Uncertainty Quantification of Parameters for Associated Risk to Human Health Due to Heavy Metal Content in Drinking Water using Possibility Theory: A Case Study in Ingestion

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ABSTRACT
The main aim of risk assessment is to determine the potential detriment to human health from exposure to a substance or activity that under plausible circumstances can cause to human health. Risk assessment models involve inputs which may not be precisely known [7]. The uncertainty of the inputs gets propagated to the output risk. So, we need to quantify the uncertainty so as to be aware of the risk involved in any decision making process. Uncertainties can be modeled and analyzed using different theories, viz. Probability theory, Possibility theory, Evidence theory etc. Modeling of an uncertain parameter depends on the nature of the information available[1]. In this paper, I considered uncertainty quantification of parameters in the case of radiological risk assessment.

I have analyzed the propagation of the risk in terms of Possibility theory (Fuzzy theory). Fuzzy method is discussed in this paper, taking the parameters of the input of the model as Fuzzy number. A case study is carried out with this method taking the parameters of the input as triangular Fuzzy Number.

Keywords
Risk Assessment, Uncertainty, Variability, Fuzzy number.

1. INTRODUCTION
Human being is always exposed to radiation either from natural or anthropogenic sources in the environment. While there have been natural nuclides since the beginning the earth's existence, manmade nuclides have been released from nuclear installations and fallouts from the nuclear test and nuclear accident. Also produced water is the most significant source of waste generated in the production phase of oil and gas operations[9]. Once discharged into the ocean, a number of heavy metals and poly aromatic hydrocarbon in produced water may introduce toxicity and bioaccumulation in marine organisms. These compounds are harmful to human health and therefore human can be affected through intake of such water. Consequently, we can say that human health can also be indirectly (or directly) affected through different pathways such as inhalation, ingestion, submersion and dermal contact.

When hazardous substances are released into the environment, an evaluation is necessary to determine the possible impact such substances may have on human health and other biota. For this purpose, risk assessment is performed to quantify the potential detriment to human and evaluate the effectiveness of proposed remediation measures. The assessment is performed using 'models' and a 'model' is a function of parameters which are usually affected by aleatory and epistemic uncertainty[6]. Aleatory uncertainty and epistemic uncertainty are two distinct facets of uncertainty in risk assessment. Aleatory uncertainty arises from heterogeneity or the random character of natural processes while epistemic uncertainty arises from the partial character of our knowledge of the natural world. Epistemic uncertainty can be reduced by further study while aleatory cannot be reduced. Here, we have considered that parameters are affected by epistemic uncertainty (fuzzy number).

If the representation of the input parameters of the risk model is in probabilistic sense, the output risk distribution may reflect probabilistic information. However, resalable and sufficient data is required to estimate and characterized the probability distribution of the input variables. If uncertainty does not arise due to randomness, or if the information are partial, not fully reliable, receive of information from more than one sources or inherent imprecision, then probability theory is inappropriate to represent such kind of uncertainty

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To overcome this limitation of probability theory Zadeh (1965) introduced fuzzy set theory which can be used to incorporate epistemic uncertainty. Uncertainty can be quantified using fuzzy set in terms of interval and it can be calculated using alpha-cut method.

1.1 Exposure Pathways
An exposure pathway is any route that a chemical may travel from an environmental source to a receptor. An exposure mainly chemical source, release mechanism (e.g., leaking, leaching, wind erosion), a transport and/or exposure medium(e.g., air, water, soil, sediment, food), an exposure points with receptors present or potentially present(actual location where exposure is possible),and a route of entry (inhalation, ingestion, dermal contact)[5].

In this case study, I take an ingestion risk model and evaluate the ingestion risk for heavy metal mainly Zn,Cu,Ni,Pb and As to assess the human health from drinking water contaminated.

2. BASIC CONCEPT OF FUZZY SET THEORY [2], [6]
In this section, some necessary backgrounds and notions of fuzzy set theory are reviewed.

Definition 2.1: Let *X* be a universal set. Then the fuzzy subset *A* of *X* is defined by its membership function

$$\mu_A : X \rightarrow [0,1]$$

Which assign a real number $\mu_A(x)$ in the interval [0, 1], to each element $x \in A$, where the value of $\mu_A(x)$ at *x* shows the grade of membership of *x* in *A*.

Definition 2.2: Given a fuzzy set *A* in *X* and any real number $\alpha \in [0, 1]$. Then the α -cut or α -level or cut worthy set of *A*, denoted by ${}^{\alpha}A$ is the crisp set

$${}^{\alpha}A = \{x \in X : \mu_A(x) \geq \alpha\}$$

The strong *a* cut, denoted by ${}^{\alpha+}A$ is the crisp set

$${}^{\alpha}A = \{x \in X : \mu_A(x) > \alpha\}$$

Definition 2.3: The support of a fuzzy set *A* defined on *X* is a crisp set defined as

$$\text{Supp }(A)\{x \in X : \mu_A(x) > 0\}$$

Definition 2.4: The height of a fuzzy set *A*, denoted by *h*(*A*) is the largest membership grade obtain by any element in the set and it is denoted as $h(A) = \sup_{x \in X} \mu_A(x)$

Definition 2.5: A fuzzy number is a convex normalized fuzzy set of the real line *R* whose membership function is piecewise continuous.

Definition 2.6: A triangular fuzzy number A can be defined as a triplet (*a*, *b*, *c*). Its membership function is defined as:

$$\mu_A(x) = \begin{cases} \dfrac{x-a}{b-a}, a \leq x \leq b \\ \dfrac{c-x}{c-b}, b \leq x \leq c \end{cases}$$

3. A CASE STUDY ON HUMAN HEALTH RISK DUE TO HEAVY METAL

In this case study, I have been considered some realistic data form [8]. From the prescribed data, I have taken the data in terms of minimum, most likely and maximum value of activity of the heavy metal Zn,Cu, Ni, Pb and As in two sources of water, one is tubewell water and other source from ring well, PWS and supply water. Using this data, calculate the health risk for the heavy metal by Fuzzy Method and compare the total risk of these two sources.

Since nothing is known about the nature of the parameters, we can model as possibility theory in this case study. In the possibility, the standard way of modeling such a parameter is a Fuzzy number, where the most likely value may be considered either as mean or mode or median. In this case we have considered the most likely value as mean. We take the most likely value as core and the min and max value is taking as end points of the support of the triangular Fuzzy number. Here we used the Risk cal. Software for calculation[4].

Table 1: Values of heavy metal content in water

Heavy metal	Tube well water			Ring well, PWS and supply water			Representation
	Min	**Most likely Value(MLV)**	**Max**	**Min**	**Most likely Value(MLV)**	**Max**	
Zn	0.55	1.9935	3.91	0.09	0 .9835	2.20	Fuzzy
Cu	0.013	0.0276	0.049	0.014	0.0499	0.178	Fuzzy
Ni	0.019	0.0479	0.084	0.011	0.03329	0.076	Fuzzy
Pb	0.03	0.1147	0.40	0.02	0.09625	0.23	Fuzzy
As	0.006	0.0335	0.118	0.002	0.01967	0.069	Fuzzy

Table 2: Intake of water (L/Year) (As per FGR-13)[3]

Min	**Most likely Value(MLV)**	**Max**
803	1095	1482

Table 3:Risk factor (As per FGR-13)

Heavy metal	Risk factor
Zn	7.77E-11
Cu	2.95E-12
Ni	4.54E-11
Pb	1.15E-12
As	2.29E-12

4. RESULTS AND DISCUSSIONS

I have considered the following model for the risk assessment

Risk due to ingestion of water:
Risk(/Yr) = water activity(Bq/L) × water intake (L/Yr) × Risk factor(/Bq).

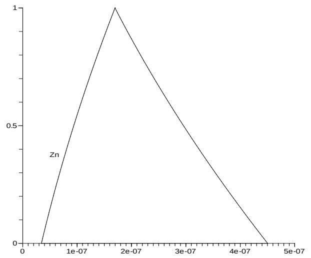

Figure.1 Risk due to Zn in Tube well water

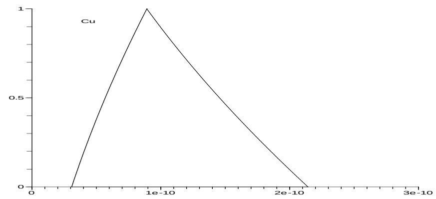

Figure.2 Risk due to Cu in Tube well water

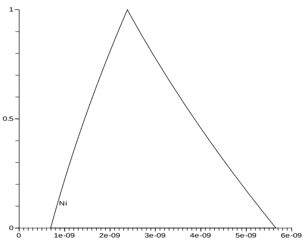

Figure.3 Risk due to Ni in Tube well water

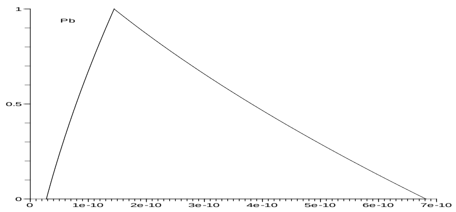

Figure.4 Risk due to Pb in Tube well water

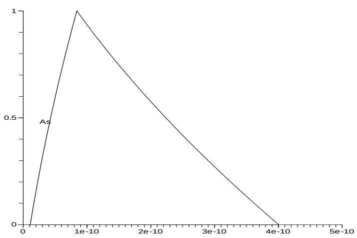

Figure.5 Risk due to As in Tube well water

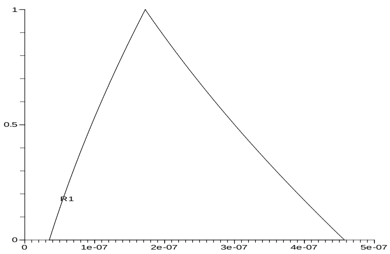

Figure.6 Total Risk(R1) due to Tube well water

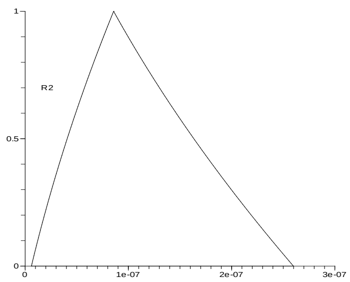

Figure.7 Total Risk(R2) due to Ring well, PWS and supply water

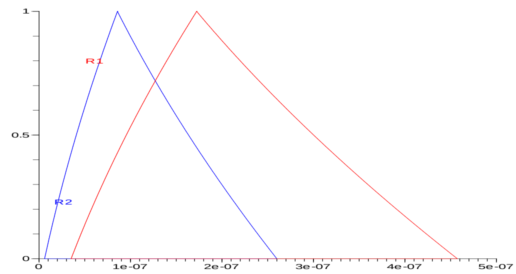

Figure.8 Comparisons of Total Risk(R1 &R2)

The objective of the uncertainty analysis is to quantify uncertainty in model output. Quantification of uncertainty helps in effective uncertainty management and increases confidence in the results. Here, we compare risk for heavy metal contained in Tube well water and water from the Ring well, PWS and supply water. Fig. 1 and fig.2 shows risk due to Zn and Cu in tube well water. The risk due to heavy metal Ni is shown in fig. 3. In Fig 4 and fig.5 shows risk due to Pb and As in tube well water. Fig. 6 represent the total risk R1,i.e. risk due to all the heavy matels Zn,Cu,Ni,Pb and As contain in tube well water. Similarly we can evaluate the total risk R2 for the ring well,PWS and supply water, which shows in fig.7. Fig. 8 shows the comparison of both the risk R1 and R2. The red fig. indicates the total risk due to tube well water and in blue fig. indicate the total risk due to ring well,PWS and supply water. In the Fig.6 the resultant Fuzzy number gives the core value as **1.723088e-07** and the support of the Fuzzy number is **[3.50784e-08, 4.571902e-07].** In the Fig.7 the resultant Fuzzy number gives the core value as **8.569911e-08,** and the support of the Fuzzy number is **[6.071707e-09, 2.59851e-07]**. From the figure we observe that uncertainty in risk calculation is more in case of tube well water as compared to the water source of ring well,PWS and supply water. The finding from this study can be immensely valuable for decision-maker seeking to formulate more effective strategies to reduce risk of human health due to heavy metal content in drinking water.

5. REFERENCES

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