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Multimedia health risk assessment: A case study of scenario-uncertainty

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Abstract: Assisted by framework of multimedia total exposure model for hazard waste sites (CalTOX), potential influences of scenario-uncertainty on multimedia health risk assessment (MHRA) and decision-making were quantitatively analyzed in a primary extent under the Chinese scenario case by deliberately varying the two key scenario-elements, namely conceptual exposure pathways combination and aim receptor cohorts choice. Results show that the independent change of one exposure pathway or receptor cohort could lead variation of MHRA results in the range of 3.6×10^{-6}−1.4×10^{-5} or 6.7×10^{-6}−2.3×10^{-5}. And randomly simultaneous change of those two elements could lead variation of MHRA results at the range of 7.7×10^{-8}−2.3×10^{-5}. On the basis of the corresponding sensitivity analysis, pathways which made a valid contribution to the final modeling risk value occupied only 16.7% of all considered pathways. Afterwards, comparative analysis between influence of parameter-uncertainty and influence of scenario-uncertainty was made. In consideration of interrelationship among all types of uncertainties and financial reasonability during MHRA procedures, the integrated method how to optimize the entire procedures of MHRA was presented innovatively based on sensitivity analysis, scenario-discussion and nest Monte Carlo simulation or fuzzy mathematics.

Key words: scenario-uncertainty; multimedia health risk assessment (MHRA); comparative analysis; parameter-uncertainty

1 Introduction

Environmental risk assessment (ERA), as an assistant tool for decision-making, is more and more widely utilized in evaluating potential risk of hazard contaminant on human health or to eco-system [1−3]. Exposure pathways considered in ERA developed from past single medium, single pathway to recent multimedia, multi-pathways, multi-receptors [4−5]. With considerable improvement of risk assessment system, uncertainties remain a primary threat to the confidence level of MHRA (multimedia health risk assessment) for its increasingly systematic complexity [6−8]. The widely accepted components of systematic uncertainties include parameter-uncertainty, model-uncertainty and scenario-uncertainty [9]. Recent studies mainly focused on evaluating the effects of parameter-uncertainty quantitatively because it could be analyzed much simply. However, little work is conducted on the analysis of model-uncertainty and scenario- uncertainty [9−10]. Based on Refs. [11−13], it was convinced that the parameter-uncertainty could be controlled to good extent through the classical Monte Carlo simulation, artificial neural net method and fuzzy computing. On such background that some systematic safety analysts insisted model-uncertainty or scenario-uncertainty make smaller effects compared with parameter-uncertainty [14−15]. The possible effects of model uncertainty and scenario-uncertainty on the confidence level of MHRA were qualitatively analyzed by only a few researchers [16−17]. However, some of them presented that the scenario-uncertainty and model-uncertainty might play more important roles than parameter-uncertainty in overall uncertainties of MHRA [16−17]. The corresponding studies were limited largely due to the characteristics of scenario-uncertainty and model-uncertainty which includes characters of subjectivity, randomness and vague definition. Recently, a method for a quantitative analysis of scenario-uncertainty or model-uncertainty is seldom available in literatures, so does the way to reducing the possible influence of them.

With analysis about entire sources of systematic uncertainties, in this work, the scenario-uncertainty was considered as the probably chief origin of overall

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systematic uncertainties. The objectives of this manuscript were to quantitatively analyze the effects of scenario-uncertainty in a primary extent and then tried to find ways to optimize MHRA procedures by decreasing corresponding uncertainties. Soil from a contaminated site of one Chinese coastal city was selected as a scenario case to demonstrate the methodology. On the basis of analysis about possible exposure pathways in the scenario case, CalTOX was selected as a proper risk assessing tool. Afterwards, through the variation of the special scenario sets used for simulating the experts' subjective fault, possible influences of the scenario-uncertainty on MHRA results were quantitatively studied in a primary extent by the CalTOX model framework. Besides, according to literatures and practical experiences, the MHRA results were discussed from not only the view of the uncertainty-control and decision-making but also from the view of financial reasonability. At last, the optimized MHRA procedures were presented innovatively in consideration of inherent relationship of all three uncertainty types and financial reasonability during MHRA procedures.

2 Materials and methods

2.1 Definition of systematic uncertainties

Uncertainty is the difference between estimated value and truth-value generally. The widely accepted classification of uncertainties during MHRA procedures is from US EPA [9−10]: 1) Parameter-uncertainty, which is mainly caused by sampling error, variability, and measuring error; 2) Model-uncertainty, which is mainly caused by model simplified error and modeling relation error; 3) Scenario-uncertainty, which is mainly caused by scenario-describing error, summation and statistics error, imperfect analysis error and professional judging error. Further, scenario-describing error springs from providing incorrect or imperfect information to assessment. Summation and statistics error springs from assuming contaminant, which has a homogeneous concentration in measure of time and space. Imperfect analysis error springs from including or excluding special concerning exposure pathways. Professional judging error springs from combining improper pathways, choosing wrong mode, assessing method or untypical determination.

2.2 Case study

In this work, soil from a contaminated site of one Chinese coastal city was selected as a scenario case to demonstrate the methodology. The water head site of the city is sited on the suburban district, and the soil is likely contaminated by the heavy metal in some extent for the long-term waste water irrigation. In order to evaluate the potential risk of the soil heavy metal to the possible receptor cohorts, heavy metal Cr in soil from the water head site of the city was studied through the crossing-method sampling, and then soil samples were dissolved out and extracted by the HI-HF-HCI-HNO_3 acid method. At last, the concentrations of heavy metal Cr in these treated samples were detected by the AAS (Hitachi Z-5000). The results show that the average concentration of the Cr samples was 115.12 mg/kg, with a standard deviation 13.71 mg/kg. According to GB15618—1995, the concentration of Cr might cause unacceptable risk.

The important first step to implement risk assessment for a contaminated site is to develop conceptual materials multimedia flow the figure of the contaminated site. Figure 1 indicates the possible ways of conceptual materials multimedia flow involves in this scenario case. According to Fig. 1, the possible contaminated media included domestic air, vegetables, corps, farm animals, domestic water and soil. The corresponding exposure pathways includes ingestion of drinking water, ingestion of soil, ingestion of crop, dermal contact of soil, inhalation of shower air, ingestion of domestic animals, ingestion of milk, ingestion of shower water, ingestion of vegetables, dermal contact of shower water, inhalation of shower air, and inhalation of indoor and outdoor air.

Except the special scenario input-parameters (in Appendix A), the other parameters all referred to values recommended by the US EPA [18−19] in the entire paper, such as materials chemical physics properties, the risk accepted threshold.

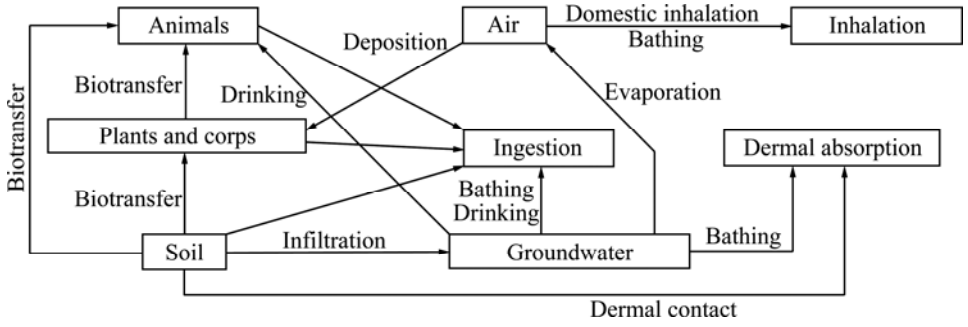

Fig. 1 Conceptual materials multimedia flow figure of contaminated site

2.3 Framework of multimedia assessment model

Multimedia total exposure model for hazard waste sites [20], called CalTOX for abbreviation, is designed by the Lawrence Berkeley National Laboratory, USA, and has been developed for performing site-specific risk assessment. CalTOX is designed for modeling contaminants in soil inter-transporting among air, soil, surface water, groundwater and sediment mediums based on the fugacity approach developed by MACKAY [4], which evaluates the correspondingly possible risk to the human health. CalTOX is based on the Microsoft Windows operating platform, and is developed to the CalTOX 4.0 version which can be utilized efficiently by its pivot table form. CalTOX is designed with the conceptual materials transporting flow figure (Fig. 2) and contains the 30 possible exposure pathways (Table 1) [19−22].

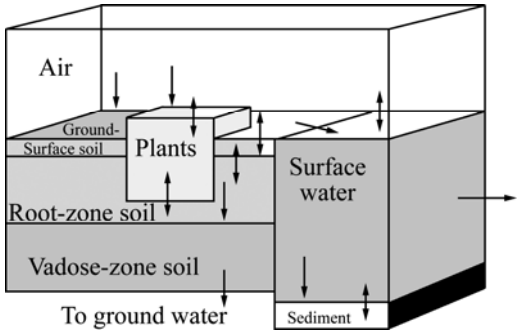

Fig. 2 Conceptual materials transporting flow figure in CalTOX

According to Table 1 and Fig. 2, the contaminated media and the exposure pathways considered in CalTOX contain almost all of the contaminated media and the exposure pathways of the scenario case. Therefore, CalTOX was fit with the scenario case theoretically.

2.4 Theory

Study presented that considering and modeling different pathways, using different reference standards, adopting different factors of materials' migration transformation rule, aiming at different receptor cohorts in different models and so on, might all give rise to the issues of uncertainty on MHRA results as the sources of scenario-uncertainty. Due to practices of employing the different models in MHRA, the sources of scenario-uncertainty, such as accepted risk standard and adopting different factors of materials' migration transformation rule, were always limited to the domestic regulations. Therefore, the aim receptor choice and the different pathways considered in the special site-scenario became chief uncertain elements of scenario-uncertainty, and might give much more influence on final decision-making.

Table 1 Conceptual exposure pathways considered in CalTOX

No.	Name
1	All inhalation exposures indoors active
2	All inhalation exposures indoors resting
3	Inhalation exposure in shower/bath
4	Inhalation exposures outdoors active
5	Inhalation of air particles indoors
6	Transfer of soil dust to indoor air
7	Transfer of soil vapors to indoor air
8	On-site inhalation by animals
9	Use of ground water as tap water
10	Use of surface water as tap water
11	Ingestion of tap water
12	Use of ground water for irrigation
13	Use of surface water for irrigation
14	Contaminant transfer, air to plants surfaces
15	Contaminant transfer, grnd. soil to plant surfaces
16	Contaminant transfer, root soil to plant tissues
17	On-site grazing of animals
18	Use of ground water for feeding animals
19	Use of surface water for feeding animals
20	Ingestion of home-grown exposed produce
21	Ingestion of home-grown unexposed produce
22	Ingestion of home-grown meat
23	Ingestion of home-grown milk
24	Ingestion of home-grown eggs
25	Ingestion of locally caught fish
26	Direct soil ingestion
27	Soil contact exposure at home or at work
28	Dermal exposure during shower/bath
29	Dermal and ingestion exposures while swimming
30	Breast-milk ingestion by infants

In order to reflect and primarily quantize possible effects of scenario-uncertainty triggered by two key elements in MHRA procedures, at first, owing to the supposed counter-accordance of experts, the three series of the different scenario sets were designed excluding only one exposure pathway from the overall 30 exposure pathways considered in CalTOX: 1) Scenario-1 was the scenario in which each different exposure pathway from all 30 pathways considered was excluded, respectively; 2) Scenario-2 was the scenario in which aim receptor cohorts was changing into 17 different receptor cohorts, respectively; 3) Scenario-3 was the four scenarios which randomly excluded the two exposure pathways from all

30 exposure pathways considered, and then modeling for the every receptor cohorts, respectively. On the basis of the case study, MHRA procedures under condition of every different scenario series were performed on the premise that input-parameters of the entire corresponding risk modeling were handled with the Monte Carlo simulation in order to control the parameter-uncertainty. Furthermore, the sensitivity analysis was done to make sure which exposure pathway made bigger contribution to gross risk value. MHRA results of different scenario sets were discussed not only from the view of the decision-making but also the view of financial reasonability. Ultimately, the innovative suggestions were given to optimize the whole MHRA procedures considering all three types of uncertainties.

3 Results and discussion

3.1 Independent scenario-variation of exposure pathway

Only one-sixth of all 30 exposure pathways, including the NO.1 (ignoring all inhalation exposures indoors active pathway), NO.2 (ignoring all inhalation exposures indoors resting pathway), NO.4 (ignoring inhalation exposures outdoors active pathway), NO.5 (ignoring inhalation of air particles indoors pathway), and NO.6 (ignoring transfer of soil dust to indoor air pathway), made a valid contributions to the final MHRA results. Figure 3 shows that the independent change of one exposure pathway could lead variation of MHRA results in the range of 3.6×10^{-6}–1.4×10^{-5}. Compared with risk value of NO.31 (including all 30 pathways), the single-factor scenario-variation made the assessing risk results varying in the range of one order of magnitude generally. Moreover, some conditions led the risk value, such as 3.6×10^{-6}, approaching to the accepted-threshold, 1×10^{-6} (US EPA) in Fig. 3. All the trials above kept the same receptor cohorts.

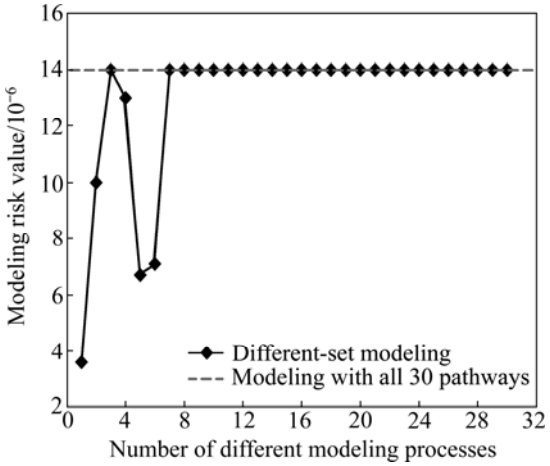

Fig. 3 Modeling risk value of one exposure pathway variation (Note: The NO.X trial means one time modeling process without considering the NO.X exposure pathway; NO.31 trial means the modeling process which contains all 30 exposure pathways)

3.2 Independent scenario-variation of receptor cohorts

The maximum risk was mainly caused in the cohorts of the male and the female at the age of 0−3. And the risk value was decreasing with the increasing age of the cohorts generally. The potential risk of the male and female at the same age cohorts differed, and generally the risk value of the male was a little higher than the corresponding risk value of the female at the same age. And the figures which manifested the maximum risk value, 2.30×10^{-5}, appeared at the receptor cohorts of NO.2 (male at the age of 0−1) and NO.3 (male at the age of 0−3). By contrast, the minimum risk value, 6.7×10^{-6}, appeared at the NO.17 (female at the age above 19). The risk value of the residential receptor cohorts was likely to be the average value of the risk results of the 17 different receptor cohorts (Fig. 4). Comparing maximum risk result with the minimum risk result, the single-factor scenario-variation made the assessed risk results difference at the range of one order of magnitude generally. All trials above kept all the 30 exposure pathways considered.

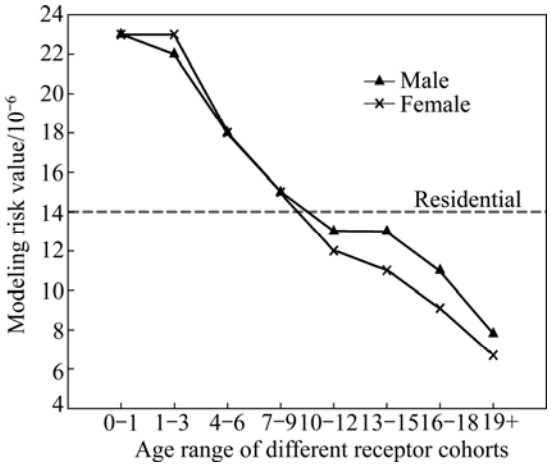

Fig. 4 Modeling risk value to different receptor cohorts (Note: The different receptor cohorts contains residential; male(M): age(0−1), age(1, 2, 3), age(4, 5, 6), age(7, 8, 9), age(10, 11, 12), age(13, 14, 15), age(16, 17, 18), age(19+); female(F): age(0−1), age(1, 2, 3), age(4, 5, 6), age(7, 8, 9), age(10, 11, 12), age(13, 14, 15), age(16, 17, 18), age(19+), and correspondingly match to the NO.1−17)

3.3 Randomly simultaneous scenario-variation of two elements

By the co-effect with the varying receptor cohorts and the varying exposure pathways (excluded two exposure pathways from all the 30 exposure pathways

randomly), the assessed risk value led to a variation in the maximum range of three orders of magnitude. On the condition of excluding NO.5 and NO.6 exposure pathways from all the 30 exposure pathways, the outputting risk value reached the peak of 1.5×10^{-6}, the lowest point of 7.7×10^{-8} (Fig. 5). On the condition of excluding NO.2 and NO.3 exposure pathways from the all 30 exposure pathways, the outputting risk value reached the peak of 1.4×10^{-5}, the lowest point of 4.1×10^{-6} (Fig. 6). On the condition of excluding NO.1 and NO.5 exposure pathways from the all 30 exposure pathways, the outputting risk value reached the peak of 6.2×10^{-6}, the lowest point of 1.3×10^{-6} (Fig. 7). On the condition of excluding NO.29 and NO.30 exposure pathways from the all 30 exposure pathways, the outputting risk value was at the max of 2.3×10^{-5}, at the min of 6.7×10^{-6} (Fig. 8). From these data, the minimal and maximal relative effects were the NO.17 7.7×10^{-8} (Fig. 5) and NO.2 2.3×10^{-5} (Fig. 8), respectively, similarly fluctuating around the accepted threshold 1×10^{-6}. Furthermore, male receptor cohorts was much tender than that of the corresponding female receptor cohorts. Besides, the representativeness of the receptor cohorts of the residential was not proper to every scenario obviously.

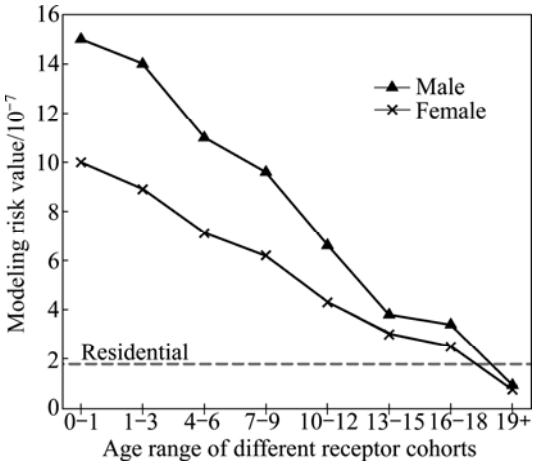

Fig. 5 Modeling risk value excluding NO.5 and NO.6 exposure pathways

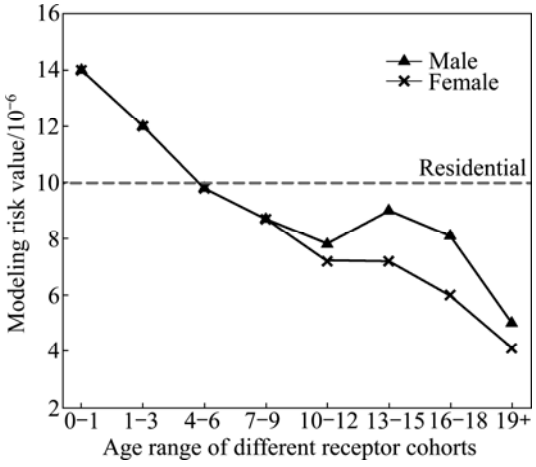

Fig. 6 Modeling risk value excluding NO.2 and NO.3 exposure pathways

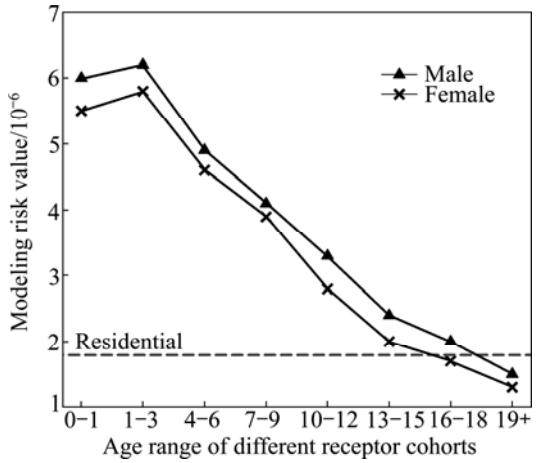

Fig. 7 Modeling risk value excluding NO.1 and NO.5 exposure pathways

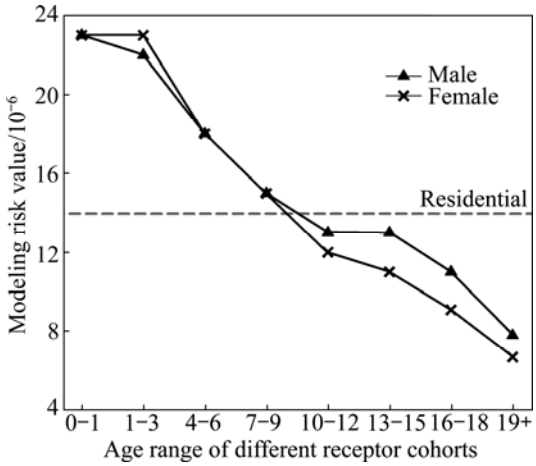

Fig. 8 Modeling risk value excluding NO.29 and NO.30 exposure pathways

3.4 Discussion

3.4.1 Comparative analysis between scenario-uncertainty and parameter-uncertainty

A few researchers presented the scenario-uncertainty would give rise to a big error in the decision-making. The risk value variation in this work, three orders of magnitude at max, proved that the scenario-uncertainty had even bigger influence compared with the parameter-uncertainty by the data quantized by a key element-cross analysis. Analogously, a classical trial from the LINKOV and the Fruit Working Group [23] indicated the scenario-uncertainty would be possible to cause the difference of the assessed results error to seven orders of magnitude to the extreme extent, much more than the one order of magnitude caused by the influence of parameter-uncertainty to the final modeling risk values. In short, more attentions must be

paid to the scenario-uncertainty especially in China where utilizing the MHRA model is almost a blank space. These conclusions made the references in future model building processes in China. The ways how to control and further exactly quantize the scenario-uncertainty should be the future study destination.

3.4.2 Decision-making error

The value of 1×10^{-6} is a widely believed accepted-risk standard made by the US EPA. Through the independent scenario-variation of the receptor cohorts or the one exposure pathway, the risk value was mainly above the 1×10^{-6}. However, the modeling risk values of about 10% trials were approaching to the 1×10^{-6} (i.e., Fig. 3: NO.1, 3.60×10^{-6} and Fig. 4: NO.17, 6.70×10^{-6}) or fluctuated around the 1×10^{-6} (i.e., Fig. 5). And when considering the scenario-variation of two elements simultaneously, the varying ranges of the modeling risk values were obviously extended (i.e., varying between 7.70×10^{-8} and 1.50×10^{-6} in Fig. 5). Our finding was added to the increasing evidences that the scenario-uncertainty could give enough effect leading to a decision-making error. Facing those problems, a few researchers deemed collecting more and more information was right the way to verify the final modeling risk value whether is above the set-standard or not. From the analysis on the risk values, it was unfeasible. Firstly, the aimless collection would be without any sense, and from the financial point of view, this information collection part was proved to be increasing the cost of the MHRA largely. On basis of the corresponding sensitivity analysis, there were only 16.7% of all the 30 exposure pathways which made a useful contribution to the final modeling risk value. This finding provided a key reference for reasonably reducing the cost of the assessment process by using the limit manpower and material resources to collect the more important information of scenario, and make a reasonable decision at last.

Secondly, from the view of choosing the receptor cohorts, though the risk value-fluctuation seemed to be a little less than the exposure pathway-variation risk value-fluctuation, the corresponding variation of the modeling risk value could also lead to wrong decision-making (Fig. 6). This finding was added to the increasing evidences that the common-representative residential-receptor cohorts, in fact, could not fit every scenario. Moreover, cohorts of our fragile children and pregnant women must arouse increasing attentions, and these trials provided a knowledge base for improving our own MHRA system, perfecting our law about the standard-setting and the transporting factors setting, in order to make a scientific future decision.

3.4.3 Suggestion

Though the influence of the scenario-variation on decision-makers was the chief topic in this work, all the three uncertainties should be considered synthetically in practice. According to Refs. [24−29] and the experiences of recent practices, the procedures with all the types of the MHRA uncertainties considered are recommended as follows:

1) Aiming at the contaminated source and the target pollutants, the experts build the conceptual pollutant transporting flow figure and the possible exposure pathways in the multimedia surrounding through the Delphi approach. And then, on the basis of the experience and the necessary simplification, establish the algorithm of the every sub-pathway for the aim pollutant. Secondly, according to the goal of the MHRA, to determine which standards will be adopted (i.e., the accepted threshold value of the aim receptor cohorts).

2) To confirm the most suitable assessing model, the intercomparison among different models would be studied based on the established conceptual pollutant transporting flow figure (to pay attention to the appropriateness of the scenario-model- parameter).

3) To collect the information by every possible ways, and then make a primary sensitivity analysis to guarantee which parameters make larger effect on MHRA result based on the selected assessing model and preliminary Monte Carlo simulation. Following the results of the sensitivity analysis, the parameters will be classified to four classes: ① The most contributed parameters, and must be presented by the proper probability distribution for the Monte Carlo simulation. ② The contributed parameters which cannot be collected with some limits, handling the problem by the fuzzy mathematics which not only need less information but also give equal probability to every possible value. ③ The inferior-important parameters, only needing an experienced value. ④ The parameters have little influence on the modeling risk value, using the available value or even ignoring them. Surely, the information of the large-contribution parameters should be collected further in order to reduce the parameter-uncertainty.

4) Finally, the plant-tree decision-making software can assist the decision-makers to make, to the further extent, an optimized decision.

4 Conclusions

1) It is found that independent change of one exposure pathway or one receptor cohort could lead variation of MHRA results in the range of 3.6×10^{-6}–1.4×10^{-5} or 6.7×10^{-6}–2.3×10^{-5}. And randomly simultaneous change of those two elements could lead variation of MHRA results in the range of 7.7×10^{-8}–2.3×10^{-5}. According to the MHRA results under different scenario sets, the effects of scenario-uncertainty

could drive the MHRA results varying at larger orders of magnitude (one to three orders of magnitude in this work) than one order of magnitude caused by effects of parameter-uncertainty.

2) On the basis of the sensitivity analysis, exposure pathways which make a valid contribution to the final modeling risk value occupy only 16.7% of all the considered exposure pathways. This conclusion provides a reference for reasonably reducing the unnecessary cost of the assessment procedures under the limited manpower and material resources.

3) Considering the proved importance of scenario-uncertainty and financial reasonability of assessment procedures, innovatively screening procedures are recommended and believed to promote reduction of all kinds of uncertainties by overall four steps.

4) Although the results of this case study cannot be generalized, this manuscript provides a theoretical reference to the future development of MHRA model in China.

Appendix A

Chinese city scenario case parameter	Value used	Average value	Coeff. Var.
Contaminated area/m^2	7.71×10^{11}	7.71×10^{11}	0.50
Annual average precipitation/$(m\cdot d^{-1})$	3.15×10^{-3}	3.15×10^{-3}	0.07
Flux; surface water into landscape/$(m\cdot d^{-1})$	0.00	0.00	0.10
Land surface runoff/$(m\cdot d^{-1})$	1.12×10^{-3}	1.12×10^{-3}	1.00
Atmospheric dust load/$(kg\cdot m^{-3})$	6.15×10^{-8}	6.15×10^{-8}	0.20
Dry deposition velocity, air particles/$(m\cdot d^{-1})$	5.00×10^{2}	5.00×10^{2}	0.30
Aerosol organic fraction	2.00×10^{-1}	2.00×10^{-1}	1.00
Volume fraction of water in leaf	5.00×10^{-1}	5.00×10^{-1}	0.05
Volume fraction of air in leaf	1.80×10^{-1}	1.80×10^{-1}	0.20
Volume fraction of lipid in leaf	2.00×10^{-3}	2.00×10^{-3}	0.20
Volume fraction of water in stem	4.00×10^{-1}	4.00×10^{-1}	0.15
Volume fraction of water in root	6.00×10^{-1}	6.00×10^{-1}	0.15
Primary production dry vegetation/$(kg\cdot m^{-2}\cdot y^{-1})$	9.00×10^{-1}	9.00×10^{-1}	1.00
One-sided leaf area index	3.63	3.63	0.40
Wet interception fraction	1.00×10^{-1}	1.00×10^{-1}	0.10
Avg thickness of leaf surface(cuticle)/m	2.00×10^{-6}	2.00×10^{-6}	0.20
Stem wet density/$(kg\cdot m^{-3})$	8.30×10^{2}	8.30×10^{2}	0.20
Leaf wet density/$(kg\cdot m^{-3})$	8.20×10^{2}	8.20×10^{2}	0.30
Root wet density/$(kg\cdot m^{-3})$	8.00×10^{2}	8.00×10^{2}	0.05
Veg attenuation fctr, dry interception/$(m^2\cdot kg^{-1})$	2.90	2.90	0.01
Stomata area frctn (area stomata/area leaf)	7.00×10^{-3}	7.00×10^{-3}	0.20
Effective pore depth	2.50×10^{-5}	2.50×10^{-5}	0.20
Boundary layer thickness over leafs	2.00×10^{-3}	2.00×10^{-3}	1.00
Leaf surface erosion half-life/d	1.40×10^{1}	1.40×10^{1}	1.00
Ground-water recharge/$(m\cdot d^{-1})$	1.59×10^{-4}	1.59×10^{-4}	1.00
Evaporation of water from surface water/$(m\cdot d^{-1})$	4.32×10^{-4}	4.32×10^{-4}	1.00
Thickness of the ground soil layer/m	1.00×10^{-2}	1.00×10^{-2}	1.00
Soil particle density/$(kg\cdot m^{-3})$	2.60×10^{3}	2.60×10^{3}	0.05
Water content in surface soil (volume fraction)/%	1.86×10^{-1}	1.86×10^{-1}	0.60
Air content in the surface soil (volume fraction)/%	2.79×10^{-1}	2.79×10^{-1}	0.17
Erosion of surface soil/$(kg\cdot m^{-2}\cdot d^{-1})$	5.46×10^{-4}	5.46×10^{-4}	1.00
Bioturbation/$(m^2\cdot d^{-1})$	1.20×10^{-4}	1.20×10^{-4}	1.00
Thickness of the root-zone soil/m	7.94×10^{-1}	7.94×10^{-1}	0.41
Water content of root-zone soil (volume fraction)/%	2.00×10^{-1}	2.00×10^{-1}	0.61

Air content of root-zone soil (volume fraction)/%	2.38×10^{-1}	2.38×10^{-1}	0.31
Thickness of the vadose-zone soil/m	7.01×10^{-1}	7.01×10^{-1}	0.28
Water content; vadose-zone soil (volume fraction)/%	1.94×10^{-1}	1.94×10^{-1}	0.56
Air content of vadose-zone soil (volume fraction)/%	2.01×10^{-1}	2.01×10^{-1}	0.41
Thickness of the aquifer layer/m	3.00	3.00	0.30
Solid material density in aquifer/($kg\cdot m^{-3}$)	2.60×10^{3}	2.60×10^{3}	0.05
Porosity of the aquifer zone	2.00×10^{-1}	2.00×10^{-1}	0.20
Fraction of land area in surface water	1.93×10^{-1}	1.93×10^{-1}	0.20
Average depth of surface waters/m	5.00	5.00	1.00
Suspended sediment in surface water/($kg\cdot m^{-3}$)	8.00×10^{-1}	8.00×10^{-1}	1.00
Suspended sediment deposition/($kg\cdot m^{-2}\cdot d^{-1}$)	1.05×10^{1}	1.05×10^{1}	0.30
Thickness of the sediment layer/m	5.00×10^{-2}	5.00×10^{-2}	1.00
Solid material density in sediment/($kg\cdot m^{-3}$)	2.60×10^{3}	2.60×10^{3}	0.05
Porosity of the sediment zone	2.00×10^{-1}	2.00×10^{-1}	0.20
Sediment burial rate/($m\cdot d^{-1}$)	1.00×10^{-6}	1.00×10^{-6}	5.00
Ambient environmental temperature/K	2.82×10^{2}	2.82×10^{2}	0.05
Surface water current/($m\cdot d^{-1}$)	0.00	0.00	1.00
Organic carbon fraction in upper soil zone	1.53×10^{-2}	1.53×10^{-2}	1.63
Organic carbon fraction in vadose zone	1.99×10^{-3}	1.99×10^{-3}	0.15
Organic carbon fraction in aquifer zone	1.99×10^{-3}	1.99×10^{-3}	0.15
Organic carbon fraction in sediments	2.00×10^{-2}	2.00×10^{-2}	1.00
Bndry lyr thickness in air above soil/m	5.00×10^{-3}	5.00×10^{-3}	0.20
Yearly average wind speed/($m\cdot d^{-1}$)	3.82×10^{5}	3.82×10^{5}	0.08

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