Management of Contaminated Territories Radiological Principles and Practice

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Abstract. The current status of internationally agreed principles and guidance for the management of contaminated territories and the international development of intervention guidance since the Chernobyl accident is reviewed. The experience gained after the Chernobyl accident indicates that the international advice on intervention existing at the time of the Chernobyl accident was not fully understood by decision makers neither in Western Europe nor in the former USSR and that the guidance failed to address adequately the difficult social problems which can arise after a serious nuclear accident.

The differences between CIS practice and international guidance, both conceptually and practically, are identified. The general response of the authorities in the former USSR regarding many early actions for protection of the affected population after the Chernobyl accident were broadly reasonable and consistent with internationally established guidelines pertaining at the time of the accident. During the years following the accident, decisions on countermeasures in the former USSR were based on four different criteria: annual dose, lifetime dose, temporary permissible levels in foodstuffs and surface contamination density of ^{137}Cs. Due to socio-psychological and political factors, requirements for radiation protection were made more and more strict.

The CIS criteria of today for different protective actions and strategies are given in terms of annual doses or activity concentrations af ^{137}Cs in different foodstuffs. International guidance is given as *intervention levels* in terms of *avertable doses* by specific countermeasures and as *action levels.* Action levels refer to different protective actions or protection strategies. Action levels are levels above which remedial actions are taken and below which they are not, and they refer to the maximum *residual dose* without any action. The CIS criteria are conceptually a system of *action levels* rather than a set of intervention levels. The numerical values of these action levels are not directly comparable to international numerical guidance, but they seem not to be in direct conflict.

Unresolved issues have been identified to be the interaction between radiological and non-radiological factors in decision-making. Both radiological and non-radiological factors will influence the level of protective actions being introduced. Social-psychological countermeasures are a new category of action, in the sense that social protection philosophy has not yet been developed to fully include their application after a nuclear accident. It has been suggested that the inclusion of such countermeasures into the intervention decision making framework should be as a part of the radiation protection framework. It is argued here that optimization of the overall health protection is *not* a question of developing radiation protection philosophy to fully include socio-psychological factors. It is rather a question of including these factors - in parallel with the radiological protection factors - in cooperation between radiation protection experts and psychological specialists under the responsibility of the decision maker. The overall optimization of the total health protection is thus the responsibility of the decision maker(s) with guidance from radiation proction experts as well as experts in the fields of social and psychological sciences.

1. Introduction

The experience after the Chernobyl accident was that many actions taken led to an unnecessarily large expenditure of national resources, and many instances occurred of contradictory national responses. Therefore, there was a strong need for a simple set of internationally consistent intervention levels and action levels and for clear guidance on application of the principles in planning and preparedness for response to nuclear accidents or radiological emergencies. Therefore, the international radiation protection organizations ICRP and IAEA both have prepared a set of clear and coherent intervention principles and also numerical values for generic intervention levels.

The protective measures taken in the CIS after the Chernobyl accident included long-term countermeasures such as relocation of the population and continuing agricultural countermeasures. The levels at which these measures were introduced were based on different rationales. During the years following the accident, these levels have been adjusted by the competent authorities in the CIS. This work is still in progress in Russia, Belarus and Ukraine.

2. Evolution of international guidance on intervention after the Chernobyl accident

At the time of the Chernobyl accident guidance on protection of the public after a nuclear accident in which radionuclides have been dispersed into the environment existed both internationally and in the CIS. The experience gained after the Chernobyl accident indicates, however, that the international advice on intervention was not fully understood by the decision makers, neither in Western Europe nor in the former USSR. The intervention guidance was mixed up with dose limits for practices and the guidance failed to address adequately the difficult social problems which can arise after a serious nuclear accident.

2.1. International Guidance at time of the Chernobyl Accident

The basic principles given by the ICRP [1] and IAEA [2] for planning intervention in accident situations and for setting intervention levels were the following at the time of the Chernobyl accident:

(a) Serious deterministic effects should be avoided by the introduction of countermeasures to limit individual dose to levels below the thresholds for these effects;

(b) The risk from stochastic effects should be limited by introducing countermeasures which achieve a positive net benefit to the individuals involved;

(c) The overall incidence of stochastic effects should be limited, as far as reasonably practicable, by reducing the collective dose equivalent.

Upper dose levels above which the introduction of the countermeasure was almost certain and lower dose levels, below which introduction of the countermeasure was not warranted were given for irradiation of the whole body and individual organs. Between the recommended upper and lower dose levels, site-specific intervention levels were expected to be set by national authorities. The intervention levels covered both the early and intermediate phase after an accident. For the late phase no values were recommended, since it was considered that the main questions facing the decision maker would be whether and when normal living could be resumed, and that the situations would vary too widely to give any generic numbers for that purpose. The ICRP and IAEA *two-tier-system* on intervention levels is summarised in Table 1.

Table 1. ICRP and IAEA intervention level ranges for introducing countermeasures.

Countermeasures	Whole body	Single organs
Sheltering	5 – 50 mSv	50 – 500 mSv
Iodine prophylaxis	–	50 – 500 mSv
Evacuation	50 – 500 mSv	500 – 5,000 mSv
Relocation[a)]	50 – 500 mSv/y	not anticipated
Control of foodstuffs[a)]	5 – 50 mSv/y	50 – 500 mSv/y

[a)] The projected dose for relocation and foodstuff control were only defined for the first year.

2.2. Main problems in the past recommendations

Regarding the international guidance on intervention levels a number of problems were identified when applying it after the Chernobyl accident, although the basic principles still were considered to be valid. Confusion was created because intervention levels for introducing countermeasures were interpreted as doses *received* and not as doses *averted* which wrongly was interpreted as if these intervention levels were dose limits. In addition, major difficulties in the application were:

- how to apply intervention levels, *eg*, in the case of foodstuffs, did the intervention level refer to the sum of food items or to each of the foodstuffs separately ?
- how to compare the dose with the intervention level; was the projected dose or the avertable dose relevant ?
- how was the principle (c) to be applied ? What was the relationship between principles (b) and (c) ?

Major confusion was also created by the references in the ICRP Publication 40 [1] to the dose limits in justifying the numerical values of the intervention levels.

2.3. Current status on internationally agreed intervention principles

The latest recommendations from the International Commission on Radiological Protection [3] outline the systems of protection for *practices* and *interventions*. Human activities that *add* radiation exposure to that which people normally incur due to background radiation, or that increase the likelihood of their incurring exposure, are termed *practices*. The human activities that seek to reduce the existing exposure, or the existing likelihood of incurring exposure which is not part of a controlled practice, are termed *interventions*.

The dose limits recommended by the ICRP are intended for use in the control of practices. The use of these dose limits, or of any other pre-determined dose limits as the basis for deciding on intervention might involve measures that would be out of all proportion to the benefit obtained by the intervention.

In some situations the sources, the pathways and the exposed individuals are already in place when the decisions on control measures are being considered, and protection can therefore only be achieved by intervention. The avertable dose by the protective action, ΔE, can be found as the difference between the dose *without* any actions and the dose *after* *implementation* of a protective action. If a protective measure were introduced at time t_1 and lifted at time t_2, the avertable dose, ΔE would be equal to the time-integral of the dose per unit time over this time interval, τ. The concept of an avertable dose is shown in Fig. 1.

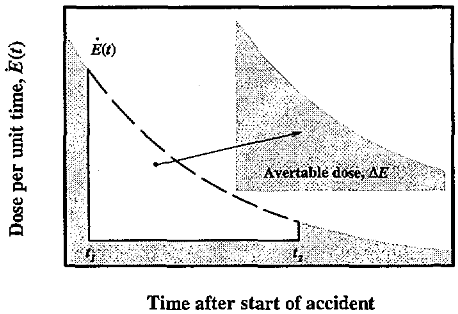

Fig. 1. Avertable dose when the protective measure is introduced at time t_1 and lifted again at time t_2. The length of the time interval is $\tau = t_2 - t_1$.

The process of justification and optimization *both* apply to the protective action, so it is necessary to consider them *together* when reaching a decision. *Justification* is the process of deciding that the disadvantages of each component of intervention, i.e. of each protective action or, in the case of accidents, each countermeasure, are more than offset by the reductions in the dose (avertable dose) likely to be achieved.

Optimization is the process of deciding on the method, scale and duration of the action so as to obtain the *maximum net benefit.* In simple terms, the difference between the disadvantages and the benefits, expressed in the same terms, e.g. monetary terms, should be positive for each countermeasure adopted and should be *maximised* by setting the details of that countermeasure.

Intervention levels refer to the dose that is expected to be averted (avertable dose) by a *specific countermeasure* over the period it is in effect. If an intervention level is exceeded, *ie*, if the expected avertable individual dose is greater than the intervention level, then it is indicated that the specific protective action is likely to be appropriate for that situation. The intervention level for a specific countermeasure can be determined from optimization as indicated above. The optimized intervention level would be expressed either as an avertable *individual dose* per unit time or as an avertable *collective dose* per unit mass of a given foodstuff.

Table 2. Summary of recommended intervention levels from ICRP Publication 63 [4] and IAEA Safety Series No. 109 [5] for urgent and longer-term countermeasures.

Protective measure	IAEA generic optimized intervention levels	ICRP range of optimized values
Sheltering (less than 1 day)	10 mSv	5 – 50 mSv
Administration of stable iodine	100 mGy to thyroid	50 – 500 mSv to thyroid
Evacuation (less than 1 week)	50 mSv	50 – 500 mSv to thyroid
Temporary relocation	initiate at 30 mSv in a month suspend at 10 mSv in a month	almost always justified at a dose level of 1 Sv optimized range of: 5 – 15 mSv/month
Permanent resettlement	if lifetime dose would exceed 1 Sv	–

Recommendations from the ICRP [4] and IAEA [5] on intervention levels for urgent and longer term countermeasures are shown in Table 2. They represent the international consensus achieved on intervention levels as recommended by six international organisations [7]. For foodstuff restrictions and agricultural countermeasures, the intervention/action levels for long-lived β-emitters like ^{137}Cs is in the range from a few hundreds to a few tens of thousands of becquerels per kg foodstuff [5].

3. Evolution of intervention guidance in CIS

The protective measures taken in the CIS after the Chernobyl accident included early countermeasures like sheltering, administering stable iodine and evacuating those parts of the population who might be exposed to the plume. Long-term countermeasures, such as relocation and foodstuff restrictions, were taken to mitigate the effects of lower, but still significant levels of radiation from surface and soil contamination. The levels at which these measures were introduced were based on different rationales, and the levels have been changed by the competent authorities during the years following the accident.

3.1. Russia

Since the early years of development of nuclear power in the USSR, serious attention has been given to the planning of measures to protect the population in the event of a release of radioactive materials into the atmosphere from a nuclear reactor. A two level set of criteria, level A and level B, was used for different protective actions [8,9].

Based on measured radionuclide composition in the environment obtained in the first days of the Chernobyl accident and corresponding long-term predictions of external radiation doses and intake of radionuclides of caesium into the body, it was considered appropriate to establish a Temporary Permissible Level (TPL) of dose of 100 mSv to the whole body in the first year. Of these 50 mSv was allocated to internal radiation and 50 mSv to external radiation. For the following years of 1987, 1988 and 1989 the TPLs were 30, 25 and 25 mSv, respectively [10].

Since the accident, surface contamination criteria have been used to delineate affected areas for such matters as the payment of compensation. Strict Control Zones are those areas with a surface contamination density of ^{137}Cs above 15 Ci/km^2 (555 kBq/m^2) and Controlled Zones with a surface contamination density between 5 and 15 Ci/km^2 (185–555 kBq/m^2).

In 1988 the USSR NCRP developed the concept of safe living of the population based on a so-called lifetime dose limit (LDL) [12]. This was adopted to limit the lifetime risk of late health effects. The USSR Ministry of Public Health approved the LDL-concept with its numerical value set at 350 mSv. In areas where it was envisaged that the LDL would be exceeded, protective measures should be implemented, including relocating the population. The LDL concept was critically analyzed in the International Chernobyl Project. The concept was a simplified reflection of the scientific and practical experience of that time reflecting the situation in 1988-1989 in the regions affected by the Chernobyl accident. This one-level system of decision-making on protective measures would, however, not allow any optimization of the whole complex of possible protective measures. The LDL concept was rejected by the USSR Supreme Soviet in April 1990.

In April 1990, the Supreme Soviet of the USSR implemented criteria for relocation in terms of surface contamination density. A surface contamination level for ^{137}Cs of 40 Ci/km^2 (1480 kBq/m^2) was adopted as the criterion for compulsory relocation [11]. For pregnant women and children, the level was 15 Ci/km^2 (555 kBq/m^2).

A Committee of the USSR Academy of Sciences was assigned to develop an alternative concept [13]. According to this concept the main criterion for further implementation of protective measures was the annual effective dose from Chernobyl fallout, starting from 1991. When this dose were less than 1 mSv, no intervention were needed. If the dose would exceed 1 mSv, a complex of protective measures should be carried out. Implementation of radiation protection measures should simultaneously be aimed at relaxing socio-psychological tension and stress. Achievement of these goals should be optimised with the constraint that the average individual effective dose should not exceed 5 mSv in 1991, and a maximum possible reduction to 1 mSv/y in the future.

With the countermeasures already adopted there were no settlements where the actual individual doses in 1991 could exceed the maximum level of 5 mSv/y. This level was established as a control level and not as a level for relocation. In territories where actual doses exceeded 1 mSv/y the population had the right to be relocated. One of the main point of the concept was to avoid mass relocations. Based on this concept the Chernobyl All-Union Laws as well as Republican Laws were prepared and adopted in 1991.

It should be emphasized that some important points of the laws appeared to be internally inconsistent and in contradiction with the concept. In addition to the effective dose the surface contamination density of ^{137}Cs was used in the Laws as an index for protective measures, including mandatory relocation. Radiation and social protection measures should be implemented at a surface contamination density of ^{137}Cs above 37 kBq/m^2. As a result of this very strict criterion the regions officially recognized as affected by the accident increased from a few to seventeen and the population from a few hundred thousands to about three millions. The consequences were that decisons were made on additional obligatory mass relocation, and it became impossible to achieve an optimised protection from a complex of countermeasures. In addition, the implementation of the Laws created additional social problems and consequently negative consequences.

It became clear already in 1992 that the regulatory documents connected with both the elimination of the consequences of the Chernobyl accident and other applications needed to be further improved and developed. The objective of implementing protective and rehabilitative measures in contaminated territories in the Russian Federation was to improve the policy taking into account the new accumulated data and experience. Some concrete recommendations for this were made [14]. The main recommendations were a shift in protection policy from strict measures of protection (mandatory relocation, rigid limitations to lifestyle and economic activities etc.) to rehabilitation of territories and restoration of normal life and economic conditions and a shift from providing compensations and allowances to individuals to allowances for improving social and economical conditions in the public sector.

The new concept was worked out [15] and adopted by the Russian NCRP, mainly applicable to existing post-accidental situations. In accordance with the concept the objective was to provide a high health standard for the population living in these areas. The territories contaminated by radionuclides were to be subdivided into *zones*. This zoning was based on the annual effective individual dose to the population due to the contamination. Two zones of annual doses were suggested:

- *zone of radiation control (1–5 mSv/y)*, and
- *zone of restricted residence and voluntary relocation (5–20 mSv/y)*.

Those who desire to leave the zone of 5–20 mSv/y can obtain help from governmental bodies. It is not desirable for families with children to settle here for living. People who plan to settle in those areas should be explained the possible health risks. The zoning should be reconsidered once every three years.

In 1994 there were no settlements in Russian territory where the annual dose could exceed 20 mSv. In territories where the effective doses were below 1 mSv/y lifestyle and economic activities were free from any restrictions. This dose level defines in practice a border between normal and abnormal conditions [15]. A few levels of residual dose were established for social and health protection.

Considering the situation in 1995 it should be emphasized that there are practically no settlements where the annual individual doses exceed 5 mSv.

In fact, the action levels of 5 and 20 mSv/y regulate the settlement of people for living and restoration of life in the territories affected by the contamination from the Chernobyl accident. The levels are not for regulation of relocation which is a countermeasure not to be implemented in the late phase of a post-accident activity. Decisions on relocation should be taken in the earlier phases of the accident (this is considered in the new Russian regualtions, see para. 4.1). Therefore, the Russian regulation level of 20 mSv/y is *not* an action level for relocation.

3.2. Ukraine

The Ukrainian strategy for setting criteria in terms of intervention levels for countermeasures on the radioactive contaminated territories in Ukraine has been changing during all the years following the Chernobyl accident. The evolution in the criteria is shown in Fig. 2.

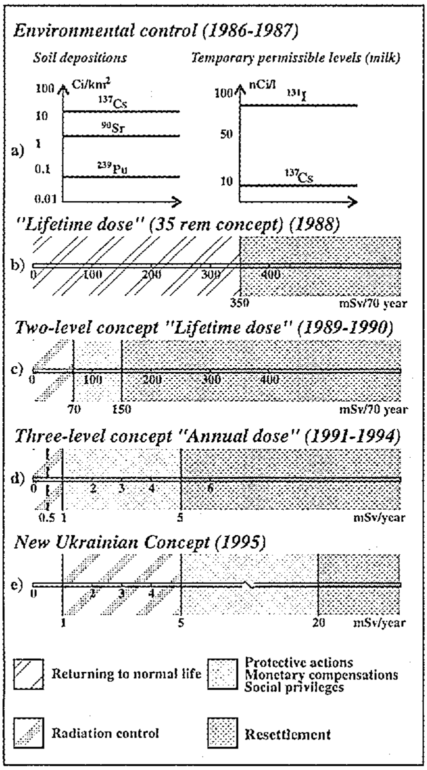

Fig.2. Evolution of Ukrainian criteria for countermeasures during the years following the Chernobyl accident.

At the early stages of the accident (first few years), the level of environmetal radioactive contamination and radiation, *eg*, γ-exposure rate in air, surface contamination density and activity concentration in foodstuffs were used as the main criteria for the introduction of protective actions (Fig. 3 (a)).

In 1988 the total dose from all exposure pathways due to the accident were proposed as as a criterion for decision making on protective actions. In accordance to the recommendations of the National Committee on Radiation Protection of USSR, the first of these dose criteria was the so-called "lifetime dose concept" (Fig. 3(b)). This dose was considered to be a conservatively estimated total dose from external and internal exposure from all exposure pathways due to the accident over a time period of 70 years under normal living conditions in the contaminated territories. A lifetime dose level of 350 mSv was suggested. Because of a number of reasons, mainly due to the reaction of the public, this concept - refered to as the "35-rem concept" - was never accepted.

In 1989-1991 the "two-tier-lifetime-dose concept" for decision making was considered in Ukraine (Fig. 3(c)). Two lifetime dose levels over 70 years of 70 mSv and 150 mSv were suggested as intervention levels. This concept has not been applied in Ukraine as well.

In 1991 the so-called "three-tier-annual dose concept (Fig. 3(d)) for intervention was proposed in Ukraine. In accordance to this concept the annual dose for decision making in certain settlements was to be the sum of the external γ-dose from deposited activity, the internal dose from ingestion of locally grown contaminated foodstuffs containing ^{137}Cs and ^{90}Sr, and the inhalation dose from resuspension of plutonium.

This "three-tier-annual-dose concept" for intervention has been used in Ukraine up until 1995. The intervention levels were 1 mSv/y and 5 mSv/y and since 1994 also 0.5 mSv/y. In accordance to these levels all contaminated territories in Ukraine were divided in zones. Different sets of countermeasures, monetary compensations and privileges were introduced in each zone. The radiological control were provided in the territories where the annual doses were 0.5–1 mSv. The complex of protective actions were to be taken in territories where the annual doses were in the range 1–5 mSv. In territories where the annual doses exceeded 5 mSv relocation (resettlement) were to be considered.

3.3. Belarus

After the accident, surface contamination criteria have been used to delineate areas affected by the Chernobyl accident. Strict Control Zones are those areas with a surface contamination density of ^{137}Cs above 15 Ci/km^2 (555 kBq/m^2) and Controlled Zones with a surface contamination density between 5 and 15 Ci/km^2 (185–555 kBq/m^2).

In 1988 the USSR NCRP developed the concept of safe living of the population based on a so-called lifetime dose limit (LDL) [12]. This was adopted to limit the lifetime risk of late health effects. The USSR Ministry of Public Health approved the LDL-concept with its numerical value set at 350 mSv. In areas where it was envisaged that the LDL would be exceeded, protective measures should be implemented, including relocating the population. The LDL concept was rejected by the USSR Supreme Soviet in April 1990.

In April 1990, the Supreme Soviet of the USSR implemented criteria for relocation in terms of surface contamination density. A surface contamination level for ^{137}Cs of 40 Ci/km^2 (1480 kBq/m^2) was adopted as the criterion for compulsory relocation [11]. In Belarus a level of 15 Ci/km^2 (555 kBq/m^2) was adopted as the criterion for compulsory relocation.

A Committee of the USSR Academy of Sciences was assigned to develop an alternative concept [13]. According to this concept the main criterion for further implementation of protective measures is the annual effective dose from Chernobyl fallout, starting from 1991. When this dose were less than 1 mSv, no intervention were needed. If the dose would exceed 1 mSv, a complex of protective measures should be carried out. Achievement of these goals should be optimised with the constraint that the average individual effective dose should not exceed 5 mSv in 1991, and a maximum possible reduction to 1 mSv/y in the future. Based on this concept the Chernobyl All-Union Laws as well as Republican Laws were prepared and adopted in 1991.

The basic documents that regulate the use of countermeasures in the Republic of Belarus are the following:

(1) *Republican concept of living in the territories contaminated with radionuclides as a result of the Chernobyl Nuclear Power Plant catastrophe, adopted by the Bureau of the Presidium of the Belarussian Academy of Sciences of 19 December, 1990;*

(2) *Concept of residing the population in the regions affected by the Chernobyl Nuclear Power Plant catastrophe, adopted by the decree of 8 April, 1991, N164.*

The essence of the second concept is that two levels of annual individual effective doses of "Chernobyl origin" were established for introduction of countermeasures:

- when annual individual effective doses do not exceed 1 mSv no interventions should be made;
- when annual individual effective doses fall in the range of 1–5 mSv a complex of protective measures should be used aimed at constantly reducing the dose rate;
- when annual individual effective doses exceed 5 mSv resettlement should be implemented.

According the the Republican concept the level of 5 mSv/y from the Chernobyl accident should constantly be reduced. The reduction rate were defined as:

1990	5 mSv/y
1993	3 mSv/y
1995	2 mSv/y
1998	1 mSv/y

The above mentioned concepts have been used as basis of the law of the Republic of Belarus *On Social Protection of the Citizens Affected by the Chernobyl Nuclear Power Plant Catastrophe*.

4. Current status on intervention in CIS

The basic intervention philosophy in the three republics have been under constant evolution. At present, the different concepts being developed include - in addition to radiation protection factors - social protection considerations. The development also includes a suggestion to unify the systems of radiation protection for interventions and practices.

4.1. Russia

New basic recommendations applicable to the existing contaminated territories and possible future accidental situations are being developed to include all experience on liquidation of the consequences of nuclear accidents and nuclear weapons tests. The guidance will be based on both radiation and non-radiation risks and will be expressed in *three* sets of different intervention levels:

(a) *General Intervention Levels* (projected doses) establishing strategies of intervention;

(b) *Specified Intervention Levels* (avertable doses or risks) for radiation protection purposes;

(c) *Specified Intervention Levels* (residual doses or risks) for social protection purposes.

The last set of levels was primary introduced for social protection of the population in the Altai region affected by the nuclear weapons tests at the Semipalatinsk test site. Obviously, this set of levels should have a wider application and should be improved taking into account new data and new experience.

The General Intervention Levels include two principal levels: *an upper dose level* (the dose constraint) above which the introduction of any countermeasures is compulsary in preventing people from receiving doses above this level, and *a lower dose level* having the role of a non-action level. In addition to the general recommendations on intervention strategy and intervention levels, specific recommendations on methodology of risk analysis for post-accidental situations and optimization of strategies of protective and rehabilitation measures are being developed for approval. These developments are using the results from the EU/CIS cooperative research projects (ECPs and JSPs). The new recommendations are expected to be finalized in 1996.

4.2. Ukraine

At present, in the large part of the affected territory of Ukraine the annual individual effective doses do not exceed 1 mSv. This level of dose is identical to the dose limit for exposure of the population in practices used in many countries including Ukraine. However, because the exposure from the Chernobyl accident and the exposure from non-accidental sources were considered separately, the social security of inhabitants receiving the same doses depends on the origin of the source giving rise to the exposure.

Taking into account this curiosity the possibility of a new concept of intervention in territories contaminated by the Chernobyl accident is now being considered. It is proposed to determine the annual dose for intervention as the sum of accidental doses (from all Chernobyl exposure pathways) and industrial exposure (practices).

Annual dose levels of 1, 5 and 20 mSv are considered as the international levels for the whole Ukrainian territory (Fig. 3(e)). The protective actions related to these levels are:

- no special protective actions have to be implemented if the annual dose in settlements is below 1 mSv;
- radiological control has to be provided in territories where the annual doses are in the range of 1–5 mSv; effective protective actions should be introduced for the settlements where the annual doses are in the range of 5–20 mSv;
- the possibility of resettlement must be considered if the annual doses would exceed 20 mSv.

Such type of guidance for interventions is a compromise and, in some sense, a composition of practice and intervention criteria for the late phase of the Chernobyl accident. Therefore, the realization of this guidance is possible only if the additional accidental exposure is comparable to the exposure from normal practices for most of the territories.

This concept has been revised and already accepted not only by single scientists but also by the National Commission of Radiation Protection of Ukraine, the health Ministry, the Ministry of Chernobyl and the Council of Ministers. At present, it is under consideration by the Supreme Soviet of Ukraine.

4.3. Belarus

At present, Belarussian scientists develop a concept of protective measures in a rehabilitation period for the population living in territories of the Republic of Belarus affected by the Chernobyl accident. This concept is at the stage of adoption.

According to the concept, in territories where the annual individual effective doses do not exceed 1 mSv, living conditions and economic activities should not be limited by radiation protection factors. Consequently, additional exposure of the population due to radioactive fall-out resulting in annual individual effective doses lower than 1 mSv is permissible and should not require any limitations (Article 3 of the law *On social protection of citizens affected by the Chernobyl nuclear power plant catastrophe*). Monitoring of objects in the natural environment and of agricultural production should be carried out to calculate and estimate real radiation doses to the population and to implement, if needed, limited and local protection measures.

In territories where annual individual effective doses exceed 1 mSv but are lower than 5 mSv, well-grounded activities aimed at further reduction of individual and collective doses should be implemented. These measure would include, in addition to radiation monitoring of the natural environment and of agricultural production, local decontamination of sites where the external exposure is the dominating exposure pathway.

In territories where the annual individual effective doses exceed 5 mSv, residing would not be recommended and economic activities would be limited.

5. Differences between CIS guidance and international guidance on intervention

According to the international guidance from ICRP and IAEA intervention levels refer to the dose that is expected to be averted (avertable dose) by a *specific countermeasure* over the period it is in effect. If an intervention level is exceeded, *ie*, if the expected avertable individual dose is greater than the intervention level, then it is indicated that the specific protective action is likely to be appropriate for that situation. Intervention levels are specific to accident situations.

Action levels refer to different protective measures or strategies like agricultural countermeasures or radon reducing measures in houses and they relate to the residual dose without any remedial actions taken.

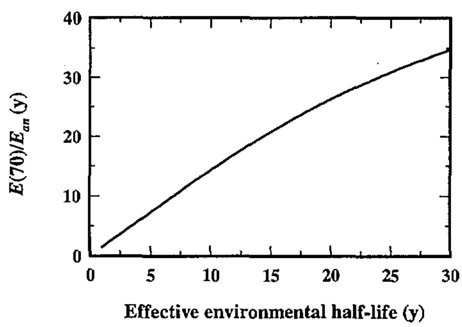

Fig. 3. Ratio of lifetime dose over 70 years, E(70), to annual dose, E_{an}, as a function of the effective environmental half-life of the source of exposure.

The intervention guidance used in the CIS republics all have the character of action levels expressed as annual doses above which different protective actions would be needed. For a given exposure situation there would be a fixed ratio of avertable dose to action level as shown in Fig. 3. An action level for resettlement of, say 20 mSv/y, would be equivalent to an avertable lifetime dose of 150–300 mSv over the following 70 years if the effective environmental half-life is 5–10 years. CIS action levels are thus another way to express avertable doses, and, conceptually, they are in line with international guidance. However, the numerical values differ somewhat from international numerical guidance with a tendency of CIS-levels being lower than international numerical guidance.

6. Unresolved issues

Following a nuclear or radiological emergency, especially in the later phases, many complex human, social and economic considerations will have to be taken into account by the responsible authorities. The decisions and protective actions taken may themselves induce social and psychological impacts. Internationally, the application of different intervention levels in similar circumstances resulting from a single accident would cause much confusion in the public mind. At the national level, taking decisions about lines of demarcation between those areas where protective measures are applied and those where they are not, might create anxiety or even fear by people living on the 'safe' side of the demarcation line. From the experience in CIS following the Chernobyl accident, countermeasures to mitigate social-psychological impacts have obviously been needed.

It has been suggested that the inclusion of such countermeasures into the intervention decision making framework should be as a part of the radiation protection framework. This suggestion seems awkward as radiation protection factors are related to the level of protection achieved including those factors describing the dose distribution averted and costs and other disadvantages incurred in averting doses. The level of socio-psychological impact would depend not only on the presence of radiation but to a large extent on other non-radiological protection factors, such as the attitude of the mass media, the politial climate and the general level of information in the population. Non-radiological protection factors would also be different from country to country, and would probably be highly dependent on the existing political situation. To include socio-psychological factors in the radiation protection framework would thus give very random levels of radiation protection which could result in loss of credibility of the radiation protection community.

Therefore, to achieve an optimized overall health protection, non-radiological protection factors should enter the optimization process in parallel with radiological protection factors to form an optimized countermeasure strategy. The optimization of the overall health protection would thus be the responsibility of the decision maker with guidance from radiation proction experts as well as experts in the fields of social and psychological sciences. It is of great importance that the decision makers present the protection strategy to the public in a transparent way so all the factors and their relative importance in reaching the optimized strategy are revealed.

7. Conclusions

Following the accident at Chernobyl, it became evident that some clarification of the basic principles for intervention was necessary. In particular, it became clear from the experience of the Chernobyl accident recovery that there was a need for a simple set of internally consistent intervention levels that could have some generic application internationally. Such a set of values was considered desirable to increase public confidence in authorities charged with dealing with the aftermath of an accident.

Over the past decade considerable progress has been made in developing internationally recognized principles for decisions on protective measures following accidents involving radioactive material. The development of ICRP Publication No. 63 [4] and IAEA Safety Series No. 109 [5] represents an international understanding on the principles for intervention and numerical values for generic intervention levels. The recommendations in Safety Series No. 109 form the basis for the standards and numerical guidance related to intervention contained in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources of the FAO, the IAEA, the International Labour Organisation, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, the Pan American Health Organization and the WHO [7].

The guidance on protective actions in CIS is still being developed. The philosophy is based on the concept of action levels for specific countermeasures as well as for strategies of countermeasures. For resettlement, an action level of 20 mSv/y is suggested which would correspond to an avertable effective lifetime dose of about 300 mSv if the effective half-life of ^{137}Cs in the environment is about 10 years. The ICRP and IAEA intervention level for permanent resettlement is given as an avertable effective lifetime dose of 1 Sv. The international recommended action levels for foodstuff countermeasures is 1,000 Bg/kg of ^{137}Cs [7], which is identical to the WHO recommendation for foodstuffs moving in international trade. For specific strategies of foodstuff countermeasures, optimized action levels would be of the order of a few hundreds of Bq/kg of ^{137}Cs. CIS action levels for ^{137}Cs in foodstuffs appear to be somewhat lower than the international recommended action levels.

Radiological protection factors have been used in developing international numerical guidance on intervention level for implementing countermeasures to reduce doses after a nuclear or radiological emergency, but explicit guidance is not provided on how psychological and social factors should be included in the optimization of overall health protection. However, the optimization of radiation protection and certain psychological and social protection should probably not be carried out independently as separate and independent entities, as the overall health protection would depend on both radiological and non-radiological protection factors. The overall health protection should thus be based on an optimized countermeasure strategy, which would be the responsibility of the decision maker(s) with guidance from radiation proction experts as well as experts in the fields of social and psychological sciences.

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