Adherence of Chemical, Biological, and Radiological Contaminants to Sediments Found in Water Storage Tanks

INTRODUCTION [1, 2]

Many large and small drinking water distribution systems store treated water in storage tanks. The tanks serve as primary water sources or as reserves for emergency water use. Tanks also help equalize water demand and maintain pressure in the distribution system.

Unless used frequently or cleaned regularly, a substantial build-up of sediments can occur in tanks. The sediments can contain material that has sloughed off from corroded tank linings or material brought into the tank from the source water. Although rare, waterborne illnesses have resulted from organisms introduced into the tank when open vents, hatches, or inadequate covers allow matter, birds, or other animals to gain access.

The type and quantity of sediments varies widely depending on many factors including the amount of water passing through the tank, the characteristics of the water, the amount of mixing the water receives, and the tank's maintenance schedule.

Sediment accumulation can impact water quality and potentially cause health concerns. Direct monitoring of the tank water itself might not detect potential problems because chemicals or microorganisms can adhere to sediments or biofilm (the communities of microorganisms attached to a surface.)

In addition to the concerns about the impact of sediments on water quality, sediments can serve as sinks for chemical, biological, or radiological agents if the distribution system becomes contaminated. The presence of these contaminants on sediment materials would require special decontamination and disposal practices following intentional or unintentional contamination incidents.

SEDIMENT ADHERENCE INVESTIGATION [2]

To help define the potential difficulties involved in remediating water tanks if they became contaminated with CBR agents, the United States Environmental Protection Agency conducted a study to determine the extent to which contaminants adhered to tank sediments. The study involved donated sediment and drinking water samples collected from 25 tanks located in 12 different states. The tanks contained finished water that originated from both ground and surface water sources.

The amounts collected and the characteristics of the sediments varied widely. Eight of the samples contained enough water and sediment to use in the contaminant adherence study.

This study tested the adherence of four contaminants:

- Nonradioactive cesium (Cs-133), which acted as a surrogate for radioactive Cs-137
- Lindane, an organochlorine pesticide
- *Escherichia coli* (*E. coli*, strain K-12)
- *Bacillus anthracis* Sterne (*Ba*S)

B. anthracis Sterne acted as non-virulent surrogate for pathogenic *B. anthracis*. *E. coli* is a bacterium of interest to the drinking water community since it has been linked to disease outbreaks. The K-12 strain used in this study is non-virulent.

The small range of pHs in the storage tank water made pH an unlikely significant variable; however, for consistency, all the water used for adherence tests was adjusted to pH 7.5 and 8.5.

Researchers characterized the sediment samples by particle size, pH, total exchange capacity, percent total organic carbon, and percent organic matter. Table 1 presents the basic properties of the sediments.

Table 1. Characteristics of the Study Sediments Collected From Drinking Water Tanks

Drinking Water Tank Location [a]	Particle Size			pH	Total Exchange Capacity (mmol/L/100g)	Total Organic Carbon %	Organic Matter %
	Clay %	Silt %	Sand %				
Alabama	2.73	2.33	94.94	7.8	12.2	0.42	0.88
Arizona	7.35	34.34	58.31	6.7	154.14	9.42	4.08
Arkansas	3.91	14.44	81.65	6.7	12.17	2.78	11.45
North Carolina	7.63	23.39	68.98	7.6	110.8	3.11	5.45
Ohio 1	1.36	6.7	91.94	7.1	26.7	0.25	0.89
Ohio 4	1.68	21.67	76.65	6.6	57.34	2.09	5.9
Tennessee	0.4	1.06	98.54	8.2	3	0.42	0.43
Illinois	41.68	21.39	36.93	7.6	9.66	1.69	16.52

[a] The location name was used to identify the sediment.

RESULTS FOR CESIUM AND LINDANE [2]

Prior to beginning the adhesion study, researchers tested the sediments for background levels of nonradioactive Cs-133 and lindane. Samples Alabama, Arizona, Arkansas, and Ohio 4 contained Cs-133 at levels ranging from 0.3 to 0.4 µg/kg. Researchers considered the background concentrations too small to interfere with the adherence experiments results.

At the beginning of the adhesion study, researchers spiked the drinking water samples with Cs-133 or lindane and adjusted to pH 7.5 and 8.5. They placed measured portions of the sediments into centrifuge tubes and added the contaminated (i.e. spiked) water. They rotated the tubes for 16 hours at room temperature (22 to 24 °C). Following the 16 hours of contact the researchers tested the water and sediments and calculated percent adherence. Table 2 presents the results.

The average cesium adherence ranged from 5% to 88%. The average adherences for lindane ranged from 7% to 88%. As expected, the small range in pH had no statistical significance in adherence.

Table 2. Average Adherence to Sediments for Cesium-133 and Lindane at pH 7.5 and 8.5

Sediment	pH	Cesium Average % Adherence	Cesium % SD	Lindane Average % Adherence	Lindane % SD
Alabama	7.5	38	5	37	1
	8.5	32	6	31	6
Arizona	7.5	58	6	86	2
	8.5	57	6	83	1
Arkansas	7.5	88	3	41	2
	8.5	82	2	43	10
North Carolina	7.5	20	1	40	7
	8.5	21	2	27	12
Ohio 1	7.5	67	5	87	0
	8.5	60	8	88	0
Ohio 4	7.5	28	6	39	3
	8.5	11	5	44	2
Tennessee	7.5	5	5	7	1
	8.5	9	1	7	2
Illinois [a]	7.5	20	11	27	3

[a] Sample size was insufficient to also run tests at pH 8.5.

RESULTS FOR *E. COLI* AND *B. ANTHRACIS* STERNE [2]

Prior to beginning the adherence study, researchers determined that the sediments contained no viable background concentrations of *E. coli* or *BaS*.

At the beginning of the adherence study, researchers spiked drinking water samples with *E. coli* or *BaS* at relatively high densities of about10^6 colony forming units per ml and adjusted to pH 7.5 and 8.5. They placed measured portions of the sediments in centrifuge tubes and added the contaminated water and rotated the tubes for 6 hours at 2 to 8 °C.

Following the 6 hours of contact, researchers used tryptic soy agar enumeration to determine the concentration of organisms in the sediments.

Researchers did not sterilize the samples and soy agar is a non-specific culture media, so the non-diluted rinse from several of the sediment samples produced flora colonies when plated. The colonies did not, however, demonstrate morphologies consistent with *E. coli* or *BaS*. With each adherence experiment, researchers also rotated a sediment sample with uncontaminated tank water and plated the resulting solution at a tenfold dilution. These dilutions produced no growth of *E. coli*, *BaS*, or any other background microorganism.

Table 3 presents the adherence results for *E. coli* and *BaS.*

All adherences for *E. coli* were greater than 50% except for the pH 8.5 Ohio 1 (27%) and pH 7.5 (42%) Illinois samples. All *BaS* samples had average adherences greater than 90%, except the Tennessee (86% at pH 7.5 and 82% at pH 8.5) and North Carolina samples (31% at pH 7.5 and 49% at pH 8.5).

Overall, pH differences in the contaminated drinking water were within the experimental uncertainty of the measurements, thus no significant differences could be observed. However, the *E. coli* adherence in the Ohio 1 sample showed a significant difference between pH 7.5 and 8.5; and the *BaS* adherence in the North Carolina sample showed a significant difference between pH 7.5 and 8.5.

Table 3. Average Adherence to Sediments for *E. coli* and *B. anthracis* Sterne at pH 7.5 and 8.5

Sediment	pH	*E. coli* Average % Adherence	*E. coli* Δ% A	*B. anthracis* Sterne Average % Adherence	*B. anthracis* Sterne Δ% A
Alabama	7.5	76	4	91	32
	8.5	72	27	92	13
Arizona	7.5	79	17	98	17
	8.5	77	18	98	15
Arkansas	7.5	100	20	100	18
	8.5	99	121	100	22
North Carolina	7.5	66	39	31	5
	8.5	78	21	49	9
Ohio 1	7.5	72	36	93	72
	8.5	27	3	99	28
Ohio 4	7.5	85	27	99	23
	8.5	88	28	99	33
Tennessee	7.5	54	6	86	11
	8.5	54	2	82	20
Illinois [a]	7.5	42	18	98	33

NOTE. — Δ% A = combined experimental uncertainty.

[a] Sample size was insufficient to also run tests at pH 8.5

CONCLUSIONS [2]

Experimental conditions optimized the amount of contact between the sediments and contaminated drinking water through centrifugation (cesium and lindane) and settling (*E. coli* and *BaS*), so that potential adherence could be observed. In a water storage tank, the degree of contact will depend on conditions in the tank, as well as characteristics of the contaminants and the sediments.

In general, the biological contaminants adhered more readily than the chemical contaminants. Overall, pH differences in the contaminated drinking water were often within the experimental uncertainty of the measurements, thus no significant differences could be observed.

The results of this investigation suggest that when sediment is present, chemical and biological contaminants may adhere to the sediment.

CONTACT INFORMATION

For more information, visit the EPA Web site (http:// www2.epa.gov/homeland-security-research).

Technical Contact: Jeff Szabo (szabo.jeff@epa.gov)

General Feedback/Questions: Kathy Nickel (nickel.kathy@epa.gov)

If you have difficulty accessing this PDF document, please contact Kathy Nickel (Nickel.Kathy@epa.gov) or Amelia McCall (McCall.Amelia@epa.gov) for assistance.

REFERENCES

[1] U.S. EPA. 2002. *Finished Water Storage Facilities*. (Total Coliform Rule, Distribution System Issue Paper.) Washington DC: US EPA, Office of Water.

[2] U.S. EPA. 2014. *Adherence of Chemical, Biological, and Radiological Contaminants to Drinking Water Storage Tank Sediment.* Washington, DC: U.S. Environmental Protection Agency. EPA/600/R-14/222

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