ENVIRONMENTAL EFFECTS OF THE THERMAL EFFLUENT DISCHARGED FROM NPP CERNAVODA UNIT 1 INTO THE DANUBE RIVER – PARTIAL RESULTS

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Abstract: The thermal discharge from NPP Cernavoda Unit 1 was monitored for thirteen month on at least a monthly basis. Besides temperatures, several physical, chemical and biological parameters were also recorded, in the discharge canal, the Danube area influenced by the discharge and the water adduction canal. During the entire monitoring period, no adverse environmental effects of the thermal water discharge were identified. The usual temperature difference between the ambient and the thermal effluent was less than 8.3°C, higher temperature being recorded during the colder months, when Unit 1 was working with partly recycled cooling water (up to 18.1°C on March, 03, 2003).

Key words: Danube river, NPP Cernavoda, thermal discharge, environmental impact

INTRODUCTION

Starting from the vital necessity to assess the impact of any industrial human activity upon the state of the environment and human health, as much as in the case of obtaining energy from nuclear plants, and having in view the catastrophic consequences which can happen accidentally in connection with one of the components comprising this complex system of producing electricity, the investor of the NPP Cernavoda is permanently concerned with the monitoring and ecological aspects in view to increase the capacity of production by building new units in conditions of full security. One of the numerous activities potentially generating ecological stress, which can affect the aquatic ecosystem, is the discharge of thermal water originating in NPP Cernavoda cooling system.

METHODS

The interest area was estimated as extending from 44°21.8' N to 44°24.6 N and from 28°01.6'E to 28°04.2'E (Fig. 1). The coordinates interval covers the Danube, beginning from approximately 1.3 km upstream from the discharge canal to about 4 km downstream. Based on previous models of the thermal plume, it was hypothesized that the ΔT=1°C isotherm will exceed in no time this distance downstream from the discharge canal.

The discharge canal is situated on the right bank, it is ≈50 m wide and the centre of the discharge mouth has the approximate coordinates 44°22.37'N and 28°02.30'. The depth in the discharge section is variable, depending on the Danube level. The mean depth was estimated at ≈4 m for an average Danube level of 250 cm at Cernavoda hydrological station.

The thermal discharge from Cernavoda NPP Unit 1 into the Danube was monitored for 13 months (August 2002 - August 2003) on at least a monthly basis. The main goals of the monitoring were to measure the extent of the thermal plume in different environmental conditions, collecting sufficient data to estimate it for the simultaneous functioning of Units 1 and 2 and to evaluate the actual environmental effects (physico-chemical and biological) and to predict their future evolution.

The thermal plume was mapped 1-2 times/month, a period of unusually low Danube levels permitting to measure the extent of the plume in extreme conditions. The collected data allowed establishing a clear relation between the heat quantity and Danube discharge (level) on the one hand and the extent of the plume on the other hand.

Water samples were collected for laboratory analyses in five stations: St.1 in the Danube, about 850 m upstream of the discharge canal (control), St.2 in the discharge canal, about 100 m upstream the discharge mouth, St. 3, St.4 and St. 4 in the Danube thermal plume, distributed at irregular intervals downstream from the discharge canal in such manner as to cover several thermal zones; the sampling stations were supplemented with St.C1 in front of the drainage basin and St.C2 in front of a municipal discharge of wastewaters (Fig. 1).

To ensure a good comparability of the analytical results the station locations were kept as stable as possible during the entire period of field activity (July 2002 – March 2003).

Dissolved oxygen, oxygen saturation, conductivity, pH and Eh were measured *in situ*. Water, phyto- and zooplankton samples were collected for laboratory determinations of chlorophyll, nutrients, suspended solids, turbidity, true and apparent colour and biological associations. All analyses were made according to common methodology in use [UNESCO (1968, 1973, 1976); Ex-Im Bank (1998); Gomoiu *et al.* (1998); Hach Company (1989); Krebs (1999); Parsons *et al.* (1984); Vollenweider (1969)].

RESULTS AND DISCUSSIONS

Some of the results of field measurements concerning the thermal plume are presented here as examples (Table 1).

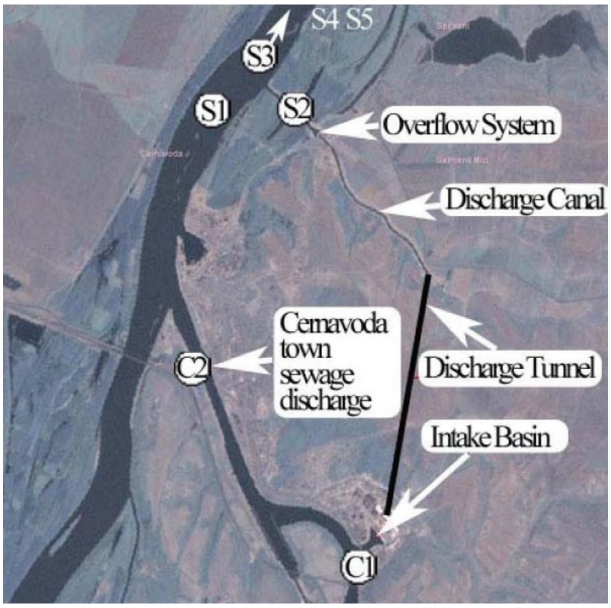

Fig. 1 General view of the NPP Cernavoda. Area and monitoring stations location

From the beginning it has to be mentioned that no unwanted environmental event due to the discharge of the thermal effluent from NPP Cernavoda Unit 1 into Danube was identified during the entire monitoring period. Also, no significant changes in the environmental conditions, excepting the temperature increase, were detected at any time.

The results of the field works and laboratory analyses have led to the following conclusions:

Table 1 Main parameters of the Danube River flow and thermal plume

Month	Danube level(1, m	Discharge, m^3/s	T_{am}, °C	ΔT, °C	ΔT=3°C isotherm length m	ΔT=3°C isotherm maximum width m
Jul, 2002	37	1330	24.9	8.3	1700	120
Aug, 2002	292	2300	23.4	7.5	550	115
Sep, 23	15	1260	20.9	7.8	1690	227
Oct, 2002	229	2150	13.4	7.9	623	136
Nov, 2002	371	2840	9.0	12.5	612	91
Dec, 2002	340	2590	2.9	16.3	2227	102
Jan, 2003	450	3280	1.5	14.2	765	68
Feb, 2003	130	1690	2.2	18.1	2545	205
Mar, 2003	289	2410	7.2	10.2	545	136
Apr, 2003	222	2210	14.4	7.3	615	148
May 09, 2003	193	1950	18.9	8.2	727	227
Jul 29, 2003	-40	435	27.2	7.9	1636	341
Aug 12, 2003	-95	600	25.2	7.6	1545	330

Notes: (1 – at Cernavoda hydrological station
(2 – estimated average speed.

1. The topographic features of the Danube riverbed in the interest area influence significantly the mixing process, especially at low waters level (Fig. 2).

2. During the field measurements, the temperature difference between the ambient and the thermal effluent was never greater than 8.3°C (July 30, 2002), usually being <8°C during the months when Unit 1 worked in a normal regime. However, during the colder months, when Unit 1 was working with partly recycled cooling water the temperature difference increased gradually up to a maximum of 18.1°C recorded on March 03 (Table 1).

3. During the observation time interval, the lengths of the ΔT = 3°C isotherm varied from 450 m to a maximum of 2545 m, also recorded in March 03 (Figure 3). Besides the temperature difference, the quality of the mixing depends on the Danube level, being poor at low levels.

4. No significant changes of the physico-chemical parameters investigated during the monitoring period were detected. However, some systematic differences were recorded: lower O_2 concentrations and higher pH values in the discharge canal and thermal plume comparatively with the ambient water. Both are the results of lower gas (O_2 and CO_2) solubility in water at higher temperature. It is worth mentioning that in the oxygen case the concentrations difference was always lower than the one corresponding to the temperature difference (higher O_2 saturation in warmer water), thus demonstrating the efficiency of the overflow system.

5. Another systematic difference was revealed for the suspended solids concentration and the apparent and true colour, significantly reduced in the discharge canal and the thermal plume. The explanation resides in the time the cooling water spends in the Danube – Black Sea canal. The sedimentation during this time lowers the content of suspended solids and the turbidity and as a result the apparent colour improves. This aspect of the environmental change induced by the thermal effluent should be regarded as an improvement of the Danube water quality. The few cases when these parameters presented higher values in the discharge canal are attributable to anthropogenic influences unrelated to the thermal water discharge (canal bank consolidation works and/or dredging in the adduction canal).

6. The nutrient and chlorophylls variances during the same sampling event are within the limits of natural variability. A temporal variability related to the phytoplankton biological cycle is clearly evident for all stations and the higher temperature in the thermal plume does not apparently affect it. Ammonium concentrations were always lower than the permissible limits, usually by almost one order of magnitude. Occasionally, higher concentrations were found in the discharge canal. The most plausible cause is however the supplementary ammonium introduced in the adduction canal by the discharge of urban wastewaters from Cernavoda, upstream of the cooling water intake.

The biological monitoring of the area under the effect of the thermal discharge from Cernavoda NPP Unit 1 concluded in some interesting findings, which may be resumed as follows:

1. Natural variability of the planktonic populations in the Danube River is high and the associations form "patches" of different structures and abundances. The analysis of the number of phytoplankton species and density distribution per taxonomic groups in each station from the Danube River Cernavoda NPP area of interest shows that almost always the values are similar for the St.1 (control station) and St.4 (Danubian thermal plume) and St.C1 ("reservoir" for water intake in the cooling system) and St.2 (thermal water discharging canal), much higher in the first case than in the second. Plankton populations in the zone of St.C1 are different from those living in the Danube River; they are the result of "selection" made by the lentic habitat in a community originating from a lotic habitat.

2. It seems that the most important factor for the phytoplankton populations is the state of water movement; the lentic character (standing water) of the St.C1 zone, which changes the structure of phytoplankton populations, selects and retains those species having calm waters as optimum biotope, more than the increasing of water temperature does. So, that is why the phytoplankton from St.C1 has a greater resemblance with the one from St.2 (thermal water discharging canal) than with the phytoplankton from the Danube River stations.

3. For the zooplankton populations the things are similar with those from phytoplankton. Comparing the specific diversity in different samples/stations we can affirm that the lowest values were recorded usually in St. 2 (thermal discharge canal) and St. C1 (intake canal). Probably, the state of biotic populations in the thermal discharge canal depends much more upon the "quality" of the initial populations entering with water as cooling agent than upon the heating of water crossing the technological installations.

4. Monthly analysis shows that usually the zooplankton populations in St. 4 are the most abundant, as a consequence of beneficial inffluence of the thermal plume, very similar to the populations from St. 1. Rotatoria and Cladocera generally exhibit a slight increase in the thermal canal, the heated water probably being a stimulative factor for their reproductive capacity.

5. On concluding the analysis of plankton found in the thermal discharge canal it is worth mentioning that during

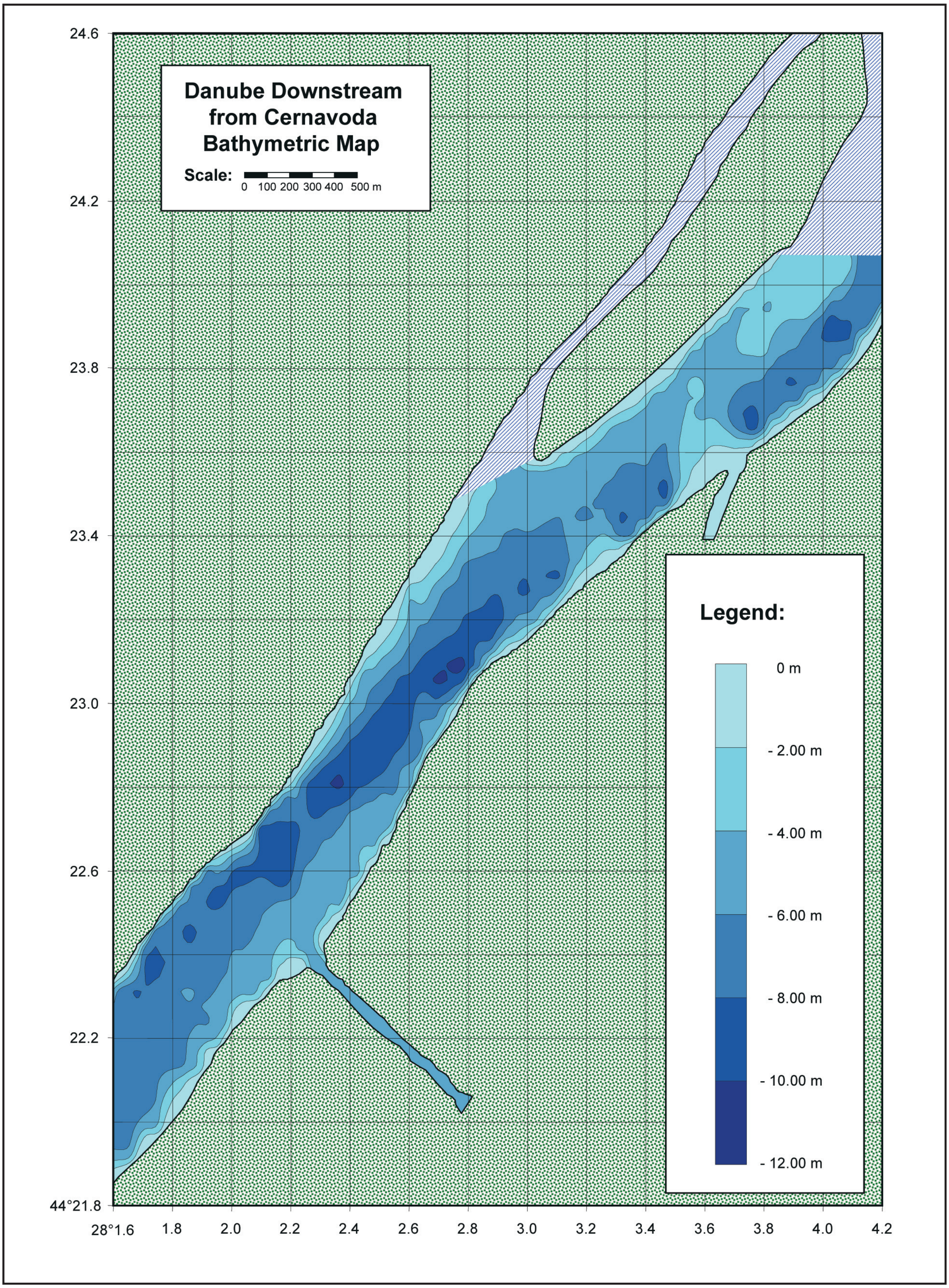

Fig. 2 Bathymetric map of the Danube river in the region of the NPP Cernavoda Unit 1 discharge canal

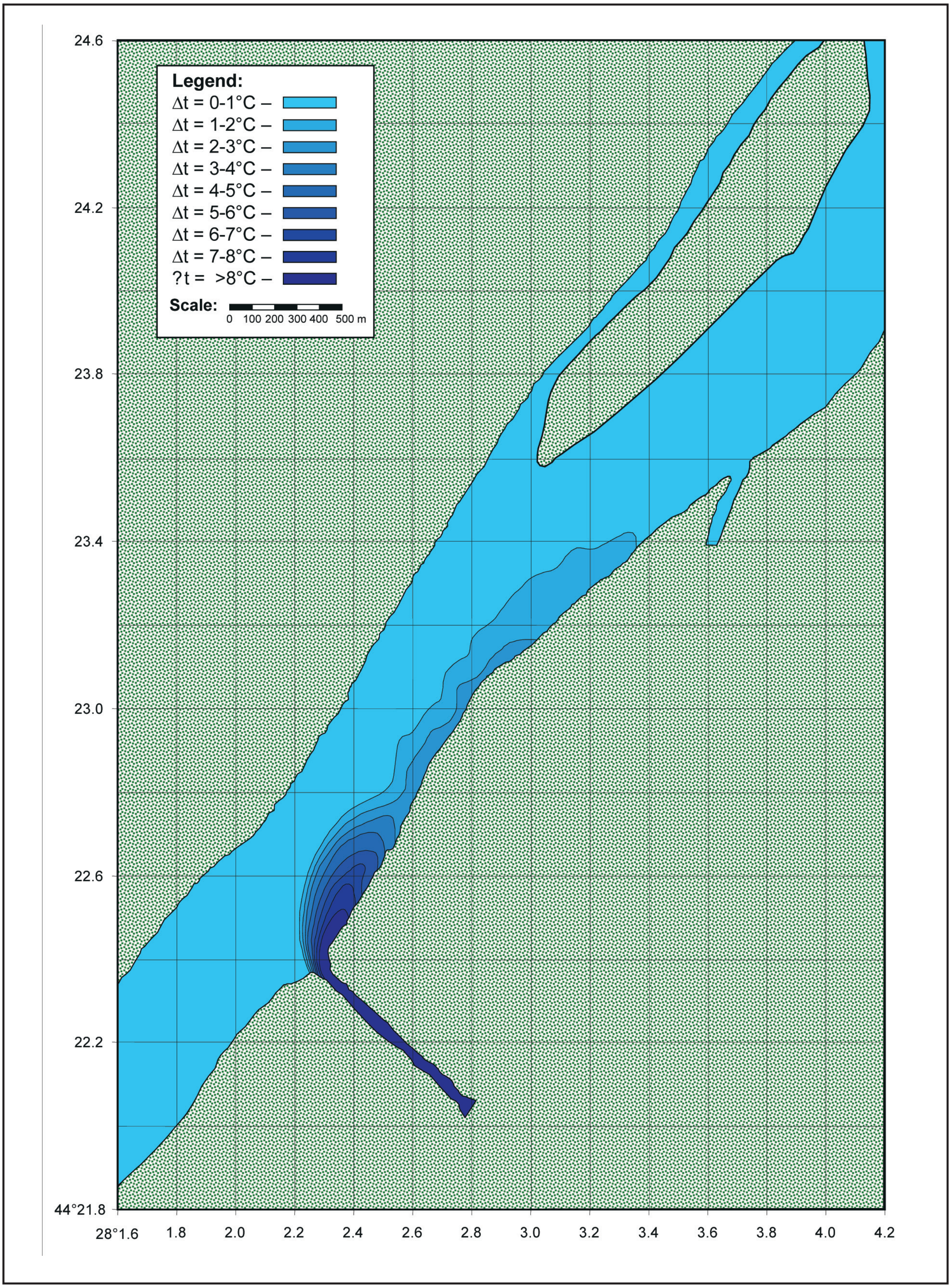

Fig. 3 Thermal plume of the NPP Cernavoda Unit 1 discharge – May, 09, 2003 (Danube level 193 cm)

the summer time the supplementary heated water in canal *vs.* "normal" aquatic environment in the research area, cannot be a limiting factor for the zooplankton populations; those zooplankton species with a large thermophilic capacity are present in the ecological system being represented by different populations with adults and development stages. No adverse effects of the temperature increase on the zooplanktonic population from the discharge canal were detected. On the contrary the population is well developed and diversified providing an appreciated food source for fish.

6. Under normal conditions the thermal discharge from NPP Cernavoda Unit 1 does not have a significant environmental impact onto the Danube River. The largest areas potentially affected by the thermal effluent from Unit 1 occur especially at low Danube levels (discharges) but also at the high temperatures differences characteristic to the colder months, when Unit 1 is recycling a part of the cooling water. For the last case the areas may be limited by a careful monitoring of the temperatures in the intake basin, which should not be allowed to exceed the temperature of the Danube water by more than 4 or 5°C.

SELECTED REFERENCES

UNESCO, (1968) - Zooplankton sampling – Monographs on oceanographic methodology, 2. The Unesco Press, Paris: 174 pp

UNESCO, (1973) - A guide to the measurement of marine primary production under some special conditions – Monographs on oceanographic methodology, 3. The Unesco Press, Paris: 73 pp

UNESCO, (1976) - Zooplankton fixation and preservation (Edited by H.F. Steedman) – Monographs on oceanographic methodology, 4. UNESCO Press, Paris: 350 pp

Ex-Im Bank, (1998) - Nuclear Guidelines for Projects Utilizing Non-U.S. Sourced NSSS Systems, Except for Soviet Designed Systems

Gomoiu, M. T., Secrieru, D., Oaie, Gh., Cristescu, M., Nicolescu, N., Marinescu, V., (1998) - Ecological state of the River Danube Ecosystems in 1995 – GEOECOMARINA, 3, GeoEcoMar Bucuresti – Constanta: 37 – 88

Hach Company, (1989) - Water Analysis Handbook – Hach Company, Loveland, Colorado, USA, 691 p

Krebs, J. Ch., (1999) - Ecological Methodology – 2nd Edition. Addison Wesley Longman, Inc., Benjamin/Cummings: 620 pp

Parsons T. R., Maita Y., Lalli C. M., (1984) - A Manual of Chemical and Biological Methods for Seawater Analysis - Pergamon Press, 173 pp

Vollenweider, R. A.(1969) - A Manual on Methods for Measuring Primary Production – in Aquatic Environments. IBP handbook No. 12, Blackwell Scientific Publications, Oxford and Edinburgh: 213 pp