AWWA Webinar Program: Drinking Water Contamination: Lessons Learned from Operational Upsets and Failures
Wednesday, January 27, 2016

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Lauren Wasserstrom is an engineer at American Water Works Association in the Engineering and Technical Services Department. In this capacity, Lauren provides technical advice, information and process guidance to AWWA’s volunteers on matters related to water quality, water research, conservation, and sustainable infrastructure. Prior to joining AWWA, Lauren spent the last three years at the EPA in Cincinnati, Ohio conducting research related to corrosion and metal accumulation in water distribution systems to assess the relationship between pipe scale formation and water treatment history, and the potential behavior for contaminant release over time.

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Panel of Experts

Steve E. Hrudey
Professor Emeritus
University of Alberta

Brian Jobb
Manager, Training Institute
Walkerton Clean Water Centre

Ian Douglas
Water Quality Engineer
City of Ottawa

Agenda

I. Lessons About Contamination from Operational Upsets and Failures  
   Steve Hrudey

II. North Battleford, SK Cryptosporidium Outbreak  
   Brian Jobb

III. Case Study: Treatment Failure in “Anytown”, North America  
    Ian Douglas
Ask the Experts

Enter your question into the question pane at the lower right hand side of the screen.

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Lessons About Contamination from Operational Upsets and Failures

Steve E. Hrudey
Professor Emeritus
University of Alberta
Rationale for This Presentation

• Producing high quality, safe drinking water 24/7 365 days a year is challenging because “stuff happens”
• This presentation illustrates how case studies of authentic events can assist in staff training to prevent bad outcomes

Learning Objectives

• Viewers will learn about available resources that enable insights from authentic episodes of drinking water contamination
• Viewers will be able to see how challenging experiences of others can be translated into learning options for their own systems
Agenda

- An Overview of the case study approach
- Consider a key background issue
- Sample highlights of 3 example case studies
- Some general guiding principles
- Next 2 presentations will focus on 1 case study each

Why Learn the Hard Way?

- Messages for you are drawn from a 2014 book published with AWWA
- Driven by Walkerton disaster in May 2000 - 7 deaths, 2300 ill
- Vital Support from the Canadian Water Network
Do Not Learn the Hard Way?

• Most frontline personnel will likely not experience major disaster first hand
• Makes sense to make disaster experience “live” for the majority to avoid becoming involved in a disaster
• Experience can change your view of the world, e.g. buying a new car

A Case Study Approach

• Case studies can make learning more effective by adding reality to the learning experience
• Case studies can be adapted for training to reflect local realities
• A basic premise is that operators do not want to harm their neighbors
A Case Study Approach

Common questions:

• Could these failures have happened to your system?
• Would all of the failures which occurred have been detected by your system management?
• Would your system (equipment & management) have responded effectively?

The Easy Answer - Human Error

• Making mistakes is normal human behavior
• Hindsight is usually 20:20 vision, but...

• Trevor Kletz (1922-2013): “Saying an accident is due to human failing is about as helpful as saying that a fall is due to gravity. It is true, but it does not lead to constructive action. Instead it merely tempts us to tell someone to be more careful....”
The Easy Answer - Human Error

To understand what has gone wrong, you have to experience it as it happens in real time - not only with the benefit of total hindsight and oversight.

As much as possible, you must experience what happened the way that events actually happened.

Serious Incidents Do Happen

- Book resource has 9 pathogen, 7 chemical contamination and 4 close call case studies
- A few classic older cases but several from the past decade
- Now will provide a quick overview of 1 chemical and 2 pathogen case studies
Camelford, England, July 1988

Nokia Finland, Nov-Dec 2007
Nokia Finland, Nov-Dec 2007

Maatiala Water Works

Nokia Finland, Nov-Dec 2007

[Map showing locations of Maatiala Water Works, Kullenyuori Wastewater Treatment Plant, Nokia River, and Nokia River.]
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Östersund, Sweden Nov-Dec 2010

Diagram showing water treatment process:
- Lake Borlønn
- Chlorination
- Sand Filtration
- Chlorination
- Distribution
Östersund, Sweden Nov-Dec 2010

Contaminated creek Minnesgårdets Waterworks

Östersund, Sweden Nov-Dec 2010

Lake Stora sjön

current flow

Minnesgårdets Waterworks

Contaminated creek
Guidance for Operators

1. **Never say never!** Contamination can strike any system. The test for you will be how quickly you recognize trouble and deal **with it effectively**.

2. **Do not underestimate the capacity of fecal (human or animal) waste to make water unsafe**

3. **Learn from experience** – do not just survive it. Learn from your mistakes and those around you.

4. **Recognize when you do not understand what is happening**, admit it and seek help to understand.

5. **Do not overlook the obvious** – if you would not eat there, do not make drinking water there.

Guidance for Operators

6. **Treat water operations like defensive driving** – expect mistakes by others.

7. **Make sure you understand why you must do regulated things** – if you only do things because you are told to, you are on your way to complacency.

8. **Maintain healthy skepticism about the first explanations of what is wrong**.

9. **Do not let others (managers, politicians) pin blame on you** – if you know that improvements are needed, document those needs in detail.

10. **Take pride in the public health responsibility you carry and maintain!**
Summary

• Makes **no sense** to learn the hard way
• Water utilities need to document all major incidents and use them effectively in training operators
• Free excerpt of the Book resource is available at: [www.awwa.org/esdw](http://www.awwa.org/esdw)

Thank you for your interest
Ask the Experts

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North Battleford, SK Cryptosporidium Outbreak

Brian Jobb
Manager, Training Institute
Walkerton Clean Water Centre
Rationale

Mistakes made by others are examined in this presentation with the hopes that these same mistakes can be avoided in the future by studying and learning from them.

Learning Objectives

• Participants will be able to review their operational procedures to determine whether or not these problems could happen in the systems they operate.
• Participants will learn how to predict and possibly prevent problems before they occur.
Agenda

- Description of the North Battleford system
- Brief account of past problems
- The cause of this Cryptosporidium outbreak
- Questions to ask about participant’s systems
- Lessons to be learned from this waterborne disease outbreak

North Battleford, Saskatchewan
March – April 2001

- Population 14,000
- Agricultural region with catchment area > 60,000 population
North Battleford, Saskatchewan

Surface water plant originally built to serve a hospital around 1950, taken over by North Battleford in 1961, expanded and upgraded in 1981

Sewage outfall 3.5 km upstream of the water intake
North Battleford: Prior-History

- The City’s treated sewage discharges into the river via a canal
- Impact of the sewage effluent on drinking water had been a concern since 1963
- Fecal coliforms had been detected in raw water at the drinking water plant in the past
- Conventional treatment with chlorination was accepted as mitigating this risk
North Battleford: Prior-History

- A 1998 consultant’s report identified two major treatment issues at the surface water plant:
  1) Lack of rapid mixing at the point of coagulant chemical addition
  2) Significant difference in performance between filters
- Consultant’s recommendations were not addressed prior to the 2001 outbreak

North Battleford: Prior-History

- Numerous problems had been identified prior to the 2001 outbreak
- Operators had expressed concerns about poor operational practices and risks to public health
- Operational staff were told to “keep quiet” by senior management and city council
- A boil water advisory was called in Sept. 2000 due to coliform bacteria and chronically low chlorine levels
North Battleford: Prior-History

- Following the Sept 2000 boil water advisory, the regulator requested several reports including:
  - Evaluation of treatment performance
  - Quality Assurance / Quality Control (QA/QC) plan to include written operating procedures
  - Routine monitoring plan
  - Emergency response plan

- Guidance on producing these reports was provided by the regulator
- No action to complete the reports was taken by the Director of Public Works or the City
- Plant Foreman retired mid-December 2000 due to stress
- Public Works Director (no training or expertise) took over as Plant Foreman
North Battleford: Prior-History

- Mid-January 2001 operators complained to City Council in writing about:
  - poor condition of the plants
  - lack of inventory and equipment
  - lack of an experienced and certified supervisor
  - the need for continuing operator education
- Operators did not receive a reply from Council

North Battleford: The Cause

Solids Contact Unit (SCU) – upflow, sludge blanket clarifier
North Battleford: The Cause

• Maintenance was done on March 20, 2001 to repair the Solids Contact Unit (SCU)
• Common practice is to retain sludge to re-establish the floc blanket
• Sludge was not retained for this purpose
• The SCU was filled with raw water containing an elevated dosage of coagulation chemicals

North Battleford: The Cause

• Standard 5 minute sedimentation test normally yielded ~ 10% sludge settling
• This test showed zero sludge settling the day following the repairs
• Problems with sludge blanket formation and SCU operation persisted for over 4 weeks
• Filtered turbidity was consistently between 0.3 and 1.0 NTU for 22 days
• No experienced operator - Public Works Director was notified twice about lack of settling
North Battleford: The Cause

- On April 24, 2001, a Public Health Inspector (PHI) contacted Public Works Director concerning an outbreak of cryptosporidiosis.
- The Director of Public Works mentioned the problem with forming a floc blanket in the SCU.
- PHI did not appreciate the significance of this treatment problem.
- PHI reported to the Medical Officer of Health that there were “no problems at the water plant”.

North Battleford: The Cause

- By 4:00 PM on April 24, 10 laboratory-confirmed cases of cryptosporidiosis reported.
- The Public Works Director was asked about any water treatment problems.
- At 8:00 AM on April 25, the regulator was informed who recognized the significance of the clarifier performance.
- A drinking water advisory was called at 1:00 PM on April 25.
• This outbreak was caused by a human strain of *Cryptosporidium parvum* (now called *C. hominis*).

• Human fecal waste was believed to be the source of contamination (i.e. the sewage outfall).

• Estimated 5,800 to 7,100 cases of gastroenteritis occurred in the area between March 20 and April 26, 2001.
Questions to Ponder

- Are there personnel problems that effect your ability to produce safe drinking water?
- Is there a mechanism for reporting such problems?
- Does your organization discourage looking for and acting on problems?
- Have you overlooked signals of contamination?
- Are operating protocols in place to allow you to function safely if senior personnel leave?
- Is senior management and Council aware of the importance of operations?

Lessons

- Each barrier must be fully understood in relation to the nature of the contamination threat
- “Low” filtered turbidity (< 0.3 NTU) may not be sufficient to prevent Cryptosporidium contamination
- Personnel issues can work against safe practices
- Waterborne Cryptosporidium outbreaks are slow to be detected by public health authorities
- Risks to drinking water safety from sewage effluent are often not recognized
Ask the Experts

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Case Study: Treatment Failure in “Anytown”, North America

Ian Douglas
Water Quality Engineer
City of Ottawa
Case study: rationale

- Multiple system failure → challenge for operators!
- Utility was willing to share their difficult experience
- “Close call” event: 2-week Boil Water Advisory

Case study: learning objectives

✓ Application of treatment principles & critical thinking
✓ Lessons for other treatment plant operators?
✓ How would I respond in a similar situation?
Agenda

• Background on “Anytown”
• Source water & treatment
• Chronology of events
• Troubleshooting
• Lessons learned

Anytown, North America, Nov 2011

• Anytown (North America) is a community of about 9,000 located in a rural agricultural and recreational lake area

• Surface water: The Small River – moderately impacted source with high organics (DOC=6 mg/L; Colour = 40–70 TCU)

• An original waterworks (88 years old) was replaced with a new water treatment plant, commissioned in March, 2010.

• Rated capacity of 18 ML/d; average production = 5 ML/d.
Anytown – treatment plant

Anytown: the Case

Monday, Nov.28 (Day 1)

• 1:35 PM – staff member notice no water flow in washroom; SCADA: water level dropping rapidly in water tower, alarms

• 1:53 PM – Superintendent was notified that a contractor decommissioning the old water works had crushed a 16” diameter water main, located within 240 ft. of water tower.

• 1:55 PM – widespread loss of pressure in distribution system & plant high-lift pumps ramped to full flow due to level control

• 2:00 PM – operators put high-lift pumps in manual and isolated water main break by valve throttling to reduce loss of water
Anytown: the Case

- 2:05 PM – Plant Superintendent notified Public Health Unit to advise that positive pressure had NOT been maintained
- 2:17 PM – water level in tower reached bottom
- 2:30 PM – Medical Officer of Health issued Boil Water Advisory and started notifying hospital, schools, restaurants, etc.
- 4:15 PM – formal media release for Boil Water Advisory
- 8:15 PM – set of bacteriological samples taken from (5) locations in distribution system; dewatering site of main break & repairs
Anytown: the Case

Tuesday, Nov. 29 (Day 2)
• water main repair & bacteriological sampling

Wednesday, Nov. 30 (Day 3)
• 7:00 AM – damaged section of water main repaired!
• 9:00 AM – water tower valved back into service; 2-3 crews flushed distribution system all day/evening
• Bacteriological results all clear from (3) sets of samples

Thursday, Dec. 1 (Day 4)
• Plant raw water on-line turbidity meter failed, replaced same day

Friday, Dec. 2 (Day 5)
• Discussion with Medical Officer of Health; prepared to lift BWA at 7:00 PM when final bacteriological results were expected

things were looking better until...
Anytown: the Case

Friday, Dec.2 (Day 5)... continued

• 5:00 PM – turbidity levels for DAF effluent began to rise unexpectedly (2 NTU → 10 NTU)

• Superintendent phoned Medical Officer of Health and advised NOT to lift BWA yet!

• System was under additional stress from higher than normal water production & 2nd water main break

• Majority of municipal staff were attending yearly Christmas party on evening of Dec.2 – called back to treatment plant!

• 5:55 PM – Filters #1,2,3 shut down due to high turbidity >1 NTU; Filter #4 started draining unexpectedly

Poor clarification from Dissolved Air Flotation (DAF) unit
Anytown: the Case

Friday, Dec.2 (Day 5)
- 6:30 PM – backwash & filter-to-waste procedures to lower filter effluent turbidity (no success)
- remaining staff worked through night to stabilize treatment process (reduce flow, alum dose → 55 mg/L, injector, filter backwash)
- Staff coverage became an additional challenge due to extended overtime shifts/exhaustion

Saturday Dec.3 (Day 6)
- 4:00 AM – turbidity in filter effluent below 1 NTU and stable
- 6:00 AM – Superintendent phoned MOH → advisory lifted (microbial samples clear, filter turbidity stable); notified residents & businesses

Anytown: the Case

Saturday, Dec.3 (Day 6)
- 4:00 PM – treatment plant once again not responding to process adjustments; filter turbidity > 1 NTU (ie. non-compliance); grab=10 NTU
- UV reactor automatically shutdown (below 80%); Regulator notified “chlorine, not UV” was primary disinfectant, free chlorine concentration increased to 5.0 mg/L, reduce flow to increase CT
- Plant electrician brought in to verify control valves and instrument signals

Sunday, Dec.4 (Day 7)
- treatment process recovered intermittently, mostly unresponsive to process adjustments; concerns about Cryptosporidium
- 3:30 PM – Medical Officer of Health notified and Boil Water Advisory put back into effect; called treatment engineer from nearby utility to help
- 7:00 PM – Engineer, technologist, & operator: TEAM “troubleshoot” process
Anytown – treatment plant

Anytown: troubleshooting

i. raw water quality: review plant records indicated change in recent days (low water level, heavy rainfall) Turb=1.5 → 2.6–3.0 NTU, Colour = 40 → 70

ii. DAF clarifier performance: visual inspection indicated an “even” mat of white foamy bubbles: “ideal” settling test, clarifier influent sample to lab → cloudy, no discrete particles observed; turbidity = 10 NTU after 1 hour

DAF clarifier not the problem...coagulation!
iii. jar testing:
- operators found optimum alum dose=50 mg/L (2 NTU);
- engineer could not replicate jar test results: 70-90 mg/L optimal; 20-50 failed;
- engineer repeated jar test with “fresh” raw water sample (same result);
- check operator pipette technique: weighed 50 µL on balance: 40 → 70 actual!
### Anytown: troubleshooting

iv. **alum dose:**
- set to target dose of 80 mg/L (SCADA)
- applied as “neat” alum through hose to top of mixing tank
- measured **actual** dose using graduated cylinder & stopwatch = 45 mg/L!
- pump problems; adjusted pump stroke 50% → 95% to achieve 80 mg/L
- actual alum dose = 80 mg/L (verified by drawdown method)

v. **chemical feed location:**
- observed poor dispersion & short-circuiting → moved alum injection to inlet of 1<sup>st</sup> mix chamber
- polymer feed re-started at 0.02 mg/L at 2<sup>nd</sup> mix tank (pin floc)
**Results:** within 4 hours, treatment process recovered and stable

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**Anytown: the Case**

**Thursday, Dec. 8 (Day 11)**

- 6:00 am – treatment process recovered and stable
- daily bacteriological samples clear
- Boil Water Advisory finally lifted on Thursday, December 8th

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**Anytown: what actually happened?**

**Perfect storm!** higher plant loads during previous week (main break, flushing); Alum dose was at low end of operating range & actual dosage much lower than SCADA indication; change in raw water quality (organic & particle loading) requiring much higher alum dose. Operator did not have accurate knowledge of actual coagulant dose & misleading jar test results.

coagulation failure $\rightarrow$ DAF clarifier failure $\rightarrow$ filter turbidity breakthrough $\rightarrow$ UV shutdown

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**Anytown: the Case**

**Operator lessons learned**

1) raw water monitoring to detect significant changes
2) use of “ideal” settling test for clarification performance
3) coagulation “road map” to determine dose/pH for all raw water conditions
4) accurate jar test procedure & training
5) verification & cross-check of coagulant dose (drawdowns, manual calc.)
6) review coagulant & polymer application points (mixing, short circuiting)
7) Be aware of SCADA interlocks and controls!
8) QA/QC measures for key process indicators (eg. cross-checks)
9) Public health advisory “triggers”: process thresholds for safe drinking water
10) Apply key treatment principles & careful troubleshooting $\rightarrow$ team!
Questions to Ponder

- Would your system have been able to respond any differently to these circumstances?

- Do you have the capability to run your system effectively in manual mode when SCADA problems/challenges arise?

- Are operational staff able to verify and cross-check chemical feed rates regardless of what instrumentation indicates (e.g., draw-down testing)?

- Do you have an optimal coagulation “road map” to guide operators for all potential raw water conditions?

Questions to Ponder

- Do you have an accurate jar test procedure & operator training for use in process troubleshooting?

- Do you have a list of critical water customers (e.g., hospitals, institutions) that might be affected by loss of a water supply?

- Do you have key staff resources available to respond during extended emergencies (cover-off, worker fatigue)?

- Do you have a networking arrangement to allow for assistance from other water utilities during emergencies?
Ask the Experts

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Bookstore Resources

- **Ensuring Safe Drinking Water: Learning from Frontline Experience with Contamination**
  - Catalog No. 20752

- **M12 Simplified Procedures for Water Examination, Sixth Edition**
  - Catalog No. 30012-6E

- **M56 Nitrification Prevention and Control in Drinking Water, Second Edition**
  - Catalog No. 30056-2E

- **AWWA C651-14 Disinfecting Water Mains**
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Presenter Biography Information

Brian Jobb has over 30 years of experience in drinking water research, troubleshooting, technical advisory and training. He has worked for several public and private-sector organizations and has managed the Walkerton Clean Water Centre’s Training Institute since 2008. Brian has been actively involved in the AWWA for three decades; he served as Chair of the Ontario Section AWWA (OWWA) in 2004-05 and was the recipient of the OWWA Norman J. Howard Award for sincerity in serving the industry. Brian is Chair of the AWWA Small Systems Division, Continuing Education Committee and was the recipient of the AWWA SSD Soaring to the Summit Award in 2013. Brian has led the development of Ontario’s mandatory and specialized training courses and he also delivers courses for operators and decision-makers. He has successfully distilled state-of-the-art research into practical concepts and coached numerous drinking water operators through the maze of modern treatment techniques.

Ian Douglas has 25 years of experience in design, research and plant operations. For the City of Ottawa, he has worked on more than 50 research and optimization projects with the Water Research Foundation, Natural Sciences & Engineering Research Council of Canada, Health Canada, and a number of Canadian universities. Ottawa has become a leader in process optimization and applied research. In 2010, he was appointed as an Adjunct Professor in the Department of Civil Engineering at the University of Toronto.

Professor Hrudey has maintained a diverse, interdisciplinary career in the environmental health sciences and risk management. He has been recognized with a number of major awards including a Queen Elizabeth II Diamond Jubilee Medal from the Royal Society of Canada for service to scholarship in science, the top research award (2012 A.P. Black Award) of the American Water Works Association and the 2013 Research Excellence Summit Award of the Association of Professional Engineers and Geoscientists of Alberta (APEGA). In April 2016 he will become President of APEGA the 75,000-member agency that self-regulates these applied science professions. Professor Hrudey has published extensively in both academic and public venues having co-authored or edited 10 books, including the widely acclaimed 2004 IWA book inspired by the Walkerton tragedy: Safe Drinking Water – Lessons from Recent Outbreaks in Affluent Nations and the 2014 AWWA book: Ensuring Safe Drinking Water – Learning from Frontline Experience with Contamination; 27 book chapters, and 180 refereed journal articles. Professor Hrudey service to expert panels includes the Research Advisory Panel to the Walkerton Inquiry (2000-2002), the Expert Panel on Safe Drinking Water for First Nations in Canada (2006) and Chair of an international expert panel on disinfection by-products and bladder cancer in Washington, D.C. (2014-15) for the Water Research Foundation (WRF).

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