Development of complex methods of stabilization or uptake of radioactive Cs from contaminated soils depending on the type/rate of contamination and destination of land areas

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After testing (New Mexico, 1945) and use (Hiroshima and Nagasaki, 1945) of nuclear weapons, all of humanity and life on earth are facing a new threat, perhaps the most serious threat in terms of close (foreseeable) future. Over the past decades since then fifteen high-power and super-power nuclear and thermonuclear explosions (also a number of explosions of les power) have been made in atmosphere, underwater and underground areas.

Production of nuclear weapons, as well as establishment and development of nuclear power engineering caused the new man-made hazards because of hundreds of accidents due to human error, equipment failure, natural disasters. We can say with a high degree of certainty that the list of the largest man-made nuclear accidents is as follows: **1944, Oak Ridge National Laboratory, Tennessee, United States; 1948, Unit "A" plant "Mayak", Chelyabinsk Region, USSR; 1949, Unit "A" plant "Mayak", Chelyabinsk Region, USSR; 1952, NPP Chalk River, Ontario, USA; 1955, the American experimental reactor EBR-1, Idaho, United States; 1957, Unit "A" "Mayak", Chelyabinsk Region, USSR; 1957, nuclear reactor Windscale, UK ; 1969, nuclear reactor, Lyutsens, Switzerland; 1969, NPP "St. Lawrence", France; 1967, "Mayak", Chelyabinsk Region, USSR; 1970, the factory "Red Sormovo", Nizhny Novgorod, USSR; 1975, NPP "Browns Ferry", Alabama, United States; 1979 year Threemile Island, Pennsylvania. US; 1986, Chernobyl NPP, Ukraine; 1999, NPP Tokaimura, Ibaraki prefecture, Japan; 16. 2004, NPP Mihama Tokyo prefecture Japan**

The mentioned and other (less devastating) accidents resulted in the death, severe health, evacuation and displacement of hundreds of thousands of people. Considerable areas become unsuitable for life and industrial or agricultural activities. Great harm has been caused to the environment. The sad example of Chernobyl shows that radioactivity and the associated serious consequences are real and hardly avoidable threat not only in the perspective of large-scale military operations, but also for today's realities. **The scale and nature of threats determine the fundamental character of the problem, which requires both analysis and application of the already proposed decisions and developing of the novel integrated methods and approaches based on research in different fundamental and applied sciences.**

Taking into account that Georgia is in the list of 10 countries significantly affected after Chernobyl accident and that the mainly amortized Metsamor NPP is very close to Georgia and its capital Tbilisi, several sites contaminated with ^{134}Cs and ^{137}Cs were indicated in Georgia (Anaseuli, Gonio, Poti shipyard, many small areas in Western Georgia contaminated after Chernobyl accident), the problem becomes very acute and urgent also for our country (as well as for all South Caucasus Countries).

After every nuclear accident a new important source of radionuclide emission has occurred. One of the most hazardous parts is the emission of ^{134}Cs and ^{137}Cs isotopes. Aaccording to the data of Tokyo Electric Power Company for the period of the time between 12 and 31 March 2011 the total amount of radionuclides released into air was:

Noble gas - appr. $5x10^{17}$Bq;

^{131}I - appr. $5x10^{17}$Bq;

^{134}Cs - appr. $1x10^{16}$Bq;

^{137}Cs - appr. $1x10^{16}$Bq

Considering the half-live times for radionuclides (30 years - ^{137}Cs, 2.06 years - ^{134}Cs, 8,04 days - ^{131}I), most attention should be paid to radionuclides of Cs and, especially, to ^{137}Cs.

The most examined and tested method of regulating Cs uptake from the soils was the use of potassium fertilizers to suppress the uptake of Cs from soils and provide safe food. This approach was used by US government for clean-up of areas radioactively contaminated during testing the nuclear weapons. Another approach was proposed in our laboratory and experiments with an opposite purpose – to enhance the uptake of Cs and provide the clean-up of contaminated soils – were taken. In both types of experiment the total amount of potassium, as well as the part of potassium available for plants and microorganisms, was regulated.

In normal conditions only about 2-5 % of total potassium in soil is directly available for plants. Thus, reducing of the available part can provide the reduced uptake of K and enhanced uptake of Cs, while increase of the available part can provide the enhanced uptake of K and reduced uptake of Cs more efficiently than regulating of total amount of potassium in soils. Depending on contamination type and rate, also designation of land («buffer» or remediation zone, agricultural land, pre-residential/residential area) the uptake of Cs can be controlled through regulation of content of available potassium in soils.

Widely used approach: suppress of uptake of Cs from soils and prevention of transfer to food chain through sharp increase of total content of potassium in soils

Many-time extent of K-fertilizers

Elimination of Cs in plants and food chain

- **Suppress of phytoremediation of Cs contaminated radioactive soils;**
- **"Keeping" of Cs radio-nuclides in contaminated soils and enhanced threat of their long-term migration to surface and ground water;**
- **Abnormally high content of radioactive potassium in soils and imbalance between main minerals in soils;**

Proposed approach: enhance of uptake of Cs from soils and through sharp dicrease of total and available content of potassium in soils

No K-fertilizers! Use of crops with very high consumption of K! Many-time decrease of potassium content in soils and enhance of phytoremediation!

Decontamination of Cs containing soils! Return of decontaminated areas to residential and agricultural areas

- **Transfer of radio-nuclides to plants and possible transfer to food chain of animals;**
- **Generation of big amount of secondary radioactive waste: vegetation mass contaminated with Cs radio-nuclides;**
- **Additional security measures to prevent food contamination**

Proposed approach: suppress of vital functions of plants and decrease of fertility caused by potassium defficiency

Sharp enhance of phytoremediation rate!

Use of phyto-hormones and improving of vital functions (respiratory functions, phptpsynthesis) of plants

Decontamination of Cs containing soils!
Return of decontaminated areas to residential and agricultural areas

- **Generation of big amount of secondary radioactive waste: vegetation mass contaminated with Cs radio-nuclides;**
- **Additional security measures to prevent food contamination**

Proposed approach: processing of newly generated radioactive waste

- Vacuum distillation of contaminated crops to alcohols;
- Processing of alcohol bards and contaminated plant mass in bio-reactors and chemical reactors to fuels, feed additives and fertilizers

Decontamination of radioactive Cs containing soils!
Return of decontaminated areas to residential and agricultural areas!
Many-time reducing of the total amount of radioactive waste and decrease of corresponding costs due to producing of demanded products.

Proposed approach: efficient use of microwave radiation in all tratment prcesses

- Vacuum distillation of alcohols;
- Processing of alcohol bards and contaminated plant mass in bio-reactors and chemical reactors to fuels, feed additives and fertilizers;
- Direct pretreatment of processed soils and other contaminated materials.

Almost two-time increase of treatment efficiency due to the use of microwave energy for heating and accelerating of chemical and physical processes

Proposed approaches can be used both for enhancing and for eliminating Cs transfer to plants, mobilization or immobilization of Cs nuclides in soils and for efficient processing of secondary radioactive waste generated during the phytoremediation. Use of microwave energy provides almost two-time increase of treatment efficiency due to the use of microwave energy for heating and accelerating of chemical and physical processes