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Application of GIS for Population Dose Assessment in the Chernobyl Accident Area

B.I.Yatsalo[*)], M.I.Balonov [#)], V.Yu.Golikov [#)] and V.I.Didenko [*)]
[*)] Obninsk Institute of Nuclear Power Engineering, Obninsk, Kaluga reg., Russia,
[#)] Institute of Radiation Hygiene, St.-Petersburg, Russia
yatsalo@obninsk.ru

INTRODUCTION

Simple dose models may be useful for preliminary, crude or conservative estimations of doses to the population. However, after the Chernobyl accident experts were faced with the practical task on assessing the most probable/real dose of external and internal exposure in different groups of population. And simplified models were not able to incorporate in and reflect a lot of site specific characteristics (inhomogeneity of contamination, the structure of land use, implementation of the countermeasures (CMs), behaviour of the population, etc.). In connection with this the further steps on development of special dose estimation methods taking into account the features of the Chernobyl contamination were undertaken (see, e.g., [1-3]).

Description of original approaches on actual implementation of up-to-date information technologies – geoinformation systems (GIS) for estimation of doses to the local population in Bryansk region (Russia) are briefly presented in this paper.

DOSE MODELS AND GIS

The development of updated approaches to evaluating the long-term consequences of the Chernobyl accident is based on the experience of authors (#) in assessing population doses and of (*) in creating Decision Support Systems (DSS) in radioecology with the use of GIS technologies. These approaches present some incorporation of updated dose models [1-3] into modified ***PRANA DSS***. Geographic Information System *PRANA* (***P***rotection and ***R***ehabilitation of environment ***A***fter ***N***uclear ***A***ccident) is a site-specific DSS for countermeasure analysis and decision-making support on rehabilitation of radioactive contaminated territories in the long-term period of liquidating the consequences of a nuclear accident [4].

'Dose block' is a key component of a modified version of the *PRANA DSS* on rehabilitation of contaminated territories after the Chernobyl accident.

The basic model of external exposure (from ^{134,137}Cs) consists of four sub-models for the following issues [1,2]:

- absorbed dose rate in air at a reference site in the settlement;
- conversion factor from absorbed dose rate in air to effective dose rate;
- absorbed dose rate in air at various types of rural or urban locations relative to the reference site; and
- occupancy times of different population groups at various types of locations.

Input information for indicated sub-models comprises monitoring data on surface density contamination (including contamination a settlement and its vicinity) along with corresponding demographic data and settlement characteristics [1,2].

The (basic) model of internal exposure (from ^{137}Cs and ^{90}Sr) consists of sub-models for assessing contamination of the main foodstuffs. The following information (for the time period under consideration) is used for estimation of mean effective internal dose (reconstructed or forecasted) to the local population [1,3]:

- contamination (concentration of ^{137}Cs and ^{90}Sr) of private milk and potato;
- contamination of mushrooms;
- monitoring data on surface density contamination (with radionuclides ^{137}Cs and ^{90}Sr) of a settlement and its neighbourhood;
- data on type of soil (first of all for pastures, hayfields and arable lands);
- type of settlement (village, small town, town, etc.);
- the structure of population diet/food basket.

The best way to comprise all the data indicated is the implementation of *vector map of landuse* along with data associated with each polygon of such a map. This approach was realised in the *PRANA DSS*.

When estimating internal and external doses to the local population the following components of *PRANA* are used:

- electronic maps for territories under investigation (at present the library of real electronic maps includes 5 contaminated districts of Bryansk region);
- databases (including database associated with polygons of vector electronic maps, and database for model

and other input parameters);

- updated and specially modified mathematical models for assessing external and internal doses to the local population;
- corresponding computer modules and user interface.

Library of electronic maps includes different layers of *vector maps of landuse* for territories under consideration. Created electronic maps comprise all the main categories of land use in accordance with their spatial location, coordinates and geometry/configuration (i.e., polygons of vector maps):

- arable lands;
- natural agricultural lands (pastures and hayfields);
- forests;
- swamps;
- water plots;
- gardens;
- settlements;
- some other plots.

Databases associated with *polygons of vector maps* include the following data for each polygon:

- for each settlement:
  - monitoring data on surface density contamination (with ^{137}Cs and ^{90}Sr);
  - monitoring data on contamination of private production;
  - data on private production;
  - monitoring data on internal and external doses to the local population (see Fig.1);
  - demographic data, local diet, behaviour and location and other factors;
- - for each element of land use (agricultural fields, forests, etc.):
  - - monitoring data on surface density contamination;
  - - physical and agrochemical soil characteristics;
  - - available data on countermeasure adopted earlier (for agricultural fields and settlements).

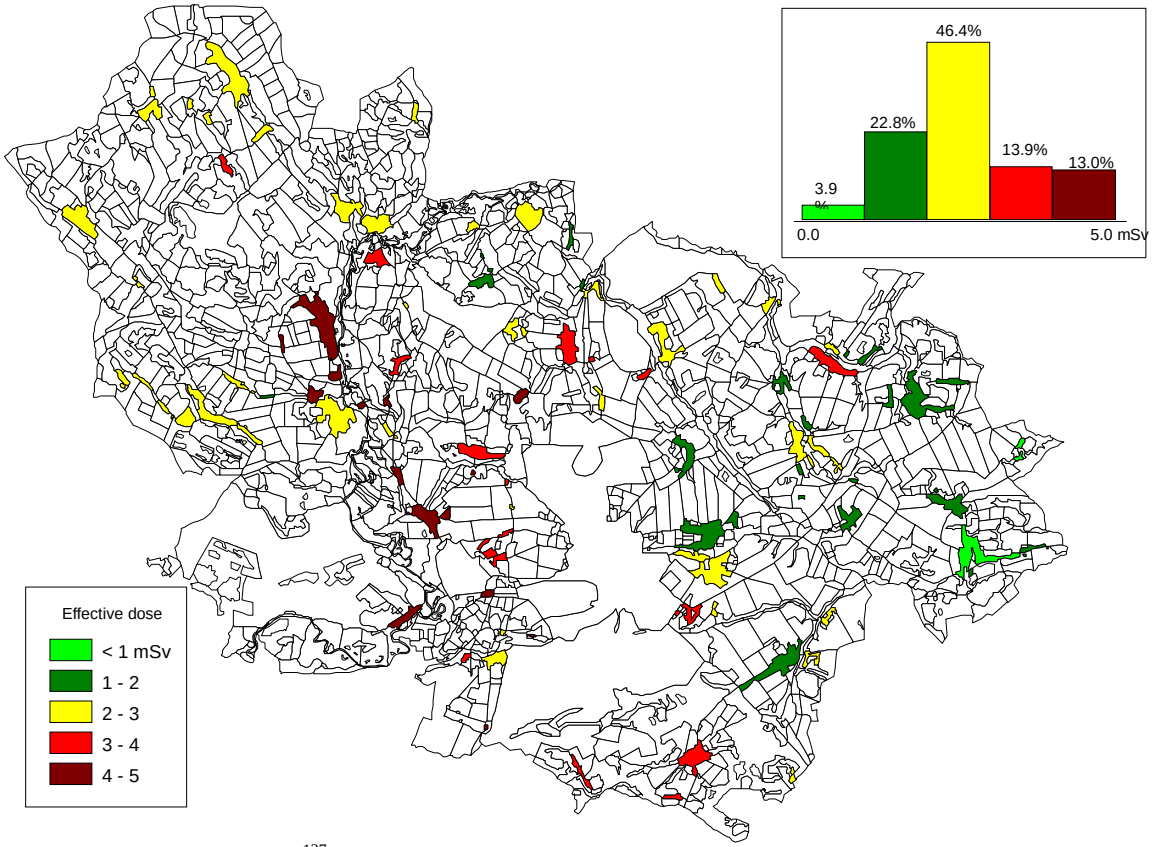

Fig.1 Map of doses (from ^{137}Cs) to the rural population (monitoring data), Novozybkov district, Bryansk region, Russia

Other databases include all the parameters necessary for assessing contamination of agricultural products and internal/external doses: various transfer factors, parameters of countermeasures, productivity and production of agricultural crops, milk and meat (both for private and farm production), etc.

The questions of ‘associating a settlement and corresponding polygons of the landuse map’ have been worked over. It’s one of the key problems when assessing doses to the local population for the cases of essentially inhomogeneous character of territory contamination and/or heterogeneous structure of soil types, as well as for cases of various CMs implementation. It is especially important for the Chernobyl accident and allows estimating different scenarios of the local population behaviour and consumption of locally produced or gathered food.

A possibility of connecting landuse polygons with a settlement is especially important when assessing contribution of milk and forest products into individual effective dose to local inhabitants. Such an approach comprises also analysing results of implementation of different countermeasures, including management by the use of contaminated territories (change of crop rotation, restriction/prohibition on the use of some areas with contamination above established Intervention Levels, possible use of abandoned fields, etc.). Therefore, special attention was paid to developing and adjusting to elements of GIS the dose models with a possibility of consideration of a wide class of protective measures, [4,5].

Several variants/scenarios of connecting landuse polygons with a settlement can be considered:

- averaging of values under consideration (e.g., milk or potato contamination) for polygons of given type within the chosen boundary (e.g., within a farm);
- use of distance function (e.g., for connecting with forest or pasture);
- use of database with direct connection of a polygon with a settlement on the basis of expert judgements (using, if necessary, distance function or data on administrative boundaries) or experience of a local experts.

The examples of using *PRANA DSS* for assessing doses to the local population are presented in the Figs.2,3.

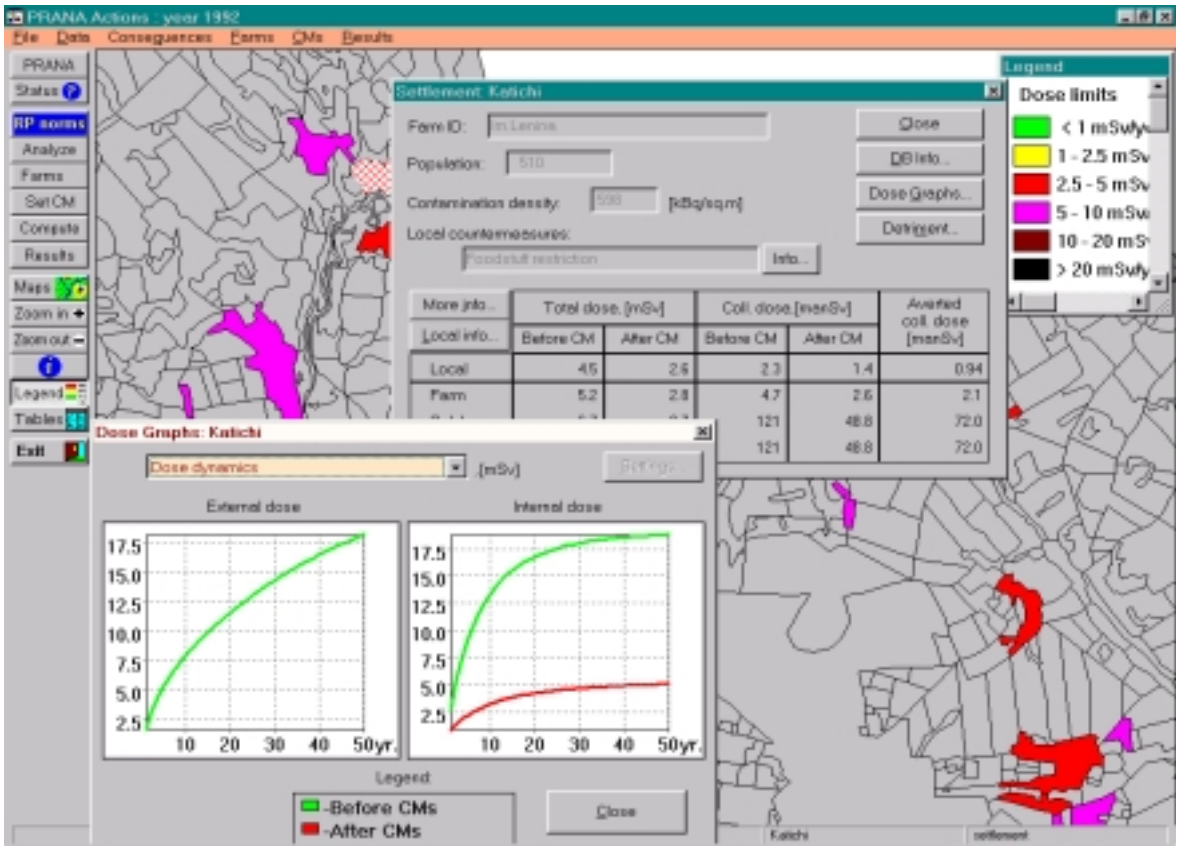

Fig.2 Model estimations of dose dynamics to the population.

External and internal dose estimates received on the basis of the *PRANA DSS* are compared with the individual dose monitoring obtained in the Bryansk. The ‘practical estimations’ of doses to the local population will be carried out during 2000 after completion of the procedures on modules/models validation/verification.

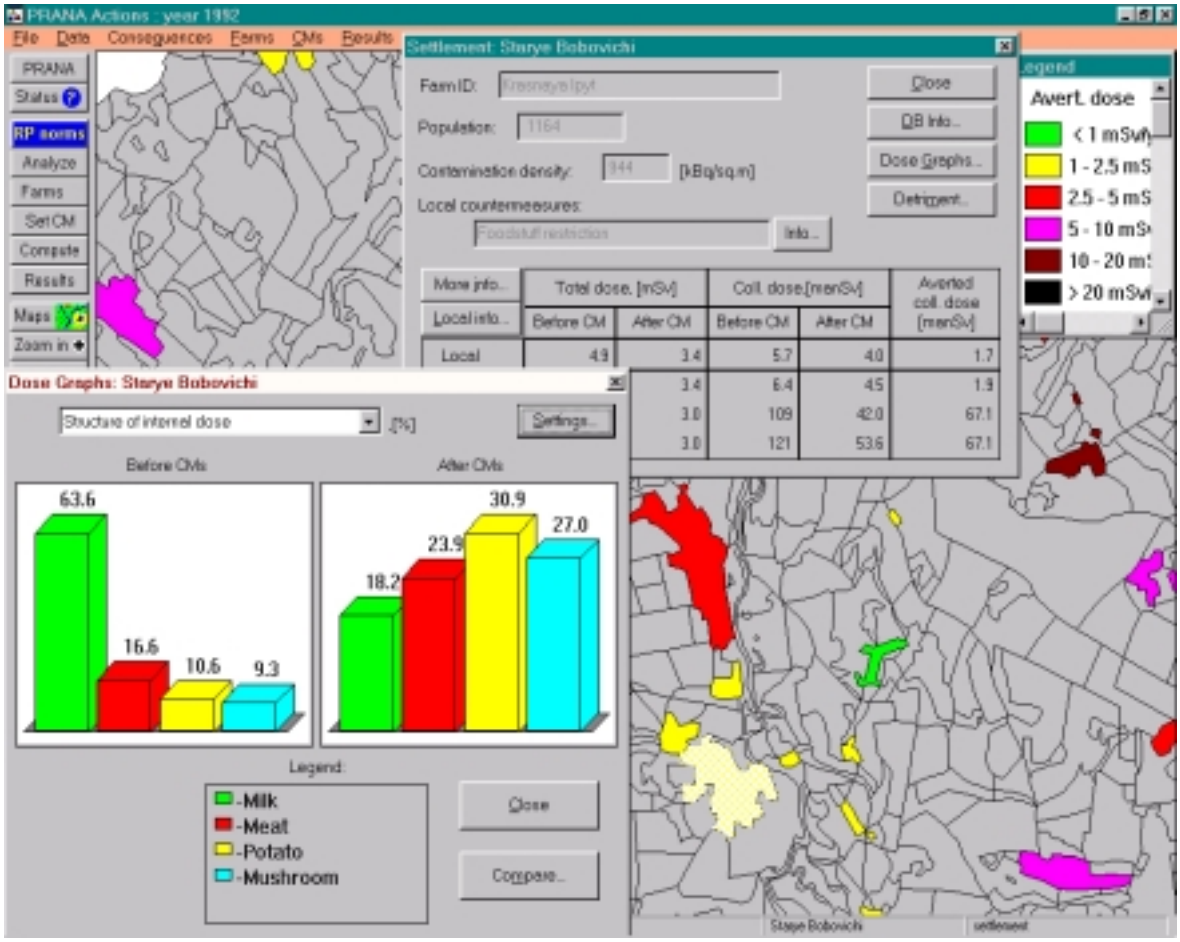

Fig. 3. The structure of internal dose before and after countermeasures, model estimates.

Several variants of dose models/modules (multilevel probabilistic and adaptive dose models), including stand-alone computer systems, are developed for different needs: for practical use, for research, as well as for training and education.

Stochastic/probabilistic variants of the models (both for internal and external exposure) for research purposes (for *uncertainty* analysis first of all) are based on the same equations as in a case of the deterministic models. However, in this case each of parameters is varied (distributed, random) quantity, that allows receiving a distribution of individual doses. The type of distribution functions and the numerical values of input parameters were obtained on the basis of the results of the field examinations in the most contaminated territories of Bryansk region. The output values of such models may be interpreted as *uncertainty* or *inhomogeneity* depending on the interpretation of input values (distributions).

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REFERENCES

1. P.Jacob and I.Likhtarev (Eds), *Pathway analysis and dose distributions*. Final Report, Joint Study Project No 5, European Commission, DG XII, Brussels: EUR 16541 EN, 1996.
2. Golikov V.Yu., Balonov M.I., Ponomarev, A.V. *Estimation of external gamma-radiation doses to the population after the Chernobyl accident*. /In: Balonov M.I. and Merwin S.E., (Eds.) The Chernobyl Papers. Vol.1. Research Enterprises; Publishing Segment; Richland; Washington; 1993: 247-288.
3. Balonov M.I. and Travnikova I.G. *Importance of diet and protective actions of internal dose from ^{137}Cs radionuclides in inhabitants of the Chernobyl region*. /In: The Chernobyl Papers, Vol. 1, ed. by S.Merwin and M.I.Balonov, Research Enterprises, Washington, 1993, pp.127-167.
4. B.Yatsalo, O.Mirzeabassov, I.Okhrimenko, I.Pichugina, B.Kulagin, *PRANA - Decision Support System for Assessment of Countermeasure Strategy in the Long-term Period of Liquidation of the Consequences of a Nuclear Accident.* - Radiat. Prot. Dosim. 1997, v.73, Nos 1-4, p.291-294.
5. B.I.Yatsalo, P. Hedemann Jensen and R.M.Alexakhin, *Methodological approaches to analysis of*

agricultural countermeasures on radioactive contaminated areas: estimation of effectiveness and comparison of different alternatives. - Radiat. Prot. Dosim. 1997, v.74, No 1/2, p.55-61.