Impact of Quaternary Ammonium Compounds on Food Industry Wastewater Treatment Plants

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History

- 1993 - Jack in the Box e coli incident; four children die and many more became sick in Western states
- Quaternary ammonium compound use in sanitation subsequently became more prevalent
- In the 1990’s, several meat plants experienced either inhibition or complete die-off of their wastewater treatment systems; quaternary ammonium compounds suspected as the cause
What is a Quaternary Ammonium Compound?

• Typically known as “Quats”
• Many individual chemicals
• Present in thousands of end-use formulations, many of which are blends of various Quats
• Common uses include disinfectants, surfactants, fabric softeners, antistatic agents, and wood preservation
Quat Types

- Each Quat has its own chemical and anti-microbiological characteristics
- USEPA has clustered Quats into four categories:
  a. Group I: The alkyl or hydroxyl (straight chain) substituted Quats
  b. Group II: The non-halogenated benzyl substituted Quats including hydroxybenzyl, hydroxyethylbenzyl, naphylmethyl, dodecyhlbenzhyl, and alkyl benzyl)
  c. Group III: The di- and tri-chlorobenzyl substituted Quats
  d. Group IV: Quats with unusual substitutes (charged heterocyclic compounds)
Alkyl dimethyl benzyl ammonium chloride (ADBAC)

- ADBAC is considered by USEPA to be the “model compound” for Quat Reregistration Eligibility Decision (RED) data development
- ADBAC is one of the most widely used Quats
- 24 compounds are considered ADBAC based on their general structures
Example ADBAC Structure

- Characterized by having a positively charged nitrogen (cation) covalently bonded to three alkyl group substituents and a benzyl substituent.
- \( R = C_nH_{2n+1} \), where \( n = 8 \) to \( 18 \), with a mixture of carbon chain lengths, predominantly 12, 14 or 16.
What’s This Mean?

- Chemical structure determines chemical behavior
- Will be strongly cationic, so will attach to surfaces, both organic and inorganic
- Compound will be stable and hard to break, so has long lasting biocidal effect
- Anions, e.g. soaps or detergents, can attach to it, and hard water constituents, e.g. carbonate and sulfate
How Does ADBAC Work?

- ADBAC has a strong positive charge
- Bacteria have a negative charge
- ADBAC will attach to the bacteria and cause the cytoplasmic membrane to leak, damaging and eventually killing the bacteria
Disappearance of Quat in Wastewater Systems

- Certain Quats will biodegrade
- Biodegradation poor under anaerobic conditions
- Biodegradability of QACs under aerobic conditions increases with decreasing alkyl (“R”) chain length
- Removal also occurs via partitioning to sludge and other biosolids
- Combination of partitioning and biodegradation can occur in a matter of days
- 90% removal cited in literature
Toxicity of Quat in Wastewater Systems

- Can be inhibitory or toxic at certain concentrations; inhibition increases with decreasing chain length of alkyl ("R") group
- Is not believed to accumulate
- Will bind with anionic surfactants which creates a compound with different physiochemical properties; toxicity may be reduced due to the change in properties; new compound is hydrophobic and will partition to sludge
- Systems will acclimate to a degree, but slug loads can be a problem
Inhibitory Levels of Quat in Wastewater Systems

- DAF process: >100 ppm
- Anaerobic process: 5 – 15 ppm
- Aerobic process
  a. CBOD removal: 10 – 30 ppm
  b. Nitrification: 2 – 5 ppm

Note: based on concentrations of the active ingredient(s)

- Inhibition not always immediately apparent
DAF Process

- Will bind to and interfere with anionic polymers
- Decreases floc particle size and subsequently lowers removal efficiency
- Binds to and degrades flotation skimmings; raises FFA and PV
Anaerobic Process

- QAC will impact methanogens more than acetogens
- Methanogens are “extremely sensitive to toxic substances in their environment”
- Build-up of volatile acids and lowered pH will exacerbate the problem
Aerobic Process

- CBOD removal impact likely to be short unless significant QAC concentrations present
- Nitrification inhibition occurs at much lower QAC levels and lasts longer
- Role of water temperature in WWTP performance is increased when QACs present
- Build-up of nitrites can contribute to other problems, e.g. chlorine demand
How Can I Measure Quat Levels?

- Test strips: Hydrion, LaMotte, EM Quant; unit range is typically in increments of 50 or 100 ppm, hard to read
- Hach has a low range test kit for levels up to 5 ppm
- Potentiometric titration most accurate; ASTM Method D5806-95 for Quats used as disinfectants
Opportunities for Trouble

• Attitude of more is better
• Shock use on weekends during low flow conditions
• Spills or dumping
Opportunities for Improvement

• Track QAC usage and test as necessary
• Work with sanitation
• Manage spills
• Some QACs are less toxic than others, so determine what choices are available
• Communication between the production plant and the wastewater plant
• Have a plan of action prepared in advance in case problems do occur
Questions?