Chlorine: the Achilles Heel?

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Cohasset Water Dept.

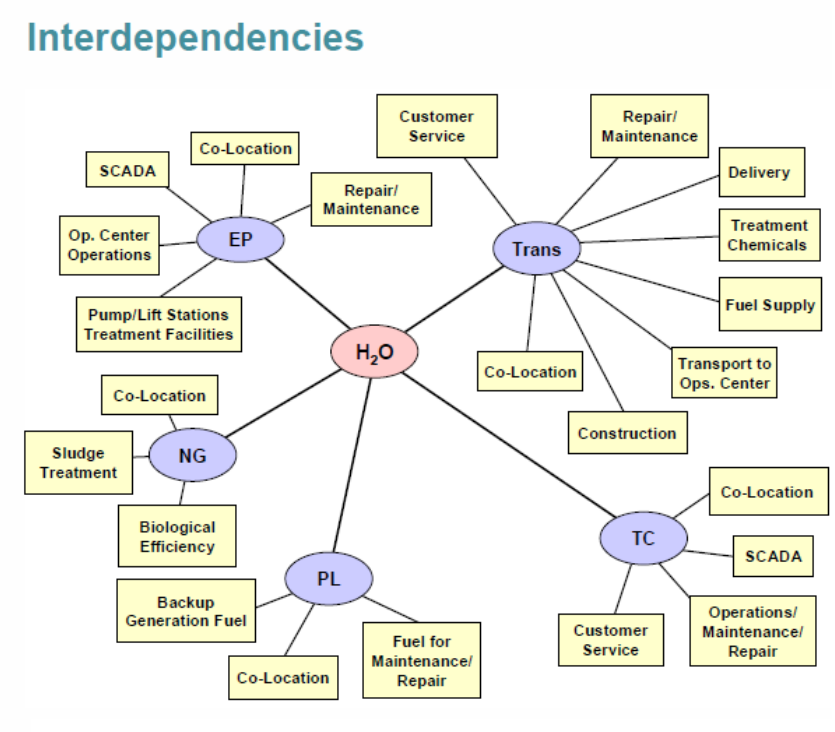
- I have been an elected Water Commissioner in Cohasset, Mass. Since 1997. Just reelected to 5th term.
- We serve about 7,000 residents, 2,500 accounts, 400 hydrants, 750 valves, 2 tanks, 1 wellfield, 2 reservoirs. Lily Pond Water Treatment Plant uses conventional filtration, fluoridation, and chlorination.
- I am not an “expert” on water infrastructure security; this is more an essay than a formal analysis.
- From 1999-Jan. 2009 I worked for Clean Water Action.
- Now I work in IT security, where responsible disclosure of potential threats, not ‘security by obscurity” is the preferred method.

Cohasset – security measures

- Vulnerability assessment as required
- Fences & gates
- Locks
- Alarms, especially on storage tanks
- Motion detectors
- Video surveillance
- Isolate SCADA from the internet
- We think we've done everything that is reasonably necessary.

Water system interdependencies

- But, the protection of our water system depends also on may factors outside of our control
- The treatment chemicals we use is a critical factor.

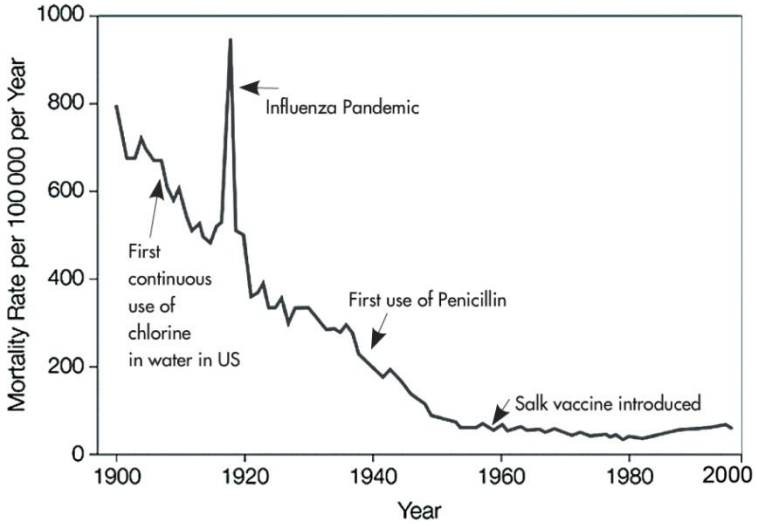


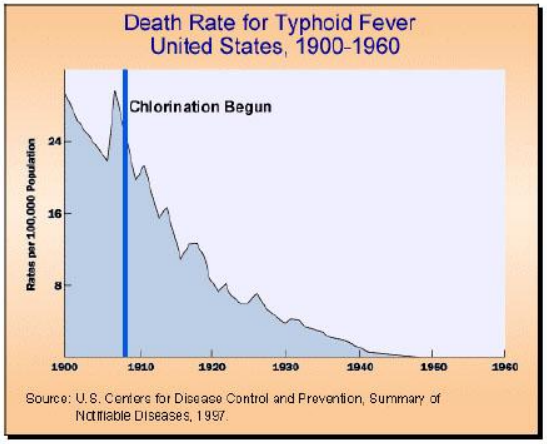
Disinfection	Large Systems (>10,000 persons)	Small Systems (<10,000 persons)
Chlorine Gas	84%	61%
Sodium hypochlorite	20	34
Calcium hypochlorite	<1	5
Chloramines	29	-
Ozone	6	-
UV	-	-
Chlorine dioxide	8	-

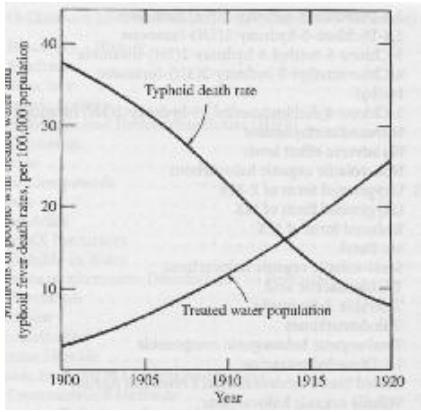
Source - American Water Works Association (1998 data)

Chlorine - Positives

- Chlorination of drinking water is one of the top 5 engineering accomplishments of the modern age.
- Chlorination of the US drinking water supply wiped out typhoid and cholera, and reduced the overall mortality rate in the US.

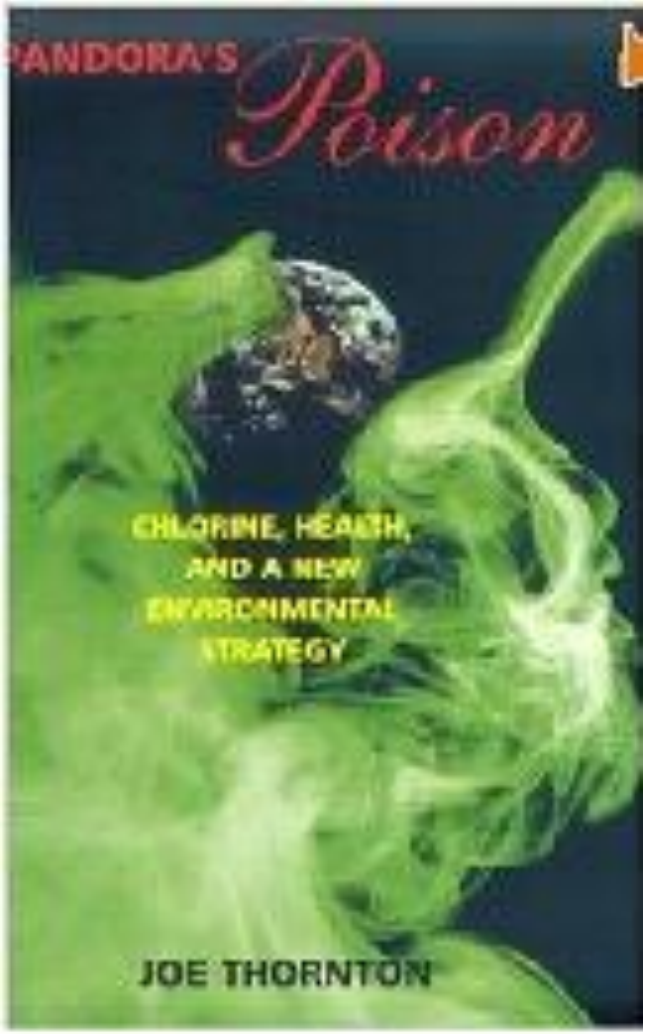






Chlorine - Negatives

- Chlorine is very toxic, used as weapon in WWI.
- Disinfection Byproducts (DPBs)
- Occupational exposure on the job
- Chlorine explosions on site at the plant
- Terrorist use of chlorine as an explosive
- Vector of attack?



Chlorine Explosions & Accidents

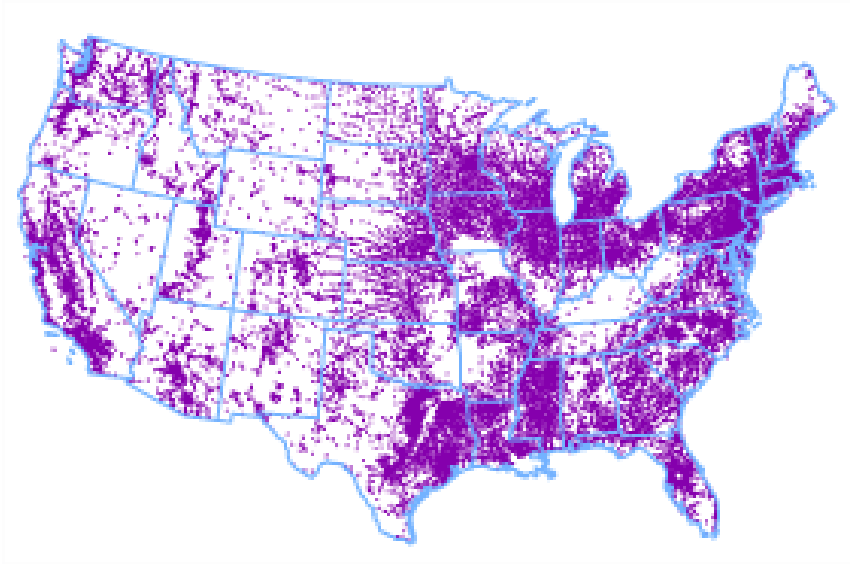
- The Chlorine Institute estimates a chlorine tanker terrorist attack could release a toxic cloud up to 15 miles. The Naval Research Laboratory estimates this size cloud could kill or injure up to 100,000 people in under a half hour.
- In Jan 2005 a chlorine cloud was release in South Carolina when a train collided with a parked train releasing 11,500 gallons of chlorine gas, killing ten and injuring more than 250.

Al Qaeda's Modus Operandi

- They use our own systems against us.
- Take advantage of existing security vulnerabilities.
- Meticulous planning & preparation that takes years.
- They are good at applying the maxim of military strategy as defined by B.H. Liddell Hart to "concentrate your strengths against the enemies weaknesses."
- Goal: to strike terror, kill Americans, and injure the US economy.
- Have said they intend to "poison" our drinking water supply – how would they be able to do that?
- That would cause fear & terror, and materially harm the US economy.

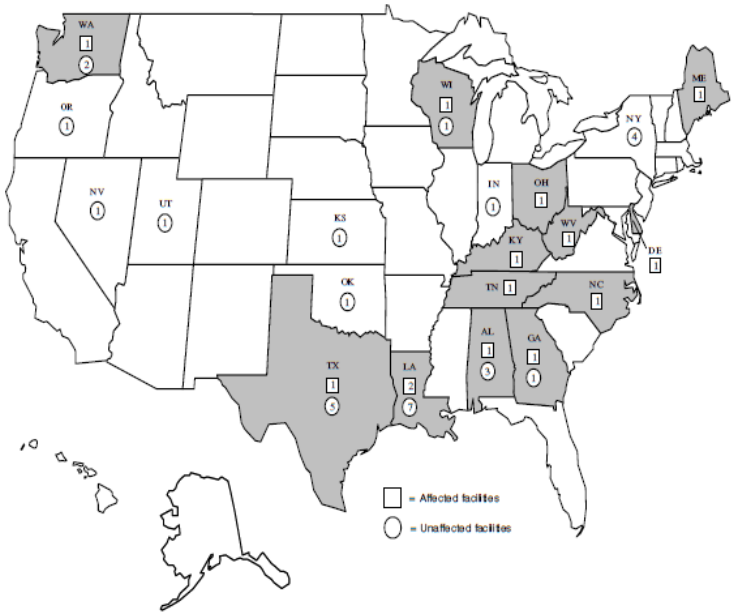
Our Strategic Advantage: Fragmentation of Water Infrastructure

- 155,693 public water systems in the United States, serving 286 million Americans.
- However, 8% of U.S. community water systems provide water to 82% of the U.S. population through large municipal water systems.
- But, that's still 12,445 systems, a lot of ground to cover.
- However, 404 large systems serve 46% of the population served by CWS; but that is still a lot to cover.
- How could all, or a significant portion thereof, be attacked at the same time in a mass attack?



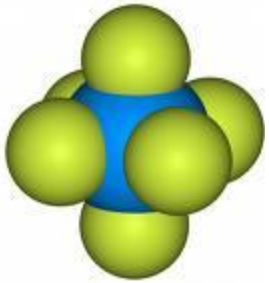
Our Strategic Vulnerability:
Concentration of Chlorine Production

- 84% of large water systems use chlorine
- Only about 43 producers of chlorine in the US
- Only about 4-6% of chlorine production used for water treatment
- Production concentrated, 38% of chlorine production is in coastal Louisiana.



Use Chlorine as Attack Vector?

- It is a potential attack vector that is not being protected against – I don't see any evidence that anyone is considering this possibility.
- Uranium Hexafluoride, a toxic radioactive gas, has been suggested as a possible contaminant.
- There are also a number of biotoxins that are chlorine-resistant, that could be used - anthrax for example.
- Chlorine plants are potentially vulnerable.
- In 2001, activists scaled the fence of a large Dow Chemical plant near Baton Rouge, Louisiana, and gained access to the control panel that regulates discharges into the Mississippi River.
- This would be a type of product tampering, which could also take place during transportation of the chlorine in rail cars or trucks.
- Chlorine tankers are vulnerable/



Chemical Agents (milligrams per liter (mg/l) unless otherwise noted)	Acute Concentration[a]	Recommended Guidelines	
	0.5 L	5 L/Day	15 L/day
Chemical Warfare Agents			
Hydrogen cyanide	25	6.0	2.0
Tabun (GA, microgram/liter (µ/l))	50	70.0	22.5
Sarin (GB , µ/l)	50	13.8	4.6
Soman (GD, µ/l)	50	6.0	2.0
VX (µ/l)	50	7.5	2.5
Lewisite (Arsenic fraction)	100-130	80.0	27.0
Sulfur Mustard (µ/l)		140.0	47.0
3-quinuclidinyl benzilate (BZ, µ/l)		7.0	2.3
lysergic acid diethylamide (LSD)	0.050		
Industrial Chemical Poisons			
Cyanides	25	6.0	2.0
Arsenic	100-130	80.0	27.0
Fluoride	3000		
Cadmium	15		
Mercury	75-300		
Dieldrin	5000		
Sodium fluoroacetate[c]		None provided	
Parathion[c]		None provided	

Biotoxin	Weaponized	Water threat	NOAEL, 2 L/day[a]	Stable in water	Chlorine tolerance[b]
Aflatoxin	Yes	Yes	75 µg/l	Probably stable	Probably tolerant
Anatoxin A	Unknown	Probable	Unknown	Inactivated in days	Probably tolerant
Botulinum toxins	Yes	Yes	0.0004 µg/l	Stable	Inactivated, 6 ppm, 20 min
Microcystins	Possible	Yes	1.0 µg/l[c]	Probably stable	Resistant at 100 ppm
Ricin	Yes	Yes	15 µg/l	Stable	Resistant at 10 ppm
Saxitoxin	Possible	Yes	0.4 µg/l	Stable	Resistant at 10 ppm
Staphylococcal enterotoxins	Probable	Yes	0.1 µg/l	Probably stable	Unknown
T-2 mycotoxin	Probable	Yes	65 µg/l[d]	Stable	Resistant
Tetrodotoxin	Possible	Yes	1 µg/l	Probably stable	Inactivated, 50 ppm

NOAEL, no-observed-adverse-effect level.
[a]Estimated as 7.5 times the NOAEL calculated for consumption of 15 L/day. [b]Ambient temperature, ≤ 1 ppm free available chlorine, 30 min or as indicated. [c]World Health Organization drinking water standard. [d]Derived from short-term U.S. Department of Defense Tri-Service standard (22)

What's a Potential Attack Scenario?

- Target 12 largest major metropolitan water systems?
- Contaminate one or more tanker trucks that deliver to one area of the country?
- Then claim all the chlorine had been contaminated; that uncertainty, especially if at least one had been confirmed, would shut down all CWS that use chlorine gas for awhile.
- Odds of this taking place are very, very low but not impossible.
- Other scenario, potentially more likely: they blow up enough chlorine tankers to reduce the amount of chlorine, which shuts down water treatment plants all across the US, as well as wreaking havoc and taking lives from the explosions and release of toxic chlorine gas.

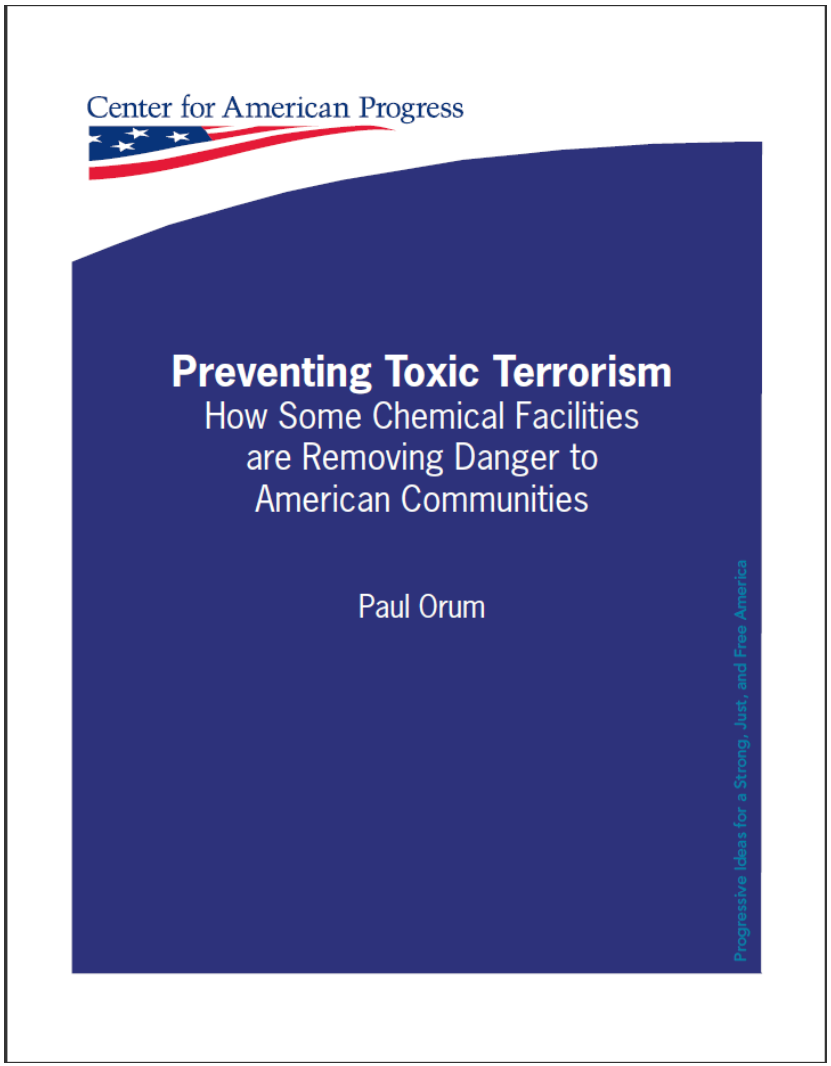
Chlorine Alternatives?

- There are alternatives to chlorine, with pros and cons for each.
- Cost and effectiveness are key factors, as well as the effects on water quality.
- Changing disinfectants doesn't eliminate risk, just changes it.
- Diversification of the disinfections used nationally, as much as is feasible, would help reduce this strategic vulnerability.

Chlorine Gas	- Highly effective against most pathogens - Provides "residual" protection required for drinking water -Operationally the most reliable - Generally the most cost-effective option	- Byproduct formation (THMs, HAAs[1]) - Special operator training needed - Additional regulatory requirements (EPA's Risk Management Program) - Not effective against Cryptosporidium
Sodium hypochlorite	- Same efficacy and residual protection as chlorine gas - Fewer training requirements than chlorine gas - Fewer regulations than chlorine gas	- Limited shelf-life - Same byproducts as chlorine gas, plus bromate and chlorate - Higher chemical costs than chlorine gas - Corrosive; requires special handling
Calcium hypochlorite	- Same efficacy and residual protection as gas - Much more stable than sodium hypochlorite, allowing long-term storage - Fewer Safety Regulations	- Same byproducts as chlorine gas - Higher chemical costs than chlorine gas - Fire or explosive hazard if handled improperly
Chloramines	- Reduced formation of THMs, HAAs - More stable residual than chlorine - Excellent secondary disinfectant	- Weaker disinfectant than chlorine - Requires shipments and use of ammonia gas or compounds - Toxic for kidney dialysis patients and tropical fish
Ozone	- Produces no chlorinated THMs, Haas Fewer safety regulations - Effective against Cryptosporidium - Provides better taste and odor control than chlorination	- More complicated than chlorine or UV systems - No residual protection for drinking water - Hazardous gas requires special handling - Byproduct formation (bromate, brominated organics and ketones) - Generally higher cost than chlorine
UV	- No chemical generation, storage, or handling - Effective against Cryptosporidium - No known byproducts at levels of concern	- No residual protection for drinking water - Less effective in turbid water - No taste and odor control - Generally higher cost than chlorine
Chlorine dioxide	- Effective against Cryptosporidium - No formation of THMs, Haas - Provides better taste and odor control than chlorination	- Byproduct Formation (chlorite, chlorate) - Requires on-site generation equipment and handling of chemicals - Generally higher cost than chlorine

Alternatives Are Being Adopted

- Since 9/11 many water systems have considered changing from chlorine.
- There have been many chlorine railcar accidents that have also raised the question.
- The Association of American Railroads has called for adoption of less toxic alternatives.
- This report cited 166 water systems that have switched from chlorine liquid bleach, reducing the risk of accidents from rail transport of chlorine for 33 million people, and 42 who switched to UV.
- Cost to switch from chlorine was estimated at $1.50 per person served.



Final Thoughts

- The US government should encourage and pay for reducing the use of chlorine in water treatment as much as possible in next 10 years.
- Chlorine manufacturing facilities and means of transportation need to be better regulated and hardened.
- This potential vector of attack needs to be researched and reported on by Homeland Security, with further regulatory controls as deemed necessary.

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