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Introduction of KIANA radio ecological Iranian domestic code for concentration and dose calculation of radio isotopes release at normal and accidental conditions in nuclear installations and chemical facilities

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Introduction of A domestic user friendly dynamic radiological dose and model has been developed to estimate radiation doses and stochastic risks due to atmospheric and liquid discharges of radionuclides in the case of a nuclear reactor accident and normal operation in nuclear installations and can be useful for modelling and concentration calculations of dispersion of radiochemical to atmosphere in chemical facilities. In addition to individual doses from different pathways for different age groups, collective doses and stochastic risks and sewerage discharge to environment as release pathway can be calculated by the developed domestic user friendly KIANA Advance Computational Computer Code and model. The current Code can be coupled to any long-range atmospheric dispersion/short term model which can calculate radionuclide concentrations in air and on the ground and in the water surfaces predetermined time intervals or measurement data. The nuclear and radioactive installations release radionuclides to the environment, affecting the atmosphere, the terrestrial surface and the surface waters, as rivers, coastal waters, estuaries, lakes and small reservoirs. The flora, fauna and human beings are directly affected by those releases, since air and water are the main flora nutrients, flora is part of the fauna diet, and flora and fauna constitute the human being feed. User Friendly KIANA Advance Computational Computer Code application is a code that designed to automate the calculation of radionuclide concentrations in different environments and their impact in the nutritional chain, as well as in the human being, allowing to the researcher to center in the obtained results analysis.

Keywords: Dynamic software, environmental transfer, radionuclide, nuclear accident, Concentrations

INTRODUCTION

Though nuclear power is a good source of energy and is not generally a threat, a major reactor accident can lead to a catastrophe for people and the environment. The major health and environmental threat would be due to the escape of the fission products into the atmosphere. There have been instances of nuclear reactor accidents like the heavy water-cooled and moderated reactor at Chalk River in Canada in 1952, the graphite moderated gas cooled reactor at Sell afield in Britain in 1957, the boiling water reactor at Idaho Falls in US in 1961, the pressurized water reactor on Three Mile Island in the US in1979, the graphite moderated water cooled reactor at Chernobyl in Ukraine in 1986, the sodium cooled fast breeder reactor at Monju in Japan in 1995 (Makhijani, 1996) and the boiling water reactor at Fukushima Daiichi NPP in Japan following an earthquake and tsunami in 2011. Among them, Chernobyl and Fukushima completely changed the human perception of radiation risk. On April 26, 1986, USSR suffered a major accident, which was followed by an extensive release to the atmosphere of large quantities of radioactive materials. An explosion and fire released huge quantities of radioactive particles into the atmosphere, which spread over much of the western USSR and Europe. The Chernobyl disaster was one of two maximum classified event (level 7) on the International Nuclear Event Scale (the other being the Fukushima Daiichi nuclear disaster happened in 2011) and was the worst nuclear power plant accident in history in terms of cost and the resulting deaths. The battle to contain the contamination and avert a greater catastrophe ultimately involved over 500,000 workers and cost an estimated 18 billion rubles. During the accident itself, 31 people died, and long-term effects such as cancers and deformities are still being accounted for. Unfortunately, the other severe accident happened on March 11, 2011; a powerful earthquake (magnitude 9.0) hit off the east coast of Japan. Tsunami triggered by the earthquake surged over the east coast of the Tohoku region, including

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Fukushima. The Fukushima Daiichi NPP's cooling ability was lost and reactors were heavily damaged. Owing to controlled venting and an unexpected hydrogen explosion, a large amount of radioactive material was released into the environment. Consequently, many residents living around the NPP were exposed to radiation. In almost every respect, the consequences of the Chernobyl accident clearly exceeded those of the Fukushima accident. In both accidents, most of the radioactivity released was due to volatile radionuclides (noble gases, iodine, cesium, and tellurium) (G. Steinhauser, A. Brandl, T. E. Johnson, 2014) [39].

KIANA software tool containing many different and complex models for the simulation and evaluation of nuclear and radiological emergencies conditions can be used. The increase in functional complexity resulted in a similar increase of the complexity of the user interface. User Friendly Domestic KIANA Advance Computational Computer Code has additional requirements that have been identified as followings:

- The most important requirement was found to be a simple and easy to use user interface in contrast to the another one. Ideally, the features of the user interface should be self-explaining and the intention of the input mask should be understandable even without a manual. In particular special and rarely used features should be initialized with default values and hidden in the everyday usage of KIANA Advance Computational Computer Code. Several state-of-the-art programming languages were considered in the design process. Finally, KIANA Advance Computational Computer Code was implement using the C# programming language C# is available for almost every major computer architecture and operating system especially for HP-UX, Linux and the Windows family. To support non-expert operators an internal help system has been set up based upon C# Help by PDF format [38]. Type errors can be introduced easily, because there is no feedback other than evaluating the entered values with the human eye. Therefore several features have been introduced to improve understanding and reduce the possibility to enter invalid values in KIANA Advance Computational Computer Code [38].

THE CONTEXT

The User-Friendly KIANA Advance Computational Computer Code (software) was programmed by the Science and Research Branch of Islamic Azad University and National Nuclear Safety Department (NNSD) and Iranian Nuclear Regulatory Authority(INRA) of the AEOI under the direction and auspices of the Radiological Protection for the Public and the Environment Project which belongs to the Environmental Impact of the Radiation Monitoring Department from NNSD. The main part of Code based on S.R.S. no.19 [4] with C sharp(C#) Language but with some added improvements based on EUR 15760[3]. The models implemented in KIANA Advance Computational Computer Code will be published by Science and Research Branch of Azad University and NNSD/INRA. The KIANA Advance Computational Computer Code allows the following operations:

Computer Code has been designed and developed for this study in first time in our country. For the dose assessment, all exposure pathways have been implemented as follows [1-4]:

1. To create new study cases, on which calculations will be applied.

2. To open, consult and modify existing study cases.

3. Gaseous releases calculation and calculation of release of radio-chemical

3.1. Radionuclides dispersion calculation in atmosphere.

4. Calculation of liquid releases (aquatic environment).

4.1. Radionuclides dispersion calculation in estuaries.

4.2. Radionuclides dispersion calculation in rivers.

4.3. Radionuclides dispersion calculation in little lakes and reservoirs.

4.4. Radionuclides dispersion calculation in coastal waters.

5. Module for nutritional products transference.

6. Dose calculation module for critical groups.

7. Reports for each performed study at previous steps.

8. Graphics generation for each of the previously performed studies.

A deterministic dose calculation model called as user friendly KIANA Advance Computational Transfer of radionuclides through food chains and the subsequent internal-exposures of humans due to ingestion of contaminated foodstuffs- Internal exposure due to inhalation of radionuclides during passage of cloud and from re-suspension of deposited radionuclides- External exposure from radionuclides in the passing cloud- External exposure from radionuclides deposited on the ground. Developed code is implemented in Visual Basic. Editable parameters are number of radionuclides, of the whole area modeled, concentration and deposition outputs of an atmospheric dispersion model or measured air concentration and deposition data in days, and time interval of dose calculation in days and in years. Current User Friendly KIANA Advance Computational Computer Code can perform modeling well for unlimited isotopes, 70 years, 13 food stuffs and pasture, 8 animal products, 4 different age groups, i.e. infant, child, teen and adult, maximum and average individuals in terms of food consumption habits, correction coefficients for gamma dose rate and time spent outdoors. The Current user-friendly KIANA code can produce individual dose results annually for each isotope and pathway, and the sum for all isotopes and pathways as well, and collective total dose results. The model in Current user-friendly KIANA code can also produce monthly activity results in grass and animal food products, activity concentrations results of agricultural food products at each harvest year after the accident and during normal operation, and total risk results might be calculated as well. External input data files include age dependent food consumption rates, breathing rates and reduction factors for external radiation for maximum and average individuals, feedstuff intake rate of animals, storage times and processing factors of food products, translocation factors for plants, plant yields, distribution coefficients and fixation rates of radionuclides, soil-plant and feed-animal transfer factors, biological transfer rate for animal products [16-24].

Since the Chernobyl accident, there had been an increase in real world data to assess the capabilities of softwares, which are developed to calculate radionuclide concentrations in the environment and doses to human. Therefore, data related to the final safety analyze report (FSAR) of the typical WWER-1000 and Chernobyl accident and for normal operations we use some important relations and equations from CROM and AIREM codes was to validate and build up the structure of the developed KIANA Code and for accident conditions we had been compared with the foundations structure of Express RECASS [38]. The validated developed Code (software) was then can be useful to calculate radiological consequences in the case of hypothetical severe accidents and normal operation at typical WWER-1000 such as BNPP-1 and Akkuyu and Sinop NPPs in Turkey and IRAN. The newly developed KIANA Advance Computational Computer Code was run for different release times, and it was turned out that meteorological pattern as well as vegetation cycles of the plants were influencing doses to humans. Ingestion of radionuclides in foods can be an important contributor to the total dose received by an individual or population group. An estimate of the radionuclide concentration is needed to assess such doses. This research will be described a generic methodology to calculate the concentration of radionuclides in human food crops, and animal produce and in surface waters. this paper will be consider the important parameters such as: (a) Deposition by dry or wet processes;(b) Initial interception and retention by vegetation surfaces;(c) Translocation to the edible tissues of vegetation;(d) Post-deposition retention by vegetation and soil surfaces;(e) Uptake by roots;(f) Adhesion of soil particles on to vegetation surfaces;(g) Direct ingestion of surface soil by humans or grazing animals;(h) Transfer of radionuclides in soil, air, water and vegetation into the milk and meat of grazing animals;(i) Transfer of radionuclides in surface water to the terrestrial system by spray irrigation; (j) Transfer of radionuclides in surface water to sediment and to aquatic biota either explicitly or implicitly. Radionuclides discharged into the aquatic environment are also assimilated by living organisms. Some of the assimilated radionuclides are passed along the aquatic food chains and may eventually reach to humans. User Friendly Domestic KIANA Advance Computational Computer Code are used for dose assessments to simulate the transport of radionuclides in aquatic environments and air concentrations. Current Code that describe the transport of radionuclides from liquid discharges to aquatic foods. This paper will be described the generic methods for estimating radionuclide concentrations in water (and sediment) as well as in Rivers, Estuaries, Coastal waters, Small lakes, Large lakes that may be calculated for specific locations where members of hypothetical critical groups could use this water for drinking, fishing, irrigation or swimming, and could use the sediment for recreational or agricultural activities. These locations (at a specified distance x from the point of discharge) are selected to represent the nearest point where water usage is conceivable during the projected lifetime of an operating nuclear facility. The methodology also includes simple processes to estimate default dispersion coefficients, river flow conditions and the coastal current, if site specific values are unavailable. Cs-134, Cs-137 and I-131 were identified as the most dose contributing isotopes, and cereals, cow milk, chicken, fruits, lamb, beef, fruit vegetables and root vegetables were the most dose contributing foods respectively (Figures 1 up 10). Furthermore, the outputs were processed by correlation techniques to find out most influencing parameters on lifetime and short-term doses. It can be concluded that soil-plant transfer factors for Cs have a big influence on the lifetime(Collective) dose results, feed-animal transfer factor for Cs for cow milk and reduction factors for external radiation, beef and grain consumption amounts have also the high effect on lifetime doses. For the short-term doses, cow milk transfer factor for iodine and interception factor for the grass are also influential parameters. The design of the User-Friendly KIANA code is flexible such that it can be adopted anywhere for any nuclear power plant site with suitable modifications to the database and the KIANA code will be design the main menu of the application, being always active the menu bar such as: Database- Case- Options- View- Help-user manual

The objective of the paper is to develop a domestic user friendly dynamic radiological dose and model for accidental atmospheric release of radionuclides and normal operation from a nuclear facility, which has been coupled with a long-range atmospheric transport and Gaussians dispersion model. The research in this study is based on (i) atmospheric dispersion of radionuclides, (ii) dose and risk model development, (iii) validation of the model with FSAR of typically WWER-1000 Reactor. Models to represent the transport of radionuclides following atmospheric tests of nuclear weapons were developed during the 1950s and 1960s. Though radionuclides have been released into the environment during routine operational conditions of nuclear facilities, accidents and nuclear weapons tests, the KIANA Advance Computational Computer Code model that was developed for this study was planned to predict all of radiation doses and risks in the case of a nuclear accident and normal operation in nuclear installations. The novelties in this research are to couple a KIANA Advance Computational Computer Code dynamic dose and risk model with a long-range atmospheric transport model to predict the radiological consequences due to accidental releases and normal operation in nuclear installations, and to perform the model simulation for NPP sites in IRAN territory and with another site specification data as far as it can be acquired. Most of the mechanisms and phenomena considered in each of the existing dose and risk calculation and environmental transfer models have been compiled in the newly developed single

KIANA Advance Computational Computer Code to lead detailed modeling. An uncertainty and sensitivity analysis can also part of the study to determine the most influential parameters and their uncertainties on the results for users (if applicable). A huge amount of data, such as radioactivity concentration in foodstuffs, pasture and doses, regarding the consequences of nuclear power plants' accidents and normal conditions in literature was used for development of Computer Code and its validation.

THE NOVELTY OF THE PAPER

The main features of this software and study can be summarized as follows:

Exposure from all pathways during Normal and Accidental Conditions is included- Ingestion pathways are modeled in such a detailed way that, translocation,-transfer between soil-plant, and feed-animal, food processing and storage, weathering, and dilution in the plant are all taken into account. Time dependency in radionuclide transfer in the environment considering food harvesting, sowing times, feeding regimes, and the growing up of a person are all taken into account. Individual doses for maximum and average individuals and for four age groups are calculated. Doses in the case of implementation of countermeasures are calculated. Collective doses for big cities can be calculated. Two different methods for stochastic risk modeling are applied. A probabilistic module has also been developed; namely, uncertainty analysis can be performed (if applicable).This study is regarded as unique since. The model algorithms, which the KIANA Advance Computational Computer Code developed for this study was based on IAEA safety report series (Müller, H. and Pröhl, G., 1993), has been modified; the KIANA Advance Computational Computer Code to be able to calculate inhalation doses from re-suspension, individual doses in terms of both average and maximum habits, collective doses and late risks, andto utilize the recent knowledge in the dose and risk assessment area to theextent possible, such as dose conversion factors and risk coefficients etc. we use the four method for determination of atmospheric stability classes such as the followings:

-method of wind of fluctuations

-Method of vertical temperature gradient and wind velocities

-Pasquill-Turner method with IEM correction

-The Pasquill-Gifford method

And another novelty that had been used in the paper is use of correction allowing for the impact of the top of the atmospheric boundary layer on Plume Dispersion [1-3,40].

The long-range transport model, which the Code/ software developed for this study was coupled with, was also upgraded to increase the number of pollutants modeled to provide us easiness .Besides, extensive uncertainty and sensitivity analyses associated with 96parameters have been performed for this study. The meteorological module in the existing environmental emergency response system is associated with 3-day- Domestic forecast meteorological data acquired through the State Meteorological Directorate. The dispersion model is the Developed AIREM and DOZAE M model that has the capability to predict trajectories, concentration, and deposition patterns in the case of nuclear accidents and normal operations. However, doses, risks, and activities in the food chain are not calculated with the existing system in IRAN. Since the newly developed KIANA Advance Computational Computer Code for this study is compatible with the existing system's dispersion code, it can easily be integrated to it.

ATMOSPHERIC DISPERSION MODELS

Numerous radiation dose calculation tools have been developed over the years. They calculate trajectories, atmospheric transport and dispersion, age-dependent radiation doses, early and late health risks, monetary costs of the accidents, doses in the case of implementation of emergency actions, collective health risk, uncertainty analysis etc. Atmospheric dispersion methods in these tools can be based on simple Gaussian or numerical approaches. Short-range dispersion models usually use straight-line Gaussian plume model. These models are appropriate if the release is from a source that has dimensions, which are small compared to the distances at which concentrations are to be estimated. For example, for the distances out to 5-10 km from the source point, if the terrain is relatively flat and has uniform surface conditions in all directions and if the atmospheric conditions at the time and location of the release completely control the transport and diffusion of material in the atmosphere short-range atmospheric dispersion models are preferred. Gaussian dispersion equations should be used to estimate concentrations up to the 80 km from the source under ideal conditions of flat terrain and no spatial variations of the wind field. Consequently, for a countrywide dispersion simulation, due to topography and dispersion area, the straight-line Gaussian models cannot be appropriate tools. Therefore, long-range atmospheric dispersion models are used in this paper [33-38,40]. Dose assessment methodology in some aforementioned short range codes neglect ingestion pathway and calculation of doses in the late phase of the accident. These are coupled with simple radiation dose modeling algorithm including only inhalation and external radiation pathways i.e. Hotspot, RASCAL and RTARC (Homann, S. G., 2010, Mcguire, S. A., Ramsdell, Jr., J. V. and Athey, G. F., 2007, Stubna M. and Kusovska Z.1993) All radiation dose exposure pathways can be seen in Figure 1[1,2,4].

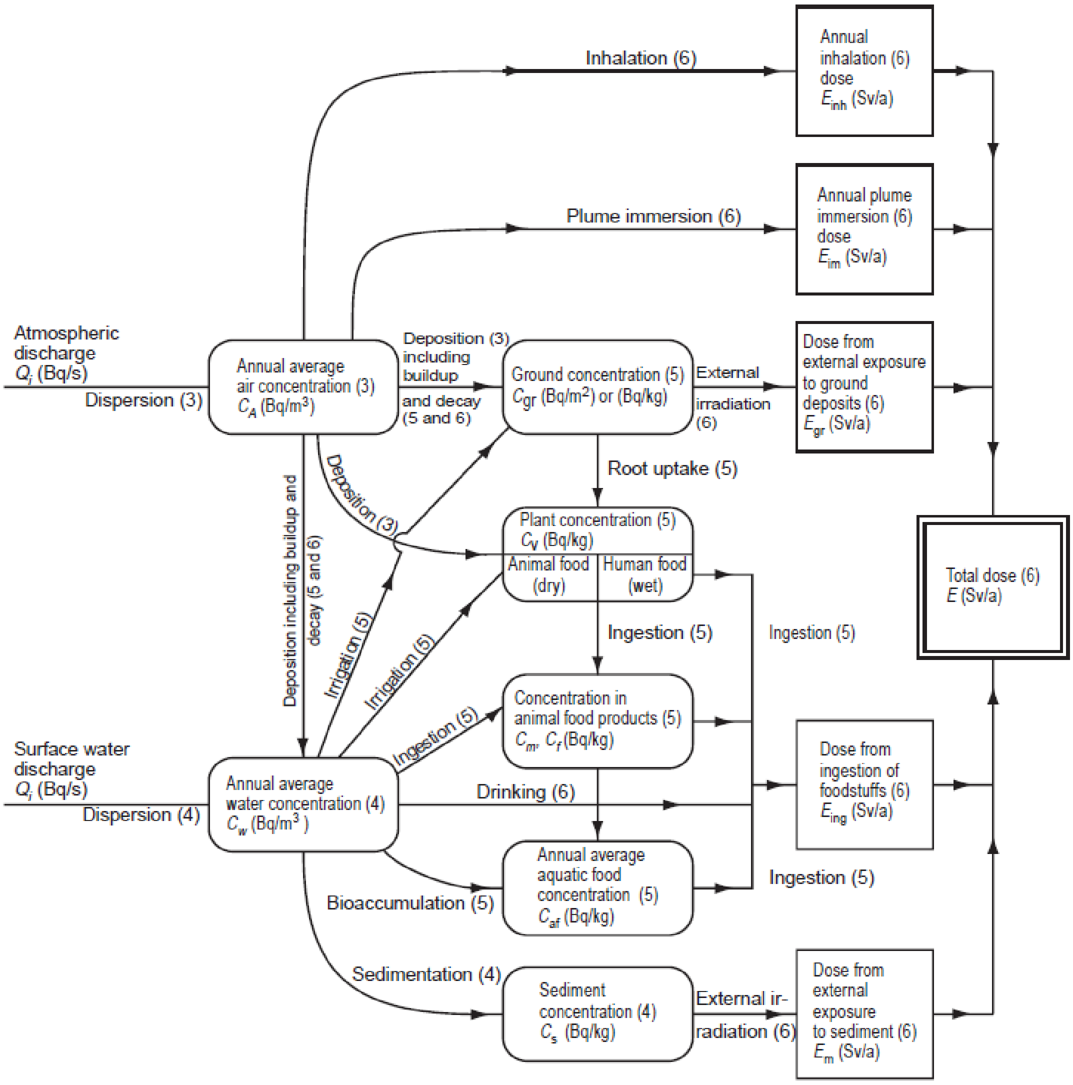


Fig.1. Radiation Dose Exposure Pathways in KIANA Advance Computational Computer Code structure [4]

Since short range codes generally calculate short-term doses incurred immediately after the accident and recommend emergency protective actions, such as intervention, sheltering and iodine pills, and long-term effects incurred from ingestion pathway are not generally calculated with these types of codes. Some of the codes having Gaussian plume methodology calculates ingestion doses but not in a dynamic or comprehensive way for real time releases i.e. GENII (Napier 2002). Long-range atmospheric transport models, on the other hand, generally focus on calculation of the trajectories, atmospheric transport and dispersion, and are used for real time emergency preparedness purposes. These numerical models use multiple wind measurements in both the horizontal and vertical directions, and include terrain effects and vertical

algorithm (Draxler, R.R., and G.D. Hess, 1997, Suh et al., 2006, 2008, 2009, Apsimon, H.M.; Goddard, A.J.H.; Wrigley, J., 1985 and Sorensen, 1998; Sorensen et al., 2007). Generally, these types of long-range dispersion codes are integrated with environmental transfer models to predict activity in the environment and the resulting doses.

RADIOECOLOGICAL MODELS

Two general classes of radio ecological models have evolved; dynamic (transient) and equilibrium (steady state). Both describe the environment in terms of various “compartments” such as plant types, animal food products’ types and soil layers. Some environmental media may be described in terms of more than one compartment, such as the roots, branches and trunk. When the equations are evaluated for sufficiently long times with unvarying values of the inputs and rate constants, the ratios of the concentrations of the

Radionuclides in the various compartments approach constant values. The system is then considered to be in equilibrium or in a steady state. These “quasi-equilibrium models”do not account for changes in plant biomass, livestock feeding regimes, or in growth and differential uptake of radioactive progeny during food chain transport. They are generally not appropriate for the assessment of critical short-term impacts from acute fallout events that may occur during the different times of the year and for applications related to the development of criteria for the implementation of actions. In the late 1970’s the dynamic radio ecological models started to emerge and led to a number of different such models. Since dynamic food chain transport models themselves are normally rather complex and require significant computing times most of the codes (e.g. Slaper et al., 1994, Hermann et al., 1984, Napier et al., 1988) neglect radiation exposure changes due to seasonal variations of radionuclides in the environment and human behaviors. For more realistic dose calculations, time dependency of the radionuclide transfer processes should be taken into account, leading to a dynamic modeling. Lots of radio ecological data is necessary for dynamic ingestion and horizontal wind shear they also treat the parameter variables more realistically, such as surface roughness, deposition and variable atmospheric stability. Numerical modeling is widely used to study long-range airborne transport and deposition of radioactive matter after a hypothetical accident and normal operations. Ladas, Mesos and Derma are those having long-range atmospheric transport and dispersion

pathway modeling. After the significant parameters are determined with respect to their effects on the results by sensitivity analysis these data may be derived locally to lead to realistic modeling, PARATI, PATWHWAY, Ecosys-87, SPADE (quasi-equilibrium),COMIDA and DYNACON are some dynamic dose models for modeling environmental transfer of radionuclides in the food chain (Rochedo et.al. 1996, Whicker and Kirchner,1987, Müller, H., Pröhl, G., 1993, Johnson and Mitchell, 1993; Mitchell, 1999, Abbott, M. L., Rood, A.S., 1993, Hwang, W.T., Lee, G.C. Suh, K.S. E. H. Kim).

Since equilibrium in the model compartments (between vegetation, soil, and animal products) is not reached for a long time, it is essential to consider seasonality in the growing cycles of crops, feeding practices of domestic animals, and dietary habits. However, because of the temporal resolution demanded for the output, a great deal of information is required as input to this type of model, and extensive computer resources are required for the implementation. By using assumptions of quasi-equilibrium (that is, relatively small changes from year to year in local conditions), the dynamic models may be simplified into equilibrium models. Knowledge of the contamination level of radionuclides in foodstuffs including crops and animal products is essential information for deciding the implementation of protective actions. The degree of contamination can be evaluated through a model prediction from the amount of radionuclides deposited on the ground, as well as through direct measurements of radionuclides in foodstuffs. In developing systems for emergency preparedness as well as providing for rapid decision-making relating to foodstuffs, the characterization of action plans based on model predictions are likely to be appropriate[1-4,13,15,21,24-32]. In the case of short-term deposition of radionuclides after a nuclear accident, the radionuclide concentration in foodstuffs is strongly dependent on the date (or season) when the deposition occurs, and on the time after the deposition due to factors such as crop growth and bio kinetics of radionuclides ingested by the animals. Therefore, these dynamic environmental transfer models are generally implemented in areal time emergency or decision support systems, which are used before and during an ongoing emergency and provide sound basis countermeasures [38,40]. In some radio ecological models, such as COMIDA, CRLP and TERNIRBU (Brown, J. and Simmonds, J., R., 1995, KrcgewskiP., 1989, Kanyar, B., Fulop N., TERNIRBU, 1996) soil compartment is modeled in such a way that it is divided into many layers: surface layer, root layer, and deep soil layer, etc. The code developed for this study took AIREM, DOZAE M & S. R.S of IAEA models as reference. The data library for unlimited isotopes is available in the new software (sub routine). All natural phenomena important for ingestion pathway modeling is taken into consideration in the new algorithm and model [4,38]. Whereas, time dependent translocation, layered soil compartment, wet interception, and mushroom pathway are not available in the current model. Generally, the computer models developed for the prediction of routine releases from NPPs are based on the annual average concentrations of radionuclides in air and on the ground [4-7]. However, for NPP routine atmospheric releases a dynamic model coupled with a long-range transport code was developed in another study (Kocar, C., 2003). In current study, to address the unique features of modeling operational radiological consequences of nuclear power plants, a few new algorithm based on the dynamic radio ecological model had been considered. Different from aforementioned dynamic model (Müller, H. and Pröhl, G., 1993), transfer mechanisms of C-14 and H-3 were coded and multi-location food supply and interregional moves of people in the computational domain were permitted. In this study, inhalation doses from both passage of the cloud and re-suspension of deposited activity are calculated and accidental releases are simulated, but the previous one is for operational releases are modeled and H-3 and C-14 releases which are of great significance for operational releases are modeled. In this study individual doses are calculated for two different habits of the people in term of food consumption and gamma reduction [1-4,40].

KIANA ADVANCE COMPUTATIONAL COMPUTER CODE STRUCTURE

A deterministic dose calculation model called KIANA Advance Computational Computer Code has been developed for this study. For the dose assessment, all exposure pathways have been implemented as follows: Transfer of radionuclides through food chains and the subsequent internal exposures of humans due to ingestion of contaminated foodstuffs- Internal exposure due to inhalation of radionuclides during passage of cloud and from re-suspension of deposited radionuclides-External exposure from radionuclides in the passing cloud-External exposure from radionuclides deposited on the ground. The design of the KIANACode is flexible such that it can be adopted anywhere for any nuclear power plant/nuclear installations site with suitable modifications to the database [1,2,4,38-40].

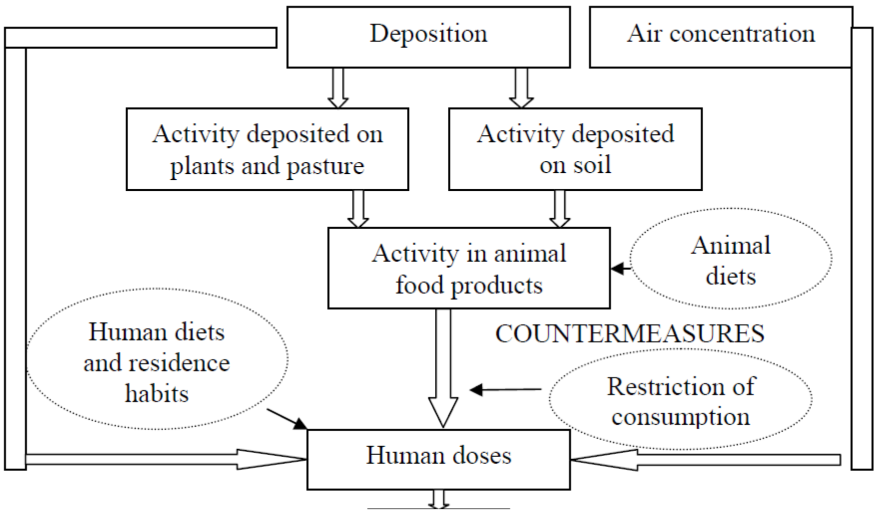


Fig.2. Summary of Code Algorithms [4,38].

INGESTION PATHWAY

Ingestion pathway calculations that used in KIANA Advance Computational Computer Code take into account the following process and data:

- *Yield of grass and agricultural food products*
- *Harvesting and sowing time of grass and agricultural products*
- *Translocation within plants*
- *Interception*
- *Weathering from plant surfaces*
- *Dilution and Non- Dilution of radionuclide concentrations due to plant growth*
- *Uptake by plant roots*
- *Migration within the soil and*
- *Plant contamination due to re-suspended soil*
- *Different livestock feeding regimes*
- *Storage times for fodder and human food products*
- *Changes in radionuclide concentrations due to food processing.*

Age dependent ingestion dose coefficients for public are taken from ICRP 72(1996). Dose coefficients for 3 months infant, 5 year old child, 15 years old teen and adult are used 104,14,15,36]. ICRP ingestion dose conversion factors take into account integration period of50 year for adults and 70 year for children .Input data to the ingestion modeling is the time integrated air concentrations, and deposited activity from any dispersion model or measured data. Ingestion of tap water and aquatic food products are not considered in KIANA Advance Computational Computer Code[1-5,8-12,38].

ACTIVITY CONCENTRATION OF PLANT PRODUCTS

The contamination of plant products as a function of time results from the direct contamination of the leaves and the activity transfer from the soil by root uptake and re-suspension:

Pasture and 13 different plant products, i.e. corn cobs, spring and winter wheat, spring and winter barley, rye, fruits, berries, and root, fruit and leafy vegetables, potatoes and beet can be modeled by KIANA Advance Computational Computer Code[8-10,38-40].

$$C_i(t) = C_{i,f}(t) + C_{i,r}(t)$$

$C_i(t)$; total contamination of plant type i,

$C_{i,f}(t)$; contamination of plant type i due to foliar uptake,

$C_{i,r}(t)$; contamination of plant type i due to root uptake.

FOLIAR UPTAKE OF RADIONUCLIDES:

Calculation of the contamination of plants must distinguish between plants that are used totally (leafy vegetables and grass) and plants of which only a special part isused. The activity concentration at time after the deposition is determined by the initial contamination of the plant and activity loss due to weathering effects (rain, wind) and radioactive decay and growth dilution. For plants that are totally consumed growth, excluding pasture grass, growth is implicitly considered because the activity deposited onto leaves is related to the yield at harvest. Interception factor is defined as the ratio of the activity initially retained by the standing vegetation immediately subsequent to the deposition event to the total activity deposited. Radionuclides to agricultural plants may be intercepted by dry process, wet process, or a combination of both. The interception fraction is dependent on the plant intensity in the area, stage of development of the plant, and generally leaf area of the crops. In the present model, a single coefficient was used and interception factors for grass and other plants were taken from Dose CAL code [1,3,4,38]; the interception factor for grass and, fruits and vegetables is assumed to be 0.3 and for the grain and cereals it is 0.005. The activity concentration at the time of harvest is given the approach for pasture grass is different because of its continuous harvest. Here, the decrease in activity due to growth dilution is explicitly considered [4,8,40].

$$C_{g,f}(t) = f_g \frac{A_g}{Y_g} \{(1-a)\exp[-(\lambda_b + \lambda_w + \lambda_r)t] + a \exp[-(\lambda_t + \lambda_r)t]\}$$

$C_{g,f}(t)$; activity concentration ($Bq.kg^{-1}$) in grass at time t after deposition,

f_g; interception factor for grass,

A_g; total activity deposited onto grass ($Bq.m^{-2}$),

Y_g; yield of grass at time of deposition ($kg.m^{-2}$),

a; fraction of activity translocated to the root zone,

λ_b; dilution rate by increase of biomass (d^{-1}),

λ_t; rate of activity decrease (d^{-1}) due to translocation to the root zone,

For the weathering rate constant λw; a value equivalent to a half-life 14 d is taken from Farmland code (NRPB, 1995) and for rate of activity decrease due to translocation to the root zone λt; 1.16x10-2 d-1 with a contribution fraction a= 0.05 using different measurement of grass contamination after the Chernobyl accident are assumed (Pröhl,1990). For plants that are only partly used for animal feeding or human consumption the translocation from leaves to the edible part of the plant has to be considered. This

Process strongly depends on the physiological behavior of the element considered. It is important for mobile elements such as cesium, iodine, tellurium whereas for immobile elements including strontium, barium, zirconium, niobium, ruthenium, cerium, plutonium only direct deposition onto edible parts of the plants play role. Translocation process is quantified by translocation factor Ti, which is defined as the fraction of the activity deposited on the foliage being transferred to the edible parts of the plant until Harvest. It is dependent on the element, plant type and time between deposition and harvest. Translocation factors for agricultural food products for cesium, strontium and other elements were taken from IAEA TRS-472 (2010). Translocation factors for only the ripening stage is applied in KIANA Advanced Computational Computer Code.

ROOT UPTAKE OF RADIONUCLIDES

The estimation of the root uptake of radionuclides assumes that the radionuclides are well mixed within the entire rooting zone. The concentration of activity due to root uptake is calculated from the concentration of activity in the soil using transfer factor TFi that gives ratio of concentration of activity in plants (fresh weight) and soil (dry weight)[4,8-10,39]:

$$C_{i,r}(t) = TF_i C_s(t)$$

$C_{i,r}(t)$; concentration of activity (Bq/kg) in plant type i due to root uptake at time t after the deposition,

TF_i; soil-plant transfer factor for plant type i,

$C_s(t)$; concentration of activity (Bq/kg) in the root zone of soil at time t.

The soil conditions which soil-plant transfer factors are based are often characterized by a low pH value together with a high organic content, and low contents of clay, potassium and calcium. Such soils are frequently found in upland areas, Scandinavia, and parts of Eastern Europe. (Pröhl, G., and Müller, H., 1993)The concentration of activity in the root zone of soil is given by:

$$C_s(t) = \frac{A_s}{L.\delta} \exp\left[-\left(\lambda_s + \lambda_f + \lambda_r\right)t\right]$$

A_s; total deposition to soil ($Bq.m^{-2}$)

L; depth of root zone (m)

ρ; density of soil ($kg.m^{-3}$)

λ_s; rate of activity decrease due to migration out of the root zone

λ_f; rate of fixation (d^{-1})

The migration rate λ_s is estimated according to;

$$\lambda_s = \frac{V_a}{L.(1 + K_d.\delta/\theta)}$$

v_a; velocity of percolation water in soil ($m.a^{-1}$)

K_d; distribution coefficient ($cm^3.g^{-1}$)

θ; water content of soil ($g.g^{-1}$)

CONTAMINATION OF ANIMAL PRODUCTS

The contamination of animal products results from the activity intake of the animals and the kinetics of the radionuclides within the animals. Inhalation of radionuclides by the animals is not considered; this pathway may be relevant for milk contamination in certain cases, but it is unimportant for resulting doses. The amount of activity ingested by the animals is calculated from the concentration of activity in the different feedstuffs and the feeding rates;

$$A_{a,m}(t) = \sum_{k=1}^{K_m} C_k(t).I_{k,m}(t)$$

$A_{a,m}(t)$; activity intake rate of the animal m ($Bq.d^{-1}$),

K_m; number of different feedstuffs fed to the animal m,

$C_k(t)$; activity concentration ($Bq.kg^{-1}$) in feedstuffs k,

$I_{k,m}(t)$; feeding rate ($kg.d^{-1}$) for feedstuffs k and animal m.

Soil ingestion is also considered in KIANA Advance Computational Computer Code. Soil intake of animals varies widely depending on the grazing management and the condition of the pasture. If the feeding of mechanically prepared hay and silage during winter and an intensive grazing regime on well fertilized pasture are assumed a mean annual intake of 2.5% of the grass dry matter intake seems to be appropriate. This nuclide independent value is equivalent to soil-plant transfer factor of 5x10-3 and it is added to the transfer and re-suspension factor in KIANA Advance Computational Computer Code. This means that for all elements with a transfer factor lower than this value, soil eating is the dominating long term pathway for the contamination for milk and meat from grazing cattle, presuming that resorption in the gut is the same for soil-bound and plant incorporated radionuclides. Seven different animal products, namely cow, sheep and goat milk, and lamb, beef cattle, egg and chicken, can be modeled by KIANA Advance Computational Computer Code. Transfer of radionuclides from fodder into animal products is calculated as follows [4,15,38]:

$$C_m(t) = TF_m \sum_{j=1}^{J} \left\{ a_{mj} \int_0^t A_{a,m}(t) \lambda_{b,mj} \exp\left[-\left(\lambda_{b,mj} + \lambda_r\right)t\right] dt \right\}$$

$C_m(t)$; activity concentration in animal product m at time t,

TF_m; transfer factor ($d.kg^{-1}$) for animal product m,

j; number of biological transfer rates,

a_{mj}; fraction of biological transfer rates,

$\lambda_{b,mj}$; biological transfer rate j (d^{-1}) for animal product m.

For sheep and goat milk transfer factors 10 times higher than for cow milk are assumed. For lamb, goat's meat, and chicken, the transfer was estimated from the feed-beef transfer factor by applying correction factors for the lower body mass. Correction factors are 3 for lamb, and goat's meat and 100 for chicken.

(Müller, H. and Pröhl, G., 1993) Biological turnover rate of animal products were taken from DOZAE M, AIREM and DoseCAL [4 ,15,38].

THE PROCESSING AND STORAGE OF FOODSTUFFS

The processing and storage of foodstuffs in order to take advantage of the radioactive decay and dilution during these processes are taken into account in the model. The enrichment of minerals in the outer layers of grains and the fractionation in the milling products is considered. Besides, the radioactive decay during processing and storage is taken into account. The storage presumes the stability of the foodstuffs or the possibility to convert the foodstuffs into stable products. Storage times are considered to be mean time between the harvest and beginning of product consumption. Concentration of activity in products is calculated from the raw product by the following relation:

$$C_k(t) = C_{ko}(t - t_{pk}) P_k \exp(-\lambda t_{pk})$$

$C_k(t)$; activity concentration (Bq/kg) in product k ready for consumption at time t,

C_{ko}; activity concentration (Bq/kg) in raw product at time t,

P_k; processing factor for product k,

λ_r; radioactive decay constant (d^{-1}),

t_{pk}; storage and processing time (d) for product k.

ACTIVITY INTAKE AND EXPOSURE

The intake of activity by humans is calculated from the time-dependent concentrations of activity in foodstuffs and the human consumption rate [4,15,38]:

$$A_h(t) = \sum_k C_k(t).V_k(t)$$

$A_h(t)$; human intake rate ($Bq.d^{-1}$) of activity,

$C_k(t)$; concentration of activity ($Bq.kg^{-1}$) of foodstuff k,

$V_k(t)$; consumption rate ($kg.d^{-1}$) of foodstuff k.

The foodstuffs are assumed to be locally produced. Food consumption data that is very important for calculating dose exposure by ingestion pathway is different depending on where people live. Country specific data on consumption of food products have been used to lead to realistic modeling. The dose Ding (t) due to ingestion of contaminated foodstuffs within time t after the deposition, is given by the following [2-4,15];

$$D_{ing}(t) = \int_0^t A_h(t).DF.dt$$

$D_{ing}(t)$; ingestion dose (Sv),

DF; age dependent dose factor for ingestion ($Sv.Bq^{-1}$)

CALCULATION OF Activity concentration of plant products

$$R_{inh} = F_{in}.c_{in} + F_{out}.c_{out}$$

contamination of plant products as a function of time results from the direct contamination of the leaves and the activity transfer from the soil by root uptake and resuspension

$$C_i(t) = C_{i,f}(t) + C_{i,r}(t)$$

$C_i(t)$; total contamination of plant type i,

$C_{i,f}(t)$; contamination of plant type i due to foliar uptake,

$C_{i,r}(t)$; contamination of plant type i due to root uptake.

Foliar uptake of radionuclides (activity concentration at the time of harvest)

$$C_{i,f}(\Delta t) = f_i \frac{A_i}{Y_i} \exp[-(\lambda_r + \lambda_w)\Delta t] \qquad (3.8)$$

$C_{i,f}(t)$; concentration of activity in plant type i at time of harvest,

f_i; interception factor for plant type i,

A_i; total deposition ($Bq.m^{-2}$) onto plant type i due to the plants leaf area index at time of deposition,

Y_i; yield ($kg.m^{-2}$) of plant type i at time of harvest,

λ_w; loss rate (d^{-1}) due to weathering,

λ_r; decay rate (d^{-1}),

Δt; time span between deposition and harvest (d).

for pasture grass is different because of its continuous harvest. Here, the decrease in activity due to growth dilution is explicitly considered

$$C_{g,f}(t) = f_g \frac{A_g}{Y_g} \{(1-a)\exp[-(\lambda_b + \lambda_w + \lambda_r)t] + a\exp[-(\lambda_t + \lambda_r)t]\}$$

Fig.3. Code Algorithms of contamination of plant products as a function of time results from the direct contamination of the leaves and the activity transfer from the soil by root uptake and re-suspension that used in construction of KIANA Advance Computational Computer Code

Translocation factors for only the ripening stage(concentration of activity in plant type i at time of harvest)

$$C_{i,f}(\Delta t) = \frac{A_i}{Y_i} T_i \exp(-\lambda_r \Delta t)$$

T_i; translocation factor for plant type i,

Y_i; yield of edible parts of plant type i ($kg.m^{-2}$).

decrease in activity due to growth dilution is explicitly considered (activity concentration ($Bq.kg^{-1}$) in grass at time t after deposition**)**

$$C_{g,f}(t) = f_g \frac{A_g}{Y_g} \{(1-a)\exp[-(\lambda_b + \lambda_w + \lambda_r)t] + a\exp[-(\lambda_t + \lambda_r)t]\}$$

$C_{g,f}(t)$; activity concentration ($Bq.kg^{-1}$) in grass at time t after deposition,

f_g; interception factor for grass,

A_g; total activity deposited onto grass ($Bq.m^{-2}$),

Y_g; yield of grass at time of deposition ($kg.m^{-2}$),

a; fraction of activity translocated to the root zone,

λ_b; dilution rate by increase of biomass (d^{-1}),

λ_t; rate of activity decrease (d^{-1}) due to translocation to the root zone,

t; time after deposition (d)

Translocation factors for only the ripening stage is applied مرحله رشد کامل

$$C_{i,f}(\Delta t) = \frac{A_i}{Y_i} T_i \exp(-\lambda_r \Delta t)$$

T_i; translocation factor for plant type i,

Y_i; yield of edible parts of plant type i ($kg.m^{-2}$).

Fig .3. (continued)

CALCULATION OF Inhalation doses for each incremental time step (in days)

$$R_{inh} = F_{in}.c_{in} + F_{out}.c_{out}$$

Inhalation doses

$$D_{inh} = C_A.V_B.DC_{inh}.R_{inh}$$

D_{inh}; total inhalation dose (Sv),

C_A; time-integrated air concentration ($Bq.m^{-3}.d$),

V_B; age dependant breathing rate ($m^3.d^{-1}$),

DC_{inh}; age dependant radionuclide specific dose conversion factor for inhalation ($Sv.Bq^{-1}$),

R_{inh}; age dependant reduction factor for staying in different locations.

Cloudshine and groundshine doses

are calculated as

$$D_c = C_a.DCF_{cshine}.R_c$$

D_c; total cloudshine dose (Sv),

C_a; time-integrated air concentration ($Bq.m^{-3}.s$),

DCF_{cshine}; age dependant cloudshine dose conversion factor ($Sv.m^3.Bq^{-1}.s^{-1}$),

R_c; reduction factor for staying at different locations.

$$R_c = \sum f_i.c_{c,i}$$

fi; age dependant fraction of time staying at location i,

cc,i ;correction coefficient for the gamma dose rate at location i relative to that in a semi-infinite homogenous cloud

Cloudshine and groundshine doses

are calculated as

$$D_{gshine}(T) = GC(t).R_g.DC_{gshine}.\exp(-\lambda_r t)$$

Fig .4. Code Algorithms calculation of Inhalation doses for each incremental time step (in days) that used in construction of KIANA Advance Computational Computer Code

CALCULATION OF Activity concentration of plant products

Root uptake of radionuclides

concentration of activity (Bq/kg) in plant type i due to root uptake at time t after the deposition

$$C_{i,r}(t) = TF_i C_s(t) \tag{3.11}$$

$C_{i,r}(t)$; concentration of activity (Bq/kg) in plant type i due to root uptake at time t after the deposition,

TF_i; soil-plant transfer factor for plant type i,

$C_s(t)$; concentration of activity (Bq/kg) in the root zone of soil at time t.

The concentration of activity in the root zone of soil is given by

$$C_s(t) = \frac{A_s}{L.\delta} \exp\left[-(\lambda_s + \lambda_f + \lambda_r)t\right]$$

A_s; total deposition to soil ($Bq.m^{-2}$)

L; depth of root zone (m)

ρ; density of soil ($kg.m^{-3}$)

λ_s; rate of activity decrease due to migration out of the root zone

λ_f; rate of fixation (d^{-1})

The migration rate λ_s is estimated according to;

$$\lambda_s = \frac{V_a}{L.(1 + K_d.\delta/\theta)}$$

v_a; velocity of percolation water in soil ($m.a^{-1}$)

K_d; distribution coefficient ($cm^3.g^{-1}$)

θ; water content of soil ($g.g^{-1}$)

Fig .5. Code Algorithms calculation of Activity concentration of plant products. Root uptake of radionuclides that used in construction of KIANA Advance Computational Computer Code

for pasture grass is different because of its continuous harvest.
Here, the decrease in activity due to growth dilution is explicitly considered

$$C_{g,f}(t) = f_g \frac{A_g}{Y_g} \{(1-a)\exp[-(\lambda_b + \lambda_w + \lambda_r)t] + a\exp[-(\lambda_t + \lambda_r)t]\}$$

decrease in activity due to growth dilution is explicitly considered (activity concentration (Bq.kg-1) in grass at time t after deposition)

$$C_{g,f}(t) = f_g \frac{A_g}{Y_\sigma} \{(1-a)\exp[-(\lambda_b + \lambda_w + \lambda_r)t] + a\exp[-(\lambda_t + \lambda_r)t]\}$$

$C_{g,f}(t)$; activity concentration ($Bq.kg^{-1}$) in grass at time t after deposition,

f_g; interception factor for grass,

A_g; total activity deposited onto grass ($Bq.m^{-2}$),

Y_g; yield of grass at time of deposition ($kg.m^{-2}$),

a; fraction of activity translocated to the root zone,

λ_b; dilution rate by increase of biomass (d^{-1}),

λ_t; rate of activity decrease (d^{-1}) due to translocation to the root zone,

t; time after deposition (d)

Translocation factors for only the ripening stage is applied مرحله رشد کامل

$$C_{i,f}(\Delta t) = \frac{A_i}{Y_i} T_i \exp(-\lambda_r \Delta t)$$

T_i; translocation factor for plant type i,

Y_i; yield of edible parts of plant type i ($kg.m^{-2}$).

Fig.5 (continued)

decrease in activity due to growth dilution is explicitly considered (activity concentration (Bq.kg-1) in grass at time t after deposition)

$$C_{g,f}(t) = f_g \frac{A_g}{Y_g} \{(1-a)\exp[-(\lambda_b + \lambda_w + \lambda_r)t] + a\exp[-(\lambda_t + \lambda_r)t]\}$$

$C_{g,f}(t)$; activity concentration ($Bq.kg^{-1}$) in grass at time t after deposition,

f_g; interception factor for grass,

A_g; total activity deposited onto grass ($Bq.m^{-2}$),

Y_g; yield of grass at time of deposition ($kg.m^{-2}$),

a; fraction of activity translocated to the root zone,

λ_b; dilution rate by increase of biomass (d^{-1}),

λ_t; rate of activity decrease (d^{-1}) due to translocation to the root zone,

t; time after deposition (d)

Translocation factors for only the ripening stage is applied مرحله رشد کامل

$$C_{i,f}(\Delta t) = \frac{A_i}{Y_i} T_i \exp(-\lambda_r \Delta t)$$

T_i; translocation factor for plant type i,

Y_i; yield of edible parts of plant type i ($kg.m^{-2}$).

Fig .6. Code Algorithms concentration activity intake rate of the animal m (Bq.d-1), that used in construction of KIANA Advance Computational Computer Code

CALCULATION OF Activity concentration of animal products

Concentration of activity in products is calculated from the raw product by the following relation:

$$C_k(t) = C_{ko}(t - t_{pk}) P_k \exp(-\lambda t_{pk})$$

$C_k(t)$; activity concentration (Bq/kg) in product k ready for consumption at time t,

C_{ko}; activity concentration (Bq/kg) in raw product at time t,

P_k; processing factor for product k,

λ_r; radioactive decay constant (d^{-1}),

t_{pk}; storage and processing time (d) for product k.

The processing and storage of foodstuffs

decrease in activity due to growth dilution is explicitly considered (activity concentratic (Bq.kg-1) in grass at time t after deposition**)**

$$C_{g,f}(t) = f_g \frac{A_g}{Y_g}\{(1-a)\exp[-(\lambda_b+\lambda_w+\lambda_r)t] + a\exp[-(\lambda_t+\lambda_r)t]\}$$

$C_{g,f}(t)$; activity concentration ($Bq.kg^{-1}$) in grass at time t after deposition,

f_g; interception factor for grass,

A_g; total activity deposited onto grass ($Bq.m^{-2}$),

Y_g; yield of grass at time of deposition ($kg.m^{-2}$),

a; fraction of activity translocated to the root zone,

λ_b; dilution rate by increase of biomass (d^{-1}),

λ_t; rate of activity decrease (d^{-1}) due to translocation to the root zone,

t; time after deposition (d)

Translocation factors for only the ripening stage is applied مرحله رشد کامل

$$C_{i,f}(\Delta t) = \frac{A_i}{Y_i} T_i \exp(-\lambda_r \Delta t)$$

T_i; translocation factor for plant type i,

Y_i; yield of edible parts of plant type i ($kg.m^{-2}$).

Fig .7. Code Algorithms of Concentration of activity in products is calculated from the raw product that used in construction of KIANA Advance Computational Computer Code

CALCULATION OF Activity concentration of animal products

intake of activity by humans is calculated from the time-dependant concentrations of activity in foodstuffs and the human consumption rate

$$A_h(t) = \sum_k C_k(t).V_k(t)$$

(3.17)

$A_h(t)$; human intake rate ($Bq.d^{-1}$) of activity,

$C_k(t)$; concentration of activity ($Bq.kg^{-1}$) of foodstuff k,

$V_k(t)$; consumption rate ($kg.d^{-1}$) of foodstuff k.

dose Ding(t) due to ingestion of contaminated foodstuffs within time t after the deposition, is given by the following

$$D_{ing}(t) = \int_0^t A_h(t).DF.dt$$

$D_{ing}(t)$; ingestion dose (Sv),

DF; age dependent dose factor for ingestion ($Sv.Bq^{-1}$)

Fig .8. Code Algorithms intake of activity by humans is calculated from the time-dependent concentrations of activity in foodstuffs and the human consumption rate that used in construction of KIANA Advance Computational Computer Code

CALCULATION OF Activity concentration of animal products

intake of activity by humans is calculated from the time-dependant concentrations of activity in foodstuffs and the human consumption rate

$$A_h(t) = \sum_k C_k(t).V_k(t)$$

(3.17)

$A_h(t)$; human intake rate ($Bq.d^{-1}$) of activity,

$C_k(t)$; concentration of activity ($Bq.kg^{-1}$) of foodstuff k,

$V_k(t)$; consumption rate ($kg.d^{-1}$) of foodstuff k.

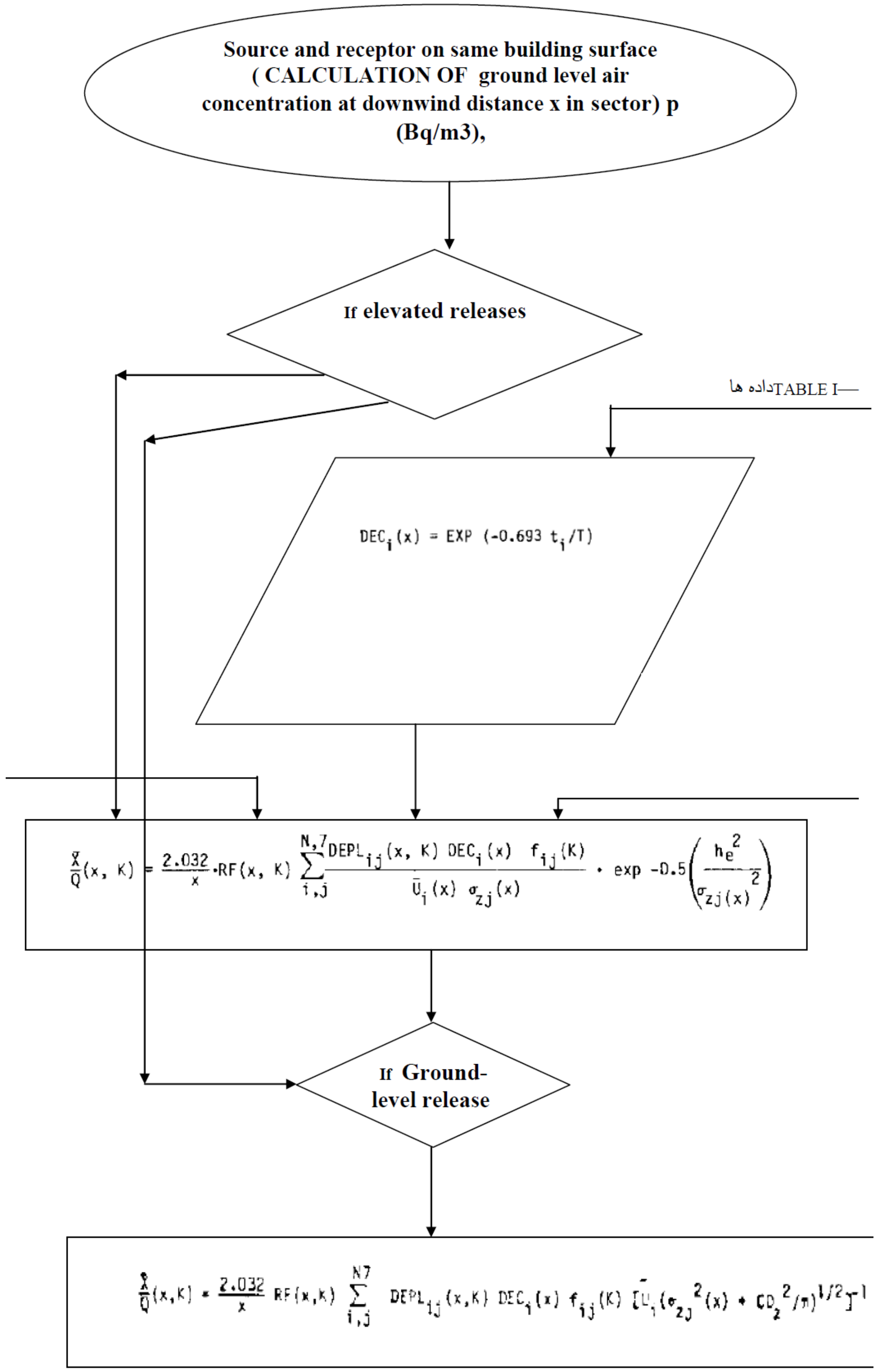
dose Ding(t) due to ingestion of contaminated foodstuffs within time t after the deposition, is given by the following

$$D_{ing}(t) = \int_0^t A_h(t).DF.dt$$

$D_{ing}(t)$; ingestion dose (Sv),

DF; age dependent dose factor for ingestion ($Sv.Bq^{-1}$)

Fig .9. Code Algorithms for dose Ding (t) due to ingestion of contaminated foodstuffs within time t after the deposition, is given by the following that used in construction of KIANA Advance Computational Computer Code


Source and receptor on same building surface (CALCULATION OF ground level air concentration at downwind distance x in sector) p (Bq/m3),
If elevated releases
داده هاTABLE I
$DEC_i(x) = EXP\ (-0.693\ t_i/T)$
$\frac{\bar{\chi}}{Q}(x, K) = \frac{2.032}{x} \cdot RF(x, K) \sum_{i,j}^{N,7} \frac{DEPL_{ij}(x, K)\ DEC_i(x)\ f_{ij}(K)}{\bar{U}_i(x)\ \sigma_{zj}(x)} \cdot \exp -0.5\left(\frac{h_e^2}{\sigma_{zj(x)}^2}\right)$
If Ground-level release
$\frac{\bar{\chi}}{Q}(x,K) = \frac{2.032}{x}\ RF(x,K) \sum_{i,j}^{N7} DEPL_{ij}(x,K)\ DEC_i(x)\ f_{ij}(K)\ [\bar{U}_i(\sigma_{zj}^2(x) + CD_z^2/\pi)^{1/2}]^{-1}$

technique for computing the *X/Q* segment values is

$$\overline{X/Q}_{seg}(K) = \frac{R_1 \, X/Q(R_1,K) + r_1 \cdot X/Q(r_1,K) + \ldots + r_n \cdot X/Q(r_n,K) + R_2 \cdot X/Q(R_n, K)}{R_1 + r_1 \ldots + r_n + R_2}$$

is

maximum additional dispersion due to the building wake

$$\frac{\overline{X}}{Q}(x,K) = \frac{2.032}{x} \, RF(x,K) \sum_{i,j}^{N7} DEPL_{ij}(x,K) \, DEC_i(x) \, f_{ij}(K) \, [\sqrt{3}\bar{U}_i \sigma_{zj}(x)]^{-1}$$

where $X/Q(x,K)$, i,j,K, U_i, $\sigma_{zj}(x)$ $f_{ij}(K)$, $DEC_i(x)$, $DEPL_{ij}(x,K)$, and $RF\ (x,K)$ have been defined previously; and

D_z = building height used to compute additional atmospheric dispersion due to the building wake, based on Yanskey et al. (1966).

$X/Q(R_1, K)$ = X/Q value at downwind distance R_1 for the directional sector K

R_1, R_2 = downwind distance of the segment boundaries

$r_1 \ldots r_n$ = selected radii between R_1 and R_2.

$X/Q_{seg}(K)$ = average value of X/Q for the segment for the directional sector K

Fig .10. Code Algorithms for calculation of ground level air concentration at downwind distance x in sector) p (Bq/m3), when Source and receptor on same building surface that used in construction of KIANA Advance Computational Computer Code

TOTAL DOSE CALCULATION

KIANA Advance Computational Computer Code calculates yearly doses for each age group and for each sector –segment after the accident. Agricultural food products' activities are calculated at each year harvest, grass and animal products' activities are calculated on monthly basis. All aforementioned pathways are included in dose calculations as shown below :

$$Dose_{total} = Dose_{inhalation} + Dose_{ingestion} + Dose_{cloudshine} + Dose_{groundshine}$$

$Dose_{total}$; total dose (Sv)

$Dose_{inhalation}$; inhalation dose (Sv)

$Dose_{ingestion}$; ingestion dose (Sv)

$Dose_{cloudshine}$; cloudshine dose (Sv)

A person is assumed to be as infant up to 1 year, as child up to 9 years, as teen up to 16 years and as adult up to 70 years; namely when calculating long term doses after the accident growing up of a person is taken into account in terms of his/her food consumption habits, sensitivity to doses and occupancy factors.

CALCULATION OF COLLECTIVE DOSES

The impact of an accident on the population as a whole depends not only on the deposition, atmospheric activity levels and dose obtained, but also on the population living in that particular area. For example the deposition, atmospheric activity levels, dose obtained and individual health risk, due to any NPP accident, may be very high, but these high values may not mean anything if there is no one living there. Consequently, better representation of the collective doses or risk of an accident, nuclear and nonnuclear, can be obtained by multiplying the individual dose or health risk by the number of people living in the receptor. For this study, average values all over the geographical regions were taken into account, since data does not vary considerably over the regions. On the other hand. Transfer factors for animal-feeds and soil-plants, and fixation rates, distribution coefficients, translocation factors, dose conversion factors and metabolic turnover rates in animals for all related isotopes, and processing factors and storage days for food products, weathering rates, interception factors and soil density, water content of soil, percolation water velocity, dilution factor of the grass, depth of root zone, the references in which Cs-137 default values were taken for validation study, were used in KIANA Advance Computational Computer Code during simulation of the case studies. Since most of these data are not dependent on location.

RESULT AND DISCUSSIONS

Dispersion of radionuclides is also an application area of KIANA Advance Computational Computer Code. User supplied inputs for KIANA Advance Computational Computer Code calculations are pollutant species characteristics, emission parameters, and gridded meteorological field sand output deposition grid definitions. The horizontal deformation of the wind field, the wind shear, and the vertical diffusivity profile are used to compute dispersion rate. Gridded meteorological data are required for regular time intervals. The meteorological data fields may be provided on one of the different vertical coordinate system: Pressure-sigma, pressure absolute, terrain-sigma or a hybrid absolute-pressure-sigma The doses and time dependent radioactivity concentration values in the food products and pasture grass predicted by KIANA Advance Computational Computer Code have been compared and validated with Methodology , data bank and Calculations of different codes such as AIREM,DOZA, DoseCAL, RECASS Express and CROM which participated in assessment for routine and accidental task for Boushehr Nuclear plant, and data measured in Finland after Chernobyl accident[4,15,38,40]. Those codes are dynamic (time-dependent), and only one of them; i.e. DoseCAL, is quasi-equilibrium. Since KIANA Advance Computational Computer Code is developed as dynamic software (such as DoseCAL), only dynamic codes' results are presented for comparison. KIANA Advance Computational Computer Code has a capability to make simulation with seven pollutants at a time at most for routine and accidental Cases in Nuclear and Chemical Installations. Since some more radionuclides considered being most important in terms of their effects in the environment are used to represent accidental release of radionuclides in the literature as same as the HYSPLIT model's source code that has been modified to simulate more pollutants to provide us easiness for this study.

In this study, dry deposition velocity is assumed to be a constant for each radionuclide and surface type. The dry deposition velocity values for agricultural surface type were used in our simulations. To strengthen our assumption, size of the particles released into environment in the case of a nuclear accident was also investigated. Release height is another important parameter for subsequent dispersion modeling in KIANA Advance Computational Computer Code Structures. Literature studies show that variations of the initial plume rise below the mixing height only slightly affect the results outside the local scale, whereas plume rise above that level led to significantly changed patterns with relatively little depositions on the local and meso-scales. Thus, a release into the atmospheric top boundary level compared with a release to the free troposphere leads to large differences in the deposition patterns and lifetimes (a week or more) of radionuclides within the atmosphere. Release height was assumed as a line source between 50-200 meter considering in Code for all the accident type and Normal Conditions in Nuclear Installations. In 1986, there was a recommendation to postpone the open fields owing of lettuce, spinach and other fast growing vegetables [4,38]. Although it is not clear to what extent this recommendation was implemented across all regions, the fact that KIANA Advance Computational Computer Code did not account for any delay in sowing. However only root uptake for leafy veg etables was taken into account in KIANA as the same as DoseCAL. Leafy vegetables activities predicted by KIANA Advance Computational Computer Code Structures are within uncertainty band of the measured values and the best of all other code results. The probability for T-test for is 0.834, which is close to one. The differences between predictions of the codes which participated in VAMP exercise, may be arised from misinterpretation of site-specific information; namely taking into account different assumptions, or using different soil-plant and feed-animal transfer factors as stated in IAEA TECDOC-904 (1996). Inhalation and external doses predicted by KIANA Advance Computational Computer Code Structures as the same as the DoseCAL calculations are rather consistent compared to other codes' predictions. Ingestion doses predicted by KIANA Advance Computational Computer Code, on the other hand, is lower compared to the other codes. Since in ingestion module of KIANA Advance computational Computer Code Structures, mushroom, fish, game animals are not taken into account, whereas other food products, i.e. fruits, root and fruit vegetables, eggs have been considered as default in KIANA.it is almost equal to beef consumption, and most of the ingestion doses calculated by most of the models participated in validation exercise were incurred from fish consumption. Hence, the difference in ingestion dose prediction in KIANA Advance Computational Computer Code can be attributed to fish pathway. Ingestion doses are highly dependent on consumption rates as seen from the differences between the doses for average and maximum individuals. Inhalation doses are the highest for the children, though the highest inhalation DCFs are of infants, breathing rates for the children are higher than for the infants. Inhalation dose for teens and adults are lower than Childs, since DCF’s for radioisotopes considered in case study for Childs are higher than those for adults except cesium isotopes. External doses are calculated for infants and others (child, teen and adult).Although DCF’s for infants are 1.5 times higher than the others, correction factor for shielding is lower for infants than others, and hence external doses are lower for infants. External ground doses are lower for infants too as far as the years passed after the accident is concern. In the case of implementation of countermeasures on food consumption restrictions in the first year after the accident, the ingestion and total doses for average individuals for all age groups can be predicted by KIANA Advance computational Computer Code. The most dose contributing isotopes are Cs-134, Cs-137 and I-131 in the first year after the accident. In the long term, Cs-134 and Cs-137(Table 1) remain in the environment due to their long radioactive half-lives. The dose consequence of Xe-133 is the least amongst others due to its very short half-life, i.e.5.25 days and its inertness. Lifetime doses incurred from Cs-137, Cs-134 and I-131 are more than 95% of total doses. Ingestion doses are the highest for the infant, child, adult and teen; respectively in the first year after the accident since ingestion DCF for I-131 for the infants is the highest. Infant ingestion doses remain the highest as years pass after the accident, since infant's growing up is taken into account and their food consumption increases when they are growing

Table 1. radionuclide release to environment after Sevier accident at typically WWER-1000 NPP such as Boushehr NPP as Case Study for Validation of Code

Activity (Bq)	Radionuclide	Activity (Bq)	Radionuclide
8.5E+09	Sr-89	2.8E+12	Cs-137
6.7E+13	Kr-90	4.6E+13	Xe-138
6.4E+13	Rb-90	4.9E+13	C-138
2.2E+07	Sr-90	3.7E+13	Br-87
2.6E+11	Sr-91	3.9E+13	Kr-87
2.1E+11	Sr-92	4.9E+13	Kr-88
1.1E+09	Mo-99	4.9E+13	Rb-88
9.3E+08	Ru-103	6.7E+13	Kr-89
1.3E+07	Ru-106	7.1E+13	Rb-89
1.3E+07	Ru-106	1.8E+08	Pr-144
1.3E+07	Ru-106	1.2E+09	Zr-95
9.3E+10	Te-131	1.2E+07	Nb-95
3.1E+13	I-131	7.4E+10	Zr-97
1.2E+10	Te-132	6.7E+10	Nb-97
8.3E+13	I-132	2.7E+11	Na-24
1.6E+11	Te-133	1.2E+12	K-42
6.8E+13	I-133	1.9E+07	Fe-59
1.7E+13	Xe-133	7.4E+07	Co-58
6.3E13	I-134	1.4E+08	Cr-51
1.8E+12	Cs-134	1.9E+07	Mn-54
5.1E+13	I-135	2.0E+08	Co-60
1.1E+13	Xe-135		

AUTHOR CONTRIBUTIONS

The theoretical analysis was carried out by A.HAGHIGHI SHAD and R.KHODADADI. Analytical solutions of the equations and Models Designing and Domestic user friendly KIANA Advance Computational Computer Code and model and C# programming of computer code were carried out by A.HAGHIGHI SHAD. The manuscript was prepared by all authors and the figures and tables by A.HAGHIGHI SHAD and D.MASTI, M.ATHARI ALLAF.

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