EUROPEAN ATLAS ON RADIOACTIVE CONTAMINATION

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Abstract

Techniques of preparation and production of the atlas on radioactive contamination in Europe resulted from the Chernobyl nuclear power plant accident as well as the structure of the atlas, are considered.

The atlas will contain around 100 full color maps with varying scales displaying spatial distribution of caesium-137 contamination density over the territories of 36 European countries; maps on natural radionuclides content in soils; reference maps and supporting texts.

Publication of the atlas undertaken within the Joint Study Project 6 (JSP6) of the CEC/CIS Collaborative Programme is planned in 1996, by the tenth anniversary of the Chernobyl accident.

Introduction

The Chernobyl nuclear power plant accident (26 April 1986) resulted in the contamination of large parts of Europe by caesium-137, strontium-90, plutonium-238, 239, 240 and americium-241. After the accident, various compilations were made of particular countries or regions in Europe of the contamination resulting from the radioactive material released during the accident. These compilations were made for different purposes and, consequently, there are significant differences in their resolution and quality. To date, no attempts has been made to compile a comprehensive presentation of the contamination over the whole territory of Europe, the continent on which the majority of released material was deposited. In many cases, improved data have since been, and continue to be, obtained through more refined and extensive monitoring, in particular, in those areas where greater contamination occurred.

The time is now opportune to prepare a comprehensive atlas of the radioactive deposition for the whole of Europe consequent upon the Chernobyl accident. The publication of such an atlas by the tenth anniversary of the accident would have wide public and scientific interest. The atlas will provide the world community with the most complete information on the state of the contamination from the Chernobyl accident to date. In addition the atlas will contain initial material for calculating dose exposures for population and other elements of the biosphere, to compile integrated environmental maps and geoinformation data bases for decision support systems in regions with most dangerous environmental situations. In addition to the above remarks, the factual content of the atlas will provide a useful and needed perspective for judging the significance of the contamination.

The compilation of the atlas is being undertaken within the Joint Study Project (JSP6) of the CEC/CIS Collaborative Programme on the Consequences of the Chernobyl Accident which is being implemented within the European Commission's Radiation Protection Research Action. the radiological data, provided by participating scientific institutes and competent authorities of about thirty European countries are being integrated in an information platform. The atlas is being jointly prepared by the CEC Joint Research Centre Ispra (Ispra, Italy), the Institute of Global Climate and Ecology (Moscow, Russia), Belhydromet (Minsk, Belarus) and Minchernobyl (Kiev, Ukraine). After data validation and intercomparison in co-operation with the above mentioned national institutes, maps will be electronically prepared by means of a geographic information system (Arcinfo).

2. Scope of the atlas

The main goals of the Atlas are: to present information on the spatial distribution of deposited long-lived artificial radionuclides; to indicate how the levels of radioactivity contamination after the Chernobyl NPP accident have increased compared to global deposition; to identify relatively "clean" territories whose contamination is mainly related to global fallout; to present material about radioactivity contamination in Europe to scientists in different fields, decision-makers and the general public; to allow the calculation of dose exposures and to estimate environmental impact of the accident; to carry out direct calculation of the total amount of radionuclides deposited across Europe as a result of the Chernobyl NPP accident; to present information to detail the patterns of radionuclides distribution and fallout on the earth's surface; to obtain data to solve the questions of radionuclides migration and transport in soils, traffic and biological chains.

3. Contents and layout of the atlas.

The atlas will contain detailed analyses and around 100 full color maps, mostly A2 format and will be largely supported by detailed text. It is subdivided into five main sections:

- In the introductory section an overview is given in order to present the phenomenon of radioactivity and its consequences for man. Besides background information on natural and artificial radioactivity, this section also contains a summary of the risks of radiation exposure and a description of the Chernobyl NPP accident.

- In the data section, caesium deposition, corrected for radioactive decay to 10 May, 1986, is presented by means of isolines. The information is presented at three geographical levels:

- European level: contains general information about the deposition pattern throughout Europe (scale 1:10,000,000).

- Country level: maps of one or two countries (depending on the geographical form) with a scale varying between 1:10,000,000 and 1:2,500,000, containing more geographical and radiological details in order to reflect the national situation.

- Hot spot level: the higher contaminated areas (i.e. parts of Scandinavia, the Alps, Greece-Rumania, Russia, Belarus and Ukraine) are highlighted by means of small scale maps (1:500,000).

The isoline values that will be used to present the caesium contamination are based on the values in SI units and will remain constant for the different scales of maps used. For the small scale maps (European level) isolines at alternating levels will be taken (see Table 1). To improve legibility, rounded values were chosen. The values change approximately logarithmic; for the three highest levels of radioactive deposition the official values applied in the CIS are considered.

Activity levels		Level of maps		
kBq/m²	Ci/km²	Europe	Country	Hot Spot
0.4	0.010		X	
1.0	0.027	X	X	
2.0	0.054		X	
4.0	0.100	X	X	
10.0	0.270		X	
20.0	0.540	X	X	X
40.0	1.000		X	X
100.0	2.700	X	X	X
185.0	5.000		X	X
555.0	15.000	X	X	X
1480.0	40.000			X
3700.0	100.000			X

Table 1: isoline values with respect to the different scales of maps

- The Reference section contains supporting information, i.e. European geology, land cover, soils and population at a scale of 1:40,000,000.

- The Meteorological section: Deposition patterns depend largely on the wind fields and precipitation patterns. To describe the meteorological aspect that contributed to the dispersion of the radioactive cloud, this chapter may show a series of daily maps containing meteorological information for the two-three weeks immediately following the accident.

- The Technical annexes contain all technical information associated with the atlas, e.g. the location where the samples were taken, summaries of the data compilation procedures and of the information presented by each country.

4. Preparation of the atlas.

The preparation of the maps of the atlas was subdivided into two main parts: collection (and digitizing where needed) and validation of radioactivity and geographic data; drawing of the maps. The study of terrain radioactive contamination after 1986, was conducted in most of the European countries by many different methods: predominantly the techniques used were soil sampling, fallout detectors (wet, dry or total deposition), in-situ gamma spectroscopy and aerial gamma spectroscopy. After integration of the data into the electronic platform, additional intercomparison was carried out to estimate the reliability of the data.

One of the important elements of this project is the use of a Geographic Information System (GIS) for the preparation and production of the maps in the atlas.

4.1. Collection of data.

Deposition data in the CIS.

The study of surface radioactive contamination after 1986, was conducted in the republics of the CIS mainly by two methods:

- soil sampling with subsequent gamma-spectrometric analysis to determine the levels of soil contamination by gamma-radionuclides (including caesium-137) and radiochemical analysis to determine the contamination by alpha and beta emitting radionuclides (including strontium-90 and plutonium-238,239+plutonium-240 and americium-241).

- air-gamma-spectrum survey which, (by using a gamma-spectrometer, navigation apparatus and computer technique mounted on a helicopter) obtains remote data on the levels of gamma-radionuclide contamination.

Both methods supplement and control each other.
Air-gamma-spectrum survey of two levels of detail (1:200,000 and 1:1,000,000) were carried out in the period 1986-1992 over the territories of the former USSR republics taking into account the peculiarities of caesium-137 fallout (see Figure 1):

- at a scale of 1:200,000 (helicopter flights at an altitude of 50 m over routes every 2 km providing integral measurements over a route every 0,4 km) over areas with levels of 1 Ci/km^2 and higher for caesium-137, as well as over the adjacent territories where small anomalies above 1 Ci/km^2 could be observed against a background of lower values;

- at a scale of 1:1,000,000 (helicopter over routes every 10 km providing integral measurements over a route every 2,0 km) over areas with levels mainly under 0.5 Ci/km^2 (since a range of 0.5-1 Ci/km^2 was usually surveyed with a scale of 1:200,000). The lowest level of mapping was 0.1 Ci/km^2 for caesium-137.

Most of samples belong to the territories of the close-in emergency zone - more than one sample per 1 km^2. The sampling in areas furthest from the Chernobyl NPP, and main patterns of accident emissions, is characterized by a value of less than 1 sample per 10,000 km^2. In these regions, air-gamma-spectrum survey becomes the main source of information.

An important result of this study was a compilation of a map on the former USSR European territory contaminated by caesium-137 on scale 1:10,000 000. This map was incorporated as an element into the primary map on the European territory contamination by caesium-137 compiled in the IGCE (Moscow) and is based on the information described above. The map shows spatial regularities in the distribution of long-lived dose-forming caesium-137 radionuclides whose fallout after the 1986 Chernobyl NPP accident were fixed over vast territories.

The direction of the caesium-137 fallouts is traced on the maps. Much pronounced is the eastern pattern spreading from the Chernobyl NPP and crossing the Russian territory to the Ural and further on to Siberia. The pattern is broken neither by water areas nor by large-size mountain massives.

Several southern patterns are traced over the Ukrain territory
They are interrupted by the Black Sea water area. The patterns are fixed in Western Georgia and over the Russian Black Sea coast.
South-western patterns are pronounced in the Ukrainian Carpathian Mountains and then they appear in the Balkan mountains.
The western patterns spreading over the territory between the Ukraine and Belarus for a number of branches spreading northward and than turning eastward, being observed over the territories of Belarus, Poland, Lithuania, Sweden, Norway, Finland, and Leningrad Oblast in Russia. Some western patterns spread to West European countries where caesium-137 anomalies with levels above 40 kBk/m^2 are recorded in the Alps.

4.1.2. Radioactivity data in Europe outside the CIS.

As a basis for the atlas, the information available in the REM data base (JSP-Ispra Joint Research Centre) was taken. These data were corrected for radioactive decay and integrated with the data set, containing aerial gamma spectroscopy measurements on 15' by 15' grid, provided by IGCE, Moscow (See Figure 1).

About 60% of the European countries responded in sending in new data. These came partly in digitized format, some on paper as tables and/or figures.

Compiling maps on Cs-137 contamination, all countries of Western Europe face considerable difficulties connected with low density of measurements. For example, in the southern Switzerland where Cs-137 contamination levels are above 40 kBq/m^2 only 26 samples were obtained for the analysis from the area of 2 thousand km^2. Similar situation takes place in Bulgaria and Slovenia.

Nevertheless, the international expert group has compiled preliminary map of Cs-137 contamination (on the base of analysis of data presented by participating countries) across the countries of Western Europe. This map was joined to the map produced by the CIS countries (Figure 1).

Since areas of low elevation in Europe exhibit a global contamination level from stratospheric nuclear tests of 50-60s were 2-3 kBk/m^2 in the early nineties, while in mountainous regions they can increase up to 4-10 kBk/m^2, one can conditionally take isoline level 10 kBk/m^2 for the lower level of the Chernobyl contamination. The area within this isoline makes about 20% of Europe (around 2 million km^2 according to initial estimates) - see Table 1.

Cs-137 (kBq/m^2)	Area (x1000 km^2)	% of the European area
>1480	3.1	0.03
555-1480	7.2	0.06
185-555	19	0.2
40-185	200	1.7
20-40	420	3.6
10-20	1350	11.6
<10	9600	82.2

Table 2: Distribution of the radioactive contamination by caesium-137 over the European territory.

Total amount of caesium deposited over the European territory is equal to 8 x 10^{16} Bq.

5. Techniques used.

One of the important elements of compiling this atlas is the use of a Geographic Information System (GIS) for the preparation and production of the maps in the atlas. A GIS is a organized collection of computer hardware and software designed to efficiently capture, store, update manipulate, analyze and display all forms of geographically (or spatially) referenced information. Certain complex spatial operations are possible with a GIS that would be very difficult, time consuming or impracticable otherwise. Individual datasets can be stored as separate layers which can then be combined with each other as required. The system being used is Arcing, a powerful GIS package developed by ESRI Inc. of California.

The overall aim is to produce maps showing the concentration of Caesium deposition across European lands following the Chernobyl accident. The information relating to the radioactivity information will be combined with a series of thematic layers (e.g. roads, rivers, coastline, national boundaries, administrative regions, population centers) which will provide the necessary cartographic background. In order to prepare the maps for the atlas, two basic datasets are being developed within the GI, i.e. supporting cartographic detail and information on radioactive deposition.

- The cartographic detail for the European and Country scale maps will be provided by information contained in the Digital Chart of the World (DCW). The DCW is an established dataset of assorted digital cartographic features for the world at a scale of

1:1,000,000. Sources of cartographic information for the "hot-spot" areas (at a scale of 1:500,000) have still to be identified and investigations in to this matter are still in-hand.

- The information on radioactive deposition from the participating institutes comes in the form of point data which can be geographically located by a latitude and longitude coordinate. The deposition data then transformed to a suitable map projection which allows cartographic data to be overlayed (e.g. coastline for checking that the values fall on land).

However, the objectives for the project require the generation of isolines of deposition to be displayed. To achieve this task, some degree of interpolation and generalization of the data must be undertaken. Within the Arcinfo package, there are numerous methods for generating isolines which range from various techniques for the generation of grids or lattices to the generation of surfaces based on triangulated irregular network.

In addition, list of all maps which will be included in the atlas, is enclosed.

List of all maps which will be included in the atlas

Scale	Name of Map	Size
1:45,000,000	Daily meteo maps for Precitation (6 maps/A3 page)	4 x A3
	Daily meteo maps for Wind Direction and Speed ("")	4 x A3
	Daily meteo maps for Pressure ('')	4 x A3
1:20,000,000	Natural Radioactivity 1	1 x A4
	Natural Radioactivity 2	1 x A4
	Natural Radioactivity 3	1 x A4
	Natural Radioactivity 4	1 x A4
1:15,000,000	Trace of deposition cloud and elevation	1 x A3
	Reference map for geology	1 x A3
	Reference map for soil	1 x A3
	Reference map for vegetation/landcover/landuse	1 x A3
	Reference map for population patterns	1 x A3
1:10,000,000	Deposition of Caesium across Europe	1 x A2
	Guide to individual maps of Cs deposition across Europe	1 x A2
	Guide to individual "hot-spots" maps	1 x A2
	Technical annex map for sampling location	1 x A2
	Country maps for:	
1:2,500,000	North Norway, North Sweden, Finland	1 x A2
1:2,500,000	South Norway, South Sweden, Finland	1 x A2
1:1,000,000	Denmark	1 x A2
1:2,500,000	Eire, United Kingdom	1 x A2
1:1,000,000	The Netherlands, Belgium, Luxembourg	1 x A2
1:2,500,000	France	1 x A2
1:2,500,000	Spain, Portugal	1 x A2
1:2,500,000	Germany, Switzerland	1 x A2
1:2,500,000	Italy, Slovenia	1 x A2
1:2,500,000	Greece, Albania, Bulgaria	1 x A2
1:2,000,000	Poland	1 x A2
1:1,500,000	Czech, Austria	1 x A2
1:1,500,000	Hungary, Slovakia	1 x A2
1:1,500,000	Romania, Moldavia	1 x A2

1:1,500,000	Estonia, Latvia, Lithuania	1 x A2
1:2,500,000	Russia	1 x A2
1:1,500,000	Belarus	1 x A2
1:2,000,000	Ukraine	1 x A2
1:500,000 *Hot Spot Maps*	Norway, Sweden and Finland	14 x A2
"	The Alps (Southern Germany, Switzerland, Italy and Austria)	4 x A2
"	Greece	2 x A2
"	Romania	3 x A2
"	Russia	15 x A2
"	Ukraine	10 x A2
"	Belarus	15 xA2

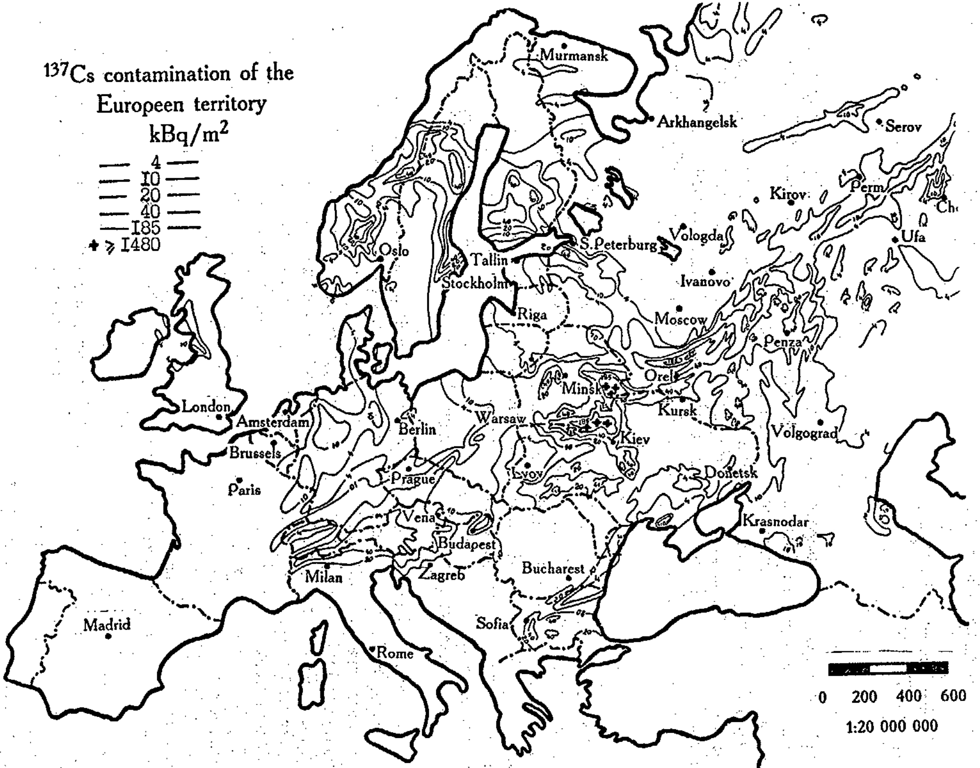
137Cs contamination of the
Europeen territory
kBq/m2
4
10
20
40
185
≥ 1480
Murmansk
Arkhangelsk
Serov
Kirov
Perm
Ufa
Vologda
S.Peterburg
Ivanovo
Moscow
Penza
Oslo
Tallin
Stockholm
Riga
Minsk
Orel
Kursk
Volgograd
London
Amsterdam
Berlin
Warsaw
Kiev
Brussels
Paris
Prague
Lvov
Donetsk
Krasnodar
Vena
Budapest
Bucharest
Milan
Zagreb
Sofia
Madrid
Rome
0 200 400 600
1:20 000 000

Fig 1