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NUCLEAR EMERGENCY: A REVIEW OF RADIOACTIVITY IN HUMAN ECOSYSTEM

Priscilla Obeng Oforiwaa [1], Liang Manchun[2], Su Guofeng[3], Li Ke[4]
[1]Tsinghua University, Beijing, China and Prisoforiwaa@gmail.com
[2] Tsinghua University, Beijing, China and Lmc@tsinghua.edu.cn
[3]Tsinghua University, Beijing, China and Sugf@tsinghua.edu.cn
[4]Tsinghua University, Beijing, China

ABSTRACT— One of the serious impacts for the environment and human health is the proper evaluation of radioactivity from elevated naturally occurring isotopes or those from industrial activities. Radionuclides produced from nuclear explosions and nuclear facilities when released into the environment may reach the human body through the food pathways.

Radionuclides from environmental sources have the ability to cause a hazard to human health through food sources. There is the need for radiological estimation for transfers from the vegetative covers through the human ecosystem. The assessment models are subdivided mainly into three categorical states; that is from the soil-plant transfer, the transfer to animals, and spatial models.

Radionuclides may enter the human ecosystem through atmospheric releases from nuclear facilities. Freshwater contamination happens via release water bodies which may affect aquatic lives.

Various assessment models have been developed based on the fallout deposition from the Chernobyl accident, however, the distinct uncertainties involved in propagating this data to a completely different geographical location cannot be ignored.

This is a review paper that analysis the Absalom model, its application in system assessment models and how they can be applied in a country-specific data to achieve a realistic model prediction in food safety from radionuclide release and the need for further research.

Keywords— Model, prediction, radionuclide, foodchain.

I.INTRODUCTION

One of the serious impacts for the environment and human health is the proper evaluation of radioactivity from elevated naturally occurring isotopes or those from industrial activities. Radionuclides produced from nuclear explosions and nuclear facilities when released into the environment may reach human body through which radionuclides can enter the human body through the food pathways. There are two important radionuclides 90Sr and 137Cs which is highly considered for the assessment of radiation exposure which is highly considered for the assessment of radiation exposure to the public because of their relatively long half-lives(~30years). Physically and chemically ^{137}Cs has a similar characteristics with potassium, whereas ^{90}Sr mimics calcium. Due to these qualities these radionuclides are easily in the food chain and ultimately animal and human bodies (H. Muller G. , 1993).

Direct deposition of radionuclides occurs as a result of water irrigation methods or atmospheric releases.

Ingestion of these radionuclide releases are quantified using foodchain models. These models include those transfer process (soil to plant transfer factor) and plant to animal transfer coefficient. Specific data focuses on soil, plant, water and animal samples (S.uematsu, 2015).

Safety is a primary embodiment of nuclear energy and the protection of the environment from radioactivity influences is a major factor in the development of nuclear emergency. Emergency situation entails various methods that combines spatial models for prediction, experimental procedure to aid decision for countermeasures during emergency situations. However, these models proved some distinct complexities in the modelling of radionuclide transfer in the terrestrial food chain. A case is made with the parameterization of irradiation models for an accurate prediction and boost confidence in the decision making during emergencies (Mu, 2014).

The study objectives are to;

- Understand the Concept of radioactivity in Food chain(Soil-Plant-Animal-Man).

- Understand the Processes involve in radionuclide transfer in the terrestrial environment.
- Review current research trend on radionuclide transfer in foodchain
- Analyze Existing Problems and Recommendation

II. LITERATURE REVIEW

RADIONUCLIDE PATHWAY PROCESSES

The released of radioactive material into the atmosphere enters the human ecosystem due to wet and dry deposition on soil and vegetative covers. Humans may risk internal exposure originating from foliage contamination as a result of radionuclide uptake.

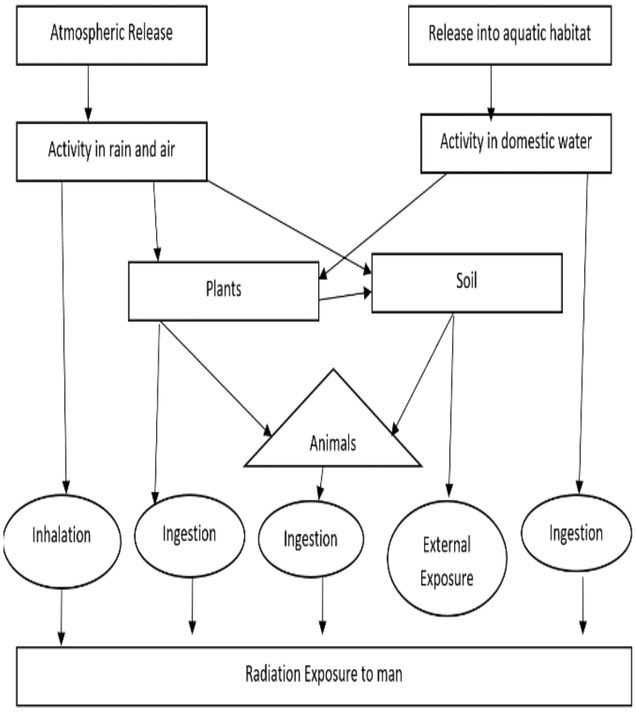

Fig.1Transfer Routes for modelling the migration of radionuclides in Human Ecosystem

Systematic Transport of Radionuclides

Translocation

Translocation has no or very little influence on the long-term-fate of radioactivity in the environment,

The most important factor influencing translocation is the physiological characteristics of radionuclides in plants during the time of deposition. There are two transport systems in the plant, the xylem and the phloem; mobile elements can be transported in either system. The xylem transports water and minerals from the soil to upper plant parts. The driving force for transport in the xylem is transpiration.

Interception of wet-deposited radionuclides

Air plays a significant role in washing out of radionuclides unto plants and soil. This concept mainly occurs during rainfall or snowstorm. The little fraction which is deposited on vegetation plays a significant role in model development.

$$f_{\mathrm{w}} = \min\left(1;\ \frac{\mathrm{LAI} \cdot k \cdot S \cdot \left(1 - e^{-\frac{\ln 2}{3 \cdot S} \cdot R}\right)}{R}\right), \qquad (1)$$

Where:
Fw = interception fraction
LAI = Leaf area index (total one-sided area of leaves per area of soil, m2 m-2)
K = element – specific factor
S = water storage capacity of the plant surface (mm)
R = amount of rainfall(mm)

Resuspension

Resuspension occurs when materials and debris are removed from the surface soil to the atmosphere by external factors such as wind, cultivation of the soil and other human influences. Resuspension plays an active role in effluent suspension of radionuclides into the soil layers. This process leads to activity redistribution of radionuclides in the soil profile, which affects the rate of concentration of these radionuclides in the soil. (H. Muller F. G., 2003)

Factors such as deposition time, human activities and surface characteristics influences resuspension. In model development processes, resuspension is mainly defined with the K symbol for easily definition. K signifies the ratio of activity concentration in air to ground surface deposit.

K factor is easily measured taking into consideration the deposition height above the ground and to the measured soil depth in which the activity is assumed to be available for resuspension.

Transfer to Animals

The radionuclide transfers from vegetative cover to animal products such as milk and meat can be ascertained through the usage of element-dependent factors. These element-dependent factors can be defined by the ratio of the activity in milk or meat to the daily activity intake under equilibrium conditions. (N.A Beresford, 2016)

However, such transfer parameters are only applied for a sustained long-term rate of animal activity intake under equilibrium conditions. feed to milk, meat, and other animal products are mostly calculated using element-dependent transfer factors, defined as the ratio of the activity in milk or meat to the daily activity intake under equilibrium conditions.

Parameters specific to animal radionuclide intake are; rate of growth, body mass, animal species and digestible feed. Animal feed usage is highly dependent on the season and agricultural practices of a particular geographic area

III. METHODOLOGY

Protective models for radionuclides during the soil to plant transfer presents certain uncertainties from some simulated models. Initially after an accidental release the factors determining the contamination of foodstuffs will largely be defined by vegetation interception and the time of year. In the dominating phase of these radionuclides, these factors go a long in the transition process.

The Absalom Model

The Absalom model mainly describes the uptake of radiocesium by plant through the concentration factor (CF). The CF is the ratio of radioactivity concentration in plant to the activity concentration in soil. These activity concentration is mainly related to the content of clay in the soil K^+ in the soil. However, the K^+ Property is scarcely recorded in the soil databases but an estimation can be made from a readily available soil data.

Mostly, the activity concentration in plants can be predicted by calculating it from the product of concentration Factor (CF) (Bq/kg) and the concentration in the soil($Bqdm^{-3}$).

$$C_{splant} = (CF)(CS_{soil}) \qquad (2)$$

However, this model simply relates the concentration of cesium isotopes.

Model Parameterization

Empirical variables of this model equation was mainly achieved by a simultaneous fitting of both equation (1) and (2) utilizing the Marquardt non-linear regression technique. Data for this model parameterization was conducted using a ryegrass pot experiment from a wide range of Belgium soils.

Table 1 Parameters for transfer modelling of cesium, strontium and iodine to animal food products

Animal Products	Dry matter intake(kg/d)	Transfer factor (d/kg, d/l)		
		Cesium	Strontium	Iodine
Cow’s milk	14	0.003	0.002	0.003
Sheep, goat milk	2	0.06	0.014	0.5
Beef	9	0.04	0.0003	0.001
Pork	3	0.4	0.002	0.003
Lamb	1.0	0.5	0.003	0.01
Chicken	0.1	4.5	0.04	0.1
Eggs	0.1	0.3	0.2	2.8

Limitations & Recommendations for Radionuclide Modelling

Various model lack parameters to help with transfer of specific foodstuffs.

- The need for a country specific values which includes the intercepted radionuclide transfer to fruits
- A need for an ability to predict changes in radionuclide activity concentrations in food products with time (including the need for biological half-life data)

Priority for further research for different transfer processes for environmental transfer

Improve data for the four important terrestrial models transfer are prioritized based on the data improvement necessity. This ranking should be regarded as a general one that may be modified for specific radionuclides. (S.uematsu, 2015)

Assessment of the radiological consequences of routine releases is not seen as a major problem. In general, the releases are low and lead to low doses, even when conservative models are applied for the dose calculations. More research in deposition, interception, and translocation would most effectively lead to an improvement of model reliability. (Absalom, 2001)

The large uncertainty in interception and translocation is also underlined by the results of probabilistic uncertainty analysis for accident consequences. The reliability of predictions in the case of radioactive contamination of farmland could be considerably enhanced, if data on the stage of development of plants would be integrated. (Center, 2000)

Table 2 Transfer Processes for Radionuclides and their Priority Medium

Transfer Process	Priority Medium
Deposition	Dose reconstruction & Accidental release
Interception	Dose reconstruction &accidental release
Weathering	Routine Release
Translocation	Dose reconstruction & Accidental release
Uptake from soil	Dose reconstruction & Accidental release
Migration in soil	Dose reconstruction & Accidental release
Resuspension	Routine Release
Transfer to animals	Dose reconstruction & Accidental release

IV. RESULTS DISCUSSIONS

Spatial Models & Limitations

Various spatial models have been developed over the years to aid in prediction analysis over the years to aid in prediction analysis over the years. These nuclear emergency systems provides predictive results of various radionuclides deposited in a particular geographic area with different soil variation and subsequent transfer to the terrestrial Foodchain. (D. Tarsitano, 2011) These modelling system such as the Real Online Decision Support (JRODOS) presents some challenges in light from the aftermath of Fukushima (S.uematsu, 2015)

Scientific Limitations of the JRODOs System based on the Absalom Model

The JRodos is the nuclear decision support system with a wide range of uses for nuclear emergency. It uses ranges from atmospheric dispersion models to food chain modelling, however in the event proceeding from the fukushima nuclear accident proved the existence of limitations for the JRODOS system. (C.Landman, 2013)

In the event of nuclear emergency and the aftermath of long-term rehabilitation process dealing with uncertain information is an intrinsic problem for decision making. Uncertain limitation related to for instance, incomplete source term and the prevailing whether results in dose assessment that differ dramatically from reality. (Center, 2000)

The food chain process in the JRODOS system proves complications with its large amount of parameters which may contain significant error. These parameters and dose might be difficult to verify. In JRODOS only deterministic results ignoring uncertainty bands are available for users. If the user wants to investigate uncertainties of the source term, multiple models run with different input which needs to be performed. In the JRODOS system, uncertainty prediction is not an important output associated with its prediction. (K.N Papamichail, 2005)

The post fukushima and Chernobyl accidents proved a high limitation with radio-ecological models which failed to predict areas of the Europe region where high radiocesium transfer through the food chain has persisted for decades for following Chernobyl (D. Tarsitano, 2011)

Application Models limitation based on Fukushima Case

In JRODOS, radionuclide transfer parameters used in model predictions were often very variable (IAEA 2010). The parameterization of food chain (H. Muller F. G., 2003) of JRodos system is based on ECOSYS-87 model (H. Muller G. , 1993). This model predates the international compilation of radionuclide transfer parameters values of the IAEA (Developing of a worldwide version odf system for prediction of eneivronmental emergency dose information ; WSPEEDI 111, 1994)which incorporates the large of data obtained in post-Chernobyl studies.

In JRodos system, biological half-live values are utilized for animal feeds instead of a transfer parameter for a particular food products which are also appropriate from local conditions. (L.Fernandez-Moguel, 2019)

Radioactive iodine 131I has proven to be a major health risk after a nuclear accident, however its environmental behaviour has been poorly studied for the modelling of the food chain in JRodos. The comparative short-lived of this radionuclides t1/2 8yrs. (B.J Howard, 2005)

Underlying limitations are;

Disparities of variable transfer for specific foodstuffs.

Lack of transfer parameters appropriate for local conditions

Variability in transfer parameters.

Software Modelling Limitations using the Absalom model (Process based models)

JRodos predicts the exchange of radionuclides to human food-stuffs which utilizes equilibrium agglomeration to depict the exchange from soil to plants (B.J Howard, 2005).

These are parametric generic data with soil categorization. Late utilization of the JRodos model under natural conditions found in Fukushima influenced regions in Japan featured a few issues. Contrasting grass fixation proportions with model with values estimated in a few Fukushima influenced zones (Uematsu et al 2016) noticed that the determined focus ratio values deviated from observed data. The model impressively disparaged the noticed radiocesium take-up into grass when utilizing estimations of soil RIP (Radiocesium Interception properties) and soil arrangement Potassium (K) concentration assessment from qualities (Absalom, 2001) .The geometric mean (GM) of the model concentration ratio values was more than an order of magnitude lower than the GM of the observed values.

The GM of the model focus proportion esteems was just about multiple times more noteworthy than that of the noticed qualities when utilizing the deliberate RIP and the K fixation (W. raskob, 2010). The determined RIP and K components of 10 and 3 individually overestimation of radiocesium sorption could be credited to various elements, the condition in the model used to compute the RIP had been gotten from European soil whose soil qualities are notably not the same as those of the soil in the Fukushima regions (S.uematsu, 2015) Agricultural soil from Fukushima had extremely lower RIP per unit clay than commonplace European soils

Secondly, overestimation of K soil arrangement fixations was additionally ascribed to overestimation of k soil structure which credited to overestimation of other model parameters, to be specific the concentration measure values. The dependence of Ca and Mg concentration on soil ph. as assumed by these models could not be demonstrated for the Japanese soils (L.Fernandez-Moguel, 2019).

Software Modelling Limitations (Data)

Another limitation lies in the fact that it is not practicable to develop a robust, sensitivity analysis using the existing version model. (improving models). Muller and Prohl (H. Muller G. , 1993) give an initial consideration of uncertainty of the default ecosystem-87 parameter values. This parameter is a site specific. (M. Van Der Perk, 2001)

FDMT is not currently set up to allow the user to solve complex dynamic systems as essentially analytical solutions are provided for basic differential equations and simplifying assumptions are made with respect to, inputs to and losses from, various components of the modelled system. The FDMT has many default values which are not based upon data, greater transparency is required on how these values have been derived and they should be taken into account with the latest IAEA data given. (improving models). In the case of transfer to animals there is evidence that the tissue-diet concentration ratio maybe a more robust parameter than the transfer coefficient. (Improving models and learning from Post-Fukushima studies) (N.A Beresford, 2016)

The JRodos system uses the geographic population by census which do not take into consideration the population of the region by grid. Moreover, the data for population is duely inherent since it does not take into account the site specific population or region data.

The summary for data limitation of the model

Not availability of the post Fukushima data(since this model was developed using the Belgian soil and characteristics)

Use of geographic population by census instead, these Geographic populations do not give an account of people migrated from the place overtime since update is not done concurrently.

Site specific data for analysis and evaluation

The empirical approach model is adopted in the RODOS system, which gives a complex and not systematic evaluation of data

V. CONCLUSION

The semi-mechanistic method considers the impact of soil qualities, a distinct example is the clay and any replaceable potassium content on the transfer of Radiocesium. It also uses bioavailable rather than the total radiocesium transfer. The mechanistic method considers the physical and chemical cycles that control radiocesium circulation and up-take in soil plant frameworks such as transport in the root zone.

Since the total radionuclide in a lot of soils does not correlate to plant available radionuclide, the assumption stating the radionuclide transfer could be predicted in the soil is an over simplification which do not correlate to plants available radionuclide.

The semi-mechanistic model relates radionuclide transfer into the soil solution which is been compared to plant available radionuclide better than total radionuclide in soil. However, Absalom works better for certain conditions mainly for grasses and European soils.

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BIOGRAPHY

Author1: Priscilla OFORIWAA

Priscilla is a PhD student at Tsinghua University, Department of Engineering Physics. Her research focuses on Nuclear Emergency Response and Radiation Protection majoring in Nuclear Science and Technology.

Prisoforiwaa@gmail.com

Author 2: Manchun LIANG

Professor Liang Manchun is an Associate Professor at Tsinghua University, Department in Engineering Physics. He is a Research lead on Nuclear Emergency and radiation safety. Professor Liang has more than ten years' experience in research.

lmc@tsinghua.edu.cn

Author 3: Guofeng SU

Professor Guofeng Su is a Professor at Tsinghua University, Department in Engineering Physics. Leader of emergency management and technology team of Department of Engineering Physics Deputy President of Hefei Institute for Public Safety Research of Tsinghua University President Assistant of Institute for Public Safety Research of Tsinghua University

Email: sugf@tsinghua.edu.cn

Author 4: Dr Li Ke

Dr Li Ke is a Post-Doc researcher at Tsinghua University Department of Engineering Physics. Currently, his research focuses on the aspect of safety science and engineering.

Email: sam_like89@sina.com

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