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A Study on Different Human Health Risk Assessment Tools for Contaminated Soil

Abhishek Dixit, Rahul Mishra and Manish Nigam

Department of Civil Engineering, PSIT College of Engineering, Kanpur, India
abhi,psit1@gmail.com

ABSTRACT

This study focused on the different tools which are used for the assessment of health risk due to contaminated soils in worldwide scenario. Some of the tools are useful for contaminated lands only but there is also availability of tools which have the features to assessment of risk for contaminated soil and water both. In this study, numbers of tools are studied with their features, developed by different countries to contaminated land management and remediation. England, Denmark England, United Kingdom, Netherland, Italy, Germany, Belgium and United States of America were also developed their different models for this problem. Addition to these models, some were also developed by different private agencies for land contamination problem exiting in lower middle income countries. DESYRE- (DEcision Support sYstem for REhabilitation of contaminated sites), SYRIADE (Spatial decision support sYstem for RegIonal Assessment of degraded Land) and GLOCOM (Global Partners in Contaminated Land Management) etc. were some of the Decision support system which were developed by the coloration of different counties. The paper has contained the overview of different tools used for contaminated land management.

Key words: Contaminated land, Remediation, Risk assessment

INTRODUCTION

Land contamination is a major environmental and infrastructural problem in industrial countries, with potential detrimental effects on human health, valuable water resources, sensitive ecological systems, property and infrastructure. The effective management of contaminated land typically involves multi-agency regulation and multidisciplinary expertise Land that is contaminated contains substances in or under the land that are actually or potentially hazardous to health or the environment or both. Land can become contaminated when hazardous substances are not used, stored or disposed of in a safe way. Contamination is not always limited to a specific site. Hazardous substances may seep through the soil into groundwater, or be carried to nearby land and waterways in rainwater or as dust. Hazardous gases can also pollute the air. The contamination can take a variety of forms therefore its impact also can be in variety of ways. Depending upon the type of contaminant present in the soil, its concentration and the pathway through which it reaches the target and consequent risk level one can predict the harm which may be caused to human health, crop, property and ecological system. Land contaminants include both chemicals and pathogens. These contaminants may cause a variety of health problem starting with minor problems like headaches, fatigues, skin rash, and eye irritation to major health issue. Risk assessment is the process of estimating the potential impact of chemical, physical, microbiological or psychosocial hazard on a specific human population or ecological system under a specific set of conditions and for a certain time frame.
Risk assessment gathers and organizes the information:

- Risks at a point in time and changes in risk over time to be estimated and whether action is necessary.
- Health guidance values to be estimated for environmental hazards that can be used and which will adequately protect public health.
- Assessment of new types of risk.
- Assessment of different types of risk.
- A comparison of the potential health impacts of various environmental health interventions.
- The identification and comparison of different factors that affect the nature and magnitude of risk.
- Risk based standards setting for regulatory exposure limits and cleans up levels.

Key factors in risk assessment:

Hazard Assessment

- Interactions with other agents in the environmental.
- Immediate or delayed onset of health effect
- Severity of health effects
- Reversibility of health effects
- Presence of a clear threshold for effects
- Potency of agents

Population

- Genetic variability
- Individual host characteristics (e.g. age, body weight etc.)
- Population characteristics

Exposure

- Duration of exposure
- Frequency and consistency of exposure
- Patterns of exposures
- Past, currents and future exposure
- Timing of exposure
- Exposure route (ingestion, inhalation or dermal contact)
- Cumulative and non cumulative exposure
- Failure of exposure control

Environmental

- Intervention strategies (e.g. containment of contaminated soil)
- Transport mechanics
- Factors affecting persistence (e.g. volatile nature of chemical)

Risk assessment of contaminated sites is somewhat different from risk assessment in most other fields. The evaluation of risk from soil contamination is not usually a preventive approach; the source is already there. In principle this makes the assessment easier because claims about exposure can be verified at the site. In practice, however, this advantage is rather limited due to the complexity of the source, the difficulties of performing experiments and (very often) the need to predict future exposure.

An analysis of the potential for adverse effects caused by a toxic chemical at a site and to determine the need for remedial action or to develop cleanup levels where remedial action is required.

Remediation of Contaminated Soil

An action including removal, chemical, physical, or biological treatment of soil, groundwater or other environmental media, intended to restore or improve the land condition impacted by chemical contamination.

Where an unacceptable risk is found to exist it is necessary to reduce the risk to an acceptable level. This may involve

a) Returning to the initial stages of the risk assessment process collecting further information and data reducing the uncertainty and reassessing the potential risk from the pollutant linkage: or
b) Apply risk management option to breaking the pollutant linkage. This may involve sources reduction, pathway management or protecting or reducing the exposure of the receptor.

The selection of appropriate remedial measures on the site must be made on a site specific basis and will be dependent on the range of factors including .The nature of the pollutant linkages present

- The contaminant (s) present
- The receptor
- Costs
- Local issues
- The nature of the pathway linking the contaminant and the receptor
- Time implications

LITERATURE REVIEW

Risk assessment is the process of estimating the potential impact of a chemical, physical, microbiological or psychosocial hazard on a specified human population or ecological system under a specific set of conditions and for a certain timeframe. Risk assessment is intended ‘to provide complete information to risk managers, specifically policymakers and regulators, so that the best possible decisions are made’ [1] Pollutants enter the environment directly as a result of accidents, spills during transportation, leakage from waste disposal or storage sites, or from industrial facilities [2] Computer based tools that address integration and evaluation of economic, social and environmental information through multiple functionalities in the light of stakeholder’s preferences and in a sustainable use and development perspective [3]. Computerized systems that help decision makers in structuring and evaluating decisions by providing easy-to-use and integrated tools for information elaboration and displaying [4].

The decision process for assessing and managing contaminated sites is controversial and difficult, in part because of its diverse aspects (economic interest, environmental restoration, social acceptance, technological application, land planning, and other influences). For these reasons, during recent years, many studies and regulatory applications have emphasized defining the decision process for the assessment and management of contaminated sites. For example, the risk-based land management approach developed by CLARINET [5] highlights three main goals: fitness for use (proper land use which is accepted by concerned people), protection for the environment, and long-term care (taking into account intergenerational effects of present choices in light of sustainability). According to

Geol [6], Health risk assessments are necessary for determining cancer risks and noncancerous hazards associated with contaminated sites.

DATA COLLECTION

A risk assessment tool can be any methodology, model or software package designed to qualify or quantify the risk posed by a contaminant in evaluating a source-pathway-receptor linkage. A tool may comprise a suite of risk based screening values, a methodology with recommended or prescribed algorithms, or a computer based package that allows site specific risk assessment to be carried out. There are number of risk assessment tools that have been developed commercially and many that have been developed specifically to support the approach to contaminated land of a particular country or region.

CLEA

Contaminated Land Exposure Assessment [7], Origin – England, Developer – UK Environmental Protection Agency, 2002

CLEA is an exposure assessment model for estimating child and adult exposure to soil contaminants for those potentially living, working and /or playing on contaminated sites over long periods of time. The software is currently designed to calculate soil guideline values (SGVs) and as such is not a fully site specific model. CLEA is a probabilistic model.

A limited number of contaminants are present in the database, for which accompanying documents are available to describe the derivation of the SGVs and the definition of health criteria used to describe the toxicity of a compound. New chemicals cannot be added to the current version 1.3.0.2 though work is ongoing on a revised version. The model includes ten exposure pathways such as ingestion of soil and dust, dermal contact, ingestion of vegetables and inhalation of vapors and dust. CLEA calculates risk levels for both threshold and non-threshold compounds assuming that the exposure duration is equal to the averaging time. Risks levels are always calculated as hazard quotients.

JAGG

Regneark til risikovurdering af **J**ord, **A**fdampning, **G**as og **G**rundvand [8], Origin - Denmark, Developer- Danish EPA, 2002

JAGG is used for assessment the risk from contaminated soils to human health and environmental receptors. The model is navigated by a series of buttons, opening excel spreadsheets. Five different fate and transport scenarios can be considered, soil, indoor air, outdoor air, landfill gas and groundwater.

P20-RTW

Publication 20 (Marsland & Carey 1999) Remedial Targets Worksheet [9], Origin -England, Developer - Marsland & Carey 1999

P20-RTW is a tool used for the site specific assessment of risks to groundwater resources from contaminated soils and groundwater. The system is intended to develop remedial targets for soil and groundwater and is navigated by a series of Excel spreadsheets. The user is required to input all the physical and chemical parameters required. For a soil source the model includes the assessment of partitioning, dilution in an underlying groundwater body and prediction of a receptor point concentration at a distant point. For groundwater sources the model predicts groundwater concentrations at a distant point.

RAM

Risk Assessment Model, Origin - New Zealand, Developer - Environmental Simulations International Ltd

Environmental Simulations International Ltd has developed this proprietary system. The aim of the model is to assess the potential risks to water resources in line with the P20 methodology developed in the UK.

RBCA Toolkit

"Risk-Based Corrective Action" Toolkit [10], Origin - Commercial, Developer - ASTM Standard Guide for Risk-Based Corrective Action, 2003

The RBCA Tool Kit for Chemical Releases is designed to meet the requirements of the ASTM Standard Guide for Risk-Based Corrective Action. It has the ability to generate generic risk-based screening levels (RBSLs) for on-site exposure, assuming default exposure factors and site properties. Alternatively the user can evaluate baseline risks and/or site-specific target levels (SSTLs) for both on-site and off-site receptor locations based on site-specific soil, groundwater and air parameters. In addition to steady-state air, soil, and groundwater exposure models, the toolkit allows transient groundwater modeling analyses to help you estimate not only how high but how soon exposure could occur. An array of default transport parameters is provided for various soil types and a chemical database is included in the model.

RISC

Risk **I**ntegrated **S**oftware for **C**lean-ups [11], Origin - Commercial, Developer Lynn R. Spence, 2001

RISC is a multimedia risk assessment tool primarily used for human health risk assessment (both in quantifying risks and calculating clean up targets) but is diverse enough that the component environmental fate and transport models can be used independently. The program has in-built databases for chemical properties and standardized soil types.

RISC can assess more than one contaminant at a time and can assess impacts in both soil and groundwater. A number of pathways can be selected e.g. ingestion of soil and vegetables, dermal contact and inhalation of indoor/outdoor air.

RISC-HUMAN

Risc-Human v3.1 [12], Origin – Netherlands, Developer - Dutch National Institute of Public Health and the Environment, 2004

Risc-Human v3.1 is a software system designed to investigate human exposure (to contaminants within both the soil and groundwater via up to 15 exposure pathways) and to calculate risk levels. Risc-Human has an inbuilt database of over 120 chemicals with on-site contaminant concentrations being added in a number of forms: concentration in soil, concentration in groundwater and concentration in contact media, for example concentration in indoor air. Adult and child exposure scenarios can be considered, with both exposure rates and exposure times potentially different between the two.

ROME

Reas**O**nable **M**aximum **E**xposure [13], Origin – Italy, Developer - Italian National Agency for Protection of the Environment, 2002

ROME, developed by the National Agency for Protection of the Environment (ANPA), is a risk assessment tool for human health (sanitary risk) and water resources (groundwater and surface water). The model adopts a risk-based tiered procedure that takes into consideration two simplified types of assessment (generic Tier 1 and site specific Tier 2), derived from the standard ASTM RBCA (Risk-Based Corrective Actions). The end use of the site, residential/green area or industrial/commercial is also considered.

A chemical/physical and toxicological database for 118 compounds and default environmental and exposure parameters are included. Different sources can be considered: shallow soil, deep soil, groundwater and free product. The human health receptors are defined as child and adult for residential purpose and workers for industrial purpose. The environmental receptors are defined as groundwater and surface water. ROME quantifies human risks and can calculate as clean-up levels or Site Specific Target Levels.

UMS

Umwelt (Environment), **M**ensch (HumanHealth), **S**chadstoff (pollutant) [14], Origin – Germany, Developing Authority - Umweltbundesamt (UBA – German protection agency), 2004

UMS is a tool used for assessing the risk from contaminated soils to human health receptors. Nine different land-use scenarios are defined within the model. Each of the nine scenarios incorporates an in-built selection of receptors. Contaminants are selected from a chemical database, to which new chemicals can be added and toxicity data is either specified or the default values adopted. Concentrations in the appropriate media are specified for each exposure pathway. The exposure pathways are pre-defined based on the selected exposure scenario, for example dust ingestion and air/dust inhalation are active pathways in the residential building. Extensive fate and transport modeling is not carried out and appears to have been replaced by a number of empirical factors, for example, the concentration in indoor air is assumed to be a factor of 100 times less than the concentration in the soil air. The model calculates a risk index, which is in turn used to calculate a risk value. Three ranges of risk value are specified to determine whether action is required on the site. Groundwater cannot be modeled as a receptor within the UMS module. However, there is a second module, which may be used in conjunction with UMS:

VLIER-HUMAAN

Origin - Belgium (Flanders), developed in Netherlands [15], Developing Authority - Smith and Goldsborough, 1994

Vlier-Humaan v2.0 has the same layout as RISC-HUMAN. The system is based on models similar to the Dutch C-Soil and HESP models, adapted for Flemish use and designed to investigate human exposure to contaminants within both soil and groundwater. Vlier-Humaan has an inbuilt database of chemicals with the ability to add new chemicals. On-site contaminant concentrations can be added in a number of forms: concentration in soil, concentration in groundwater and concentration in contact media, for example concentration in indoor air. Vlier-Humaan assesses exposure in indoor air from both soil and groundwater sources, with or without a basement or crawl-space present. Adult and child exposure scenarios can be considered, by inputting different exposure times between the two. Two output screens provide receptor point concentrations, child/adult doses and risks.

PROJECTS FOR DEVELOPMENT OF DECISION SUPPORT SYSTEM

Projects for Decision Support System are used to assess the risk or to provide the facility for remediation option selection for contaminated soil, contaminated land and some of them also applicable for groundwater contamination.

DESYRE - DEcision Support sYstem for REhabilitation of contaminated sites [16]
It is unlikely that any single person will have the knowledge to perform all the analysis required in supporting the overall decisions pertaining to the management of land contamination. It is also apparent that there are many specialist underpinning decisions (e.g. what risk levels are acceptable, what to sample, when to sample, what technologies should be used, etc.) that need to be made before general decisions on the reuse of contaminated land can be made. In order to facilitate this complex decision process several attempts have been made to codify specialist expertise into decision support tools [17].

The uses envisaged for a decision support system (DSS) include identifying realistic management choices and integrating information into a coherent framework suitable for analysis and decision-making, discerning key information that impacts decision-making from basic information. Moreover, DSS is expected to guarantee for transparency (i.e. all parameters, assumption, and data used to reach the decision should be clearly documented) and to ensure that the decisions-making process itself is documented. The integration of risk analysis models (for human health and ecosystem) with socio-economic evaluations and with criteria for technology comparison is fundamental to obtain the whole useful information for developing a correct decisional process.

SYRIADE - Spatial decision support sYstem for RegIonal Assessment of degraded Land [18]
The overall objective of the system is the ranking of potentially contaminated sites for priority of investigation, when no information on characterization and risk by site specific methodologies is available. This way, the system is intended to address not only the requirements of the Soil Thematic Strategy, but also a general and ordinary goal of regional authorities, i.e. to manage their contaminated sites in the most cost-effective way, by concentrating on those areas that could be pose a risk to human health and the environment.

SIERRA - Sino Italian Environmental Regional Risk Assessment Project [19]
SIERRA Project was funded by the Italian Ministry for Environmental Protection and developed in collaboration with the Chinese Research Academy of Environmental Sciences (CRAES; Beijing, China); started in 2009 and lasting 3 years.

GLOCOM: Global Partners in Contaminated Land Management [20]
GLOCOM is an exchange program funded by the Marie Curie Actions - International Research Staff Exchange Scheme, within the Seventh Framework Programme – People.
The project's Partners are:

- University Ca' Foscari of Venice, Italy
- Umeå University, Sweden
- Chinese Research Academy of Environmental Sciences, China
- Beijing Normal University

The general objectives of the GLOCOM exchange program are as follows:

- Increase harmonization of methods for risk assessment and management of contaminated sites in China and EU;
- Develop solutions for management of contaminated sites in China;
- Strengthen quality of research by developing international collaborations.

This will be performed through the organization of several exchange activities in the fields of contaminated soil characterization, environmental risk assessment and decision making processes. These exchange activities aim to increase quality and mutual benefit of the transfer of knowledge between the involved researchers from EU and China, in particular through the organization of workshops and training sections and the co-participation in conference and scientific publications, with the aim of identifying common ground for future research.

TIMBRE - Tailored Improvement of Brownfield Regeneration in Europe [21]
Brownfield regeneration plays a key role in sustainable land use management. The 7th Framework Programme project TIMBRE (Tailored Improvement of Brownfield Regeneration in Europe) starts from the observation, that many useful and innovative remediation technologies as well as methods to support risk assessment and decision making processes for an optimized brownfields' regeneration have been developed, but are only rarely applied using their full potential. Identified obstacles for an effective regeneration are (i) the abundance of strategies, tools, documented case studies and remediation technologies available at the EU level as well as (ii) the difficulties in adapting them to cultural, regional and site-specific requirements. TIMBRE's main objective is to overcome these

barriers by providing brownfields' owners, local authorities and stakeholders with a web-based problem- and target-oriented customizable decision support toolbox. The research activities within TIMBRE focus on the methodological approach and designed activities of TIMBRE.

RESULT

As the result of this study was the compilation of different risk assessment tools for the contaminated land. Table -1 Presents Decision support system for risk assessment of contaminated site developed by different countries.

Table -1 Decision Support System for Risk Assessment of Contaminated Site Developed by Different Countries

Model Name	Country
CLEA	**England**
JAGG	**Denmark**
P20 RTW	**England**
RAM	**United Kingdom**
RISC	**United Kingdom**
RISC HUMAN	**Netherland**
ROME	**Italy**
UMS	**Germany**
VLIER HUMAAN	**Belgium**

CONCLUSION

On the basis of this study, following conclusion can be drawn -

- RISC model have maximum number of features which are useful for a decision maker to assess risk due to contaminated land and water both.
- ROME model has maximum 118 contaminants database for risk assessment.
- CLEA model have a formulation for the assessment of risk due to contaminated land through maximum 8 pathway of exposure of contaminant.
- This study concluded that not only the three attribute of risk assessment i.e. contaminant, pathway and receptor are important but also soil properties are also have a great role in the risk assessment process.

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