Respiratory and Ocular Symptoms among Employees at an Indoor Waterpark Resort — Ohio, 2016

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Hazard Evaluations and Technical Assistance Branch

2017 Expanding Research Partnerships: State of the Science
June 22, 2017
The request — August 2015

- Municipal health department received complaints about an indoor waterpark in a resort

- Initiated an online survey of patrons and employees
  - Eye burning
  - Nose irritation
  - Difficulty breathing
  - Vomiting

- Requested technical assistance from the NIOSH health hazard evaluation (HHE) program
Indoor waterparks and the potential for illness

- Indoor waterparks are an expanding U.S. industry
  - As of 2015, 192 parks
  - Millions of visitors each year

- Air and water quality problems can lead to respiratory or irritation symptoms
  - Infectious
    * Legionella
    * Mycobacteria
  - Chemical
    * Endotoxins
    * Chlorine disinfection byproducts
Chlorine disinfection byproducts
Chlorine disinfection byproducts

\[ \text{Chlorine} + \text{Water} \rightarrow \text{Chloroform} + \text{Chloramines} \]
Chlorine disinfection byproducts

Chloroform
Chloramines

“Chlorine smell” in pools
Mucus membrane irritants
Background on the facility

- Waterpark is part of a resort hotel
- Resort (hotel) open 7 days a week, 24 hours a day
- Waterpark hours vary by season, day of the week
- Operated by the same company since 2013
- Approximately 110 employees, some < 18 years old
Regulation of the facility

- Ohio Department of Agriculture
  - Water features

- Municipal health department
  - Whirlpool spa
  - Restaurant
Waterpark features with potential for water agitation
Waterpark features with potential for water agitation

- Rain Fortress with splash area
Waterpark features with potential for water agitation

- Rain Fortress with splash area
- Children’s activity pool
Waterpark features with potential for water agitation

- Rain Fortress with splash area
- Children’s activity pool
- Water slides
Waterpark features with potential for water agitation

- Rain Fortress with splash area
- Children’s activity pool
- Water slides
- Lazy river
Waterpark features with potential for water agitation

- Rain Fortress with splash area
- Children’s activity pool
- Water slides
- Lazy river
- Whirlpool spa
Waterpark features with potential for water agitation

- Rain Fortress with splash area
- Children’s activity pool
- Water slides
- Lazy river
- Whirlpool spa
Objectives

- Characterize and assess the prevalence of symptoms among waterpark employees versus employees in other resort areas
- Determine the etiology of work-related symptoms
- Recommend ways to improve working conditions
Methods
Multidisciplinary approach

- On-site evaluation (3 days)
- Martin Luther King Jr. holiday weekend in January 2016
Questionnaires

Main questionnaire
- Work history and practices
- Medical history
- Demographics
- Symptoms related to work over the past 4 weeks
  - Began while at work and improved away from work
  - Not associated with a cold or upper respiratory infection

End-of-workday symptom questionnaire
- Each day of site visit
- Work-related if symptom began at work that day
Case definition

3 or more work-related symptoms
- Eye irritation
- Nose irritation
- Cough
- Wheeze
- Shortness of breath
- Chest tightness
- Sore throat

In a resort employee

In the past 4 weeks
Waterpark vs. non-waterpark employees

Waterpark
- Aquatics department
- Concession stand employees

Non-waterpark
- Other resort areas
  - Hotel
  - Arcade
  - Gift shop
Data analysis

- Summarized descriptive statistics

- Compared characteristics of waterpark and non-waterpark employees using the Mann-Whitney $U$ test or $\chi^2$ test

- Calculated prevalence ratios (95% confidence intervals) using 2x2 tables to identify factors associated with meeting the case definition

- Calculated adjusted prevalence ratios (95% confidence intervals) using log-binomial regression
Air sampling and testing

– Collected areas samples at 6 waterpark locations for
  • Chlorine
  • Chloroform
  • Endotoxin

– Logged temperature and relative humidity each minute
Water sampling and testing

– Tested water samples using a color-matching test kit for
  • Total chlorine
  • Free chlorine

– Collected samples from the whirlpool spa, which were cultured for
  • *Legionella*
  • Mycobacteria
Ventilation assessment

- Visually assessed HVAC* equipment
- Estimated air supply and return flow rates using blueprints
- Compared design air supply rate to consensus standards

* HVAC = heating, ventilation, and air conditioning
Results
Resort employees flow diagram

112 employees working
Resort employees flow diagram

112 employees working → 91 participants (response rate 81%)
Resort employees flow diagram

- 112 employees working
- 91 participants (response rate 81%)
- Median age 19 years (range 15–65)
- 52% male
Resort employees flow diagram

112 employees working

91 participants (response rate 81%)

29 (32%) met case definition
Resort employees flow diagram

112 employees working

91 participants (response rate 81%)

29 (32%) met case definition

45 waterpark

24 (53%) met case definition
Resort employees flow diagram

112 employees working

91 participants (response rate 81%)

45 waterpark
24 (53%) met case definition

46 non-waterpark
5 (11%) met case definition

29 (32%) met case definition
## Characteristics of waterpark and non-waterpark employees

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Waterpark employees</th>
<th>Non-waterpark employees</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 45</td>
<td>N = 46</td>
<td></td>
</tr>
<tr>
<td>Age &lt;18 years, no. (%)</td>
<td>26 (58)</td>
<td>2 (4)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Male sex, no. (%)</td>
<td>23 (51)</td>
<td>24 (52)</td>
<td>0.92</td>
</tr>
<tr>
<td>Job tenure, months; median (range)</td>
<td>7 (&lt;1–78)</td>
<td>14 (&lt;1–150)</td>
<td>0.005</td>
</tr>
<tr>
<td>Hours worked over past 4 weeks, median (range)</td>
<td>72 (15–204)</td>
<td>86 (14–240)</td>
<td>0.24</td>
</tr>
<tr>
<td>Current asthma, no. (%)</td>
<td>10 (22)</td>
<td>3 (7)</td>
<td>0.33</td>
</tr>
<tr>
<td>Current smoker, no. (%)</td>
<td>3 (7)</td>
<td>8 (17)</td>
<td>0.20</td>
</tr>
</tbody>
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## Characteristics of waterpark and non-waterpark employees

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</table>
Percentage of non-waterpark and waterpark employees with work-related symptoms in the past 4 weeks

- 24% ≥1 symptom
- 13% Eye irritation
- 62% Cough
- 56% Nose irritation
- 51% Wheeze
- 31% Shortness of breath
- 31% Chest tightness
- 9% Sore throat
Percentage of **non-waterpark** and **waterpark** employees with work-related symptoms in the past 4 weeks

- **24** employees with ≥1 symptom
- **82** employees with ≥1 symptom

Symptoms:
- **13** employees with Eye irritation
- **62** employees with Cough
- **56** employees with Nose irritation
- **42** employees with Wheeze
- **31** employees with Shortness of breath
- **31** employees with Chest tightness
- **9** employees with Sore throat

Percentage of non-waterpark employees with work-related symptoms in the past 4 weeks:

- **97**

Percentage of waterpark employees with work-related symptoms in the past 4 weeks:

- **37**
Percentage of non-waterpark and waterpark employees with work-related symptoms in the past 4 weeks

- ≥1 symptom: 82%
- Eye irritation: 62%
- Cough: 56%
- Nose irritation: 51%
- Wheeze: 42%
- Shortness of breath: 31%
- Chest tightness: 31%
- Sore throat: 9%

Percentage of non-waterpark employees: 24%
Percentage of waterpark employees: 13
## Factors associated with meeting the case definition (n = 91)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%) of employees meeting case definition</th>
<th>Prevalence ratio</th>
<th>95% confidence interval</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Waterpark employee</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>24 (53)</td>
<td>4.91</td>
<td>(2.05, 11.73)</td>
</tr>
<tr>
<td>No</td>
<td>5 (11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Current asthma</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9 (31)</td>
<td>2.70</td>
<td>(1.60, 4.56)</td>
</tr>
<tr>
<td>No</td>
<td>20 (26)</td>
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## Factors not associated with meeting the case definition (n = 91)

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<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18 years</td>
<td>11 (39)</td>
<td>1.38</td>
<td>(0.75, 2.51)</td>
</tr>
<tr>
<td>≥18 years</td>
<td>18 (28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>16 (34)</td>
<td>1.15</td>
<td>(0.63, 2.11)</td>
</tr>
<tr>
<td>Female</td>
<td>13 (30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Smoking status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>1 (9)</td>
<td>0.26</td>
<td>(0.04, 1.72)</td>
</tr>
<tr>
<td>Never or former smoker</td>
<td>27 (35)</td>
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Assessing for potential confounders

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- Assessed age, current asthma, and current smoking status
- Final model adjusted for age
Assessing for potential confounders

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- Assessed age, current asthma, and current smoking status
- Final model adjusted for age
Daily symptom questionnaire findings in **waterpark** employees

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<th>Work-related symptoms, n (%)</th>
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Air chlorine levels were LOW

Occupational exposure limit (NIOSH, ACGIH)
0.5 ppm
Air chloroform levels were LOW

Level associated with symptoms in a previous study
0.00094 ppm
Air endotoxin levels were LOW

Health-based exposure limit (Dutch Expert Committee on Occupational Standards) 90 EU/m³
Water combined chlorine levels were at or ABOVE the waterpark’s internal guidelines.
Water microbiology results

No *Legionella* or mycobacteria was detected
Air temperature was BELOW the recommended range

Recommended range for hotel pools $82^\circ F - 85^\circ F$

$52^\circ F - 77^\circ F$

over the 3 days
Relative humidity was ABOVE the recommended range

Recommended range for buildings with swimming pools
50%–60%
Ventilation equipment was NOT well maintained

- 5 of 6 HVAC units had non-operable fans

- Facility changed filter type, which may have affected intake of outdoor air
Comparison to the Model Aquatic Health Code

- Voluntary guidance developed by CDC

- Based on design specifications
  - The waterpark’s ventilation systems *can* meet the standard
  - But *did not* during our visit
Air distribution design

- To remove contaminants
  - Some air flow across pool surface
Air distribution design

- To remove contaminants
  - Some air flow across pool surface
  - Return at deck level
Air distribution design

- To remove contaminants
  - Some air flow across pool surface
  - Return at deck level

- 75% of air returned at ceiling height
Conclusions

- Waterpark employees were 4 times more likely to have work-related eye and respiratory symptoms

- High water combined chlorine and detectable air chloroform levels indicate disinfection byproduct exposure

- Ventilation systems were not operating properly

- Temperatures below and relative humidity above recommended ranges
Conclusions

Disinfection byproducts and environmental conditions likely contributed to the higher prevalence of symptoms among waterpark employees.
Limitations

- Waterpark open for fewer hours in the winter
  - Less exposure
  - Lead to underestimation

- Unable to measure exposure for each participant
  - Interfere with job duties
  - Wet equipment

- No reliable method to measure chloramines in air
Recommendations
Engineering control recommendations

- Maintain or repair the ventilation equipment
- Identify an air filter that provides sufficient filtration efficiency and minimizes air flow resistance
- Add more return air intakes and air flow at pool level
Administrative control recommendations

- Develop an HVAC preventive maintenance schedule

- Encourage waterpark users to shower before entering

- Encourage employees to promptly report symptoms. Implement a system to track and follow up.
Acknowledgments (Bold text indicates co-authors)

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- Jessica Li
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- Michelle Colvin
- Denise Giglio
- Chuck Mueller
- Donnie Booher
- Kevin Moore
- Kerton Victory

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- Tod Lindsey
- Michael Vartorella

Members of the municipal health department

Ohio Department of Health
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- Amanda Zabala*
- Elizabeth Conrey*
- Brandi Bennett
- Corey Schwab
  * also CDC

CDC
- Michael Gronostaj
- Wences Arvelo
- Byron Robinson

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.
**Legionella**

- Bacterium thrives in warm, wet environments
  - ~60 species, ~70 serogroups
  - Most common cause of human infections is *Legionella pneumophilia*

- Legionellosis
  - Legionnaire’s disease: pneumonia with high fever, chills, cough, shortness of breath, muscle aches, headaches
  - Pontiac fever: self-limited flu-like illness with fever, chills, malaise

- Outbreaks associated with
  - Recreational water venues
  - Warm water systems that produce aerosols, sprays, or mists
  - Exposure to hot tubs is a recognized risk factor
Nontuberculous mycobacteria

- Rod-shaped bacteria found in aquatic environments

- *Mycobacterium avium* complex associated with hypersensitivity pneumonitis and pneumonia in spa users and workers
  - Cough
  - Dyspnea
  - Fever
  - Chills
  - Malaise
Endotoxins

- Lipopolysaccharide complexes
- Outer cell wall of Gram-negative bacteria
- Acute airborne endotoxin exposures associated with
  - Cough
  - Wheeze
  - Shortness of breath
  - Chest tightness
  - Mucous membrane irritation
Area air sampling

- 6 waterpark locations
- Concession stand, arcade, outdoors

- Endotoxin (27 samples)
- Chlorine (26 samples)
- Chloroform (119 samples, changed every 2 hours)
Waterpark resort layout
Waterpark water quality systems

- Mechanical filtration – water pumped through strainer baskets
- Sand filtration
- Ultraviolet disinfection system

- Automated chemical controller system monitored pH and free chlorine
- Maintenance staff also test and adjust

- Aquatics department staff remove fecal matter

- Water completely changed every 2 weeks with municipal water supply
### Job titles or departments of resort employees

#### Waterpark
- 45 employees (49%)
- 42% <18 years

<table>
<thead>
<tr>
<th>Department</th>
<th>Employees</th>
</tr>
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<tbody>
<tr>
<td>Aquatics</td>
<td>39 (87%)</td>
</tr>
<tr>
<td>Concession stand</td>
<td>6 (13%)</td>
</tr>
</tbody>
</table>

#### Non-waterpark
- 46 employees (51%)
- 4% < 18 years

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<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front desk/office</td>
<td>21 (46%)</td>
</tr>
<tr>
<td>Maintenance</td>
<td>6 (13%)</td>
</tr>
<tr>
<td>Arcade</td>
<td>5 (10%)</td>
</tr>
<tr>
<td>Gift shop</td>
<td>4 (9%)</td>
</tr>
<tr>
<td>Housekeeping</td>
<td>4 (9%)</td>
</tr>
<tr>
<td>Security</td>
<td>4 (9%)</td>
</tr>
<tr>
<td>Bar</td>
<td>2 (4%)</td>
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</tbody>
</table>
Waterpark air temperature was BELOW the recommended range

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<thead>
<tr>
<th>Waterpark – Lazy River</th>
<th>Average temperature °F (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>74.4 (66.4–77.2)</td>
</tr>
<tr>
<td>Day 2</td>
<td>73.6 (70.4–74.5)</td>
</tr>
<tr>
<td>Day 3</td>
<td>68.2 (51.8–71.1)</td>
</tr>
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Recommended range (ASHRAE)
Hotel pools 82°F and 85°F

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<tr>
<td>Day 1</td>
<td>75.5 (66.1–78.6)</td>
</tr>
<tr>
<td>Day 2</td>
<td>69.1 (66.3–74.4)</td>
</tr>
<tr>
<td>Day 3</td>
<td>71.0 (59.6–72.3)</td>
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Recommended range (ASHRAE)
Whirlpool/spa 80°F and 85°F
Waterpark relative humidity was ABOVE the recommended range

<table>
<thead>
<tr>
<th>Location</th>
<th>Day</th>
<th>Average relative humidity % (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lazy River</td>
<td>1</td>
<td>89.0 (36.4–100)</td>
</tr>
<tr>
<td>Lazy River</td>
<td>2</td>
<td>69.4 (51.8–77.8)</td>
</tr>
<tr>
<td>Lazy River</td>
<td>3</td>
<td>66.7 (28.7–80.2)</td>
</tr>
<tr>
<td>Spa</td>
<td>1</td>
<td>85.6 (36.1–100)</td>
</tr>
<tr>
<td>Spa</td>
<td>2</td>
<td>27.4 (24–95.7)</td>
</tr>
<tr>
<td>Spa</td>
<td>3</td>
<td>79.6 (74.7–100)</td>
</tr>
</tbody>
</table>

Recommended range (ASHRAE)
Buildings with swimming pools 50–60%
Model Aquatic Health Code

- Voluntary guidance for public aquatic facilities
- Developed by CDC
- Uniform guidelines to help state and local jurisdictions create or update their codes
- 14 topic areas
- 2nd edition in 2016

- Generally adopts ASHRAE ventilation standards, believed to dilute contaminants to acceptable limits
Chemical reactions involved in chlorination

NaClO + H₂O ⇌ Na⁺ + OH⁻ + HClO

HYPHOCHLOROUS ACID
*Strong oxidant, chief bactericidal agent*

HOCl + H₂O ⇌ H₃O⁺ + OCl⁻

HYPHOCHLORITE ION
*Weak oxidant; formation favoured by higher pH*

free chlorine

Chemical structure of ammonia and chloramine

ammonia

chloramine

http://cnx.org/contents/VOsOd84f@2/Occurrence-Preparation-and-Com
Chemical reactions generating chloramines

\[
\begin{align*}
\text{(Bleach)} & \quad \text{NaOCl} \underset{+\text{H}_2\text{O}}{\rightleftharpoons} \text{HOCl} + \text{NaOH} \\
\text{NH}_3 \underset{+\text{HOCl}/\text{-H}_2\text{O}}{\rightarrow} \text{NH}_2\text{Cl} \underset{+\text{HOCl}/\text{-H}_2\text{O}}{\rightarrow} \text{NHCl}_2 \underset{+\text{HOCl}/\text{-H}_2\text{O}}{\rightarrow} \text{NCl}_3
\end{align*}
\]

Volutility: High, Medium, Low, High, Very High

http://homesteadlaboratory.blogspot.com/2013/08/aquaponics-water.html
Chlorine disinfection byproducts in swimming pools

http://cen.acs.org/articles/94/i31/chemical-reactions-taking-place-swimming.html
To view the full health hazard evaluation report, visit: https://www.cdc.gov/niosh/hhe/reports/pdfs/2015-0148-3272.pdf

For more information, contact CDC
1-800-CDC-INFO (232-4636)

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.