Rapid Corrosion of a Stainless Steel Air Stripper by Trichloramine

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SEVERAL WEEKS OF OPERATION

EPA PERSON DRIVES BY BUILDING AND COMPLAINS

WE ARE CALLED ABOUT A "CHLORINE ODOR" AND ANSWER "WE CANNOT STRIP CHLORINE"

I VISIT SITE TO SEE SYSTEM ...



















SOLUTIONS



SOLUTION - MATERIALS

PROTECT VESSELS

NSF 61 COATINGS

Nitrogen Trichloride - History

- 1812 Pierre Louis Dulong prepared NCl₃ lost an eye and two fingers in explosions
- Sir Humphrey Davy temporarily blinded by explosion and this caused him to hire Michael Faraday as an Assistant
- 1985 Uster Switzerland. 160-tonne ceiling slab falls and traps/ kills 12 swimmers in indoor pool. Many others injured. Stress Crack Corrosion (SCC)
- 2001 Steenwijk, Netherlands. Entire ceiling and ventilation equipment falls into indoor pool at night after closing hours - no injuries - SCC
- 2002/2006 Implicated in childhood asthma "pool chlorine hypothesis"

Corrosion accident happened in Uster, Switzerland in 1985

CHLORAMINES - TOO SIMPLIFIED

Chloramines are products of the reaction between ammonia (NH₃) and chlorine (Cl₂). The chloramines speciation depends on the relative amounts of NH₃ and Cl₂ present:

Monochloramine is the first member of the homologous series and is the principal product formed at pH 7.5-9. However, higher chlorine concentrations in the water and lower pH results in the formation of di- and tri-chloramine.

Research to Confirm Experience

- Indoor Swimming Pool Research
- Chloramine Speciation in Pool Research
- Laboratory Generation of NTC
- Use of Air Stripping to Speciate
- Simple Corrosion Test

Christina Schumalz, et. al., 2011. Trichloramine in Swimming Pools -Formation and Mass Transfer. Water Research 45, 2681-2690.

Conversion of N to NTC at pH = 7.1 & molar Cl:N ratio = 5: Urea = 75.8%; Ammonia = 37.4% NOTE: molar Cl:N of 5.0 = 12.7 Cl:N by wt.

Hery, V.C., et. al., 1995. Exposure to Chloramines in the Atmosphere of Indoor Swimming Pools. Annals of Occupational Hygiene 39 (4), 427-439.

AVERAGE SWIMMER CONTRIBUTES: 0.3 - 1.0 L of Sweat & 20 - 50 mL Urine

Nitrogen: Urea (86.9%), Ammonia (4.4%), Amino Acids (4.3%), Creatinine (3.6%), Uric Acid (0.07%)

BREAKPOINT CURVE

Figure 1 – Breakpoint Chlorination of Ammonia pH 7.3–7.5, 0.5 ppm Ammonia N, 2–hour Contact Time (Palin 1950)

Henrys Constants (M/atm):

HOCI = Ethanol = NH ₂ CI = NHCI ₂ =	612 200 94 29	AIR STRIPPING NOT SIGNIFICANT
Bromoform =	2.0	
MTBE =	1.6	NCI3 IS THE ONLY
NCI ₃ =	0.1	CHLORAMINE THAT
TCE =	0.11	AIR STRIPS
CO ₂ =	0.034	
Rn =	0.0093	
CH₄ =	0.0013	

Air Stripper Operation

 $NCI_3 \approx 60 \text{ mg/m}^3$

73.2% NCl₃ is Stripped by Process at an A:W of 10.36

Simulated Water With High CI:N

I) Form Chloramines:

2) Measure Total & Comb. Chlorine Before & After Air Stripping

Simulated Water With High CI:N Pre & Post Air Stripping

Test No.	pН	Pre T Cl	Pre F Cl	Post pH	Post T Cl	Post F Cl	wt/wt CI:N	% NTC
1	6.94	1.38	0.65	6.98	0.78	0.47	9.29	80
2	6.93	1.78	0.57	6.93	0.89	0.57	9.29	80
3	6.93	2.02	0.58	8.59	0.64	0.62	9.29	99
4	7.69	1.64	0.11	7.66	1.54	0.11	4.59	2
5	7.15	1.58	1	7.11	0.83	0.61	13.78	79

Simulated Water Tests Match Pool Chemistry Research Very Closely

Simple Corrosion Test - 300 mg/L NTC in Water with Headspace - 304 SS & Copper

+24 hrs at 70-deg F ...

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Important Points & Conclusions

- NTC is extremely corrosive to stainless steel at drinking water temperatures, especially in the air phase
- The rate of corrosion is several orders of magnitude higher in moist air versus water - true for H₂S, Allyl Chloride, etc. Density of water is approx. 784 x that of air
- In drinking water, the ONLY chlorine species to air strip is NTC
- NTC is the dominant chloramine species at pH up to 7.5+ if a high CI:N ratio is employed
- This corrosion event is extremely rare. It required: ammonia in a well supply, breakpoint chlorination, and air stripping

Important Points & Conclusions - 2

- The vast majority of drinking water systems will never be subject to a similar corrosion event
- Typical chloramination processes operate well below the CI:N ratio that will form NTC
- Stainless steels can be effectively protected from SCC with NSF61 epoxy coating
- Other research has demonstrated chloramines to be damaging to elastomers and PE piping

Effects of Chloramines

Reiber, S. 1993. Investigating the Effects of Chloramine on Elastomer Degradation. JAWWA, 85(8):101 (based on 1993 AwwARF Study)

S. Chung, et. al. 2006. An Examination of the Relative Impact of Common Potable Water Disinfectants (Chlorine, Chloramines and Chlorine Dioxide) on Plastic Piping System Components. JANA Laboratories

Rockaway, et. al. 2007. Performance of Elastomeric Components in Contact with Potable Water. AwwARF & USEPA