AGRICULTURAL PRODUCTION AS A SOURCE OF IRRADIATION OF POPULATIONS IN RADIATION ACCIDENTS

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Abstract

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Radioactive contamination of the agricultural production sphere in case of a radiation accident with radionuclide release is one of the most important sources of additional irradiation for population. As a result, realisation of the measures for mitigating the consequences of the accident in agro-industrial complex assumes the leading role in total system of measures providing radiation safety. The possibility to obtain agricultural production meeting the radiological standards is one of the main indications of effectiveness of liquidation of the accident consequences.

First, obtaining of agricultural production meeting the radiological standards provides decreasing of the total radiation dose. The evidence is obtained in the 8-year experience of liquidation of the Chernobyl NPP accident that the 70% decrease of the internal dose for population became possible through a complex of protection measures in agriculture (during the first year after the accident, the contribution of internal dose into the total one amounted to 45%, and that of external irradiation — 52%; for the 70-year period these values are 39% and 60%, respectively). Second, the possibility to obtain "pure" agricultural production is one of the most important factors of psychological stability for population. Third, obtaining of consumable (as to radionuclide content) agricultural production in private small holdings is one of the guarantees of stability of demographic sector in the accident-affected zone.

From the point of view of organization of agricultural production in liquidation of the consequences of accidents with radioactive releases into environment, some periods can be distinguished:

- the first (early) period takes 10-12 days after the accident. The main measures in the field of agricultural production are in operative assessment of the radiological situation, organization of radiation survey, express classification of agricultural products ready to consumption. If radionuclide content in food products and feeds exceeds the DILs, their consumption is prohibited. The prophylactic measures to prevent adverse iodine effects are rendered a special place. If necessary, agricultural animals are relocated.
- the second period lasts 2-3 months after the accident. At that time radiological maps of contaminated lands are made, the system of radiation control of agricultural lands and agro-industrial production is perfected, the program of technological processing of contaminated agricultural products is implemented which guarantees obtaining of non-contaminated products.
- the third period is completed after the first 1.5 post-accident years. Agroamelioration measures are carried out at that time, the main scope of measures for detailed radiological survey of contaminated lands is realised; gradually the concept of production classification is replaced by the zonal production organization guaranteeing the Derived Intervention Levels established for the given period are not exceeded. The scientifically substantiated program of agricultural production management on contaminated lands for maximum possible obtaining of pure production and rational use of agricultural lands is formed.
- the fourth period starts in 1.5-2 years after the accident. In case that the deposited mixture of radioactive substances contains the log-lived radionuclides (^{90}Sr, ^{137}Cs. ^{239}Pu, etc.), the program of obtaining production meeting the radiological standards is realised as a constant long-term complex, in parallel with realisation of long-term system of agro-industrial measures, reorientation of agro-industrial production system and processing of contaminated products.

1. INTRODUCTION

In radiation accidents with radioactive releases into the environment, four main sources of the potential irradiation of man are formed: external irradiation due to immersion into the passing radioactive cloud, inhalation of radionuclides, external irradiation as a result of the contamination of different surfaces (living quarters, soil, etc.) and internal irradiation as a result of consuming the radionuclide containing products. Contribution of each of the above listed sources into total irradiation can range greatly, as dependent on numerous factors, the most important of these including the radionuclide composition of radioactive mixture deposited, scales of the accident and biogeochemical conditions of the environment. The list of other factors can include the population's alimentary habits, the season when the event of contamination took place, and some others.

As it is shown by the analysis of radiological situations connected with the most intensive additional effects of the radiation factor on man (global radioactive fallout after nuclear weapon tests, heavy radiation accidents in the South Urals in 1957 and at the Chernobyl NPP in 1986), as well as the investigation of different hypothetical scenarios of radiation accidents, the role of internal irradiation (i.e. that caused by consumption of radionuclide containing products) is considerable enough. Thus, during the first year after the accident at the Chernobyl NPP the contribution of internal irradiation into total dose burden for the population of the zone affected by the accident amounted to 45%, and that of external irradiation — to 52%; for the 70-year irradiation these contributions amount, respectively, to 39% and 60%. For the global radioactive fallout connected with nuclear tests the contributions of internal and external irradiation into total dose burden are approximately equal [1]. The internal irradiation as a component of the natural radioactive background is of particular significance (irradiation is caused mainly by inhalation accumulation of ^{222}Rn and its decay products). The value of internal irradiation is especially high in the case of a great contribution of long-lived β-emitters (^{90}Sr) into the mixture of radionuclides, as it was the case in the South Urals accident in 1957 or if iodine radionuclides are present in this mixture (the Chernobyl NPP accident in 1986).

The larger the accident scale is (the larger the contaminated area), the more important will be the role of internal irradiation in total radiation dose. Thus, after the accident in Goiânia in 1987 when the contaminated area had the form of spots in urban region (agricultural products were obtained only from gardens and kitchen gardens) and was characterised by relatively small absolute dimensions, the contribution of internal irradiation into total dose was estimated only of 20% [2].

2. DECREASING THE INTERNAL RADIATION DOSE

The main objective in liquidation of any radiation accident is to decrease radiation doses for the population staying in the accident affected zone, and those for specialists-liquidators. From this point of view, the liquidation of consequences of the accidental release of radioactive substances into the environment it should be stressed that the limiting of internal radiation dose is, as a rule, a more economically rational task than the limiting of the external dose (in the latter case, problems have to be considered such as removal of large amounts of contaminated soils, treating them as radioactive waste, etc.).

Decreasing the internal radiation dose as a component of total irradiation is connected with the organization of manufacturing the food products meeting radiological standards (permissible radionuclide content) on the contaminated lands. It is of great social and psychological importance for retention of the infrastructure of the agricultural sector on contaminated territories and for the prevention as well as the relief of radiophobia events which show up under the Chernobyl NPP accident. In this regard the organization of manufacturing "clean" products in individual farms is very important.

Decreasing internal irradiation doses for the population in contaminated regions could be achieved by several processes [3–6].

In the first place, at the acute phase in the first several weeks, several months after the accident the manufactured products with exceeding permissible levels of radionuclide content could be barred from use.

This measure is an exceptional one and has to be applied in extreme cases during closely limited times. From the first period of the accident it is of significance to reorient management of agricultural production so that obtaining the products with exceeding of (temporary) maximum permissible radionuclide concentrations has to be excluded.

Secondly, the purpose in limiting the doses of internal irradiation is attained at the cost of storage of products not meeting radiological standards (if short-lived radionuclides are present, for example, ^{131}I) or its processing which provides a decrease of radionuclide concentration in the end food product up to necessary levels (the most illustrative example is a processing of milk contaminated by ^{90}Sr and ^{137}Cs for butter which ensures a decrease of content of these radionuclides in butter up to 10 times and higher what was widely used by the accident in the South Urals and especially after the Chernobyl NPP accident).

Thirdly, in the end, one more method of decrease of dose influence on man from internal irradiation is an introduction of the system of protective measures on contaminated areas in agroindustrial production which are connected with the complex of ameliorative methods oriented on decrease of intensity of radionuclide migration through agricultural chains and reduction of radionuclide content in food products. As compared with the first two mentioned methods of decrease of internal irradiation dose which may be considered temporary and palliative the amelioration of contaminated lands and the system of corresponding countermeasures are to be considered as the basic strategic direction by organization of agroindustrial production after the accident under conditions of environmental contamination. Naturally that in this case the real situations and hypothetical scenarios are considered when in composition of contaminating radionuclide mixture the long-lived components (^{90}Sr, ^{137}Cs, ^{239}Pu and others) are present. Only based on introduction of this group of protective measures it is possible to achieve stable maintenance of agroindustrial production on the territories subjected to radioactive contamination.

3. AMELIORATIVE MEASURES

The range of ameliorative measures associated with introduction of measures on reduction of radionuclide content in agricultural products is sufficiently wide. In a general way these measures may be classified into two groups:

(1) measures on increase of soil production, crop yield and animal productivity by simultaneous reduction of radionuclide content in products, and

(2) special measures on reduction of radionuclide content in agricultural products (for example, application of ferrocyn as a food additive for agricultural animals what leads to reduction of radionuclide content (^{137}Cs) in milk and meat.

Decision making on the maintenance of a listed group of protective measures is to be carried out in long-term perspective not only on radiological indices but with regard to the social reasonability. Generally these decisions must be based on the conception risk-profit. By taking into consideration the evidence on liquidation of radiation accidents in the South Urals and at the Chernobyl NPP these measures are presented in Table I [7, 8].

Impact and effectiveness of changing land use

Change	Reduction factor[a]	Social and economic consequences
Selection of other varieties of some crop	up to 2 - 4	very low
Selection of other, but comparable crops	up to 2 - 3	low
Green vegetables to cereals	up to factor of 5	high
Cereals to edible industrial crops, e.g., sugarbeets, oil seed	>> a factor of 10	low
Cereals to non-edible industrial crops, eg. flax	>> a factor of 10	low
Arable to cattle system	factor of 10 to 100	rather high
Sheep, goats to cattle	up to factor of 10	low
Dairy to meat system	highly dependent on technological possibilities	low
Arable system to forestry	>> a factor of 100	extremely high
Cattle system to forestry	>> a factor of 100	extremely high

$$^{a}\text{Reduction factor} = \frac{\text{activity concentration in alternative product}}{\text{activity concentration in original product}}$$

Realisation of protective measures in agricultural production in the region subjected to the influence of the accident at the Chernobyl NPP showed that on plowing lands ^{137}Cs concentration in the yield of main crops cultivated on contaminated areas decreased in the average by a factor of 2.2 and that on meadows and pastures where protective measures were realised — by a factor of 2.8 (average data on Russia during the first six years after the accident).

During the later period after the accident (if radioactive contamination of territory by long-lived radionuclides took place) the decision making for the decrease of dose loading on the population is based on conduction of long-term measures on limiting of radionuclide transfer into agricultural products. When total assessment of efficiency of protective measures in agroindustrial complex during all phases of the accident at the Chernobyl NPP was carried out the total decrease of effective equivalent dose on population living on the territory subjected to the influence of this accident will amount to about 30%. In this case of considerable significance are agroameliorative measures on meadows — critical ecosystem connected with production of milk — the basic dose-forming food product and to some extent that of meat. Effectiveness of complex of protective measures on the territory contaminated after the accident at the Chernobyl NPP is indicated in the Figure 1 which demonstrates a rapid decrease of milk and meat production (^{137}Cs content in them exceeds maximum permissible levels) during the first years after the accident. In 1993 on the territory of Bryansk region (Russia) in the most contaminated regions the total milk production with ^{137}Cs content higher than 370 Bq/l was below 2% (in these regions an intensive application of ferrocyn for reduction of ^{137}Cs concentration in milk is conducted).

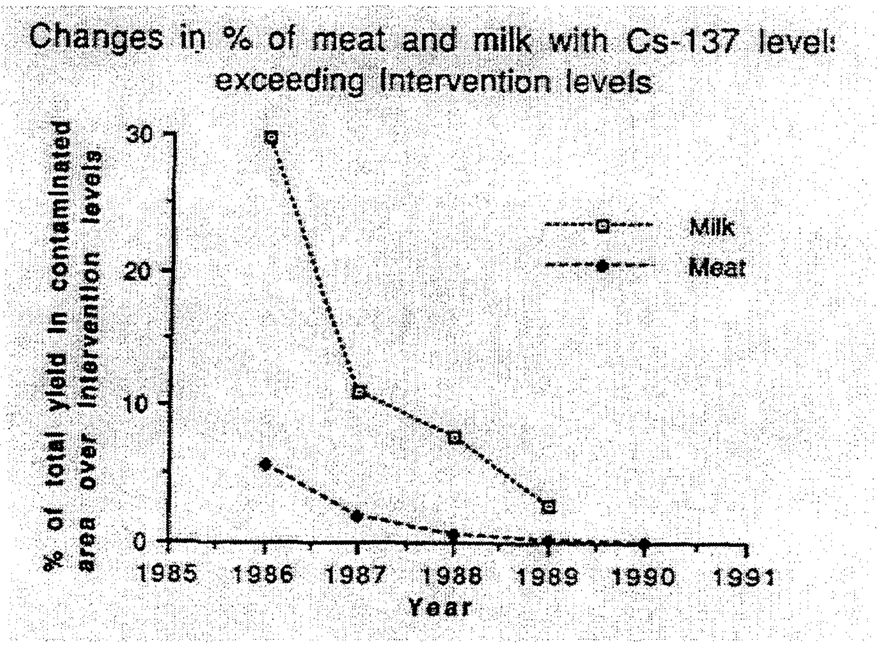

FIG. 1.

By decision making to rehabilitate contaminated areas and involving the return of the population previously settled out the estimation of effectiveness of countermeasures in agricultural production in long-term perspective is of great importance. It should be taken into account that after accidental radioactive releases into the environment sufficiently intensive "ageing" of radionuclides in soils — the basic depository for radioactive substances in agroecosystems — and decrease of biological availability of radionuclides for root assimilation were observed. Thus, total reduction of radionuclide content in agricultural products is a result of a decrease of biological radionuclide mobility following biogeochemical processes on the on hand and on the other hand the effect of protective measures in agriculture.

As the evidence of liquidation of the accident at the Chernobyl NPP shows the ecological half-lives (reduction of ^{137}Cs concentration in different agricultural products — milk, meat, grain, potato, vegetables and others — by a factor of 2) for the first 3–4 years after the accident are equal to 2-4 years and for 8 post-accidental years — up to 6-12 years ($T_{1/2}$ of ^{137}Cs is equal to 30 years). Contribution of protective measures and biogeochemical processes of decrease of ^{137}Cs mobility into total reduction of ^{137}Cs content in agricultural products is approximately equal and amounts to 48–49% whereas that of radioactive ^{137}Cs decay in this reduction is very small (of about 0.5%).

4. CONCLUSION

Assessment of real situations by liquidation of radiation accidents with radioactive releases into the environment and hypothetical scenarios of that kind of accident proves the importance of solving problems connected with maintenance of agroindustrial production in contaminated territories, limiting internal irradiation doses and elaboration of corresponding normative and recommendation documents as a part by decision making about consequences of accidental environmental contamination and providing radiation protection of the population.

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