Combined Ozonation-Nanofiltration for Drinking Water Treatment

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Chlorination Disinfection Byproducts (DBPs)

- Disinfection byproducts are formed by the reaction of chlorine with natural organic matter.
- The compounds formed include
  - trihalomethanes (THMs; e.g., chloroform, chlorodibromomethane, bromoform)
  - haloacetic acid (HAAs) (e.g., dichloroacetic acid)
  - chloropicrin and dichloroacetonitrile

Technologies for the reduction of DBP formation

- Enhanced coagulation
- Granular activated carbon
- Membrane filtration
- Alternate disinfectants
  - Chlorine dioxide
  - Chloramines
  - UV radiation
  - Ozone

Ozone

- Ozonation decreases the formation of chlorinated DBPs
- Leads to the formation of other DBPs, including
  - ketones, aldehydes, bromate
  - biodegradable organic carbon (BDOC)
- In high TOC waters, ozonation
  - is expensive
  - leads to excessive DBP formation

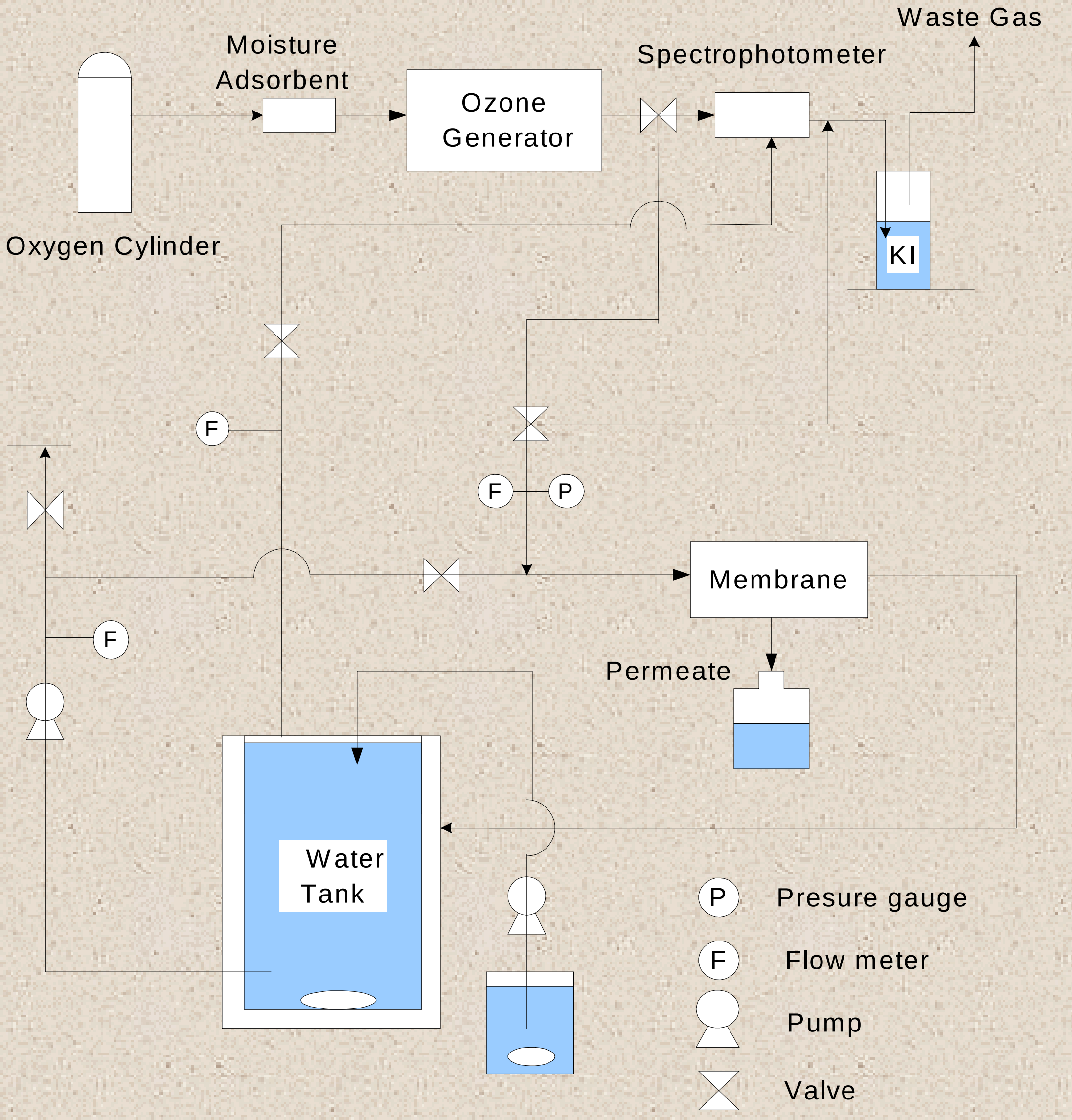
Membrane filtration

- Nanofiltration can remove >90% of natural organic matter (NOM)
  - Extent of removal depends upon operational conditions, including molecular weight cutoff and water quality
- Problems
  - low permeate flux
  - fouling
  - cleaning of membranes

Combined Ozonation /Nanofiltration

- Aim is to combine both processes to reduce problems associated with the use of the processes individually
- Ceramic membranes
  - resistant to degradation by ozone
  - less subject to NOM fouling than many polymeric membranes
  - costly compared to polymeric membranes

Experimental apparatus



Experimental details

Membrane

- TiO_2 filtration layer on an AZT (Aluminum/Zirconium/Titanium Oxide) support
- MWCOs   1 kD, 5 kD and 15 kD
  - pore size ca. 1 nm, 3 nm and 10 nm

Experimental conditions

- Cross flow filtration – cross flow velocity 1.5 m/s
- Ozone: 1.0 to 12.5 g/m^3 @ 100 ml/min
- Trans-membrane pressure – 0.21-0.23 bar
- Temperature – 20ºC
- All samples pre-filtered through a 0.45 µm filter

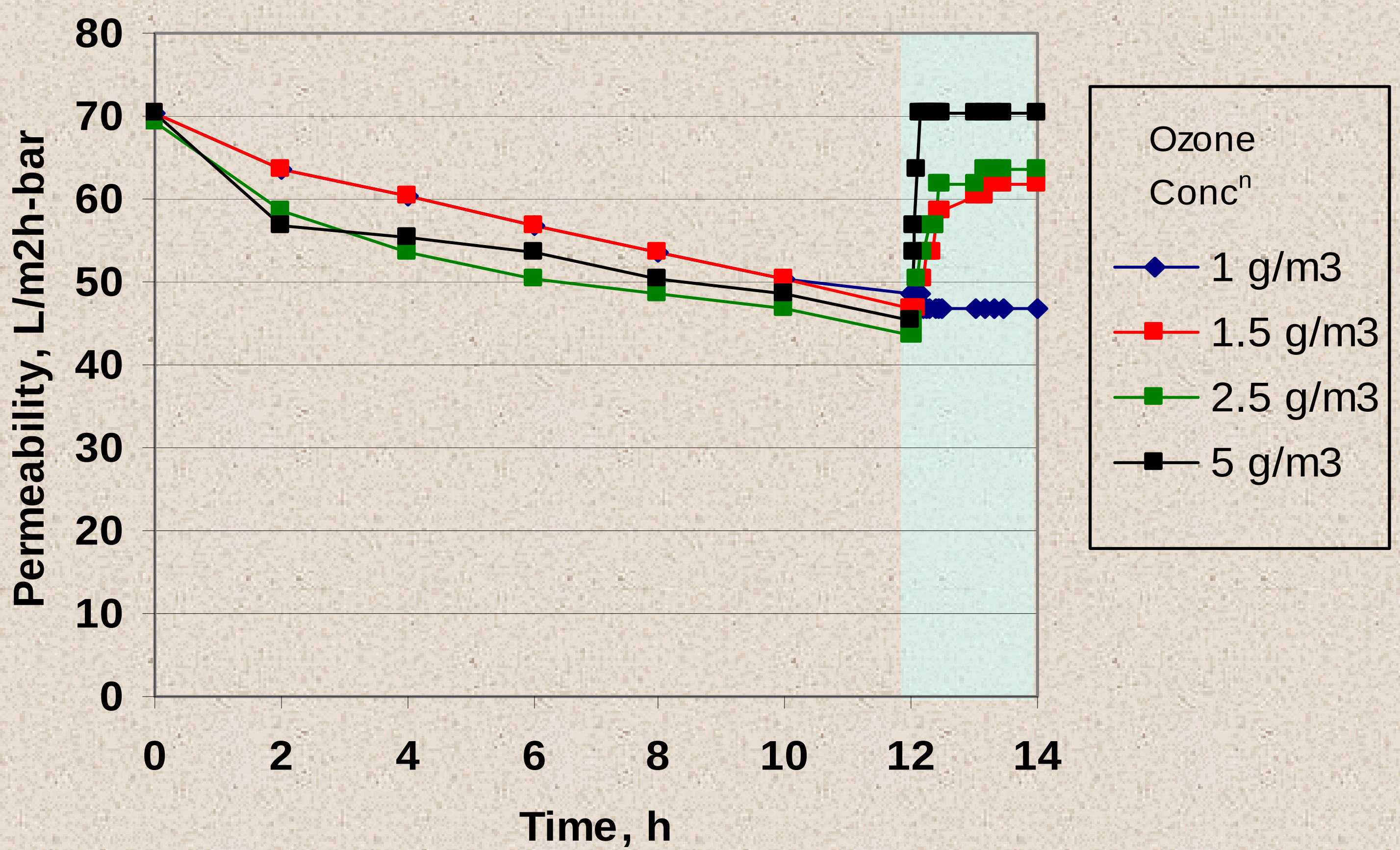
Water source

Lake Lansing (Haslett, MI)

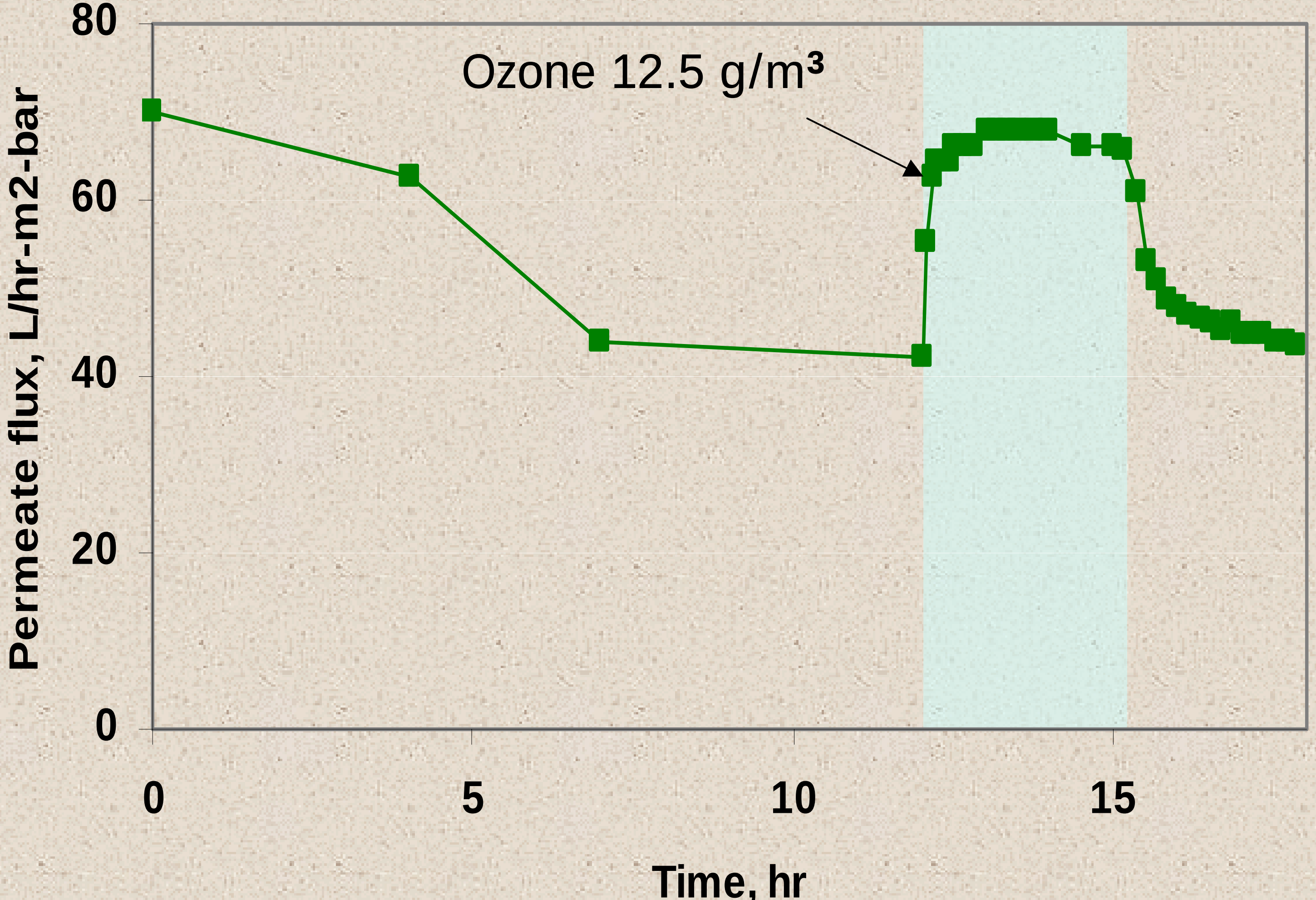
- borderline eutrophic
- algal blooms occur in Summer
- hardness - 150 mg/L as $CaCO_3$
- high dissolved organic carbon – 8 to 11 mg/L

Potential for membrane fouling is high

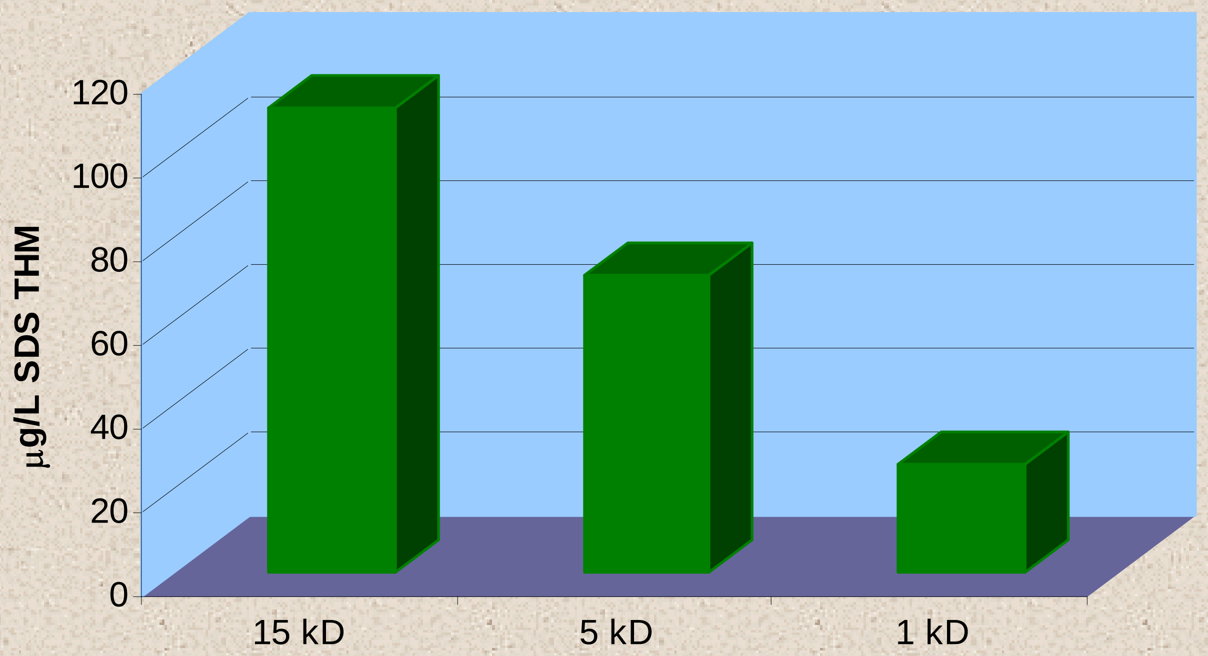
Effect of ozone dosage on permeate flux



Refouling after ozonation

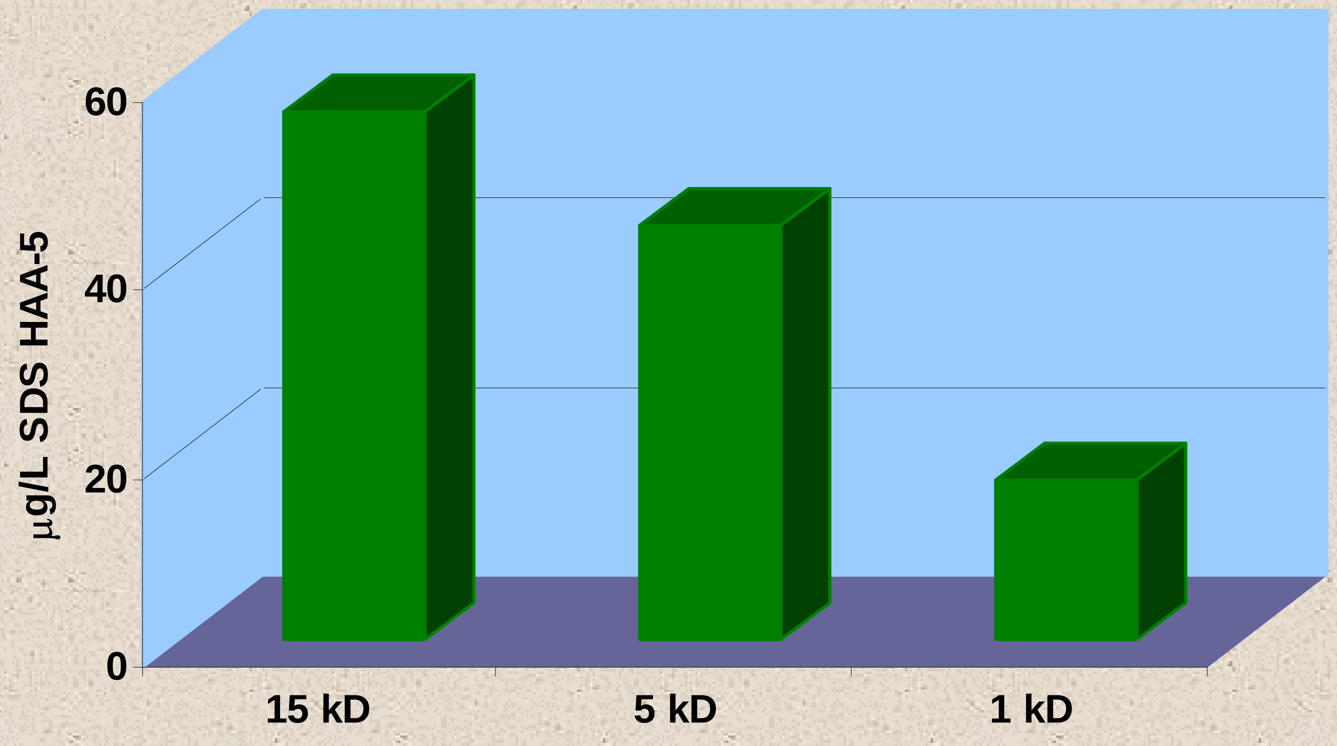


TTHM precursor removal
Effect of MWCO



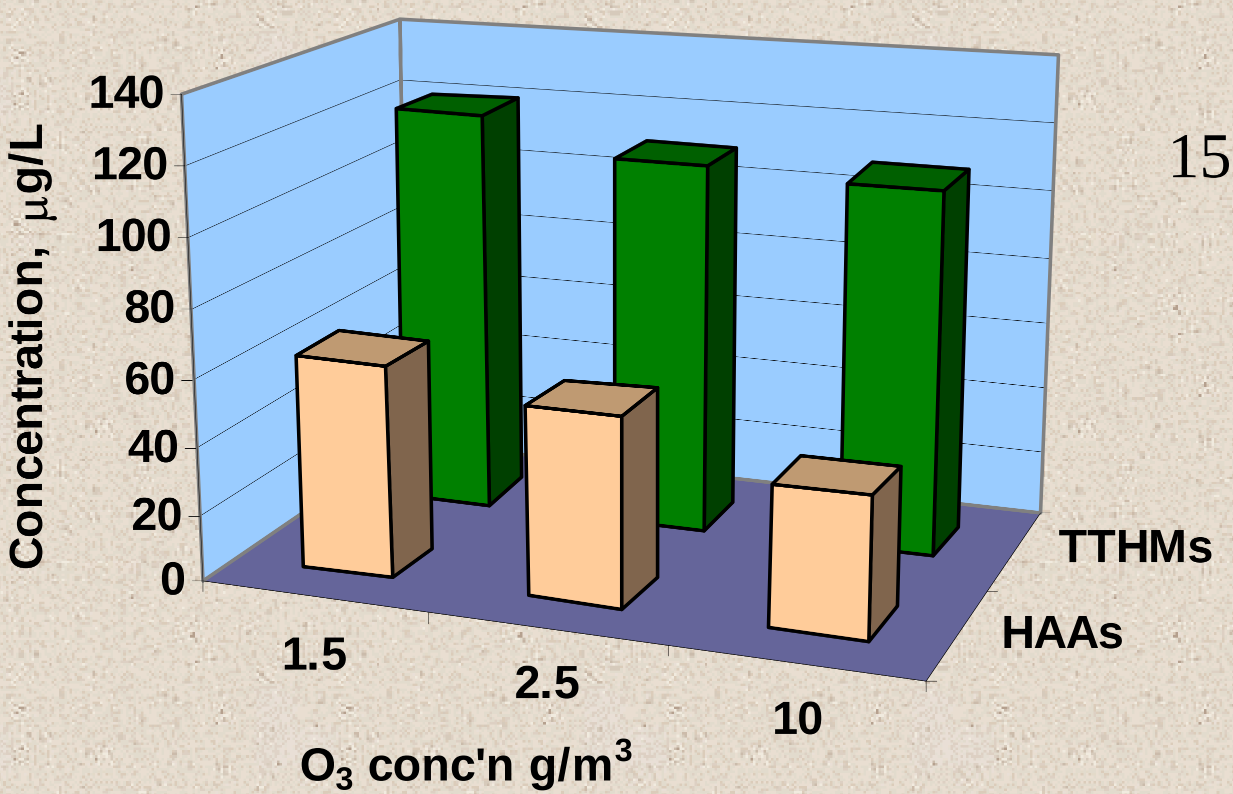
Filtered raw water – 236 ✎ 4 μg/L O_3 - 2.5 g/m^3

HAA precursor removal: Effect of MWCO



Filtered raw water – 89 ✎ 5 μg/L O_3 - 2.5 g/m^3

Effect of ozone dosage on DBP precursor removal



15 kD MWCO

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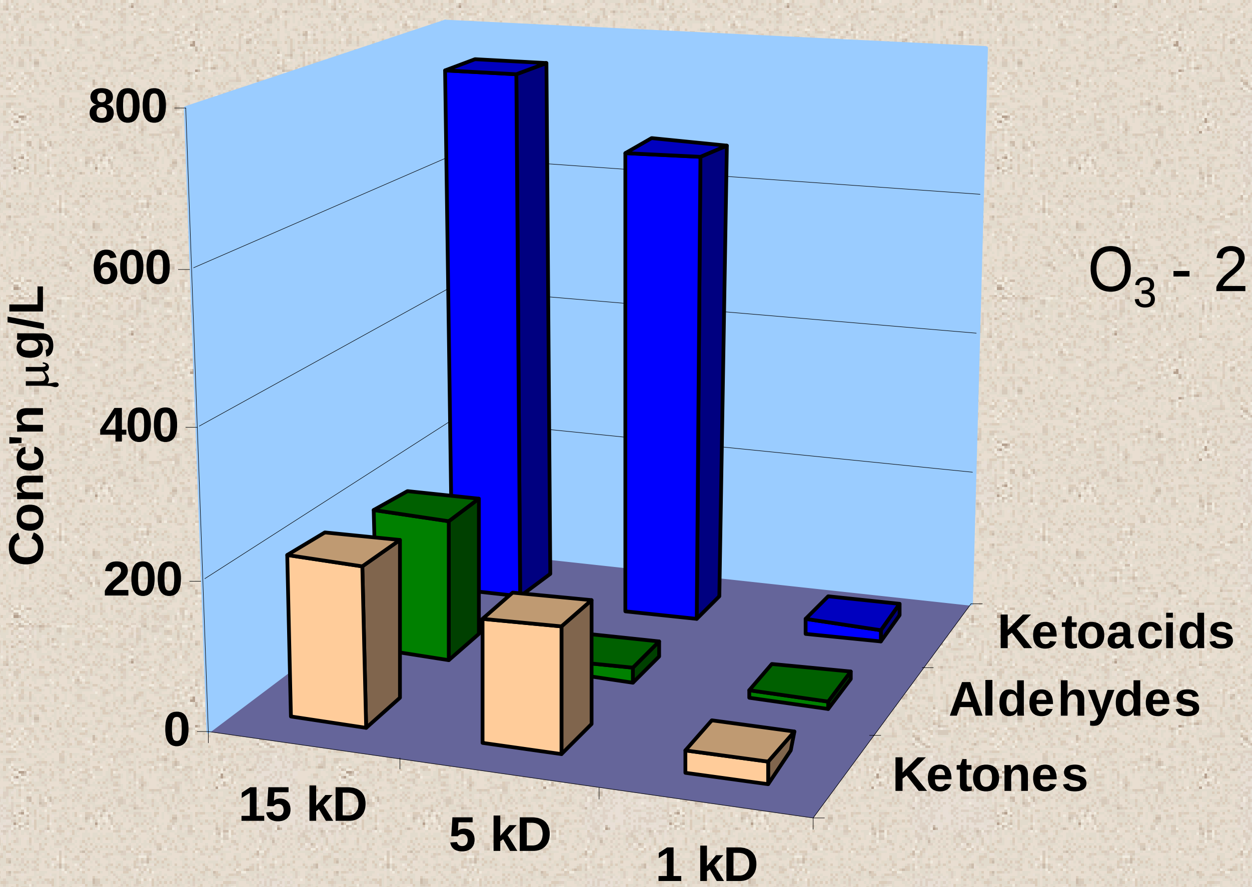
Ozone DBP removal



O_3 - 2.5 g/m^3

Summary – Fouling Studies

- Ozonation at low dosages reduces fouling; if ozone dosage is high enough no fouling occurs

- The reaction of ozone with foulants appears to be enhanced at the membrane surface, presumably due the catalytic degradation of ozone by TiO_2

Summary – DBP studies

- The combined process yields better results than for ozone alone
- Lower DBP concentrations are obtained with tighter membranes
- In the range studied, ozone dosage has little effect on THM or HAA precursor removal
- 1 kD MWCO membrane gives good removal for all the DBPs studied; 5 kD gives good removal of chlorinated DBPs