The decision making criteria on radiation protection of population in the cases of an accidental plutonium dispersion into environment

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ABSTRACT

Intervention criteria for radiation protection of general public in the case of accidental plutonium release have been elaborated on the basis of experimental radiobiological studies of affects of incorporated plutonium and of long duration medical observation for nuclear workers in Russia and the requirements of the national Radiation Safety Standards.

Generic and operational levels for decision-making are given for early and late phases following the accident. Criteria for decision making are established in terms of upper and lower generic and operational levels (UL/LL).

Criteria for urgent evacuation in the early stage directed on preventing of serious deterministic effects are defined as projected absorbed dose rate for lung $2 \cdot 10^{-2}$ Gy/day (UL) and $3 \cdot 10^{-3}$ Gy/day (LL). The UL corresponds to intake of 300 kBq of ^{239}Pu and mortal consequences during the first year after the accident as a result of acute interstitial pneumonite. The LL corresponds to intake of 40 kBq of ^{239}Pu and the threshold of serious radiological effects (disablement as a result of pneumosclerosis) and high level of stochastic effects – cancer of lung.

Other basic countermeasures are intended on to be directed mitigation of long term radiological consequences. That is why criteria for them are defined in terms of protected equivalent dose for lungs or avertable effective dose. Criteria for sheltering and individual protection of respiratory tract correspond to committed equivalent dose due to intake during two days 200 mSv (UL) and 20 mSv (LL).

Temporary relocation (1-2 years) is recommended if averted monthly effective dose is 30 mSv (UL) and 10 mSv (LL). Permanent relocation is justified if averted life-time effective dose is 1000 mSv (UL) and 200 mSv (LL).

Operational levels in terms of density of soil contamination by plutonium are calculated for practical application of the dose criteria.

INTRODUCTION

Wide scale operation on dismantling of nuclear weapons is carrying out in Russia. One of the problems of management and utilizing of nuclear weapon consists of putting into practice of countermeasures in the case of radiation accident. World experience includes accidental cases of routine maintenance of nuclear weapons with the environmental plutonium release (e.g. accidents in Palomares (Spain) and Thule (Greenland)) contaminated vast territories. According to the expert assessments, the most probable types of the accidents will be connected to the explosion or firing of TNT, accompanied by release of fissile materials into the environment.

1. RADIATION EXPOSURE PECULIARITIES IN CASE OF THE ACCIDENTAL PLUTONIUM RELEASE

The peculiarities of such accidents are as follows:

(1) the main dose - forming radionuclide is ^{239}Pu;
(2) the typical chemical form of aerosols is PuO_2;
(3) the critical pathway of intake is inhalation;
(4) the dominant type of radiation exposure is the internal exposure of lungs and in the course of time irradiation of bone surfaces and liver.

The results of estimation show that above 80% of the total Pu intake during 50 years of permanent living on the contaminated area will be caused by the first year intake; and, besides, more than 50% of total intake takes place during radioactive cloud fallouts and about 70% – during the first month after the accident (Fig.1.).

Metabolism of Pu is characterized by slow elimination from lungs (oxide of plutonium is related to type “S”), i.e. absorbed doses in alveolar interstitial region of lungs and in cells of bone surface received during the first week after the accident contribute less than 1% and 0.01% of 50 years dose, accordingly (Fig.2.).

Thus, accidental plutonium dispersion may be defined as an “inhalation” accident which is characterized by:

(i) rapid stage of the radionuclide accumulation in body; and
(ii) slow elimination of the radionuclide from the body and gradual increase of absorbed dose in time.

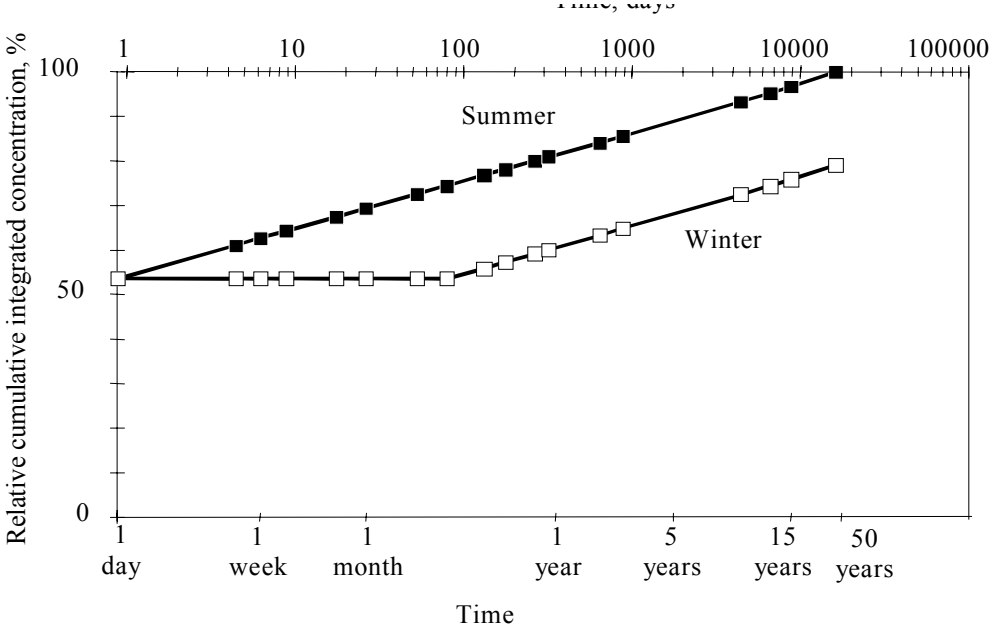

Fig. 1. Dynamics of integrated concentration of ^{239}Pu in the air.

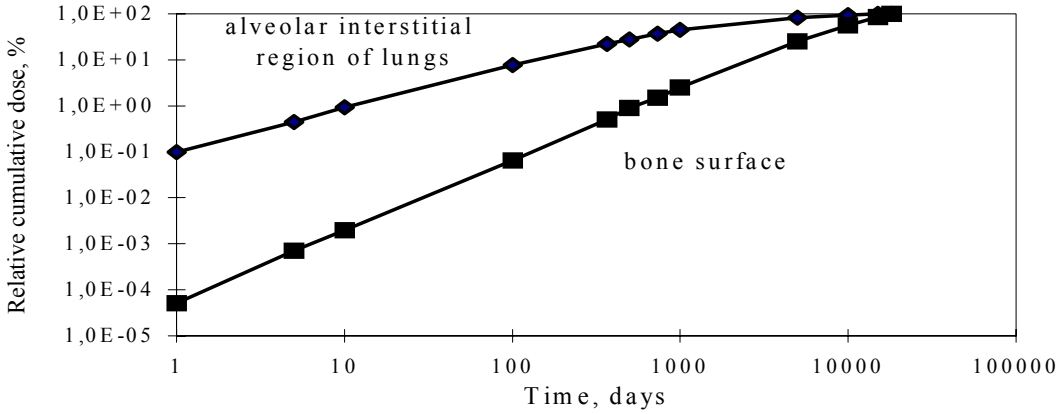

Fig. 2. Dynamics of committed absorbed dose for single intake of ^{239}Pu (type S).

2. RADIOBIOLOGICAL EFFECTS OF PLUTONIUM INHALATION INTAKE

According to analysis of experimental radiobiological studies of health effects of incorporated plutonium for various species of animals and for long-term duration of medical observation in nuclear workers [1-3], the scale of medical consequences according to the values inhalation intake was suggested as follows:

- 370 kBq - fatal cases during the first year after an accident as a result of acute interstitial pneumonitis;
- 37 kBq…370 kBq - serious deterministic effects (disability as a result of pneumosclerosis) and high risk of stochastic effects (cancer of lungs);
- 3.7 kBq….37 kBq – long-term medical consequences in a form of lung pathologies defined reliably as compared to background;
- < 3.7 kBq - does not lead to reliable defined consequences.
- This scale was used for elaboration of intervention criteria.

3. DECISION MAKING CRITERIA FOR RADIATION PROTECTION OF POPULATION

Peculiarities of dose forming and radiological consequences of an accidental plutonium dispersion lead to two conclusion: firstly, active management at the early period of an accident aimed at reducing the inhalation

intake plays a very important role in mitigating radiological consequences; and, secondly, the direct use of the dose criteria in radiation protection developed for conditions of nuclear reactor accident according to levels of predicted absorbed dose during 1… 10 days is not correct for "inhalation plutonium" accident.

According to the national Radiation Safety Standards, RSS-99 [4], decision-making in the case of a radiation accident should be based on the following principles:

(1) In order to reduce or avert exposure in intervention situation, protective action or remedial actions shall be undertaken whenever they are justified.

(2) The form, scale, and duration of any such protective actions or remedial action shall be optimized so as to produce the maximum net benefit, understood in a broad sense, under the prevailing social and economic circumstances.

However, protective actions will almost certainly be justified if the projected dose, rather than the averted dose, or dose rate to any individual is otherwise likely to lead to serious injury.

The generic criteria for decision-making are established in the form of dose intervention levels (GIL) subdivided into:

(i) integral GIL - emergency level which must be prevented, if individual of critical group (in our case, adults of age of 18...20 years old) may have received dose above this DIL;

(ii) differential GIL - emergency levels which must be averted as consequence of the certain protective action.

For each protective action the criterion has been designed as a system of two levels of hazard (Low level (LL) and Upper level (UL)). If projected dose does not exceed LL, then it is unnecessary to take protective action. If projected dose reaches and exceeds UL, it is necessary to take protective action. If projected dose exceeds LL but does not reach UL, decisions are made in accordance with specific situation and local conditions using principle of optimization and alternative countermeasures.

The first stage of dose zoning consists of elaboration of criteria of urgent countermeasures at an early phase with the aim of prevention of serious deterministic injury relating to intake of plutonium during fallouts of radioactive cloud. According to the above-mentioned medical scale, UL of serious effects may be used as projected acute intake above 300 kBq, which level corresponds to absorbed lung dose rate of $2 \cdot 10^{-2}$ Gy/day. This dose level is established as a criterion for urgent evacuation and first special medical care. Conditionally, LL of serious injury is estimated as projected intake of 40 kBq of plutonium during fallouts of radioactive cloud and it corresponds to initial absorbed lung dose rate of $3 \cdot 10^{-3}$ Gy/day.

If projected dose rate exceeds this level then the urgent evacuation must be carried out within 2 days with following dosimetrical and medical sorting of suffered population. According to the sorting results special medical care is provided.

Other protective actions are aimed at mitigating long-term stochastic consequences. That is why criteria for their implementation are defined in terms of dose equivalent in lungs or effective dose.

Criterion for sheltering is established in terms of projected dose equivalent in lungs forming as a result of plutonium inhalation intake during the initial two days and it is equal to 20 mSv (LL) and 200 mSv (UL), the values correspond to 0.2 and 2 kBq, respectively.

At the late phase of an accident the protective actions consist of temporary and permanent relocation.

There are two dose approaches concerning decision making about whether to allow the population to live permanently on the contaminated areas:

(1) life-time dose;

(2) averted dose during relocation.

Obviously, value of averted dose in the second approach depends upon the time of the beginning of relocation. It was assumed that this time is equal to 3...7 days after the accident.

Proposed criteria takes into account both approaches: LL is defined on the basis of life-time dose 350 mSv and it is equal to averted dose of 200 mSv; UL is equal to averted dose of 1000 mSv and coincides with the value recommended by national and international standards[4, 5].

Temporary relocation of population (for less 1-2 years) is recommended, if averted effective dose per month is equal to 10 mSv (LL)/30 mSv (UL). In this case annual effective dose after their return does not exceed 5 mSv and projected life-time effective dose does not exceed 350 mSv.

External border of the affected area, where protective actions or remedial actions may be undertaken is defined as an area where projected individual effective dose exceeds 5 mSv in the first year after an accident.

Elaborated dose and operational criteria are given in Table 1 summary of consistent system of radiation levels taking into account both biological and hygienic approaches and peculiarities of dose-forming and response in the case of the accident with nuclear weapon. Comparison of these criteria and adaptation of them in the USA for nuclear weapon accidents [6] is given in Table 2. Only criteria for sheltering have significant distructions.

CONCLUSION

(1) Suggested system of dose and operational criteria for radiation protection of public in the case of the plutonium release into environment is applied in the national emergency regulation related to accidents wits nuclear weapon.

(2) Takin into account social importance of consistent approaches in this problem, harmonization of national and international standards and managements is required.

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Table 1.

Generic and operational levels for intervention in the case of accidental release of plutonium into environment.

Protective action	Generic intervention level, DIL			Operation intervention level, OIL, density of ^{239}Pu contamination, MBq/m^2	
	Dose parameter, unit	LL	UL	LL	UL
Urgent evacuation	Projected absorbed dose rate in lungs during the first day, mGy/day	3	20	10	70
Sheltering, individual protection of respiratory tract and skin	Projected dose equivalent in lungs due to intake of ^{239}Pu during two initial days, mSv	20	200	$8 \cdot 10^{-3}$	$9 \cdot 10^{-2}$
Permanent relocation	Averted effective dose Sv/50year	0.2	1.0	1	7
Temporary relocation for less 1-2 years	Averted effective dose rate mSv/month	10	30	0.2	0.9
Accidental zone	Projected effective dose in the first year, mSv	5	-	$8 \cdot 10^{-3}$	

Table 2.

Comparison of derived criteria on intervention for protection of public by RUSSIA and by U.S.A.

Protective measures	Density of soil contamination by ^{239}Pu, $MBq\ m^{-2}$	
	RUSSIA	U.S.A.
External border of the radiation zone	0.008	0.0074
Urgent protective actions	10 ... 70	22
Sheltering	0.008 ... 0.09	2.2
Permanent / temporary relocation	0.2 ... 0.9	0.22