Specific Composition of the Vltava River Water - Advantages and Problems for Temelin NPP.

(Problems with Standardization of Requirements for Cooling Systems)

Václav Hanus, ČEZ, a.s. Czech Republic

Temelín Power Plant is situated in the South Bohemia and is fed with water from the river of Vltava. The river catchment area is heavily forested, mountainous with bedrock consisting of granite rocks and non-calcareous converted rocks. This determines the nature of water for the NPP. It is water with low mineral content, low hardness and high content of humic substances.

Table of raw water composition		
Parameter	**Unit**	**2010**
Insolubles	mg/l	**7.3**
COD_{Cr}	mg/l	**19.0**
TOC	mg/l	**5-8**
BOD_5	mg/l	**1.8**
pH	-	**7.4**
Alkalinity	mmol/l	**0.8**
Solubles	mg/l	**128**
Conductivity	µS/cm	**168**
Cl	mg/l	**10.4**
SO_4	mg/l	**19.6**
NO_3	mg/l	**6.4**
Pc	mg/l	**0.08**
Ca	mg/l	**15.7**
Mg	mg/l	**4.3**
NH_4	mg/l	**0.20**
Fe	mg/l	**0.60**

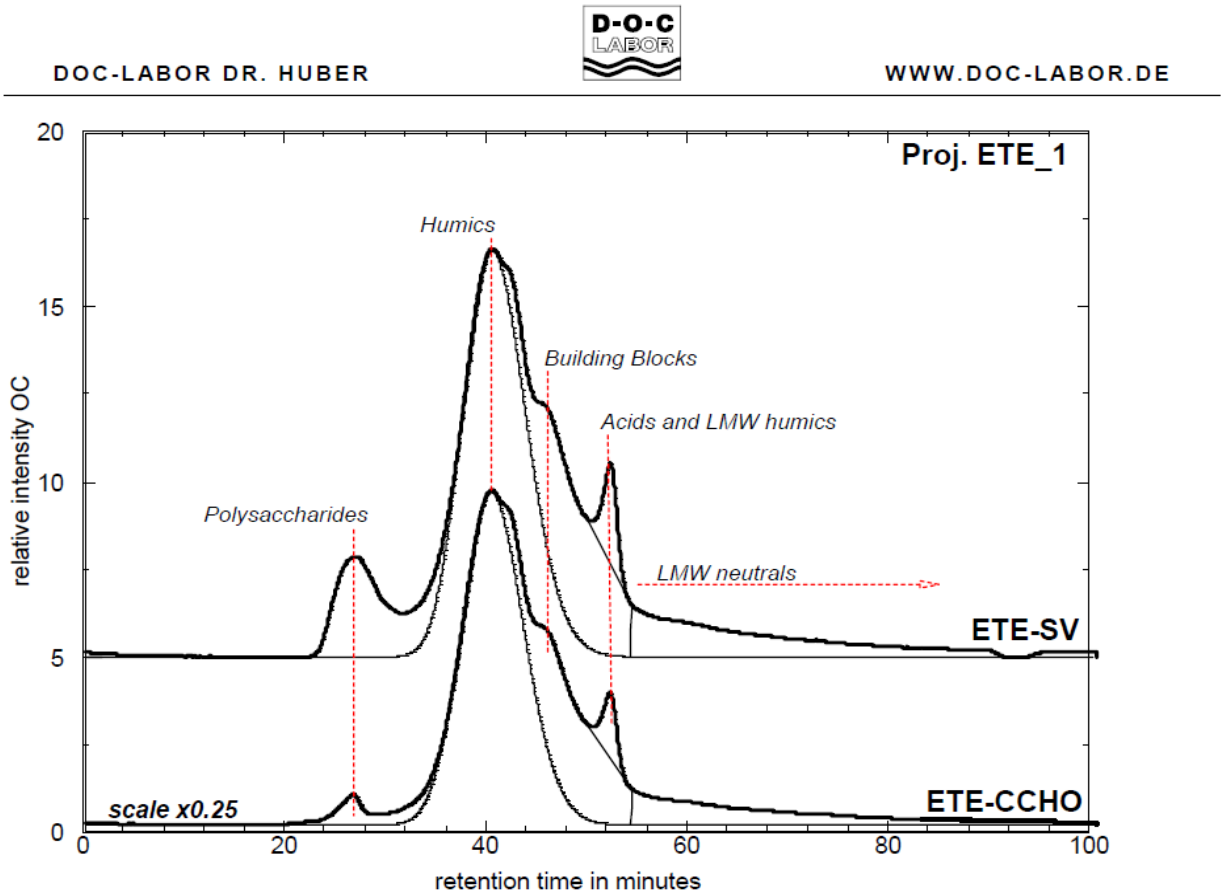
Organics in Cooling Systems in Temelin NPP

Organic substances contained in raw water of Vltava river have a complicated structure. As a consequence of that there are various manifestations of non-standard and difficult to standardize behaviour of water in various parts of Temelin NPP´s technology.
Examples:

1) The need for clarification in the acid area. This, together with low water alkalinity requires alkalization to pH 5.5 (required too high doses of Fe to much acidify the reaction mixture resulting in high residual Fe in clarified water) or use of organic coagulants to reduce Fe doses while maintaining the optimal pH.
2) Low solids cause formation of very light floccules, requiring PAA dosage for good separation in the clarifier. However, at water temperatures below 3 °C floccules are carried away together with clarified water. In the NPP we have solved this problem by application of organic coagulant.
3) Despite the use of macroporous resin in Na form to retain organic substances, TOC penetration (mostly non-ionic oligosaccharides, etc.) to generated demi water occurs in the quantity of about 150 to 200 ppb. This leads to decomposition of organic substances in the SGs and production of organic acids and CO_2 resulting mainly in distortion of cation conductivity measurement in the secondary circuit technology. (We see no complications in using demi water with the mentioned content for primary circuit purposes.)

4) When water of this composition is used as cooling circuit make-up water, organic substances decomposition occurs in cooling tower filling. Processes very similar to waste water treatment by biofiltration take place. (High hydraulic load and low metabolic load.) Efficiency of organic substances degradation in towers is certainly a function of their character and thus the plant location. In Temelín NPP the efficiency of degradation of BOD_5 is about 80%, for COD_{Cr} it is about 25%. See the figure No. 2.
5) In terms of standardization of cooling water properties in the tower circuit it is necessary to count with additional complicating factors, such as nitrification start after about 14 days after the start of cooling tower operation and the action of humic substances as a dispersant and also a slight corrosion inhibitor. For Temelín NPP it applies that all these processes are mostly positive for power plant operation. Nitrification converts ammonia leaking from the secondary circuit to the cooling circuit through vacuum pump sump to nitrates and thus solves the potential problem with collisions with legal values for discharges of ammonia into the river with debt. See the nitrogen balance diagram below - Figure No. 3 and Table No.1. In addition this nitrification lowers water pH by H^+ ions production. What we need. Humic substances along with the said H^+ ions production in nitrification allow us to operate the cooling circuit at a relatively high concentration factor of 5 to 7 without the risk of scaling. (Presumably there is a binding of Mg and Ca on humic acids.) Cooling water thickening tests were conducted, which confirmed that the Vltava river water can be thickened, concentrated far over the steady-state without the risk of solid phase creation. (Up to factor 15). Example of the thickening test is shown in the Figure No. 4. These specific properties of the Vltava river water allow us to operate the cooling circuits without any cooling water treatment and dosing of any chemicals.

The Figure No. 1 below shows a chromatographic picture of raw water composition compared with turbine condenser cooling circuit water (tower circuit). “ETE-SV” chromatogram curve represents raw river water and “ETE-CCHO” curve represents circulating cooling tower water.



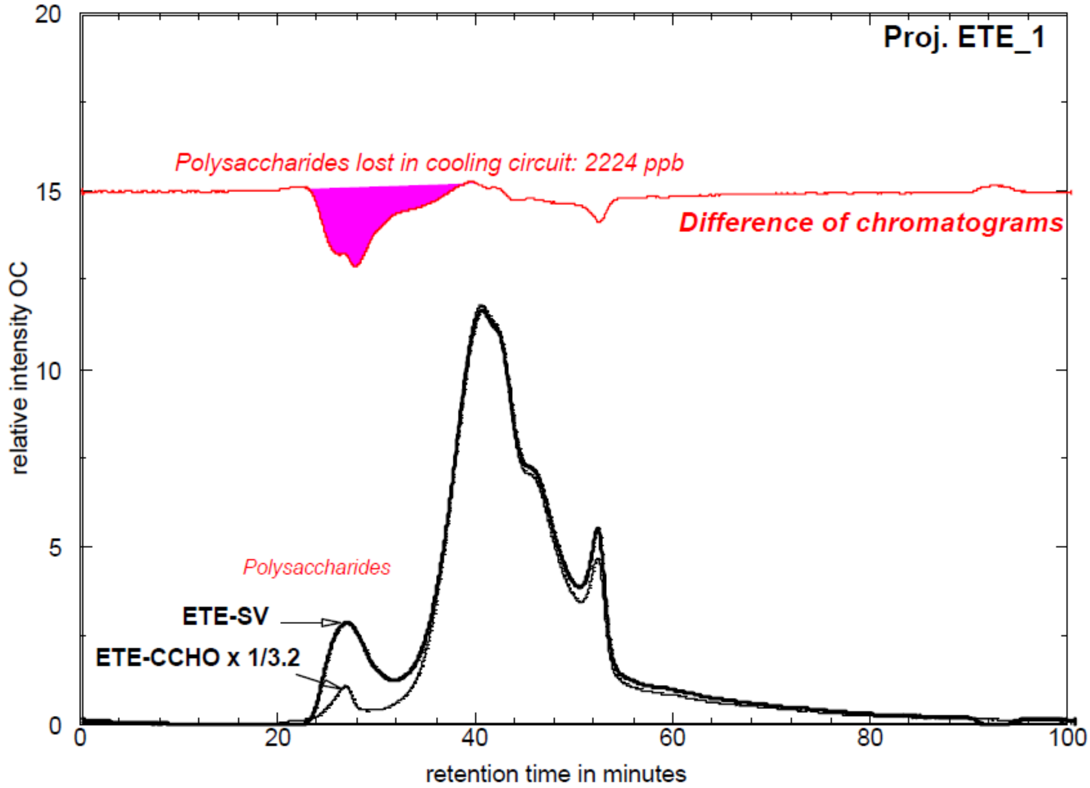
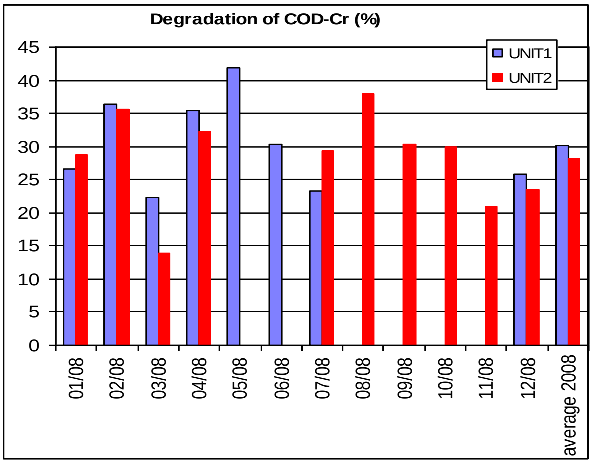


Fig 2: Cooling Towers as Biological Waste Water Treatment Plant – Degradation of organics



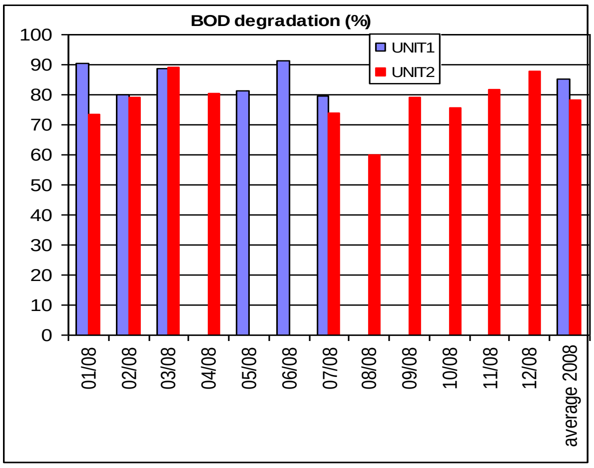
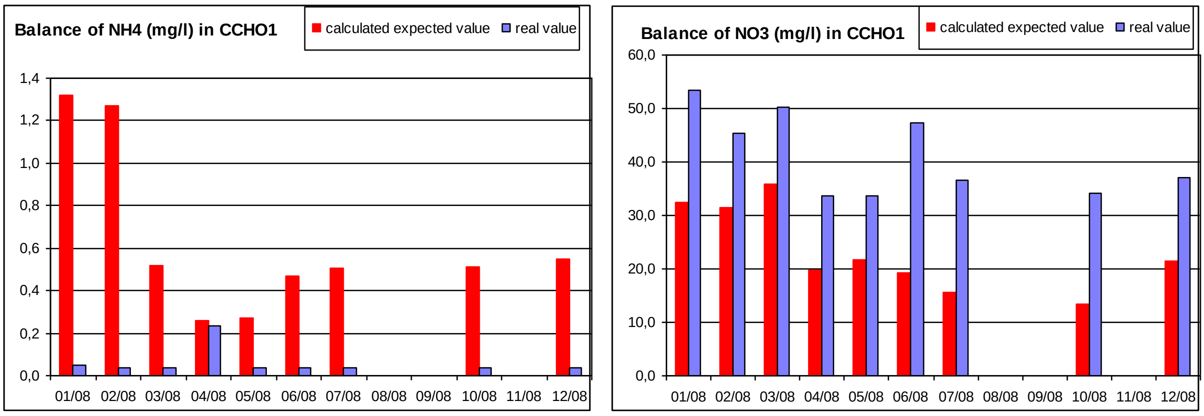


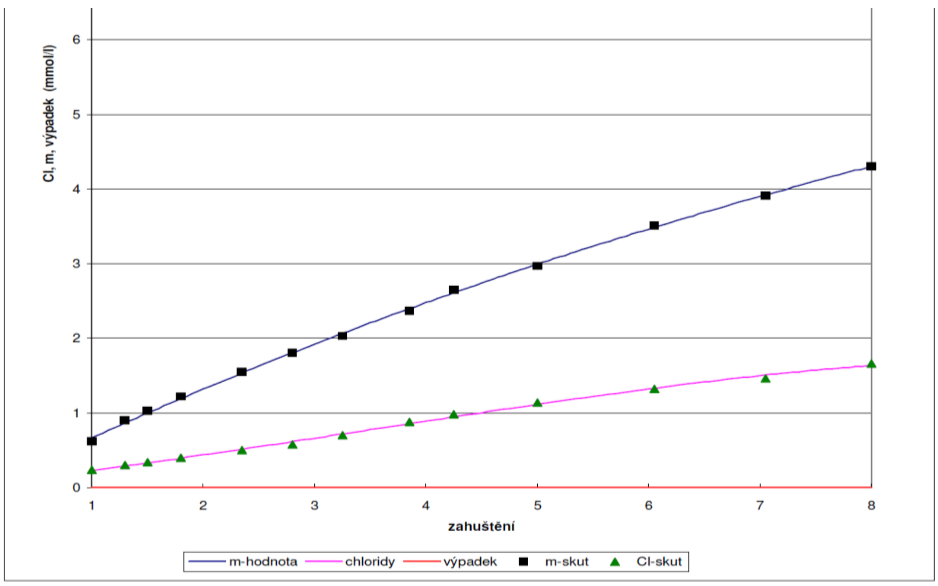
Fig. 3: Cooling Towers as Biological Waste Water Treatment Plant – Ammonia biooxidation



Tab 1: Mass Balance of Different Species over the Plant

Balance ETE in tons per year								CCHO - Condensers Cooling Circuit
	average	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	
Ca	**-52**	-61	-64	-23	-67	-36	-58	(-) loss in CCHO
Na	**35**	13	4.2	45	46	36	65	(+) growth by waste water neutralisation
HCO3	**-399**	-357	-405	-306	-389	-479	-459	(-) loss in CCHO
SO4	**267**	248	252	258	101	370	371	(+) growth by waste water neutralisation
Pc	**-0.22**	0.34	0.10	-0.04	0.00	-0.24	-1.48	(-) loss in CCHO
Zn	**0.49**					0.63	0.35	(+) TSW (corrosion inhibitor ZnCl2)
Cl	**-24**	-23	-35	-3.9	-50	-18	-11	(-) loss in CCHO
N_{anorg}	**21**	8	21	23	22	19	32	(+) growth in CCHO (NH_3 from SS)
insolubles	**-170**	-116	-301	-76	-62	-199	-267	(-) loss in CCHO
RAS	**501**	449	525	315	567	591	558	(+) growth by waste water neutralisation
BOD_5	**-49**	-40	-71	-50	-47	-41	-44	(-) loss in CCHO
COD_{Cr}	**-183**	-146	-147	-171	-176	-239	-220	(-) loss in CCHO
AOX	**-0.56**	-0.19	-0.48	-1.00	-0.46	-1.00	-0.22	(-) loss in CCHO

Fig. 4: Thickening of Raw Water Test Example



m-hodnota = alkalinity; chloridy = chlorides; výpadek = insoluble products; m-skut = measured alkalinity; Cl-skut = measured chlorides

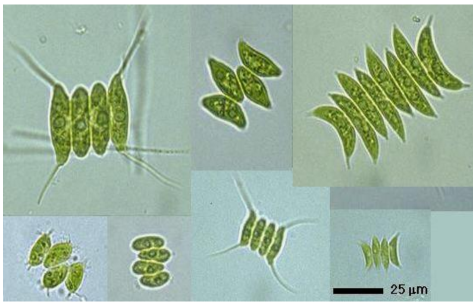
Service Water Circuits,

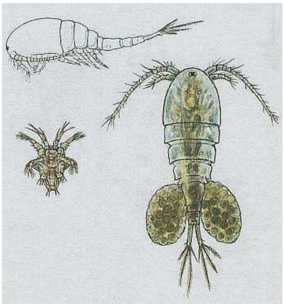
TSW showers:

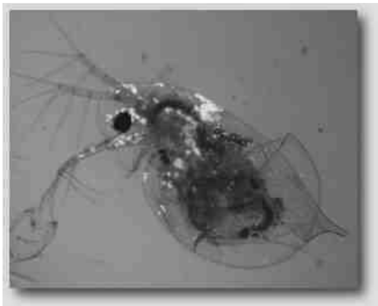
Temelin NPP is equipped with 3 independent safety systems cooled by essential (technical) service water. (TSW). Heat transfer to the atmosphere is designed extensively by 2x3 open pools. If more intensive heat transfer is necessary, water jet spraying above the pool water level is applied. See the picture above. It is an open system with intensive contact with the surroundings, causing the issues described below, and interesting behaviour which is very difficult to predict and thus standardize due to its variety and local specificity. Our TSW circuits are characterized by long delays, about 30 days and a relatively small water concentration factor of app.1.8. Make-up water from Vltava river is only filtered by sand filters. In order to ensure an optimal relationship between the cooling water and Temelín NPP technology and structures (to avoid formation of deposits, reaching a low corrosion, environmental acceptability) we went through a long evolution of operational tests with various chemicals and contractors water treatment systems. Doing so we encountered the following problems:

1) **Planktic algae.** There were period of massive development of planktic algae supported by dosing of phosphor based corrosion inhibitor. After this experience we switched to Zn based phosphate-free inhibitors. This helped, but not absolutely. Sometimes we have to add an algicide, which is costly. Lessons learned: Do not feed algae by P, monitor water trophicity and factors limiting growth of algae.

2) **Biofouling.** On one of the systems we have tested operation without any water treatment. The water was crystal clear. Without poisonous chemicals in water small testaceous animals





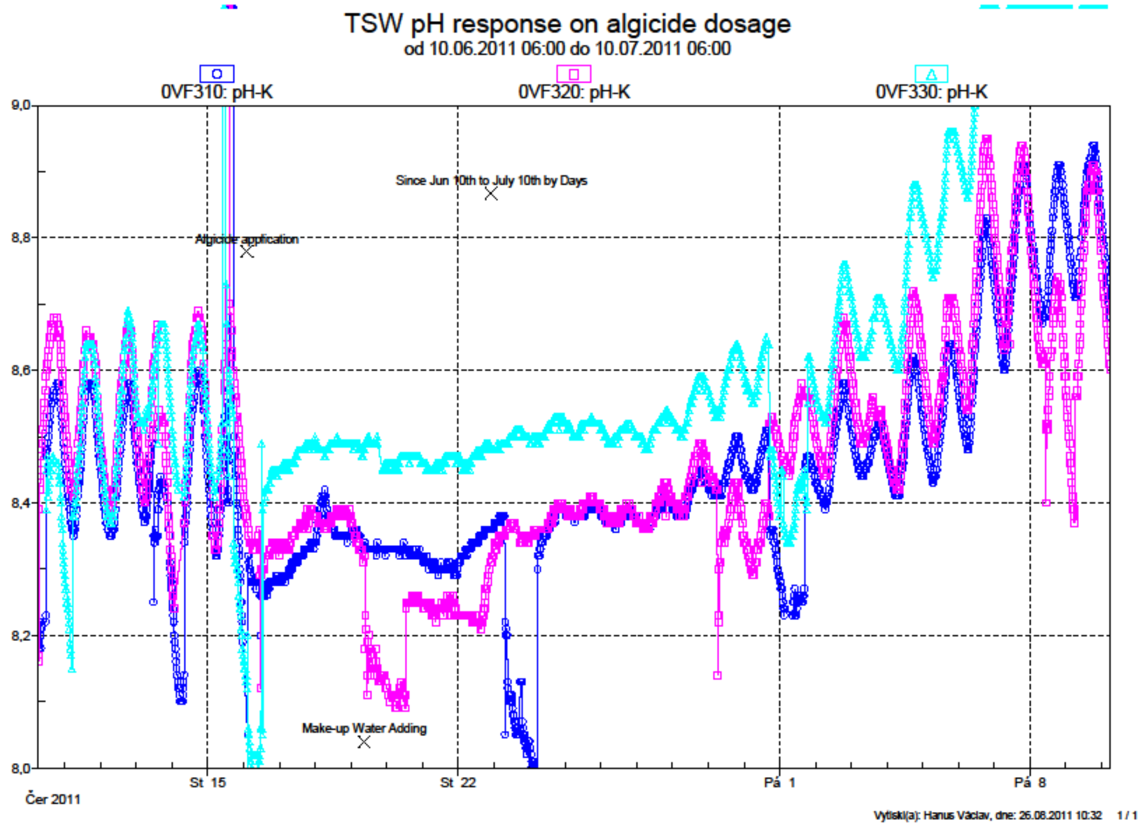


reproduced (copepods and cladoceran) decimating the planktic algae. Microbiological monitoring of circulating water quality was conducted. The water showed very low life recovery. However, in the technology there was a significant increase in hydraulic resistance of heat exchangers caused by biofouling. Normal visual inspection did not identify anything. We returned back to the use of hypobromite-based biocide. <u>Lessons learned: Circulating water analysis does not provide sufficient information on what is happening on the plant pipes and heat exchangers surfaces.</u>

3) **<u>Dandelions and grass.</u>** It is very important to care about pool and cooling towers surroundings. We have experienced clogging for some part of the technology by fallen leaves, seeds of dandelions, cut grass around the pools. This problem occurred also at screens of the turbine condenser tower cooling water system. <u>Lessons learned: Caring, well informed gardener is beneficial to the open air cooling circuits.</u>


4) **<u>Aquatic life is changing.</u>** Gradual changes of species composition of aquatic organisms occur. It is different each year. Specific response to that is required. In some cases the problem will solve itself. It happened that just before algicide application at the price of app. 6000 EUR a hydrobiologist analysed the algae using a microscope. He found that algae cells are infected by a fungus and recommended to wait. Within a week the fungus killed the algae and the problem was solved. <u>Lessons learned: A hydrobiologist help is priceless.</u>


5) **<u>Aquatic life significantly changes water chemistry.</u>** Both seasonally and daily. See chart below. Three lines represents run of TSW pH in 3 independent safety systems. There was applied algaecide of Jun $16^{th.}$ There is visible suppression of live activity (photosynthesis and breathing) for more than 14 days. This “rocking and rolling” of pH is much bigger during spring and summer. <u>Lessons learned: In our case pH volatility during day could be one of the simple indicators for algaecide intervention.</u>



6) **Problem with condition monitoring,** prediction of development and optimal intervention with chemistry. What methods are available and when are the individual methods suitable? There are more methods indicating the state of system biology, but where are the limits for intervention, what is the weight of each method? Lessons learned: There are no clear parameters together with their limits for decision making. The most valuable is a local expert with years of experience, who takes into account all available information about the system, state of biology, needs of future technology operation, weather, flexibility of local maintenance system etc.

7) **Different groups of organisms** require different approach, however it is always necessary to think about the effect on all of them. In Temelín NPP it is necessary to take into account different manifestations of life of these groups of organisms: autotrophic attached, planktic autotrophic, heterotrophic attached and planktic heterotrophic organisms.

Conclusion:

Based on our experience during design, commissioning and the operation phases I would recommend to prefer in standardization activities rather definition of methods for identification of the optimal site-specific parameters from prescription of particular values of cooling water quality. Something like to show road map for finding site specific optimal solution. This applies more as the system is technologically more "distant" from the primary circuit and in more contact with the outside environment and vice versa.