Editorial

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Risk assessment is a critical procedure in the course of effective decision-making regarding the management of environmental pollution. In recent years, numerous research efforts and advances have been made in this field. Such advances are important for guiding accurate evaluation and effective mitigation of environmental and human health risks, which are pursued by governments, industries, communities, and researchers around the world. The purpose of this special issue of *International Journal of Risk Assessment and Management* (*IJRAM*) is to present the latest research results of risk assessment for contaminated environments, and we selected four papers that deal with risk assessment for contaminated sites, groundwater systems, and lake water quality.

The insight about risks is usually limited by the randomness inherent in nature and the lack of sufficient information related to the chances of risk occurrence and the potential consequences of such occurrence. As a result, risk assessment is inherently linked with uncertainty, and the incorporation of uncertainty analysis within the risk assessment framework is thus of great importance for improving the confidence in risk assessment results and the decision-making effectiveness. Many efforts have been made by various researchers during the past years to address the uncertainty issues associated with risk

assessment, and the fuzzy set and possibility theory as well as the stochastic method were recognised as effective means for handling uncertainty.

One paper of this special issue presents a comprehensive study on human health risk assessment of contaminated sites under multiple uncertainties. This work integrated groundwater flow and contaminant transport models, exposure assessment models, physiologically-based pharmacokinetic (PBPK) models, and dose-response assessment models within a general human health risk assessment framework from contaminant source to disease endpoints for estimating the cancer risk posed by trichloroethylene (TCE) contaminated groundwater. The TCE concentration in a drinking water well was predicted using the groundwater flow and a contaminant transport model, and three exposure pathways of TCE were considered, including ingestion, inhalation and dermal contact. In particular, the carcinogenic risk of TCE to target tissues was carefully evaluated through examining TCE uptake, transport, metabolism, and excretion in human bodies using the PBPK models. Two types of uncertainties including random and non-random uncertainties arising from heterogeneous aquifer conditions, exposure assessment, PBPK models, and does-response assessment models were systematically considered, and a fuzzy-stochastic method was then developed to properly handle such uncertainties through transforming the probability density function to possibility distribution, which make the propagation of uncertainties among different models a transparent process, and this would effectively improve the decision robustness of risk management.

Another paper in this special issue developed an integrated fuzzy-stochastic risk assessment approach to evaluate the excess lifetime cancer risk posed by benzene-contaminated groundwater through quantifying both fuzzy and probabilistic uncertainties associated with contaminated site conditions and health impact criteria. Benzene concentrations required for health risk assessment model were obtained through the groundwater flow and contaminant transport model, and the hydrogeological parameters of porosity and intrinsic permeability were assumed to be associated with fuzzy uncertainty, which was handled through fuzzy set method. Particularly, this work considered the interrelationship between these two modelling parameters through a fuzzy multi-attribute decision analysis approach. By combining this approach with factorial design-based simulations, the benzene concentrations in groundwater under different fuzzy membership grades were obtained. Two parameters, including body weight and ingestion rate of contaminated water, used for exposure assessment were assumed to be associated with stochastic uncertainty, which was handled through Monte Carlo simulations. As a result, an integrated fuzzy-stochastic risk model was established, and the results obtained from this model reflect both the likelihood/probability and plausibility/possibility of risk levels for the exposed individuals within a population due to different types of uncertainty within the risk assessment process.

The third paper of this special issue presents a case study of risk assessment at a petroleum hydrocarbon site in China contaminated by leakage from an underground storage tank. Benzene was identified as the contaminant of concern, and the ingestion of benzene-contaminated groundwater was assumed to be the exposure pathway. The BIOPLUME III model was used to predict the spatial and temporal distributions of benzene concentration in groundwater at the study site under natural attenuation and pump-and-treat remediation scenarios, and the simulation results were then used for the evaluation of excess lifetime cancer risk levels. The distributions of different levels of risky zones at the study site under the two proposed remediation scenarios were thus

delineated. Although the uncertainties associated with risk assessment were not considered in this work, the obtained risk assessment results from this real world case study were useful for providing effective decision support for implementing remediation actions at the field contaminated site.

In addition to the risk assessment for contaminated site and groundwater system, this special issue also contains one paper that deals with risks associated with lake water quality. This paper reports a comparative risk assessment of lake water quality near a drinking water intake in a warm monomictic lake in Germany. Such a lake has different stratifications in winter and summer, and it mixes vertically during winter but is stratified into different layers due to temperature gradient during summer. Such seasonal stratification can generate different impacts on contaminant transport and fate in the lake. This work applied a numerical estuary and lake computer model (ELCOM) to simulate tracer transport in the lake under the impacts of seasonal stratification and different hydrodynamic conditions represented by different wind directions. The arrival time and concentrations of tracers at the drinking water intake were found to be dependent on seasonal stratification, wind direction, wind speed, distance of the tracer away from the location of concern, and the depth where the tracer was released. The simulation-based results from this work were helpful for effective decision-making to manage the environmental risks at the warm monomictic lake, and the proposed method has the potential to be applied to other lake water quality risk assessment problems.

In summary, risk assessment is a crucial component in the management of various environmental problems. The selected articles in this special issue on advances in risk assessment for contaminated environments provide an excellent overview on the latest development and practice of risk assessment within a variety of areas, and illustrate its effectiveness and importance for sound decision-making. We would like to thank all the authors who contributed to this special issue.