Ozone as effective biocide for microbiological and antifouling control water system

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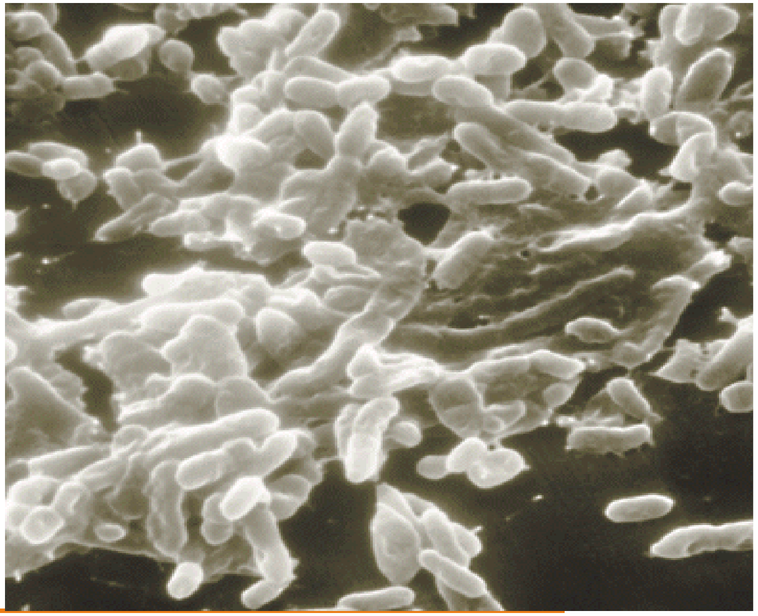
Biofilm - a universal problem

- slimy coatings of microorganism and extracellular compounds in pipelines, tanks and heat exchanger surface
- pathogenic germs (e.g. E. coli or Legionella) are living in biofilms
- biofilm reduces the efficiency of heat exchangers
- biofilm causes corrosion in metal surfaces MIC
- biofilms are extremely resistant against most disinfectants
- chlorine dioxide and ozone are the only suitable disinfectants, able to kill and to remove biofilms in water pipes and tanks



Microbiological control in water systems

- mechanical methods
  - manual cleaning of piping
- chemical methods
  - oxidizing chemicals
    - chlorine, chloramine
    - chlorine dioxide
    - ozone, peroxides and other oxidants
  - organic biocides and other chemicals

Comparison of chemical disinfectants

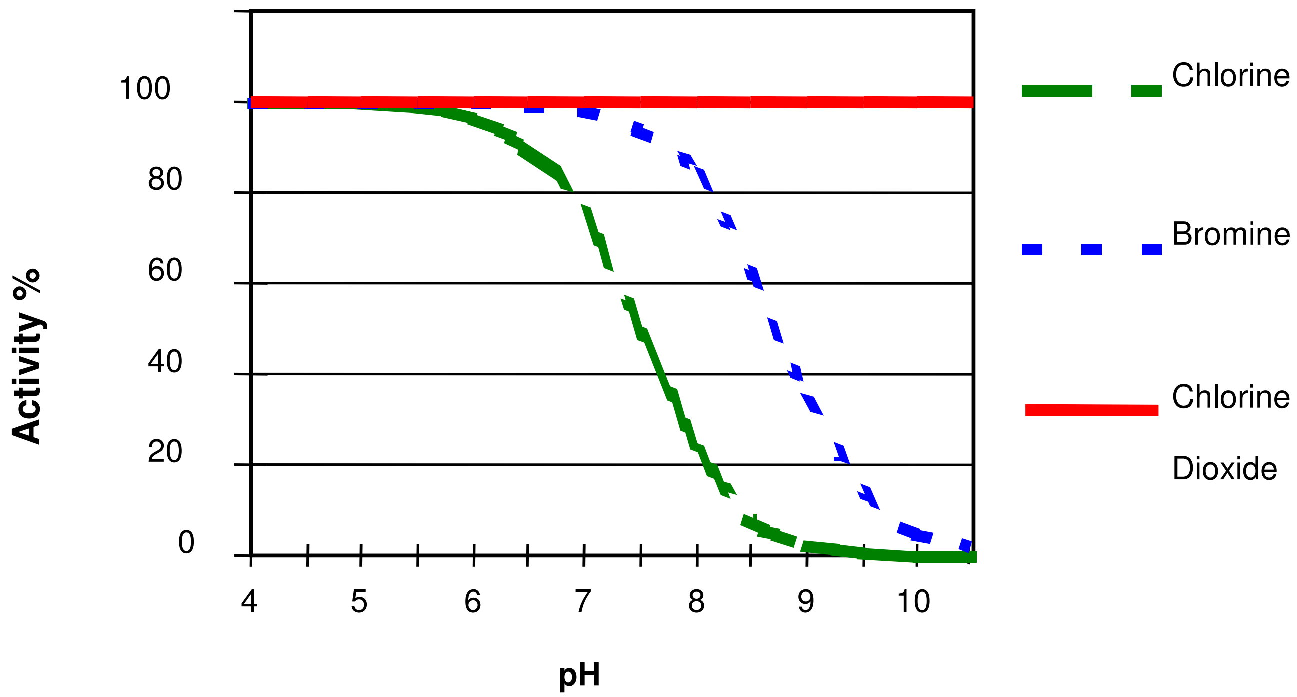
	chlorine	ClO_2	ozone
disinfection capacity	medium	strong	strongest
Oxidation potential [V]	1,49	0,95	2,07
dependence from pH-value	extreme	none	low
depot effect	hours	days	minutes
disinfection by-products	THM, AOX and other chlorinated organics	chlorite	evt. bromate
resources	Cl_2-gas, hypo-chlorite or electrolysis	HCl & $NaClO_2$	electr. energy, air or oxygen

Comparison of Disinfectants

Micro-organism	Reduction Rate	Chlorine	Chlorine Dioxide	Ozone
	(%)	c x t (ppm x min)	c x t (ppm x min)	c x t (ppm x min)
Crypto-sporidium parvum	99.9	1440	> 120	> 5
Giardia lamblia	99.9	104-122	23	1.4
Escherichia Coli	> 99.99	3-4	1.2	0.012 - 0.4

Chlorine based treatment – the best solution??

- Efficiency highly pH-dependent

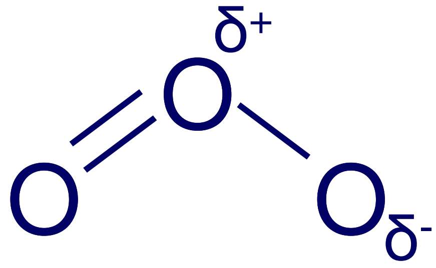


- AOX formation
- Contribution to inorganic load
- High chlorine/chloride concentrations promote corrosion in metals
- High chlorine level necessary due to bioresitance
- Removal of residual chlorine before discharge

Approaches for chemical mollusc control

- to effect mortality of adult mussels
  - high disinfectant‘s concentration are required
  - deposits of dead mussels are still present
- to effect mortality of free swimming veligers
  - high disinfectant‘s concentration are required
  - cleaned piping will be protected against re-infestation
- to effect settling-inactivation of veligers
  - low disinfectant‘s concentration are required
  - cleaned piping will be protected against re-infestation
  - best ecological valuation

Physical Properties Ozone O_3



- ozone is the strongest oxidant used in water treatment $E^0 = 2.07$ V
- solubility depending on temperature and ozone concentration in the gas phase
- has to be generated on site due to short half life time
- reacts without residuals resulting in O_2
- ozone works without formation of undesired by-products
  - no formation of THM
  - no formation of AOX

Hydroelectric Power Plant Itaipu

- bi-national project between Brazil and Paraguay
  - 1.350 km² surface reservoir,
    drainage area of 820.000 km²
  - 20 Francis-turbines with following data, each:
    - 715 MW capacity
    - 125 m altitude difference
    - 660 m³/s water flow

ITAIPU
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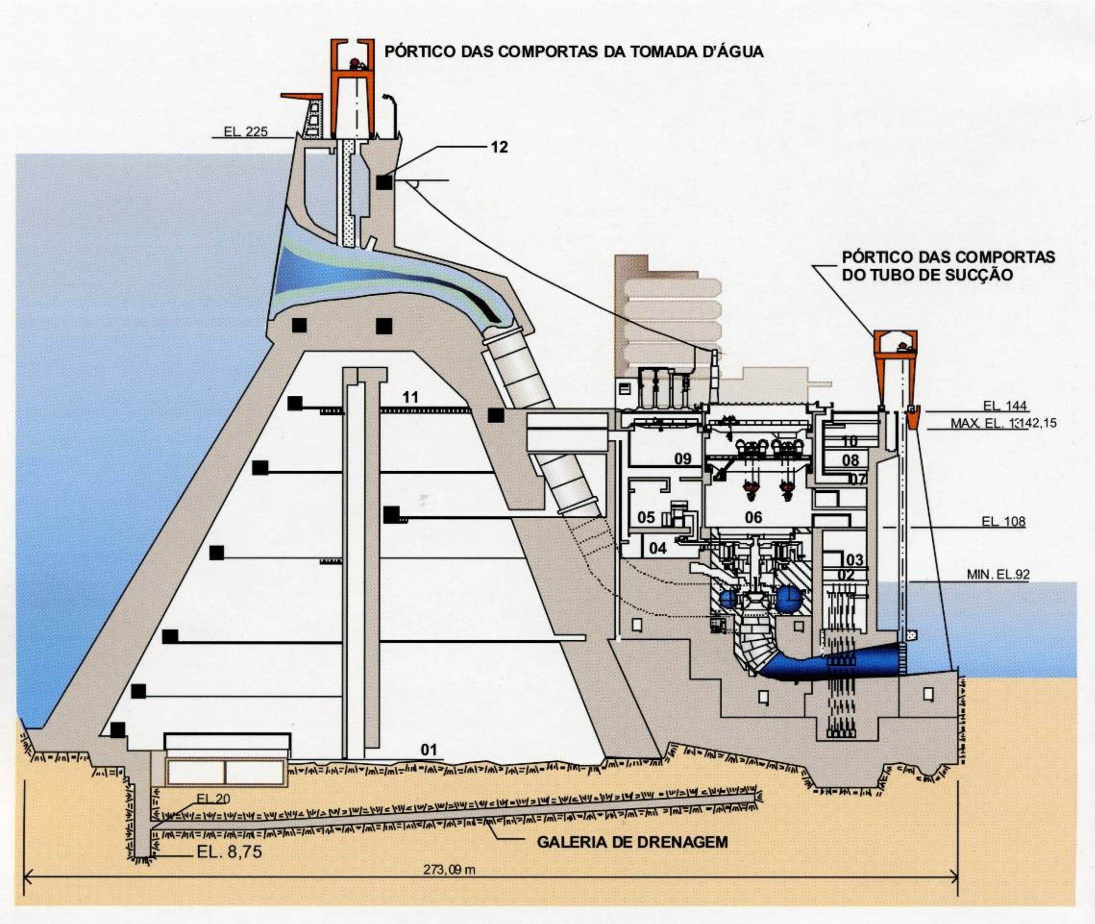
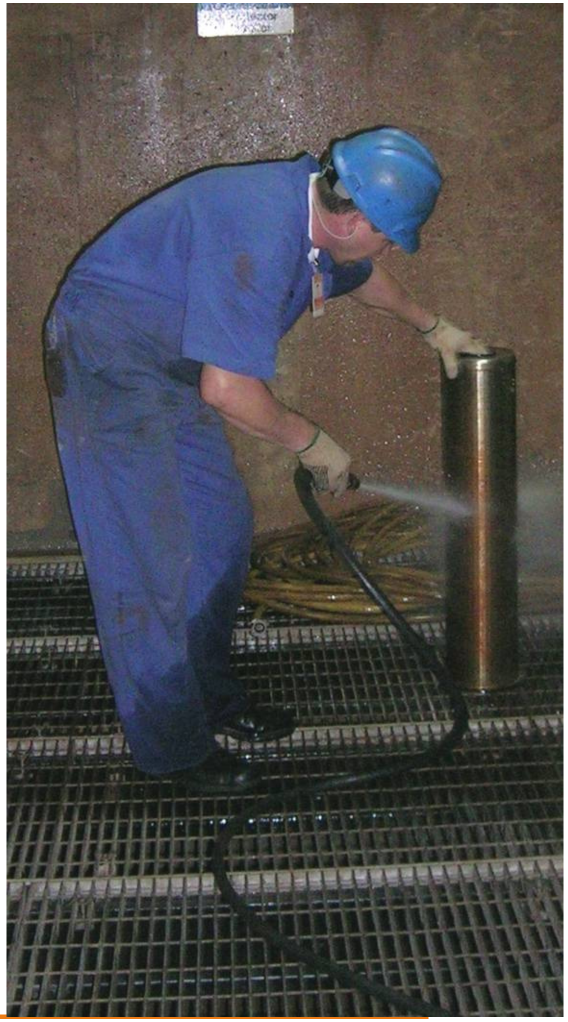
Profile of the Dam

- bypass with 2.253 m^3/h for use as cooling water
  - stainless steel cartridge filter, mesh size 2 mm
  - distribution on 11 blocks of heat exchangers

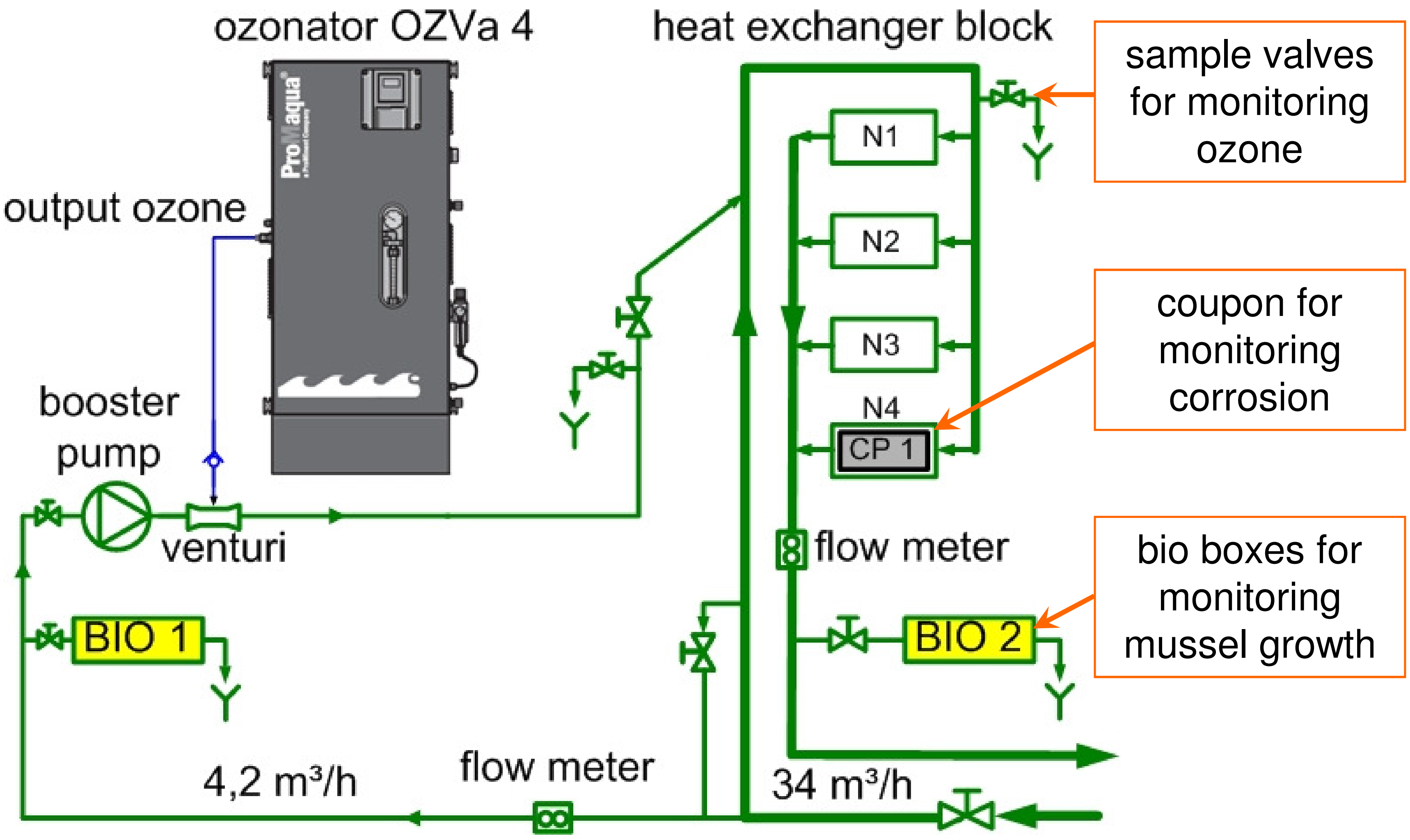


Problems caused by mussel growth

- growth of Limnoperna fortunei (Golden Mussel) on every wetted surface, even at 12,5 bar
  - blocked central filter
  - blocked heat exchangers
- frequently interruptions of the generators to clean filter and heat exchangers



Treatment of One Cooling Circuit with Ozone

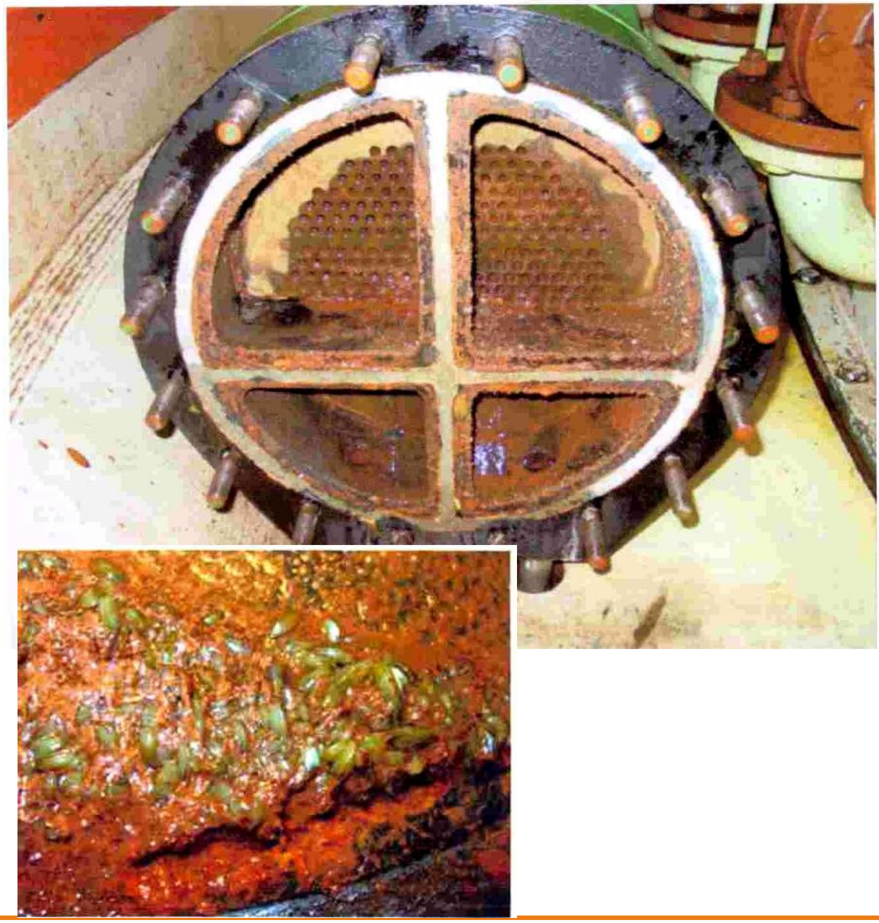


Determination of Ozone dose

- ozonation
  - dosage rates: 0.1, 0.2, 0.3, or 0.4 ppm (calculated on 34 m^3/h)
- measurement of the ozone
  - ozone detectable directly after the dosing point
  - no ozone detectable at the heat exchangers
- visual check of the heat exchangers after 3 month
- bio boxes
  - microscopic determination of plastic plates to identify dead and living veligers
  - 5 pairs of plates allow 5 tests / period
- corrosion coupon test at the heat exchanger
  - incubation period: 87 days

Results: Visual Control of the Heat Exchanger

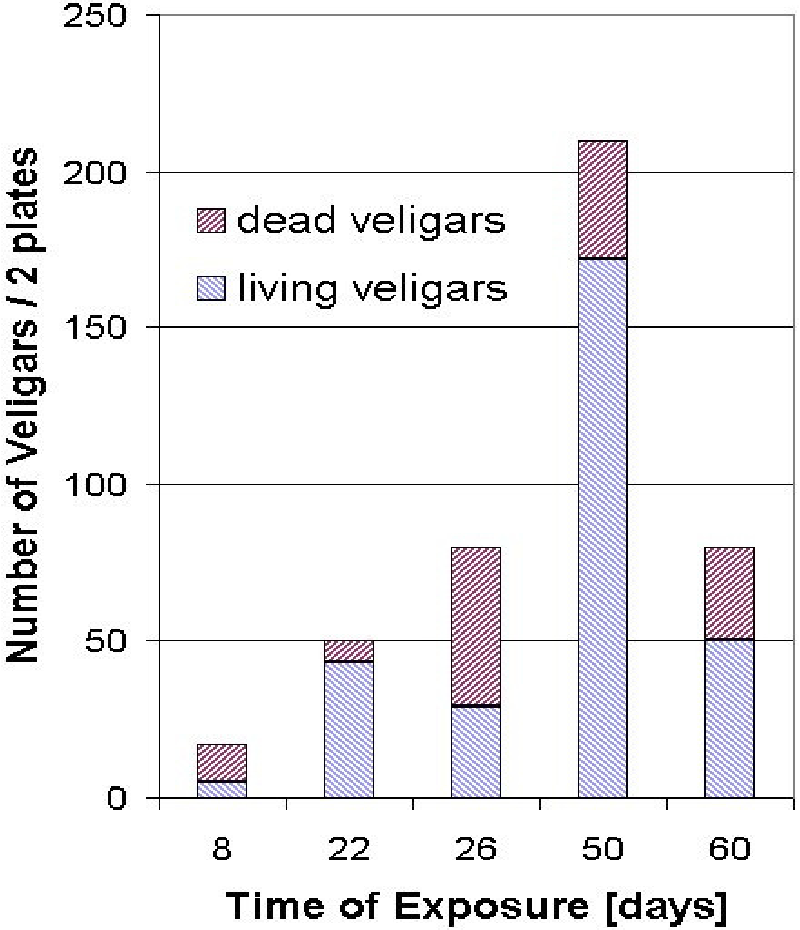
- 3 month after last cleaning without ozonation

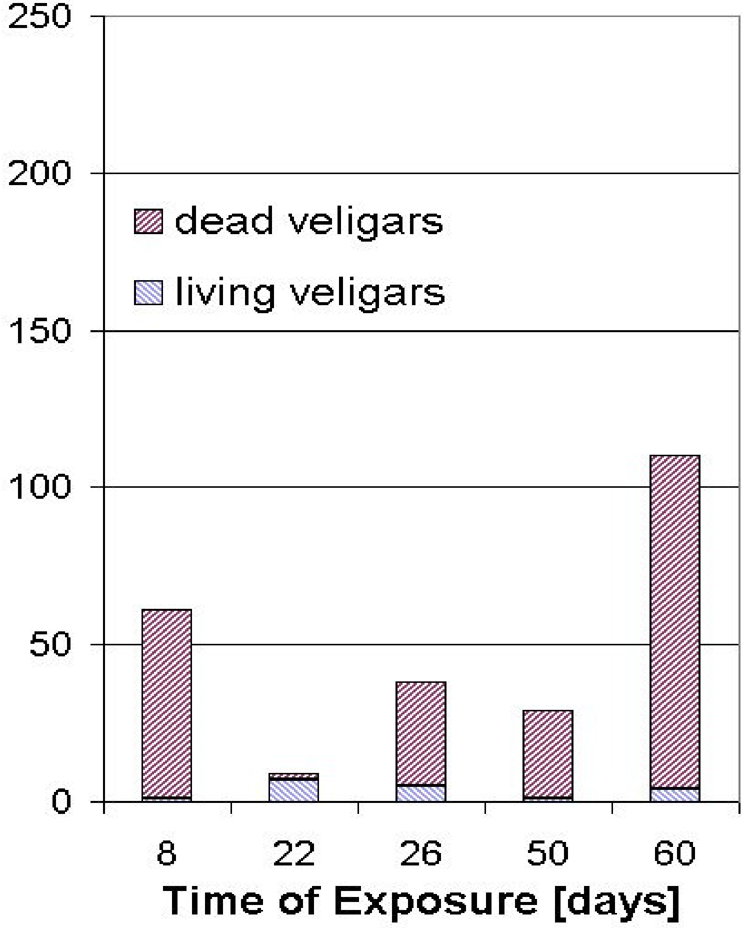


- 3 month after last cleaning with ozonation

Results: Bio Boxes

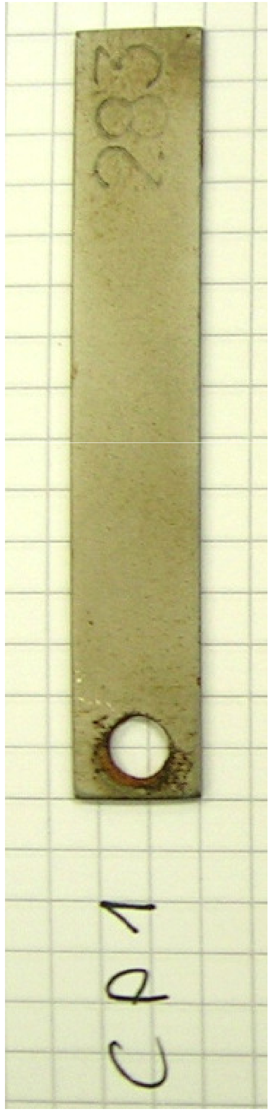
- bio box 1:
  - before ozonation
- bio box 2:
  - after ozonation (0,3 ppm)





Results: Corrosion Coupon

- no corrosive effect of the ozonation detectable
  - determination of general corrosion following international standard ASTM D2688-94
  - incubation period: 87 days
  - corrosion rate: 0,3 mpy (mpy = mils per year)
    - 0 to 2 mpy = excellent
    - 3 to 5 mpy = good
    - 6 to 10 mpy = acceptable
    - > 10 mpy = unacceptable



Summary

Experts in Chem-Feed and Water Treatment

- low dosage of ozone in natural river water avoids mussel growth in cooling water circuits
- ozonation is a very ecological water treatment
  - no precursor chemicals required (oxygen or ambient air)
  - reaction in the water back to oxygen
- ozonation is a very economical water treatment

Thank you for your attention

Experts in Chem-Feed and Water Treatment

Any question?

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