Modelling Soil Erosion, Sediment Transport and Closely Related Hydrological Processes (Proceedings of a symposium held at Vienna, July 1998). IAHS Publ. no. 249, 1998.

Radio-ecological risk assessment (RRA) provided by databases of radioisotope pollution of Ukrainian water bodies

VICTOR M. SAMOYLENKO & YURIY S. TAVROV

Scientific-Information Centre of Water Management-Environmental Monitoring and Optimization of Water Use (Environmental Centre "SIC WEMOW"), Ukrainian Environmental Association "Green World", Apt. 2, Pimonenko Str. 5, Kiev 254050, Ukraine

Abstract This paper describes experience gained in 1986–1996 by the Ukrainian Environmental Centre "SIC WEMOW" during the development of a computerized information system (IS) for the generation, acquisition, computation and interpretation of field databases (DB) on local water bodies, radioisotope pollution and other hydro-environmental parameters. The system was developed for the purpose of making recommendations for radio-ecological risk assessment (RRA) aimed at the development of counter-measures and mitigation procedures to deal with the radiological pollution situation and to improve theoretical knowledge of radio-ecological/environmental processes.

INTRODUCTION

As a result of the Chernobyl accident, large areas of the Ukraine have been subject to contamination by radioactivity, but the degree of radio-isotope pollution in different areas is variable. Local water bodies (rivers, natural and manmade lakes, ponds etc.) in the most radio-polluted districts (primarily the Ukrainian Polissya Region) are very important for local water use and for economic purposes (drinking and industrial water supply, agricultural water consumption, fish-breeding and fisheries, water stock-breeding etc.). The location and resource utilization characteristics of the water bodies in the Chernobyl accident affected zone directly influence the formation of the population internal radiation doze (IRD) and the human radio-ecological risk level because of the primary role of water in living organisms and communities. So, any assessment of the affect of the radioisotope pollution and of the necessity for social and environmental protection (EP) measures, is impossible without ready access to the field data that has been collected on the radiological contamination of water in the region, and on the general hydrology and ecology of the water resources. A computerized information system which brings together all the available information has been developed at the Ukrainian Environmental Centre "SIC WEMOW".

PRINCIPAL RESULTS

The following results were obtained using methods and procedures for the acquisition of new data, and summarizing existing water radioisotope pollution data (RPD) by homogenous and representative principles, as described by Samoylenko (1996).

The existing RPD bases, including that of the EC "SIC WEMOW", include data on the concentration of long-living radionuclides, caesium-137 and strontium-90, in water ($^{137}Cs/^{90}Sr$ dissolved, ^{137}Cs suspended), on inhabitants of the water ecosystem, near-shore zone and bottom sediments ($^{137}Cs/^{90}Sr$ contamination density). These data were measured, checked, analysed and developed for more than 3500 Ukrainian water bodies (mainly for different kinds of local reservoirs as primary RRA source) in the most radio-contaminated areas.

RPD bases were computed and interpreted both by radio-ecological stochastic means and by presentation and analysis of other corresponding hydro-environmental parameters (*viz* hydrochemical, toxic and microbiological characteristics, genesis types of bottom sediments, integral water quality parameters etc.), which determine the conditions of radionuclide storage, migration and biological accessibility, either in the water body or in the drainage basin. Additional field investigations and data collection were necessary to correct and supplement the existing data in the RPD bases for incorporation into the Information System.

In addition, the basis of the RPD investigations was provided by some basic field observing stations and test water objects (TWO) (about 150) (Samoylenko *et al.*, 1997), designed for the research of radioisotope accumulation and migration in other sections of the ecosystem and in food chains, relationships with radioactive contamination levels of water margins, and population and individual IRD formation during water use.

The principal results were realized and implemented as follows:

(a) Developing an Information System with the RPD bases and corresponding environmental-economic maps (RPD bases on more than 3,500 water objects, examples for natural and manmade lakes are given in Figs 1 and 2).

(b) Basic field observing stations and test water objects (TWO) for water body radionuclide pollution research. An example of a temporal dynamics date set for one of the basic stations is shown in Fig. 3 (this observing station pond is affected by RP counter-measures). Figures 4–8 illustrate data selected from the TWO DB, in relation to the Ukrainian environmental standards (temporary

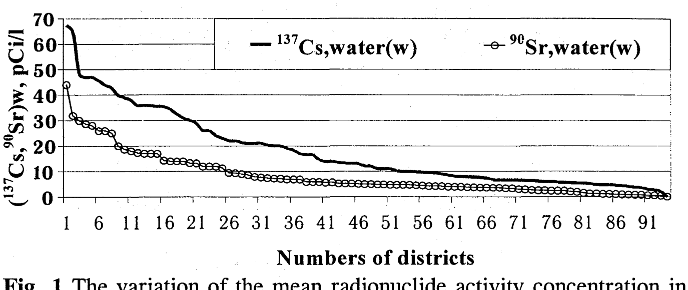

Fig. 1 The variation of the mean radionuclide activity concentration in the water of local reservoirs in the districts of the Ukrainian Polissya Region (^{137}Cs and ^{90}Sr dissolved).

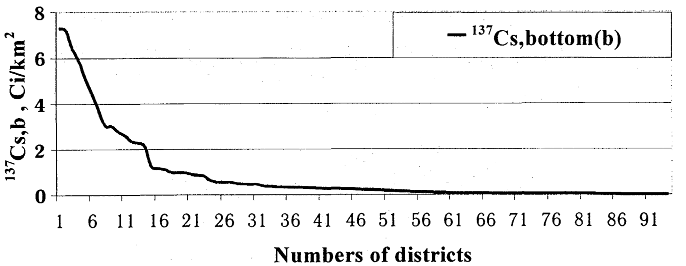

Fig. 2 The variation of the mean contamination density in the bottom sediments of local reservoirs in the districts of the Ukrainian Polissya Region (^{137}Cs in the upper stratum).

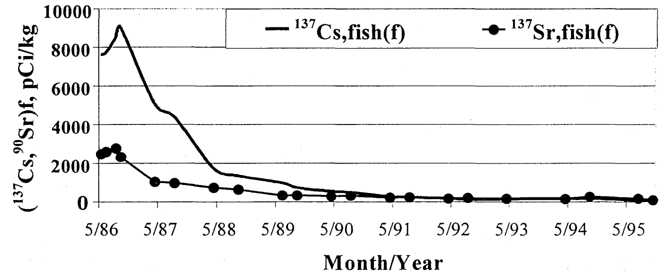

Fig. 3 The dynamics of radionuclide concentration in fish (adult carp) at the basic field observing station (a pond where mitigation measures are implemented).

accepted levels, TAL, and top accepted concentrations, TAC), in water and food products. These comparisons show that the radio-ecological parameters measured in the test water bodies are small relative to the TAL levels. However the standards for toxic and hydrochemical parameters (heavy metals, ammonia-ion concentration etc.) are exceeded and the situation is complicated if their impact is combined with the fact that the TAL has not been fully substantiated, and that synergy is possible between pollution agent effects during local water use (Samoylenko *et al.*, 1997).

(c) Modern computerized support of the IS for RPD which is compatible with information systems for international hydro-environmental databases. The Data Bases Management System (DBMS) for the RPD IS consists of five connected hyperblocks: general RPD bases DBMS; DBMS of specific tasks (RPD dynamics

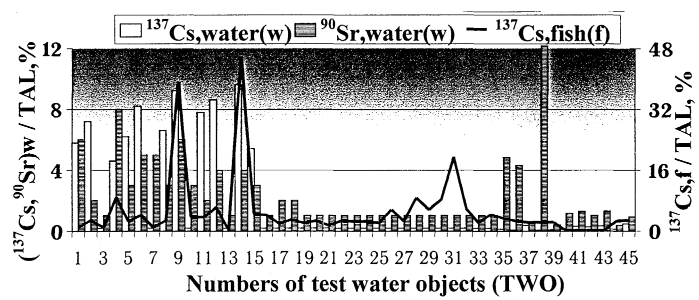

Fig. 4 Comparison of radio-ecological field data with the Ukrainian temporary accepted levels (TAL) (45 test water objects, TWO, local reservoirs, 1996).

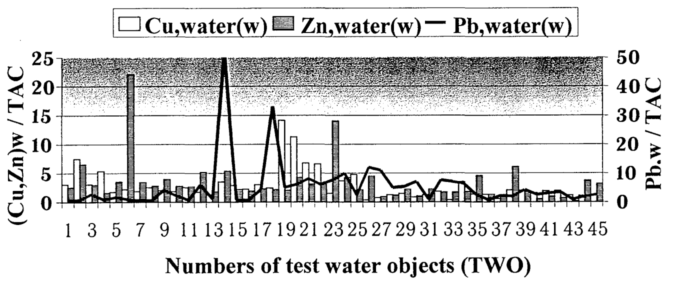

Fig. 5 Comparison of field toxicity data with the Ukrainian top accepted concentrations (TAC) (45 TWO, local reservoirs, heavy metal concentrations in the water, 1996).

etc.); DBMS for hydro-radio-environmental regionalization with GIS elements; DBMS for basic observing stations and TWO; DBMS for data filtration/restoration and radio-ecological risk estimation and prediction models.

(d) Empirical relationships and theoretical conclusions on regularities of population IRD formation in water courses from local water bodies. In this way, some tendencies were confirmed (by TWO field DB) concerning radionuclide accumulation in hydrohabitants according to the environmental conditions in water bodies (Samoylenko, 1996). So, radionuclide accumulation rate (RAR) in wild and domestic ducks from local natural and artificial lakes and ponds (as a food product for population/water-users IRD formation) showed an inverse correlation with potassium-ion (for ^{137}Cs) and calcium-ion (for ^{90}Sr) concentrations in water (Figs 9 and 10) . The same tendency is observed in the

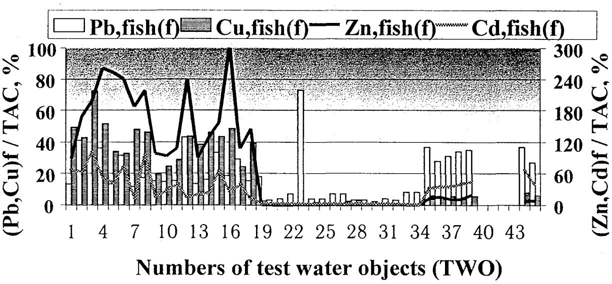

Fig. 6 Comparison of field toxicity data with the Ukrainian top accepted concentrations (TAC) (45 TWO, local reservoirs, heavy metal concentrations in fish, 1996.

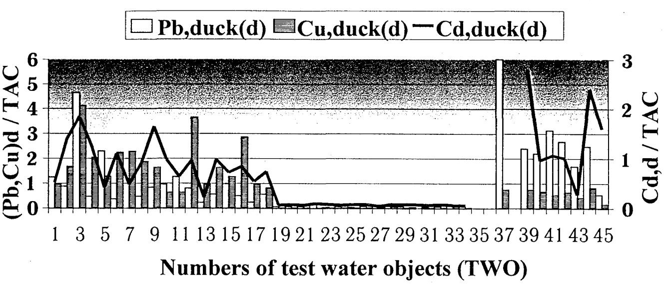

Fig. 7 Comparison of field toxicity data with the Ukrainian top accepted concentrations (TAC) (45 TWO, local reservoirs, heavy metal concentrations in ducks, 1996).

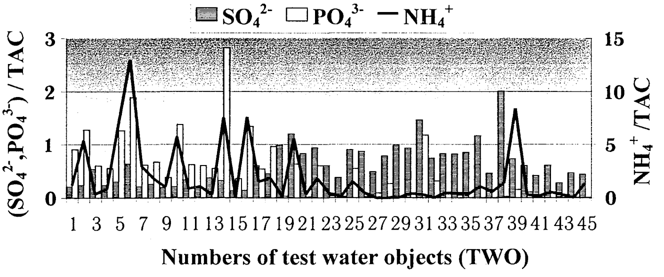

Fig. 8 Comparison of hydrochemical field data with the TAC (45 TWO, local reservoirs, sulphate, phosphate, ammonium ion in water, 1996).

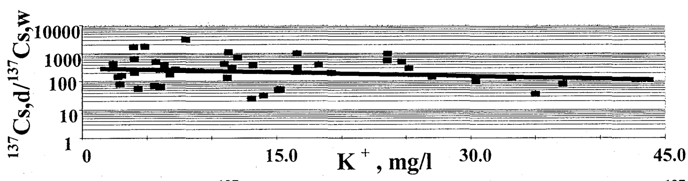

Fig. 9 Correlation of ^{137}Cs concentration ratios in ducks and water ($^{137}Cs,d/^{137}Cs,w$) with potassium ion concentrations in water (TWO, local reservoirs).

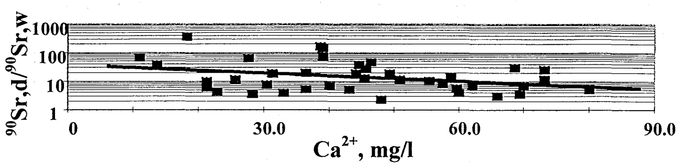

Fig. 10 Correlation of ^{90}Sr concentration ratios in ducks and water ($^{90}Sr,d/^{90}Sr,w$) with calcium-ion concentrations in water (TWO, local reservoirs).

correlation between RAR in edible fish tissues with water mineralization (Fig. 11), and duck RAR with ammonia-ion concentrations in water (Fig. 12). However, there is a positive correlation between the RAR in ducks and the variation of phosphate concentration (Figs 13 and 14). It has been possible to model IRD formation (Samoylenko *et al.*, 1997) and some examples are showed in Fig. 15.

(e) New stochastic procedure of RPD bases reliability definition and restoration and water management-radio-ecological monitoring optimization. This procedure is the practical application of a new developing branch of science called stochastic environmental hydrology (Samoylenko, 1996) which concerns the dynamics and stability of water bodies.

All the results described above represent important progress in the development of recommendations for mitigation of the radiological situation and EP counter-measures in contaminated drainage basins after the Chernobyl accident. The recommendations are initially for population groups connected with resource usage from local water bodies which include reservoirs of differing size and origin. These,

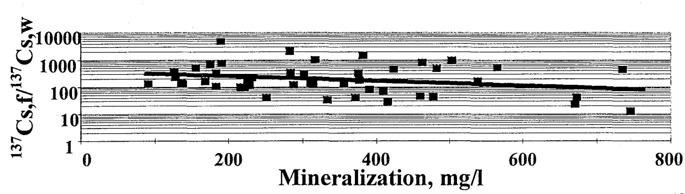

Fig. 11 Correlation of ^{137}Cs concentration ratios in fish and water ($^{137}Cs,f/^{137}Cs,w$) with water mineralization (sum of the main ions) (TWO, local reservoirs).

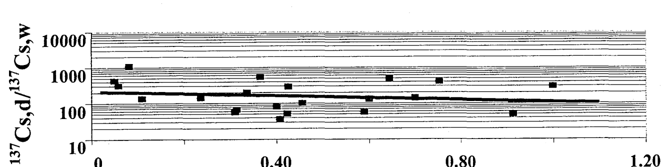

Fig. 12 The correlation of ^{137}Cs concentration ratios in ducks and water ($^{137}Cs,d/^{137}Cs,w$) with ammonium ion concentrations in water (TWO, local reservoirs).

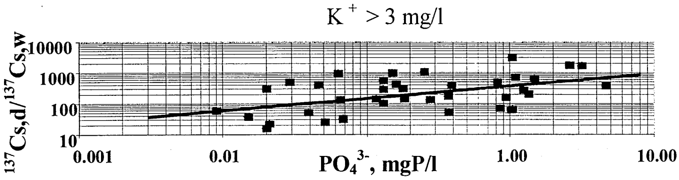

Fig. 13 Correlation of ^{137}Cs concentration ratios in ducks and water (^{137}Cs,d/^{137}Cs,w) with phosphate concentrations in water (TWO, local reservoirs).

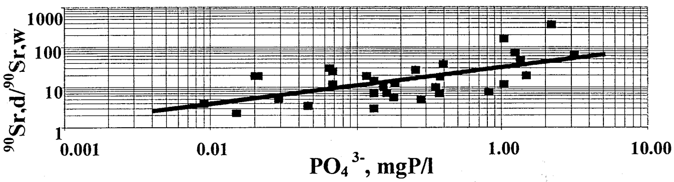

Fig. 14 Correlation of ^{90}Sr concentration ratios in ducks and water (^{90}Sr,d/^{90}Sr,w) with phosphate concentrations in water (TWO, local reservoirs).

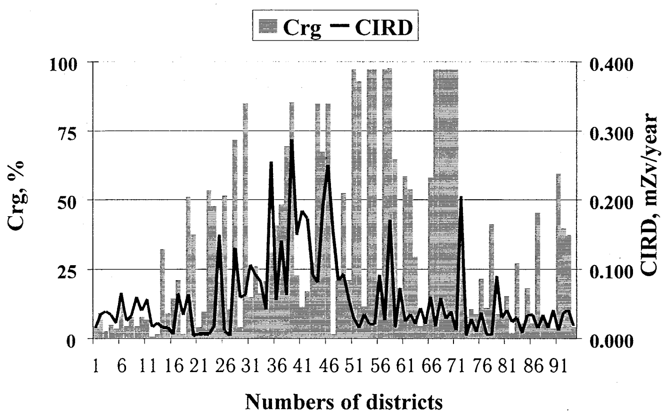

Fig. 15 The predicted percentage of the potential local water users radio-ecological risk groups (Crg, %, as compared with the total of each district population) during formation of the effective internal radiation dose (IRD) (CIRD, mZv year^{-1}: calculated value of expected average annual mean district individual IRD from ^{137}Cs and ^{90}Sr reception by water courses) in contaminated districts of the Ukrainian Polissya Region.

and the adjoining sections of rivers and/or the water margins, are the most dangerous sources of radio-ecological and hydro-environmental risk.

REFERENCES

Samoylenko, V. M. (1996) Development of lake and reservoir dynamics and stability information/simulation systems for environmental monitoring and management on Ukraine example. In: *Proc. XVIII Conf. of the Danube Countries*, C141–C146. Austrian Nat. Comm. for IHP/UNESCO and OHP/WMO, Tech. Univ. Graz, vol. 19(2).

Samoylenko, V. M., Nasvit, O. I. & Tavrov, Y. S. (1997) The creation, management and development of radioisotope pollution information system of water bodies for local use (in Russian). In: *Radio-ecology of Water Bodies in the Chernobyl Accident Affected Zone* (ed. by the Ukrainian Hydrometeorological Institute), vol. 1. *Chernobylinterinform*, 96–126. Kiev.