and analysis of 505 cases of maternal blood lead levels. Occupation and Health, 2004; 20(2), 63-64. (In Chinese)

[43] Xiang ZH, Shao DC, Wang B, et al. Changes of pregnant women blood lead concentrations and its impact factors in lead-contaminated area. Journal of Environmental & Occupational Medicine, 2010; 27(2), 83-86. (In Chinese)

[44] Yang Y, Lu XS, Li DL, et al. Effects of Environmental Lead Pollution on Blood Lead and Sex Hormone Levels among Occupationally Exposed Group in An E-waste Dismantling Area. Biomed Environ Sci, 2013; 26(6), 465-470. (In Chinese)

[45] Ruby MV, Davis A, Link TE, et al. Development of an in-vitro screening-test to evaluate the in-vivio bioaccessibility of ingested mine-waste lead. Environ Sci Technol, 1993; 27(13), 2870-2877.

[46] Cheng HZ, Gong CS, He LQ, et al. Health Risk Assessment of Lead in Urban Soil by Simulation Methods in vitro. Journal of Environment and Health, 2012; 29(3), 254-257. (In Chinese)