Disinfection of Drinking Water

with

Ultraviolet Light

Jackie Leinberger, P.Eng.

Trojan Technologies Inc.
“Millions of people will die each year from dirty water and water-related diseases.”

Chairman of the World Commission on Water for the 21st Century

“Water, this most precious commodity, is in peril in virtually all parts of the globe.”

Marq De Villiers
This could have been prevented'  
Accusations fly that Walkerton’s tainted water supply was covered up for five days; death toll continues to climb

Warning issued in Shelburne
SHELBURNES CP—Mayor Ed Crewson and other town officials were distributing leaflets last night, warning residents that a well has been closed after tests. Since the well was identified, residents have been advised not to drink water from it. The system is not foolproof.

Hospital imports 15,000 litres of bottled water

Beware of rural drinking water, Premier says

Kitchener woman’s death possibly E. coli-related
Pathogenic bacteria, viruses and protozoa in un-disinfected water and wastewater represent potential risks to Public Health

- **Bacteria**: (E.coli)
- **Viruses**: (Hepatitis, Polio)
- **Protozoa**: (Giardia)
- **Protozoa**: (Cryptosporidium)
UV light alters DNA destroying harmful bacteria and viruses.
Bacterium Structure

- Cell Wall
- Cytoplasmic Membrane
- (DNA) Nucleic Acid
Classes of Microorganisms: The Microbial World

**Viruses:** smallest (0.02-0.3 µm diameter); Rotavirus

**Bacteria:** 0.5-2.0 µm diameter; E.coli

**Protozoa:** most >2 µm - 2 mm; no cell wall; wide range of sizes and shapes; Giardia, Cryosporidium and microsporidia.

*C. parvum* oocyst

~5 µm
UV Disinfection Effectiveness

UV is effective for Cryptosporidium and Giardia control

- Least resistant
  - Cryptosporidium
  - Giardia

- Most resistant
  - Vegetative bacteria
  - Viruses / spores

UV is effective for Cryptosporidium and Giardia control
UV Dose

**UV Dose** = UV Intensity x Exposure Time

(Units are measured in mJ/cm\(^2\))

Microbe inactivation is directly related to UV Dose
# UV Inactivation of Pathogens

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>1 log</th>
<th>2 log</th>
<th>3 log</th>
<th>4 log</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryptosporidium parvum</td>
<td>3.0</td>
<td>4.9</td>
<td>6.4</td>
<td>7.9</td>
</tr>
<tr>
<td>Giardia lamblia cysts</td>
<td>NA</td>
<td>&lt;5</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Giardia muris cysts</td>
<td>1.2</td>
<td>4.7</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Vibrio cholerae</td>
<td>0.8</td>
<td>1.4</td>
<td>2.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Shigella dysenteriae</td>
<td>0.5</td>
<td>1.2</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Escherichia coli O157:H7</strong></td>
<td>1.5</td>
<td>2.8</td>
<td>4.1</td>
<td>5.6</td>
</tr>
<tr>
<td>Salmonella typhi</td>
<td>1.8-2.7</td>
<td>4.1-4.8</td>
<td>5.5-6.4</td>
<td>7.1-8.2</td>
</tr>
<tr>
<td>Shigella sonnei</td>
<td>3.2</td>
<td>4.9</td>
<td>6.5</td>
<td>8.2</td>
</tr>
<tr>
<td>Salmonella enteritidis</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Legionella pneumophila</td>
<td>3.1</td>
<td>5</td>
<td>6.9</td>
<td>9.4</td>
</tr>
<tr>
<td><strong>Hepatitis A virus</strong></td>
<td>4.1-5.5</td>
<td>8.2-14</td>
<td>12-22</td>
<td>16-30</td>
</tr>
<tr>
<td>Poliovirus Type 1</td>
<td>4-6</td>
<td>8.7-14</td>
<td>14-23</td>
<td>21-30</td>
</tr>
<tr>
<td>Coxsackie B5 virus</td>
<td>6.9</td>
<td>14</td>
<td>22</td>
<td>30</td>
</tr>
</tbody>
</table>

NA – Data Not Available

Data summarized from the US EPA Workshop on UV Disinfection of Drinking Water, April 28-29, 1999, Arlington, VA
Advantages of UV Disinfection

• Highly effective on broad range of pathogens, including: E. coli, Giardia, Cryptosporidium

• Forms no harmful disinfection by-products (eg. Trihalomethanes)

• Inactivation independent of pH and temperature

• No unpleasant taste or odor

• No transportation, storage or handling of chemicals
Advantages of UV Disinfection cont.

• Easily installed within existing water treatment facilities
• Low capital and operating costs
• Effective as a stand-alone or part of a multi-barrier treatment strategy
• Simple to operate
• Minimal hazard risk for operators
Other Disinfection Methods

- **Chlorine**
  - Applied as gas or liquid, residual in distribution system
  - Dangerous to store, handle, transport
  - Forms toxic by-products (Tri-halo-methanes)

- **Ozone**
  - Applied as gas, short-term residual in distribution system
  - More common in Europe, much more expensive than chlorine or UV

- **Membrane Filtration**
  - Physical separation process
  - Much more expensive (capital and operating cost)
  - No Residual in distribution system
Total Cost of UV vs O$_3$ and Cl

UV Light Disinfection Technology in Drinking Water Application - An Overview, EPA 811-R-96-002

[Graph showing cost comparison between different disinfection methods across various population ranges.]
Upcoming Regulations
Status of Regulations

- US EPA *Draft* Disinfection Guidance Manual was issued October 2001
- Technical review and comments are being collected
- Manual is to support two upcoming regulations:
  1. DBPR
  2. LTSESWTR
- Both rules are considering UV disinfection for Crypto and Giardia removal credits
- Plants have successfully obtained approval to use UV disinfection as an Add-on to existing disinfection technologies thus providing a multi-barrier strategy
UV Disinfection Applications
UV Treatment Applications

1. Municipal Wastewater Treatment Plants
2. Private Water Supplies
3. Municipal Drinking Water Treatment Plants
4. Industrial Process Water
5. Recreational Waters
6. Combined Sewer Overflows
7. Industrial Pollutants

Trojan Technologies Inc.
Trojan’s UV Disinfection Technologies

Municipal Wastewater Disinfection

- Used in primary, secondary or tertiary treatment

- 2,600 systems installed worldwide, serving over 20 million people
  - 11% in Canada
  - 75% in USA
  - 14% rest of world
Global Disinfection Strategies for Drinking Water

UV Disinfection in Europe

- UV is “proven” technology in European drinking water treatment
- Widely used since 1980
- Approx. 200 Trojan municipal drinking water installations in Europe (Milan Italy, Toulouse France, Antwerp Belgium, Middelburg The Netherlands, Motala Sweden, Hatfield UK)
Global Disinfection Strategies for Drinking Water

Under the U.S. Safe Drinking Water Act, the US EPA is developing regulations for improved disinfection while reducing disinfection by-products

1. Protection against chlorine-resistant bacteria (Cryptosporidium, Giardia etc.)
2. Reduction in cancer-causing disinfection by-products created from chemical disinfection
3. Development of multi-barrier disinfection strategy for public drinking water supplies

Adding UV to existing infrastructure responds ideally to all three objectives
Trojan’s full range of products to treat private and public water supplies

- Residential & Commercial Applications
- Small Communities and Industrial Applications
- Medium & Large Municipal Applications
Residential & Commercial UV Systems

- Over 130,000 systems sold – used in rural homes & cottages, farms, camps, labs, restaurants, nursing homes
- New product launched in March, 2000
- Reliable, low cost solution for private water supplies
Small Municipal Drinking Water UV Systems

- For communities with 300 to 8,000 people
- Ideal as stand-alone system or part of a multi-barrier treatment strategy
- Easily installed in existing water treatment facilities
- Available with fully-automated self-cleaning system
- Remote monitoring via modem interface
- Very low capital and operating costs
Larger Municipal Drinking Water UV Systems

• For communities with > 8,000 people
• Ideal as part of a multi-barrier treatment strategy
• Easily installed in existing water treatment facilities
• Available with fully-automated self-cleaning system
• Very low capital and operating costs
Trojan Municipal Drinking Water Systems

• Currently 627 municipal drinking water systems operate in Ontario serving 82% of the population
  (Source: Drinking Water in Ontario - MOE, 2000)

• Many will upgrade to include a multi-barrier disinfection strategy over next 2 years
Application to Newfoundland Communities

• Use as additional treatment step in existing water treatment systems
  – Add UV at stage water enters distribution

• Use as stand-alone treatment at well-head
  – Insert into pipeline where no treatment currently being provided

• Use at point-of-use on private wells
  – Small scale units available for use in private homes

• Install at schools, day-care centres, retirement centres and community centers to protect most vulnerable members of society
## Typical Smaller Community UV Systems Costs

<table>
<thead>
<tr>
<th>Community Size</th>
<th>UV System*</th>
<th>With Remote Monitoring</th>
<th>Estimated Installation Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>$800</td>
<td>-</td>
<td>$300</td>
</tr>
<tr>
<td>50</td>
<td>$1,000</td>
<td>-</td>
<td>$300</td>
</tr>
<tr>
<td>75</td>
<td>$1,200</td>
<td>-</td>
<td>$500</td>
</tr>
<tr>
<td>300</td>
<td>$8,500</td>
<td>$13,000</td>
<td>$2,000</td>
</tr>
<tr>
<td>1,000</td>
<td>$12,500</td>
<td>$17,000</td>
<td>$3,000</td>
</tr>
<tr>
<td>2,000</td>
<td>$20,500</td>
<td>$25,000</td>
<td>$4,500</td>
</tr>
<tr>
<td>5,000</td>
<td>$37,500</td>
<td>$42,000</td>
<td>$8,000</td>
</tr>
<tr>
<td>8,000</td>
<td>$48,000</td>
<td>$52,500</td>
<td>$10,000</td>
</tr>
</tbody>
</table>

* Complete with fully automated self-cleaning system

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UV Disinfection Equipment
**Project:** Fern Resort  
**System:** UV04AS20  
**Flow Rate:** 110 US GPM  
**Service:** Disinfection
Project: South Berwick, Maine
System: UV8012L with Chemical Cleaning System
Flow Rate: 160 GPM
Service: Disinfect Ground Water in a Pumphouse
**Project:** Huybergen, Netherlands  
**System:** UV02M25  
**Flow Rate:** 815 GPM  
**Service:** Disinfect Filtered Ground Water
Project: Regional Municipality of Waterloo, Ontario
System: UV01M20
Flow Rate: 225 GPM
Service: Disinfect Ground Water
Project: Indianapolis, Indiana
System: UV02M30
Flow Rate: 750 GPM
Service: Disinfection of Ground Water
Project: Ontario, NY
System: UVSWIFT-12
Flow Rate: 3 MGD
Service: Primary disinfection (treating surface water from Lake Ontario)
Tivoli Fountains, Italy –
12 MGD UV8000 System
AWWARF 2593: Inactivation of Pathogens by Innovative UV Technologies, Salt Lake City, UT
Trojan Technologies Inc.
Trojan Technologies Inc.

- Founded in 1977, in London, Ontario
- The design, manufacture and sale of UV based disinfection technologies for residential & commercial drinking water, municipal drinking water, industrial process water and wastewater markets globally.
- Singular focus on environmentally responsible disinfection technologies
- 300 dedicated professionals on staff
- Offices in Canada, USA, the UK, the Netherlands, Norway, Spain, Germany
Trojan Technologies Inc.

**Expertise:**
- $6 million invested in R&D in 2001
- Invested over $30 million in R&D since inception
- Trojan is largest private funder of UV disinfection research in the world.
- R&D and engineering expertise: 110 university & college graduates
- 16 PhD’s; 10 Masters’; 50 electrical & mechanical engineers
- Over 500 person-years of UV disinfection experience
Trojan Research & Partnerships

R&D in Drinking Water Treatment

- Cryptosporidium & Giardia research at McGill, Duke, UNC.
  (Recent outbreaks in North Battleford, Collingwood, Waterloo)
- Continuous improvement in Reactor design, UV efficiency, lamp technology

Technical advisory role to regulators

Trojan currently serves on US EPA advisory committee on municipal drinking water disinfection strategies
Questions