On the Radio-ecology of the Danube River

by G.J. Köteles

The projected growth of nuclear power in the Member States of the IAEA along the Danube River presents several radiological protection questions which can be best resolved through international co-operation. Realizing this, the riparian countries expressed willingness to participate in a joint investigation when the IAEA suggested that such a programme be initiated. The work itself had already been started in November 1975 when an "Advisory Group to Study Questions of Mutual Co-operation Between Countries in the Danube Catchment Area" recommended that an expert group be convened in the framework of a co-ordinated research programme and identified the main topics to be investigated Ref. [1]. This programme, as usual, was based on the basic principles of such co-ordination, i.e. (a) the participation of a Member State is optional; (b) the joint investigations are based on relevant national programmes; and (c) the technical and scientific recommendations of an international expert group may lead to an improvement in the relevant national activity or in its regulations.

As a result of the recommendations of this first Advisory Group, a three year co-ordinated programme was started in mid-1976 and lasted until mid-1979. In the following section the main scope of the programme and a few representative data are presented.

THE DANUBE BASIN

The Danube, with its length of 2857 km, is the eleventh longest river in the world and the longest international river in Europe. Its drainage area comprises 817 000 square kilometres or approximately one-twelfth of the continent. From its source in the Black Forest at a height of 1000 metres above sea level, to its three armed delta on the Black Sea, the Danube flows through eight countries and drains a total of twelve. This catchment area is shown in Figure 1. All eight countries through which the Danube flows are Member States of the IAEA: Austria, Bulgaria, Czechoslovakia, Federal Republic of Germany, Hungary, Romania, USSR and Yugoslavia. The Danube is fed by 129 tributaries, all more than 20 kilometres long, with 29 of them more than 200 kilometres long. Nearly 70 million people live in the drainage area and use the water in it for drinking, irrigation, fishing, industry, transportation and sports. The Danube is the main receptor of wastewater in its catchment area. The river's great influence on the ecosystem of its catchment

Dr. Koteles is a former staff member in the Division of Nuclear Safety and Environmental Protection, IAEA, where he served as Project Officer for the IAEA's Co-ordinated Research Programme on "The Problems of Radioecology of the Danube River". He is presently the Scientific Deputy Director of the "Frédéric Joliot-Curie" National Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary.

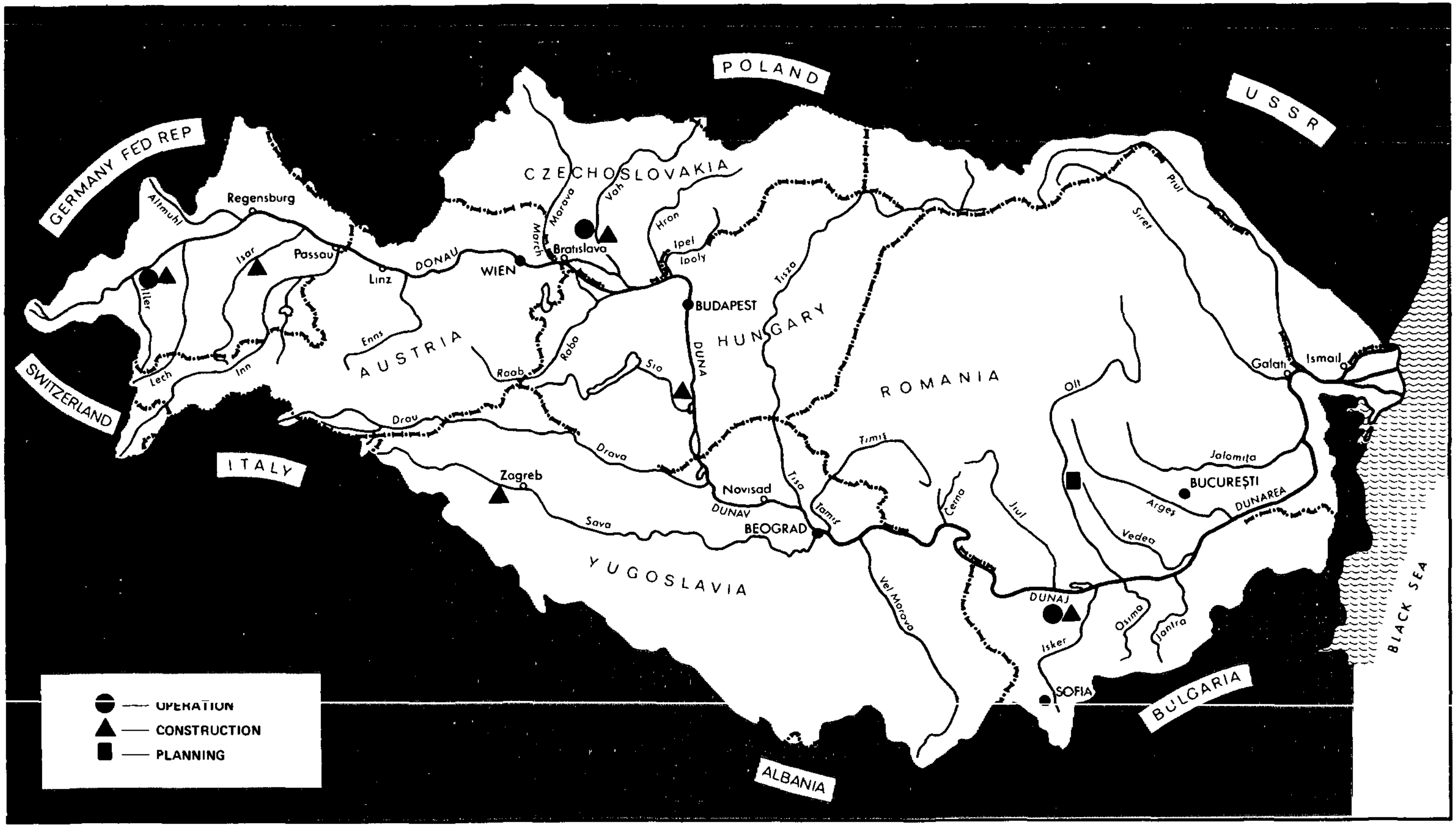

Figure 1. The hydrological map of the Danube catchment area with indications of operating (●) nuclear power stations and those under construction (▲) or being planned (■).

area will be further expanded when the planned connections between the Danube-Main-Rhine, the Danube-Oder-Elbe, the Danube-Morava-Vardar-Aegean Sea are implemented.

ELECTRIC POWER SUPPLY

In addition to the operating or projected hydroelectric power stations in the Danube valley, new factors will contribute to the complexity of the aquatic environment and to water quality, such as the development of the nuclear industry. The list of existing or projected nuclear power stations is given in Table 1 Refs. [2, 3, 4]. It can be seen that almost all riparian states plan to operate or to build nuclear power stations on the Danube or its tributaries within the next six years; the total installed nuclear capacity, which is at present approximately 2.5 GWe, will increase four-fold in 6 years and approximately six-fold by the end of the century. This growth rate is approximately three times higher than that of the European or the world average. The data also indicate that radioactive releases from nuclear power stations with a total capacity of approximately 13 400 MWe will enter the river. Of course, the amount of these releases will depend on the design of the stations and their cooling systems. However, the sources of these releases will be unevenly distributed, i.e. 60% will be released into the upper third and 75% into the upper half of the river respectively. Taking into consideration international experience with BWR and PWR reactors, it can be foreseen that, excluding tritium, 70% of the total radioactive releases will enter the upper third of the river.

Table 1. Nuclear Power Reactors in the Danube Catchment Area*

No.	Name and Location	Type	Output thermal/net electric		Status	Date of Start-up
GERMANY, Federal Republic of,						
1.	KRB Gundremmingen-A	BWR	801	237	Operating	1967
2.	KKN Niederaichbach	HWGCR	321	100	Shut-down (1974)	1972
3.	KKI Isar-1 Ohu	BWR	2575	870	Operating	1979
4.	KRB Gundremmingen-B	BWR	3840	1244	Construction	1982
5.	KRB Gundremmingen-C	BWR	3840	1244	Construction	1982
6.	KKI Isar-2 Ohu	–	3765	1230	Planned	1986
AUSTRIA						
7.	Tullnerfeld Zwentendorf	BWR	2100	692	**	
CZECHOSLOVAKIA						
8.	A-1 Bohunice Jasl.Bohunice	HWGCR	560	110	Operating	1972
9.	Bohunice-1 Trnava	PWR	1375	380	Operating	1979
10.	Bohunice-2 Trnava	PWR	1375	380	Construction	1980
11.	Levice-1 Slovakia	PWR	1375	420	Planned	

12.	Levice-2 Slovakia	PWR	1375	420	Planned	
13.	Levice-3 Slovakia	PWR	1375	420	Planned	
14.	Levice-4 Slovakia	PWR	1375	420	Planned	
15.	Brno Brno	PWR	1375	420	Planned	
HUNGARY						
16.	Paks-1 Paks	PWR	1375	408	Construction	1980
17.	Paks-2 Paks	PWR	1375	408	Construction	1981
18.	Paks-3 Paks	PWR	1375	408	Planned	1984
19.	Paks-4 Paks	PWR	1375	408	Planned	1985
YUGOSLAVIA						
20.	Krsko Krsko	PWR	1876	632	Construction	1980
ROMANIA						
21.	Olt	PWR		408	Planned	1983
22.	Cernavoda	PHWR		600	Planned	
BULGARIA						
23.	Kozloduy-1 Kozloduy	PWR	1375	408	Operating	1974
24.	Kozloduy-2 Kozloduy	PWR	1375	408	Operating	1975
25.	Kozloduy-3 Kozloduy	PWR	1375	408	Construction	1980
26.	Kozloduy-4 Kozloduy	PWR	1375	420	Construction	1980

* References [2, 3, 4]
** Scheduled for 1979 but terminated by referendum

THE AIMS AND OUT-COME OF THE CO-ORDINATED RESEARCH PROGRAMME

In several national laboratories, well-established relevant activities were under way at the time that the joint programme was initiated. Therefore the primary aims were to compare data, to harmonize measuring techniques including the most crucial factors of collecting and preparing environmental samples such as water, sediment and aquatic biota. In the next stage, the purpose of the programme was to reveal the critical pathways through which radioactive pollutants reach humans and to identify those critical groups of the population that would be most exposed due to the use of the Danube for any purpose. If it is shown that the radiation burden of these population groups is acceptably low, one can be confident that no member of the public will be exposed to significant health risks. These studies also provide information for establishing derived limits for the release of radioactive materials into the river as is required and recommended by international expert groups Ref. [5]. This framework of co-ordinated investigations seemed to be suitable and essential for ensuring the radiological safety and environmental protection of the Danube valley.

The detailed results obtained during the first three years of the programme were made available in the IAEA-TECDOC series Refs. [4, 6]. Although the investigations differed in various countries in the detail of their approach and technique, the results obtained so far have revealed many important and common factors and provided good numerical data. In several countries these investigations were needed as pre-operational survey before the construction of nuclear power plants began. In others, they form part of the routine operational surveillance of pollutants released from nuclear facilities.

A few representative data showing the range of measured radioactivity concentrations in the river water and sediment are shown as follows:

	Isotope	Concentrations
In water:	tritium	60 –400 tritium units (TU)
	cobalt-60	0.07– 60 milli-Becquerels/litre (mBq/l)
	strontium-90	1.1 – 20 mBq/l
	caesium-137	0.37– 20 mBq/l
	radium-226	7.4 – 44 mBq/l
In sediment:	cobalt-60	81 – 220 Bq/kg
	strontium-90	0.74 – 30 Bq/kg
	caesium-137	2.6 – 33 Bq/kg
	radium-226	55 – 140 Bq/kg

It should be noted that the values measured in the various laboratories were in good agreement. Since this is one of the crucial points of such international collaboration, special emphasis was put on the intercomparison of measurement data. Therefore, in the course of the programme proper reference standards were used and the participants also joined the IAEA's intercomparison and analytical quality control programme.

The rather wide range of measured values also covers the seasonal variations of certain nuclides, e.g. the concentration of caesium-137 shows significant increases every year during spring and early summer. It was suggested that the maximum values originate from the stratosphere-troposphere exchange, i.e. attributed to nuclear weapons tests The values also indicate that the radionuclides which are most important from the point of view of radiation protection are highly adsorbed by the sediment. Therefore, the movement of these nuclides across national boundaries in this international river is much slower than those dissolved in the water. Investigations, however, on the re-distribution of nuclides from the various types of sediment into the water under various circumstances (hydrological, thermal, chemical, etc.) were also carried out both *in situ* and through laboratory experiments Refs. [1, 4, 6].

For the assessment of radiation dose to the critical group of the population, however, further data were needed on the behaviour of nuclides in the environment, and on the ways in which they are transferred through it. Therefore, it was also important to initiate investigations on the radioactive content of aquatic biota. The approach involved determination of the radioactive content of biota obtained directly from the river and also through experiments carried out in the laboratory. The latter take longer to complete so no final results are available yet. The concentrations of radionuclides found in the various species being studied compared to their concentrations in the water -- the concentration factors — were found to be spread over a wide range. Of course, this is not surprising as similar ranges of values have been reported from other regions. For example, those for cobalt-60 are in the range of 2000—13 000 for algae, 240—1600 for aquatic plants, 20—3000 for fish. Even higher concentration factors for cobalt-60 were measured in plankton. In fish, strontium-90 was found to be concentrated by a factor of between 30 and 370; for caesium-137 the factor was between 50 and 3500. Great variations in the concentration factors are further expected at various sectors of the river due to the effects that hydro-electric power stations have on the populations of flora and fauna. Clear indications of such alterations were shown in conjunction with the construction of the Djerdap Dam (Iron Gate Dam) in Yugoslavia, i.e. a greater accumulation of radionuclides was observed in the head-pond region than in the river before construction began.

It has to be mentioned here that the acceptance of recommendations for sampling (e.g. relating to selection of sampling points, sample materials, the frequency of sample collection and on the primary preparation of samples) will obviously contribute to the intercomparability and reliability of data on the radioactivity concentrations in the various sectors of the river environment.

As the final aim of these environmental studies is the protection of the human population, work was initiated in a few laboratories to determine, e.g. the critical pathways for radionuclides through the food chain to man and the critical groups within the population. This work was begun after the basic data on radioactivity concentrations and the behaviour of nuclides in the specific environment had been collected. Where these studies have been completed, an estimate of the radiation exposure of individuals and critical groups of the population could be made; this exposure proved to be well below one per cent of the exposure from natural radiation.

Last but not least, one of the most valuable results of the project was the close co-operation among experts from the riparian States irrespective of their social or political systems. All of these countries were represented in the programme either as research contractors or as observers. Several international organizations, such as WHO, ECE, CMEA and the Danube Commission have also followed the work of the programme. Communications among the participating laboratories through the advisory group and research co-ordination meetings influenced the existing radioactivity monitoring programmes along the Danube, by helping to develop national systems and monitoring methods.

It has been realized that all of the programme's objectives could not be met in 3 years. Some time is still needed before all of the laboratories dealing with these problems will have collected the necessary data for a complete account of the radiological safety and environmental protection problems of their reach of the Danube. Many further environmental factors have yet to be clarified, such as the synergistic effects among thermal, chemical and radioactive pollutants and how these effects influence the long-term distribution and re-distribution of the last-mentioned of these pollutants. Investigations are also needed that would allow agreement to be reached on a common methodology for the assessment of the individual and collective doses that result from the various uses of the Danube in each riparian country. Agreement is also needed on the minimum requirements for international monitoring.

The organizational and scientific results achieved so far in this broad programme at a relatively small cost (approximately $100 000) prove that such co-ordinated research programmes can have a very favourable cost/benefit ratio. This form of collaboration can help to solve not only certain technical and scientific problems in environmental protection but also some organizational and administrative problems at national and international levels.

References

[1] IAEA's Advisory Group to Study Questions of Mutual Co-operation Between Countries in the Danube Catchment Area, AG-41, IAEA (1976)
[2] Power Reactors in Member States, IAEA, Vienna (1979).
[3] World List of Nuclear Power Plants, Nuclear News (February 1979).
[4] International Studies on the Radio-ecology of the Danube River, IAEA-TECDOC-219, IAEA, Vienna (1979)
[5] Principles for Establishing Limits for the Release of Radioactive Materials into the Environment, Safety Series No 45, IAEA, Vienna (1978).
[6] International Studies on the Radio-ecology of the Danube River, Vol 2, IAEA-TECDOC, IAEA, Vienna (in press)