ARIZONA STATE UNIVERSITY

Treatment of Emerging Chemical and Microbial Contaminants in Water using Advanced Reflective UV Technology

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Emerging Contaminants (ECs)

Xenobiotics

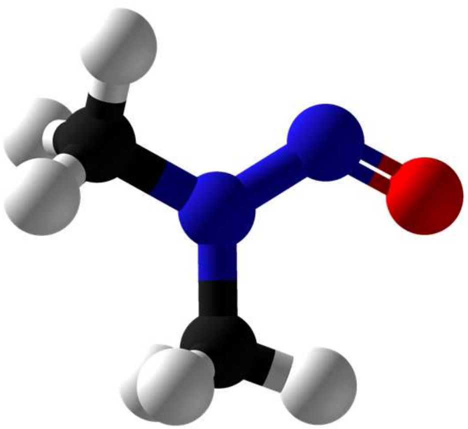
Personal Care Products

Pharmaceutical Products

Industrial By-Products and Effluents

Paints/Dyes, Deodorants, and Pesticides

Nitrosodimethylamine (NDMA)

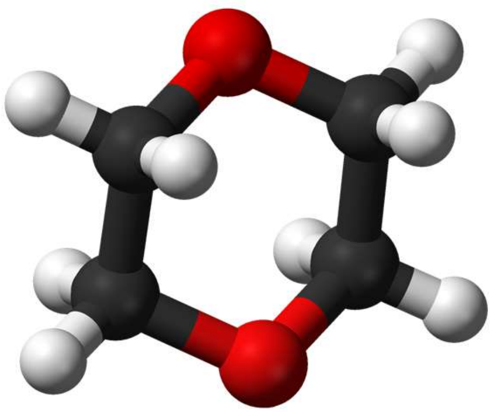


- Belongs to a highly potent family of carcinogens – nitrosamines
- US DHHS reports NDMA to form tumors in kidneys, liver, blood vessels and trachea in experimental animals (IARC,1999)
- Potency to cause cancer at low concentrations of 0.7 ng/L makes it more potent than trihalomethanes (Mitch, Gerecke et al., 2003)
- Is listed in CCL4 (2016)
- **No regulatory limit yet**

Conventional Water Treatment Techniques - NDMA

- UV irradiation is the most applied treatment technology
- Low radical conversion rate and low hydroxyl stability of H_2O_2 makes it selectively effective in certain water reuse trains (Fujioka et al., 2012; Milkos et al., 2018)
- Chlorine should not be used because of the high chances of NDMA reoccurrence
- Sulfate radicals (peroxydisulphate – PDS) have been found to be effective in the treatment of NDMA but they are known have higher sensitivity to changes in the water matrix (Feng et al., 2017)
- **No studies with AOP under dynamic/flow conditions.**

1, 4 – Dioxane (1, 4 – D)

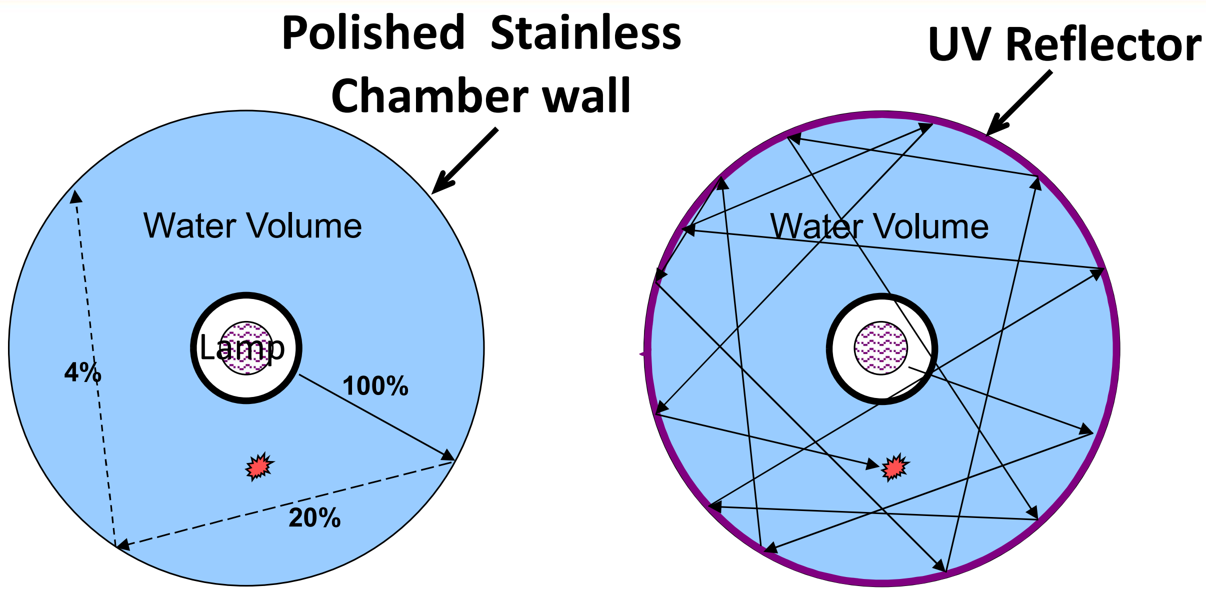


- Synthetic organic cyclic diether
- Highly miscible in water and thus non-volatile when in water
- Not easily bio-degraded
- Classified as a carcinogen to humans by all routes of exposure (U.S. EPA, 2013a)
- Is listed in CCL4 (2016)
- **No regulatory limit yet**

Conventional Treatment Techniques: 1, 4 – D

- Low Henry's constant and BP of 101˚C makes physical treatment systems like thermal destruction, air stripping and distillation inefficient (Vescovi et al., 2010; Mohr, 2010)
- With UV absorption peak of 165 – 191nm, direct photolysis is inefficient (Pickett et al., 1951)
- UV/H_2O_2: 99% remediation in 10h reaction time.
- Doses of 20 mg/L for UV/H_2O_2 and 6, 1.5 mg/L respectively for O_3/H_2O_2 to obtain 80% remediation (Ikehata et al., 2016)
- **No dynamic/flow studies reported using AOP**

Technology:
Highly Reflective Chamber: ReFleX™



Conventional Chamber

Low UV Reflection

<u>ReFleX™ Chamber</u>

<u>>99% UV Reflected</u>

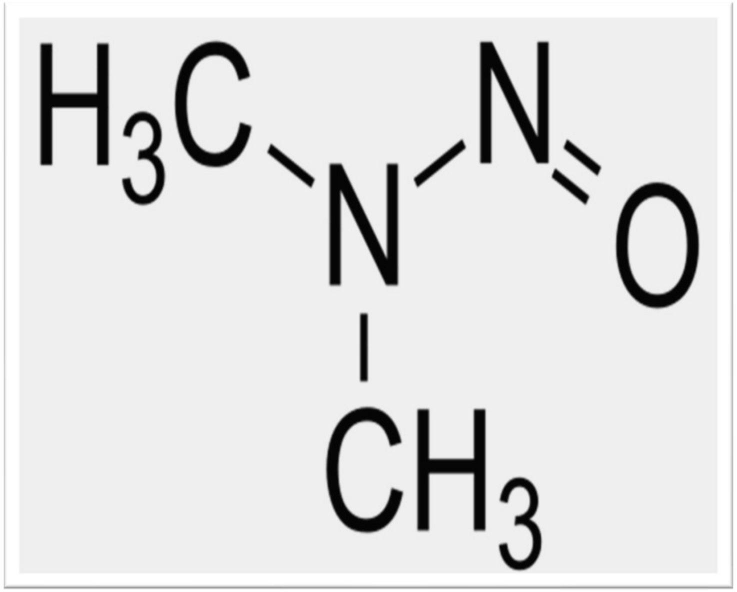
PAA verses H_2O_2

- H_2O_2 is commercially subjected to acid catalysis to form PAA.
- Ionization potential
  - H_2O_2 = 1.78eV
  - PAA = 1.96eV
- PAA has higher hydroxyl stability than H_2O_2.
- Radicals formed upon UV irradiation
  - H_2O_2: hydroxyl radicals
  - PAA: acetyloxy , methyl, weak peroxyl, acetylperoxyl and hydroxyl radicals

NDMA: A Threat and an Emerging Contaminant – Control Strategies using Peracetic Acid with Low Pressure UV and Reflective Technology

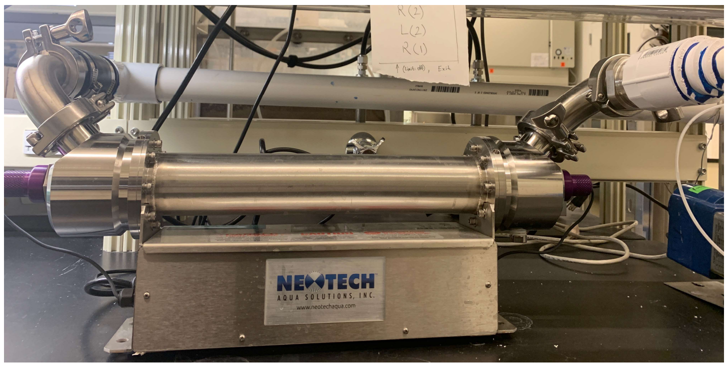
Nitrosodimethylamine (NDMA)

- Semi volatile
- Slightly yellow, water soluble, odorless
- UV absorption peak is at 222 nm
- Hepatotoxin and carcinogen at 0.7 ng/L
- Remediation by conventional treatment train or GACs is inefficient



Experimental Setup

PAA



Influent

The UV devices were generously provided by NeoTech Aqua Solutions, San Diego, CA

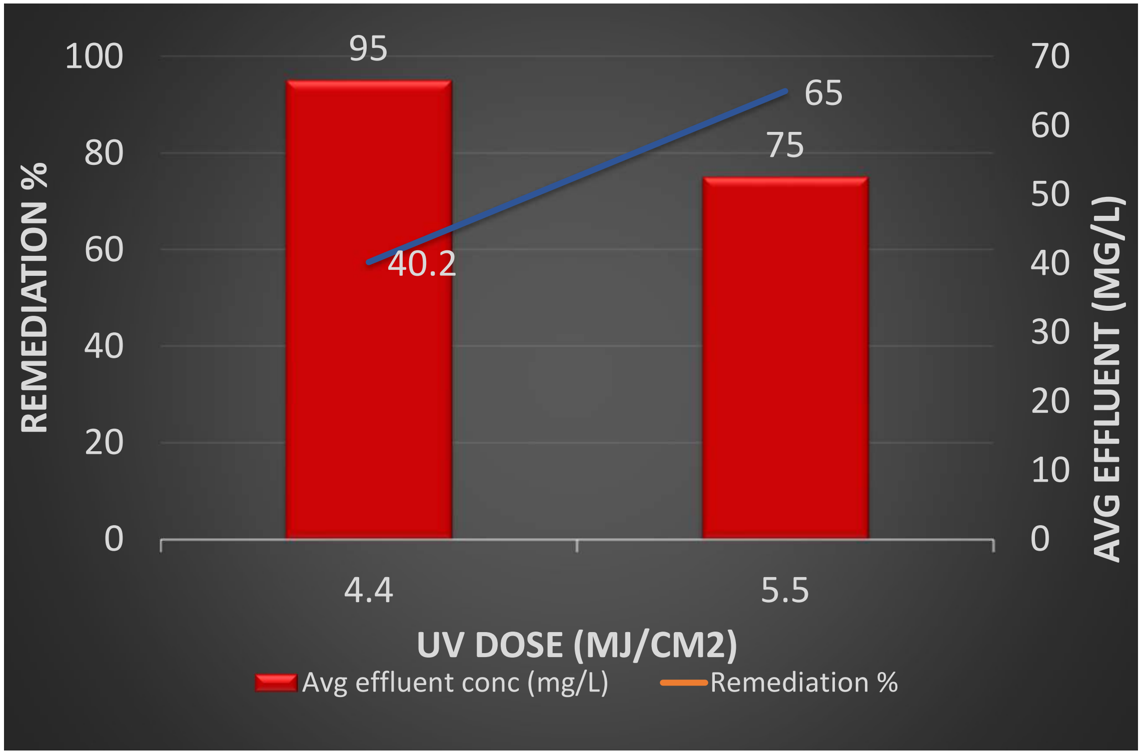
Effluent samples were analyzed by Scottsdale Water Campus in accordance with EPA 521 method to analyze nitrosamines.

Effluent

Experimental Variables

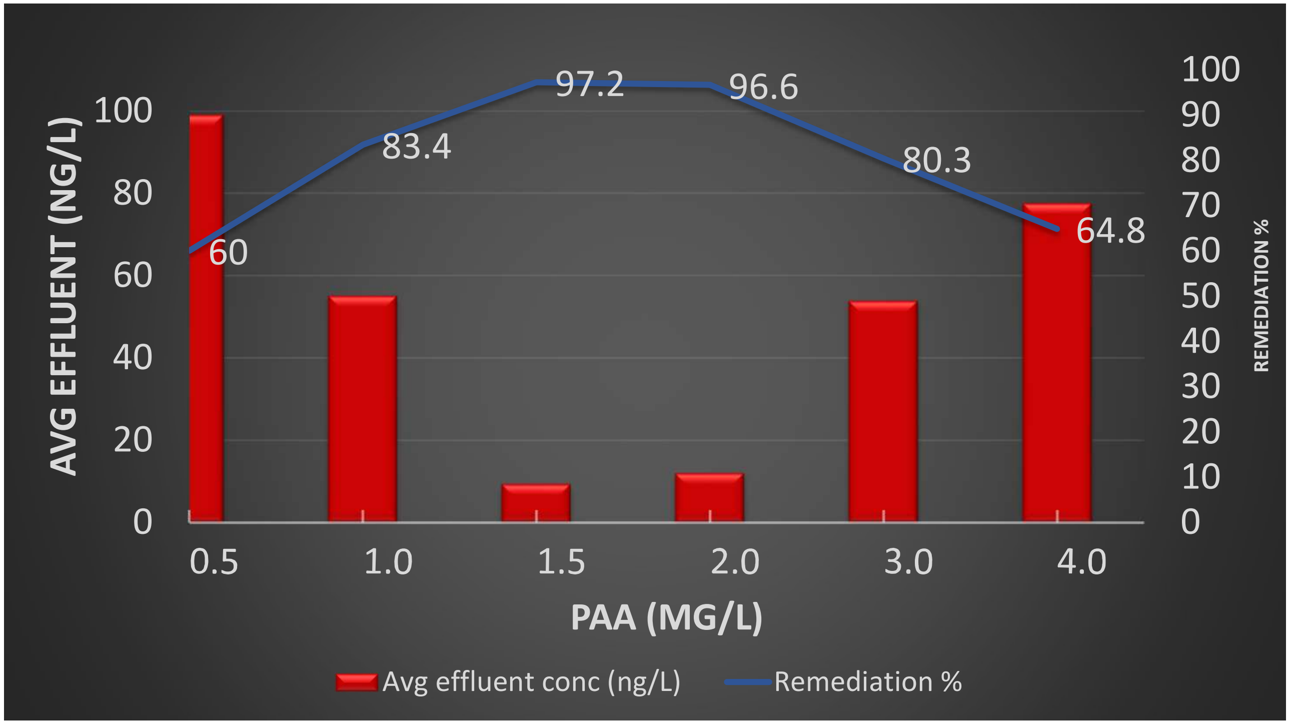
PAA (mg/L)	0.5	1	1.5	2	3	4
Flowrate (GPM)	1	1.2	5	10	20	
UV Wavelength (nm)		254			220	
Influent NDMA (ng/L)			150 to 650			

AOP of NDMA using UV 220 nm



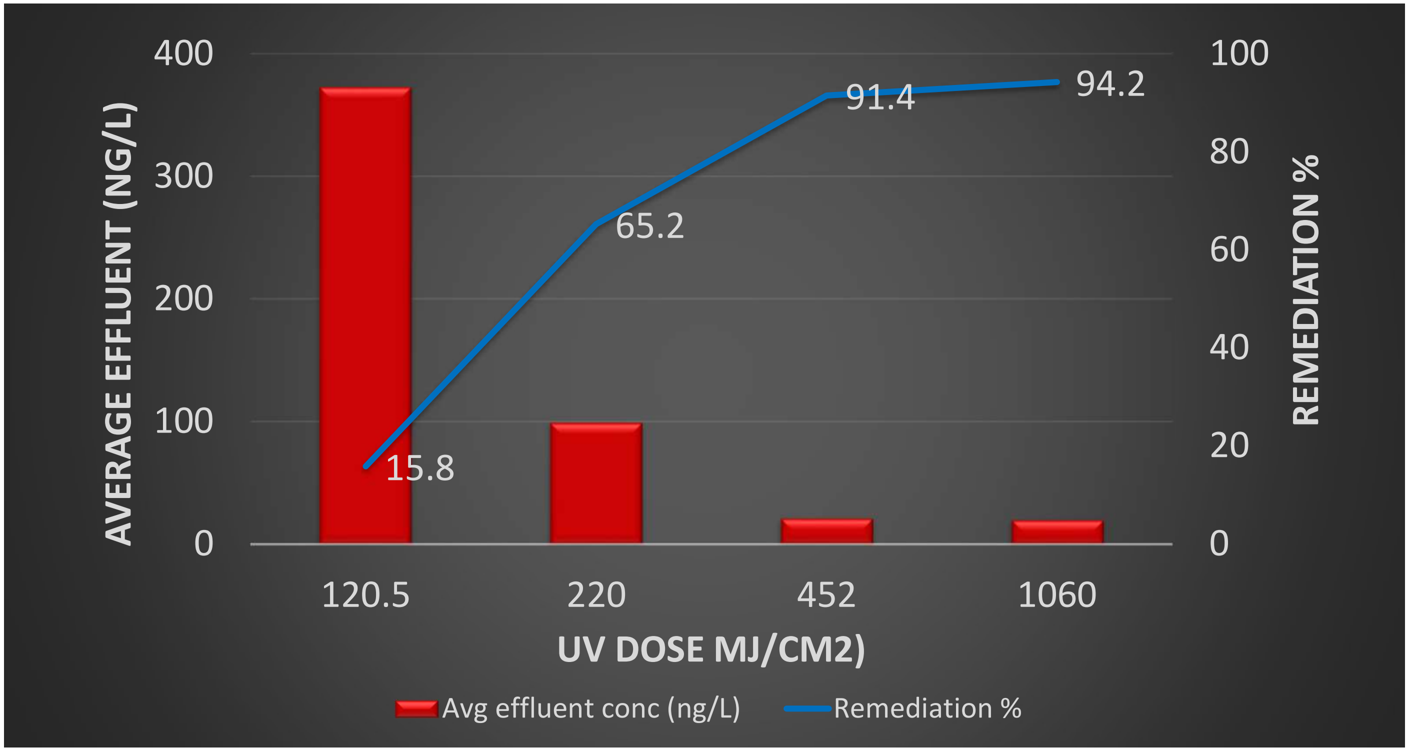
- NDMA can be efficiently remediated using low doses of UV 220 nm

Effect of PAA concentration on AOP of NDMA using UV at 220 nm



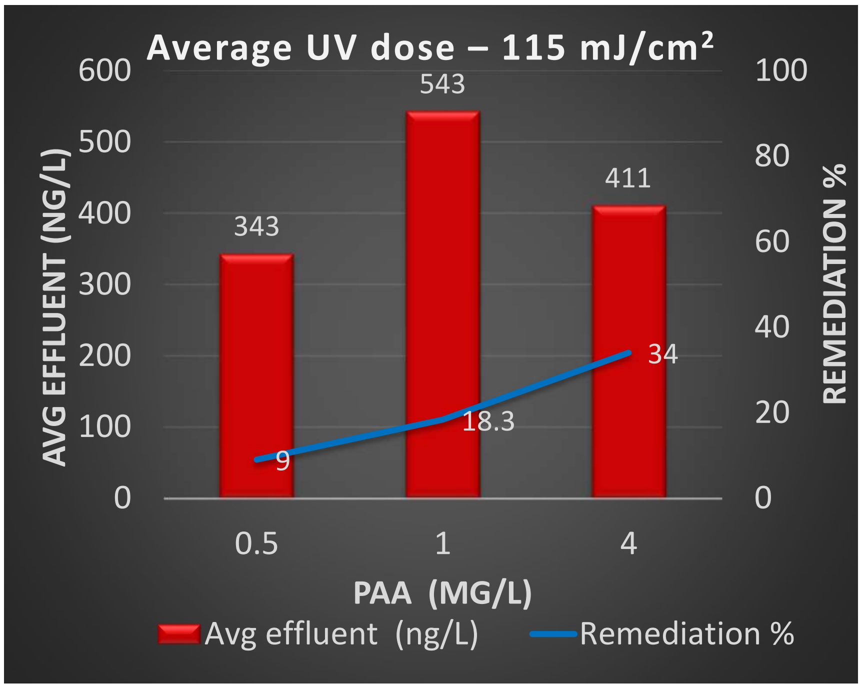
- PAA had a significant effect on NDMA remediation
- PAA > 1.5 – 2 mg/L had a negative impact on NDMA remediation

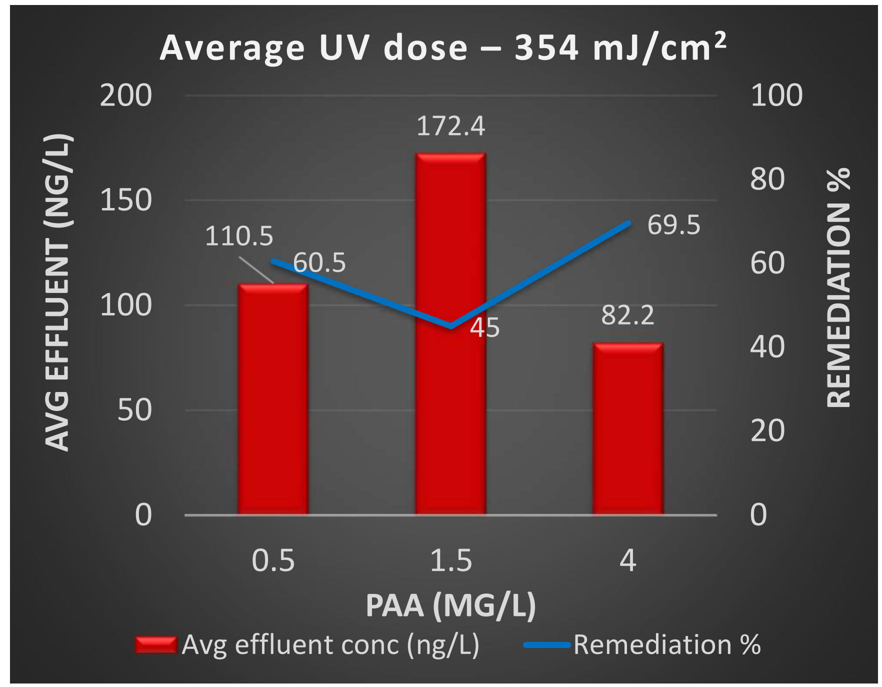
NDMA remediation using UV 254 nm



- NDMA remediation is directly dependent to UV dose
- The highest remediation was 94.2% using >1000 mJ/cm^2 UV

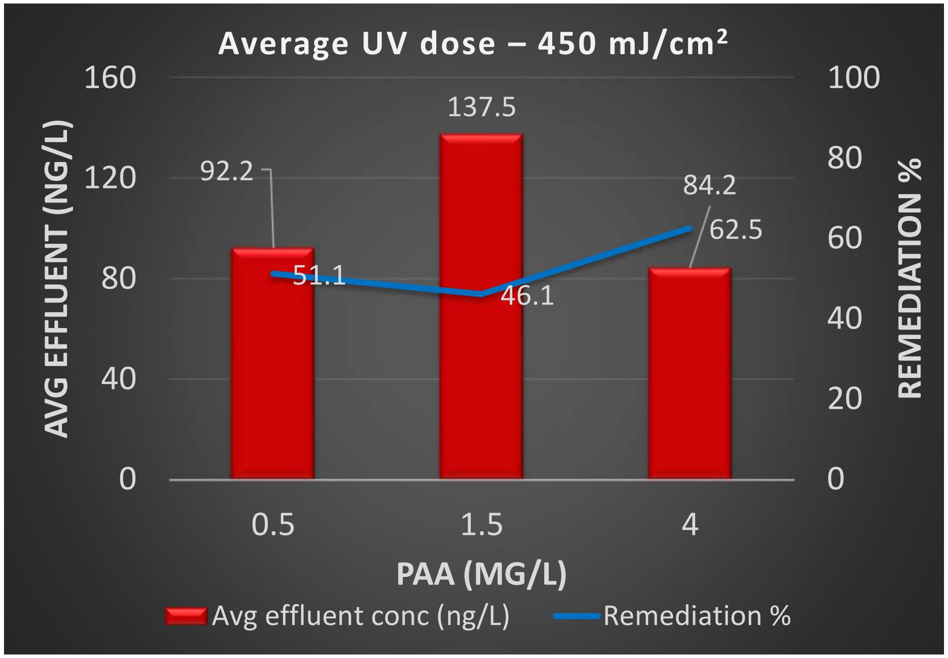
Effect of PAA dose on AOP of NDMA using UV at 254 nm

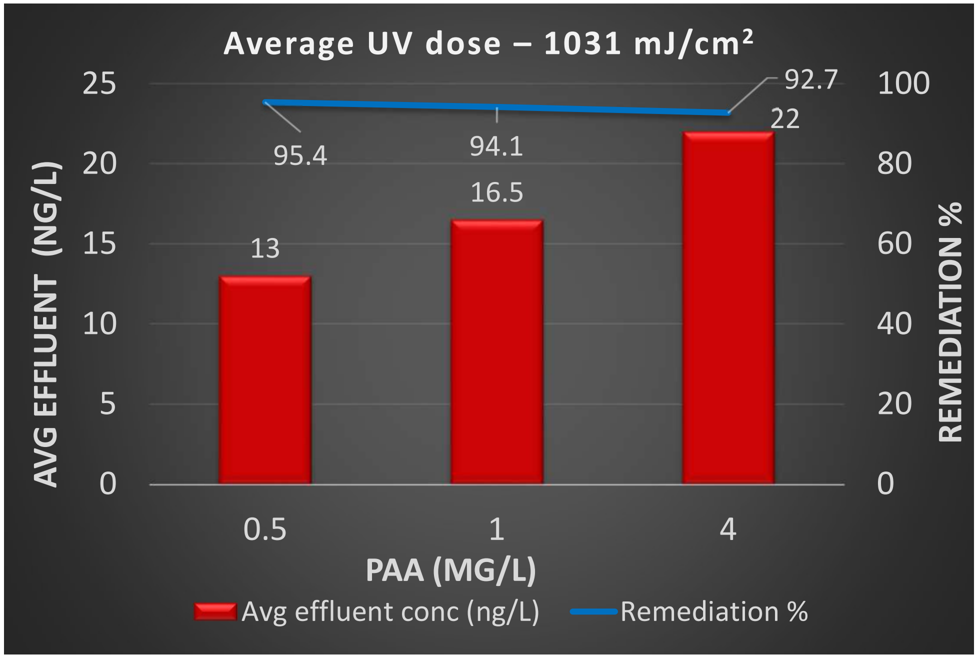




- NDMA remediation improved with increase in PAA dose
- UV dose > 300 mJ/cm^2, PAA at 1.5 mg/L resulted in decrease of percent remediation

Effect of PAA dose on AOP of NDMA using UV at 254 nm





- PAA at 1.5 mg/L consistently showed decreased NDMA remediation for UV dose >300 mJ/cm^2
- PAA dose had minimal impact on NDMA remediation for UV >1000 mJ/cm^2

Conclusion - Considerations

- 220 vs 254 nm
- PAA vs H_2O_2
- Low vs High UV dose
- Optimum PAA concentration – 0.5 mg/L (254 nm), 1.5 mg/L (220 nm)
- Optimum UV dose – 245 mJ/cm^2 (254 nm lamp), 5.5 mJ/cm^2 (220 nm lamp)

AOP Involving Reflective UV Technology and Peracetic Acid : A Promising Alternate Technology in the Treatment of 1, 4 – Dioxane in Water

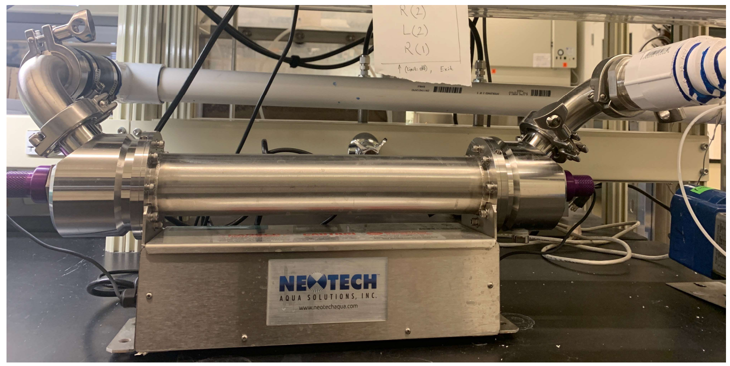
1, 4 – Dioxane (1, 4 – D)

- Cyclic diether, completely miscible in water and organic solvents. UV absorption peak of 165 to 191 nm
- IARC has classified this as a Group 2B agent (potential carcinogen pending data on humans) (IARC, 1999)
- The U.S. EPA has also recognized and classified this compound as a likely carcinogen to humans (U.S. EPA, 2013b)
- The USEPA has a Health Advisory Level (HAL) of 0.35 µg/L in drinking water (U.S. EPA, 2013b)

Experimental Setup

PAA

Influent



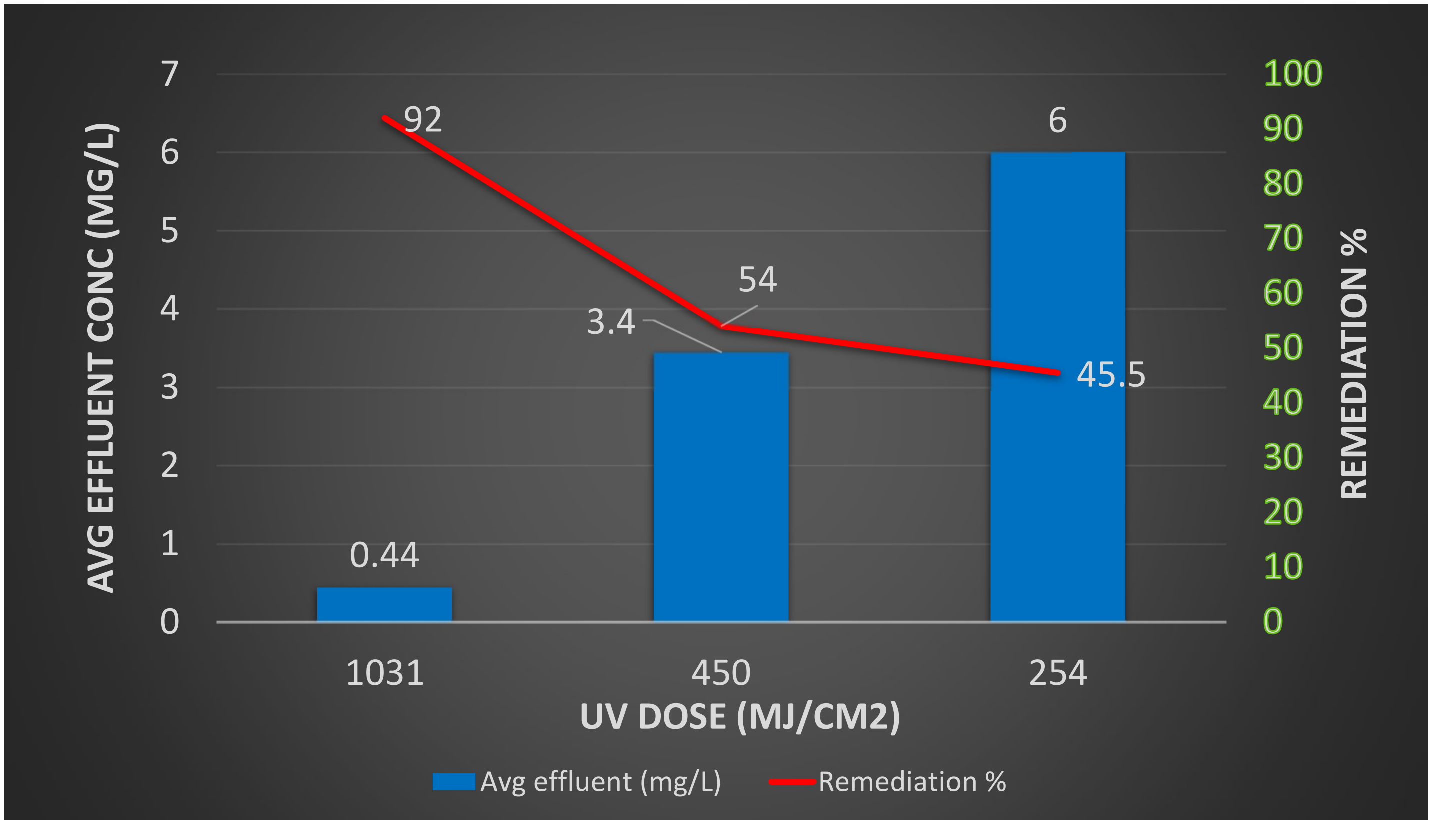
The UV devices were generously provided by NeoTech Aqua Solutions, San Diego, CA

Effluent samples were analyzed by Scottsdale Water Campus in accordance with EPA 522 method to analyze 1, 4 – D in drinking water

Effluent

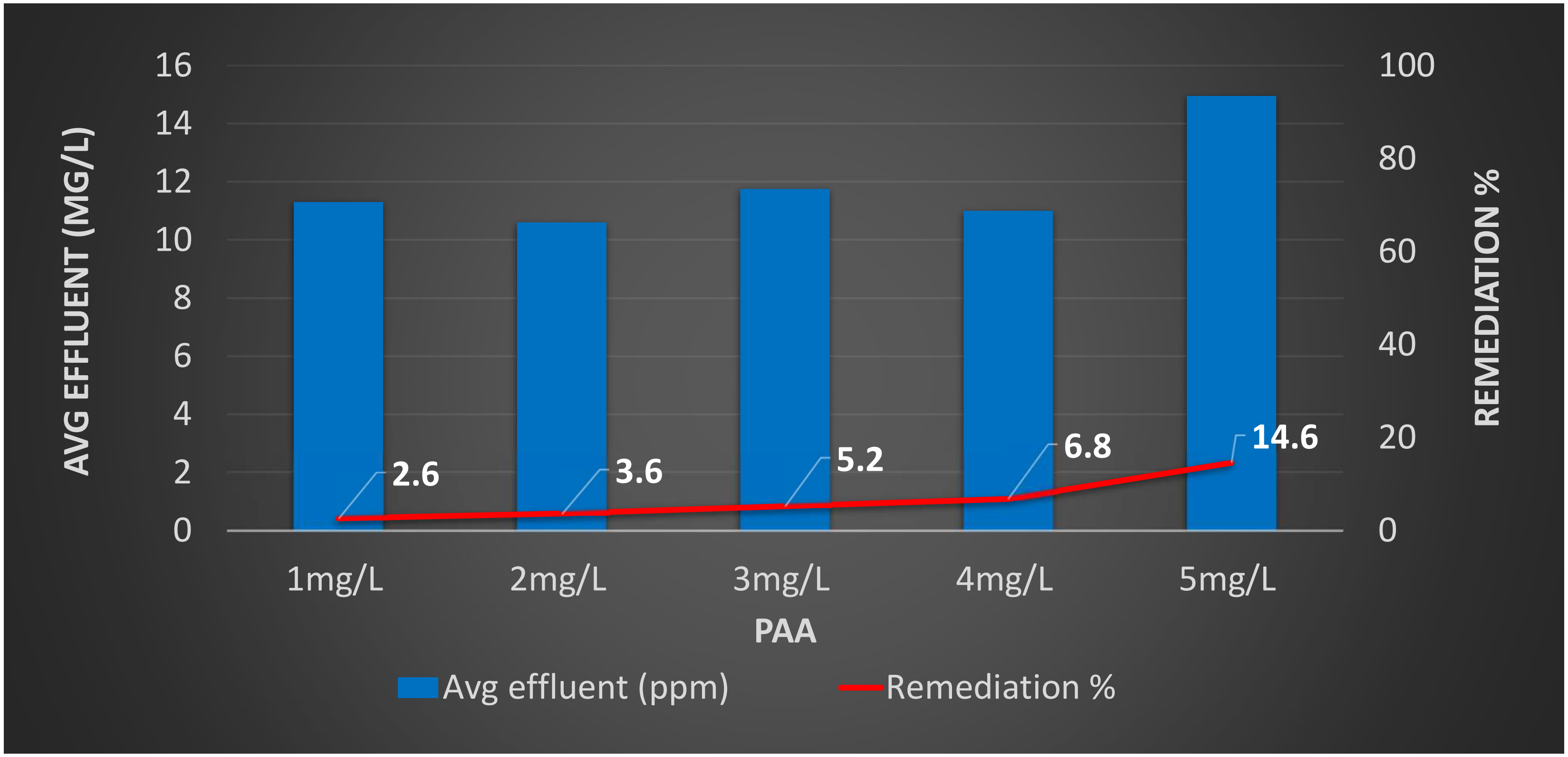
Variables	Parameters Tested					
PAA (mg/L)	1	2	3	4	5	7
Flowrate (GPM)	1	2.5	4	10	20	
UV wavelength (nm)	254					
Influent 1,4 - D (mg/L)	5 to 45					

Remediation of 1, 4 – D using UV 254 nm



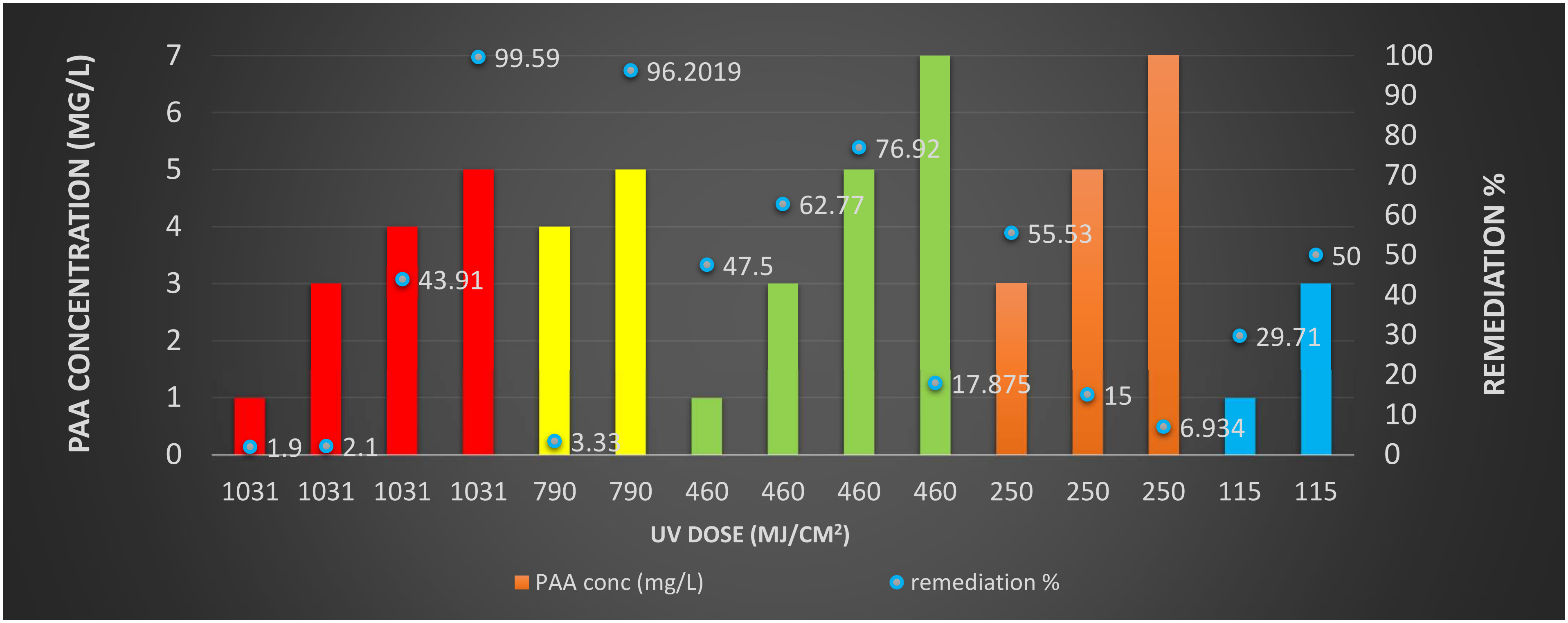
- UV doses >1000 mJ/cm^2 resulted in high percent remediation
- 1, 4 – D remediation decreased at reduced UV doses

Remediation of 1,4 – D using PAA



- PAA showed potential as a catalyst in AOP involving UV 254 nm

AOP of 1,4 – Dioxane using UV/PAA



- AOP involving UV at 790 and 460 mJ/cm^2 with PAA at 5 mg/L yielded in optimized remediation

Conclusion

- The dependency of the remediation of 1,4 dioxane on PAA dose and UV dose was established.
- UV 254nm yielded 92% remediation at 1000mJ/cm^2
- PAA yielded 14.5% remediation at 5mg/L
- UV/PAA yielded the highest remediation
    1. 99.6% at 1,000 mJ/cm^2 and 5 mg/L PAA
    2. 77% at 420 mJ/cm^2 and 5 mg/L PAA
- At PAA concentrations higher than 5mg/L, high degree of UV scavenging was observed.

Note: 1,000 mJ/cm^2 was achieved at 1 GPM flowrate
420 mJ/cm^2 was achieved at 4 GPM flowrate

Microbial contaminants in water : Inactivation of *E. coli, Legionella, Mycobacterium* and Fungal spores using UV with reflective technology and AOP involving UV/PAA

Low-Pressure UV 254 nm with Reflective Technology

E. coli	***Legionella pnemophila***	***Aspergillus niger* Spores**	***Mycobacterium avium***
> 7 log inactivation with 115 mJ/cm^2 UV	> 5 log inactivation with 125 mJ/cm^2 UV	> 2 log inactivation AOP: 530 mJ/cm^2 UV plus 2mg/L PAA	Currently in Progress


THANK YOU
ANY QUESTIONS?

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