DISINFECTION BY-PRODUCTS AND THEIR HEALTH EFFECTS

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Disinfection By-products and Their Health Effects

This presentation is a review of information contained in the Center for Disease Control and Prevention’s (CDC) Model Aquatic Health Code (MAHC) and Annex to the MAHC.
What’s Inside?

1) Preface
2) User Guide
3) Glossary, Acronyms, Initialisms
4) Design and Construction
5) Operation and Maintenance
6) Policies and Management
7) MAHC Resources
8) Appendices
AGENDA

- Definitions
- Types of DBP’s
- Factors determining DBP levels
- Health effects
- Water chemistry & air quality
- Testing
- Control measures
DISINFECTION BY-PRODUCTS
What is a Disinfection By-product?

- Disinfection By-product (DBP) means a chemical compound formed by the reaction of a disinfectant (e.g. chlorine) with a precursor (e.g. natural organic matter, nitrogenous waste from bathers) in a water system (pool, water supply).
What are the Sources of Disinfection By-products?

- Chlorine reacting with precursors such as:
  - Perspiration
  - Urine
  - Mucus
  - Skin particles
  - Hair
  - Body lotions
  - Fecal matter
  - Soil

- Municipal fill water- chloramination
Types of Disinfection By-products

- **Organic**
  - Trihalomethane (THM’s)
  - Chlorinated phenols
  - Haloketones
  - Halocetic acids
  - Haloacetonitriles

- **Inorganic**
  - Chloramines
  - Cyanogen chloride
Some Classes of Organic Disinfection By-products

- **Trihalomethane (THM’s)**
  - Total THM is sum of concentrations of:
    - Chloroform, bromoform, bromodichloromethane, and dibromochloromethane.
    - Major by-products of disinfection using HOBR and HOCL are:
      - bromoform (CHBr3)
      - chloroform (CHCl3)
    - Chloroform & bromoform:
      - highly volatile
      - can be inhaled
      - readily absorbed through skin
Inorganic DBP’s

- **Inorganic Cloramines**
  - Monochloramine (NH₂Cl)
  - Dichloramine (NHCl₂)
  - Trichloramine (NCl₃)
    - relatively volatile
    - partitions easily from water into air

- **Generated from reaction of hypochlorite with ammonia and amino-compounds**
  - Originate from sweat and urine of swimmers
Urea is a major contaminant in pool water
- Derived from swimmers urinating in the pool
- Present in sweat

Reacts with HOCl to produce trichloramine

Breakpoint destruction of ammonia is very fast

Reaction of HOCl with urea is very slow
- Urea difficult to remove quickly by shocking pool water

Most effectively minimized by changes in swimmer’s behavior and hygiene
Trichloramines

- Odor threshold is 0.1 mg/m³
  - distinctive chloramine odor
- Health symptoms start around 0.3-0.5 mg/m³
  - eye and lung irritation
- No rapid, simple, and commercially available for tests for di- and tri-chloramine exist at this time
- Odor monitoring works well as an early warning system
Factors that Determine Levels of Disinfection By-products

- **Conditions that determine production and air levels:**
  - # of swimmers
    - associated hygiene
  - Chlorine concentration
  - Water temperature
  - Concentration of organic precursors
    - chemical structure
  - Bromide content
  - Indoor air circulation
  - Extent of out-gassing of volatile DBP’s
  - pH
  - Water agitation (undisturbed v. sprayed)
  - Concentration of inorganic chloramines from fill water
Disinfection By-products

- Further research needed:
  - How much DBP’s are being created in swimming pool water
  - Production and retention rate
HEALTH EFFECTS
Outbreaks of ocular and respiratory distress associated with air quality in indoor aquatic facilities have been documented

- CDC has investigated skin and eye irritation and acute respiratory outbreaks associated with chloramines

For Lifeguards, a dose-response relationship has been identified between NCl3, measured as total chloramines, and irritant eye, nose, and throat symptoms
Numerous studies have examined the link between air quality in indoor pools and respiratory health effects, including asthma. Mixed results have been reported in swimmers, occupational categories such as lifeguards, and elite swimmers who practice regularly for extended periods of time. Several analyses of data find that the link to asthma is inconclusive. Reports indicate that the advantages of swimming in good hygienic conditions outweigh the risk of toxicity linked to chlorine and its by-products.
WATER CHEMISTRY
Water Chemistry Affects Air Quality

- High disinfectant levels in indoor pools contribute to development of DBP’s
  - Higher ratio of chlorine to nitrogen content in the water result in formation of trichloramine
  - Lower levels of chlorine/bromine result in lower levels of DBP’s in the presence of organic and inorganic contaminants
  - However, the amount of disinfectant must always be sufficient for proper disinfection
DISINFECTION BY-PRODUCTS
CONTROL AND RESPONSE
Concentration of combined chlorine

- Standard test kits measure all organic and inorganic combined chlorine compounds
- Health effects are associated with inorganic chloramines
- Little or no information about short or long-term health effects associated with organic chlorine compounds
- Similar combined chlorine levels could vary significantly in the amount of irritating inorganic chloramines in the mix
Difficult to set a regulatory maximum concentration of combined chlorine until a test is available to differentiate the irritating inorganic chloramines from the remainder of the combined chlorine mixture currently measured.
Action Level

- Action level of 0.4 ppm (mg/L) established until such tests are available
  - Intended to have pool operators conduct regular combined chlorine monitoring
    - use exceedences of action level to implement a chloramine reduction plan
Disinfection By-products
Water Quality Control

- Concentration of combined chlorine can be minimized
  - Reduce introduction of contaminants that lead to formation
    - urea, creatinine, amino acids, and personal care products
  - Effective filtration, water replacement, improved bather hygiene

- Shock dosing with chlorine to destroy inorganic chloramines that are formed
- **MAHC Air Handling System Design**
  - Purpose: health & safety of building’s patrons
  - Focuses on trichloramine as the major chemical contaminant for design considerations
  - Performance requirements have parameters for fresh air
Indoor Aquatic Facility Air Quality

- Findings/conclusions of MAHC Ventilation & Air Quality Technical Committee
  - Poor indoor air quality has increasingly been linked to health effects
  - Increased reporting of health events
  - Large indoor facilities have proliferated
  - Bather exposure times longer in these facilities
  - Does not appear that ventilation standards are adequate to keep up with aquatics needs
MAHC Ventilation Requirements

- Initial proposal for MAHC Ventilation & Air Quality requirements
  - Increased amount of outdoor air above ASHRAE 62.1 standards
  - Public comments noted:
    - increased costs for equipment and operation while lacking adequate data to support the increase
MAHC Ventilation Requirements

- In response to public comments
  - Initial proposed requirements modified
    - require compliance with ASHRAE 62.1

- Include as a priority research item
  - Develop guidance to improve indoor air quality at aquatic facilities
  - Determine if the problem is inadequate design, poor operation, poor maintenance, or a mix
MAHC Ventilation Requirements

- **MAHC Ventilation & Air Quality requirements**
  - Require compliance with ASHRAE 62.1

- **Performance Requirements**
  - Minimum amount of outdoor air
  - Minimum air delivery rate
  - Air flow/distribution
  - Relative humidity & dew point
  - Disinfection by-product removal
  - Intake locations (avoid re-entrainment of exhaust)
  - Purge
MAHC
More Information: Search on “CDC MAHC” or visit the Healthy Swimming MAHC Website: www.cdc.gov/mahc
Email: mahc@cdc.gov

CMAHC
More Information: Search on “CMAHC” or visit the CMAHC Website: www.cmahc.org
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QUESTIONS ?