Persistence of Biological and Radiological Contaminants on Wastewater Collection System Infrastructure

Introduction

The U.S. Environmental Protection Agency's (EPA's) Homeland Security Research Program (HSRP) conducts research to detect, respond to, and recover from terrorist attacks on the nation's dinking water and wastewater infrastructure. The studies summarized in this technical brief were meant to be the first step in understanding biological and radiological contaminant persistence in sewer systems.

In the event of contamination of a drinking water distribution system with a biological agent, flushing the system to remove the contaminant could result in contamination of the sewer system. In addition, contamination of an outdoor area or a building exterior with a biological agent could result in contamination of the sewer system from wash down activities or rain events. Similarly, contamination from a radiological dispersal device, improvised nuclear device or nuclear power plant accident could result in radioactive contamination entering a wastewater or stormwater collection system, also from wash down activities or rain events.

There are open questions regarding environmental contamination by biological agents like pathogenic *Bacillus anthracis* spores, which cause the disease anthrax, and which are hardy and resistant to inactivation in the environment. First, would spores adhere to and persist on persist on wastewater infrastructure? Second, if they persist, can spores be removed from the infrastructure via the normal flow in a sewer system or via disinfection? The same questions arise with radionuclides such as cesium, strontium and cobalt, which are used in products that people use every day. To determine the adherence of biological and radiological agents on wastewater infrastructure, samples of materials (i.e., coupons) commonly used in the composition of wastewater systems were exposed to flowing wastewater containing contaminants. The contaminants tested were non-radioactive simulants or a nonpathogenic surrogate for *B.anthracis.* After determining the amount of adhered contaminant, the coupons were exposed to flowing uncontaminated wastewater to determine if it would remove the contaminant that had adhered to the coupons. Data from this summary is intended to help wastewater utility employees and emergency responders make decisions about how to manage contaminated water after a biological or radiological incident, and potentially remediate contaminated infrastructure.

Experimental Design

Experiments were conducted at the EPA's Test and Evaluation Facility in Cincinnati, Ohio. The pilot scale system used was the secondary effluent test bed channels (SETBC) (Figure 1). The SETBC consists of six 6-inch (15.2 cm) diameter PVC pipes arranged horizontally with the upper section of the pipe removed, which allowed access to the open channel flow in the pipes. Unchlorinated secondary treated effluent was pumped from the adjacent Metropolitan Sewer District of Greater Cincinnati's 100 million gallons per day (mgd) (378.5 million liters per day) Mill Creek Wastewater Treatment Plant and into a manifold where flow was distributed to each pipe. Unchlorinated secondary treated effluent served as the wastewater in this study. Although secondary treated effluent is lower in solids and biological activity than raw sewage, it is more consistent in quality and more amenable to pumping through the SETBC channels. Its consistency is similar to diluted raw sewage, which occurs when rainwater enters a sewer system. Flow rates in each of the six SETBC pipe was adjusted to approximately 50 gallons per minute (gpm) (189.2 liters per minute). Each of the six PVC pipes has its own flow control valve, two sections of fabricated horizontal open grids to mount test material coupons, an injection port, and a flow monitoring sensor and a data logger.

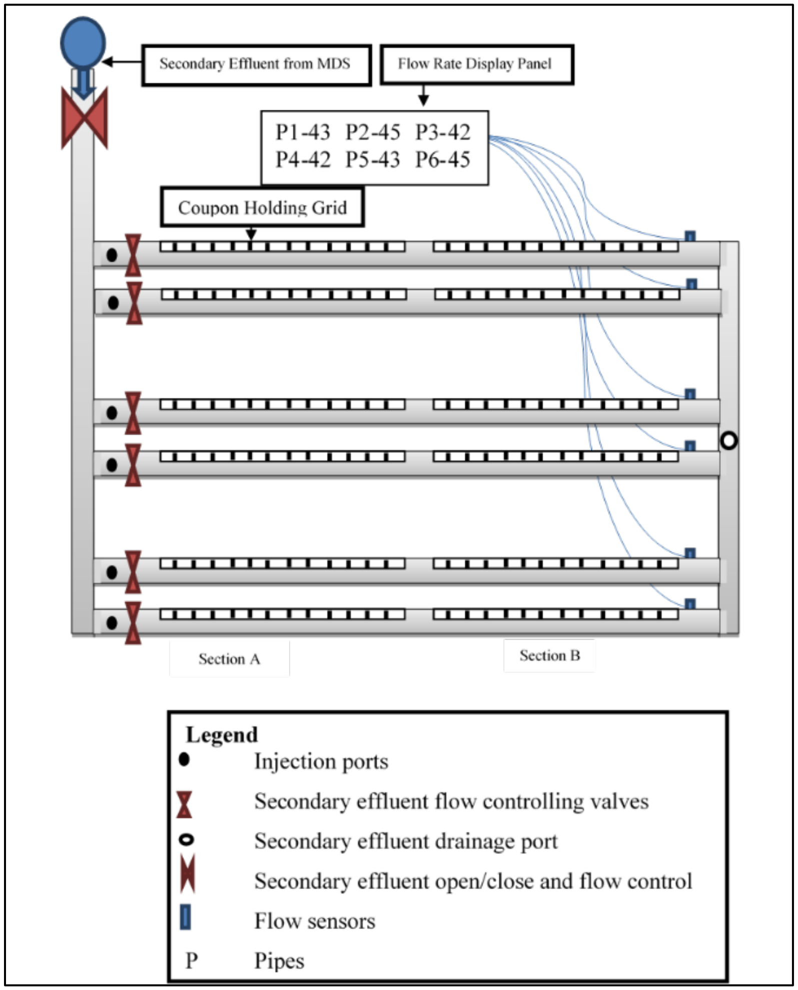

Figure 1:The SETBC show in schematic form (left) and an image of the SETBC pipes (right).

Collection system infrastructure coupons were randomly placed amongst the six channels, but each material was represented in equal numbers in each channel. Each coupon was mounted so that the face of the coupon was parallel to the direction of the water flow. Coupons were conditioned in unchlorinated secondary treated effluent for two months with flow at approximately 50 gpm in each channel.

Figure 2: Close up images of the sewer infrastructure coupons used in the SETBC

Radionuclides were simulated using non-radioactive cesium, strontium or cobalt salt solutions, which were introduced through the injection ports in each pipe to achieve a target concentration of 5 mg/L of the metal ion in the flow. Non-pathogenic *Bacillus globigii* spores were used as a surrogate for *B.* anthracis and were injected into each pipe at a flow rate calibrated to achieve a target *B. globigii* concentration of approximately 10^5 colony forming units/mL.

Coupons of each material were harvested in pairs after injection in order to determine the adherence of contaminants. The coupons were then returned to the SETBC and “clean” wastewater was allowed to flow through the system. The coupons were again removed after various time periods and sampled to determine the amount of contamination removed by the flowing wastewater. Sampling timeframes varied and are further discussed in the results.

Biological Contaminants

Data from these studies suggest that flowing sewage removes 2 to 4 log spores from all coupon materials tested except iron. Log removals of 3.2 and 3.4 via water flow were observed after 14 days of flow after injection for the high density polyethylene and concrete coupons. Flow removed 1.9, 2.3 and 2.7 log of the adhered viable spores from PVC, rubber and clay coupons, respectively, at 14 days of exposure. At 42 days of exposure to secondary effluent flow, log removals of 3.7, 3.8 and >4.0 were observed for PVC, clay and rubber coupons. No spores were detected on the polyethylene or concrete coupons at 42 days. Results using brick coupons were variable and inconclusive.

Spores were observed to remain adhered to the iron coupon above background levels for at least 42 days after injection. Log removal due to sewage flow was 1.2 at day 14 and 1.5 at day 42. Persistence on iron might be due to corrosion products on the surface of the iron impeding the flow from removing the adhered spores.

An attempt to decontaminate the remaining adhered spores was made by introducing free chlorine to the secondary effluent wastewater flow for a period of five minutes. Secondary effluent may represent a dilute raw wastewater, but it still exerted a large free chlorine demand. When enough free chlorine was added to achieve 10 and 25 mg/L in the secondary effluent, no chlorine was detected in the flow. When enough chlorine was added to achieve 50 mg/L in the secondary effluent by dilution, only 27 mg/L was detected. This demand is due to the organic and inorganic compounds in the secondary effluent and would likely be more pronounced in raw wastewater. Adding chlorine to disinfect *B. globigii* spores adhered to wastewater infrastructure coupons was not an effective decontamination method.

Should *Bacillus* spore contamination flow into a sewer during a real contamination event, the data show that most of the spores will flow with the water. Spores that do adhere to infrastructure do so in a largely transient manner, and most are washed off the infrastructure material in the days after the contamination event. There could be spores adhered to the infrastructure for at least 42 days on clay, PVC, rubber and especially on iron, where the spores were most persistent. It is possible that spores might persist longer, but times frames beyond 42 days were not addressed in this project. Adding chlorine to a wastewater system to decontaminate spores is ineffective.

Future work should examine the efficacy of other disinfectants such as chloramines or peracetic acid, which may not degrade as quickly in wastewater as free chlorine. Alternatively, levels of free chlorine above 50 mg/L could also be tested, or the amount of contact time at 50 mg/L could be increased. However, users of this data must also consider that adding chlorine to wastewater in a sewer may have unintended consequences, such as formation of disinfection by products through reaction with organic matter, or trapped chlorine vapors in the collection system.

Radiological Contaminants

This study focused on adding non-radioactive cesium, strontium and cobalt salt solutions to the flow and determining their persistence on the coupons. The data suggested that cesium and cobalt were not detectable on the collection system infrastructure coupons used in this study. Similar results were found with strontium, but results were more difficult to interpret since strontium was inherent in some coupon materials such as concrete. It is possible that some cesium, cobalt or strontium was present on the coupons, but the instrumentation used in this study was not sensitive enough to detect them. It should also be noted that the data in this study is applicable to straight runs of pipe. The coupons used in this study are not designed to replicate pipe bends or elbows.

In the future, it would be beneficial to repeat the experiments described in this report with radioactive cesium, cobalt, and/or strontium. Past studies examining the persistence of radioactive cesium on infrastructure materials in a drinking water environment did find some residual activity after flushing the surfaces with clean water and other decontamination techniques. Repeating the experiments presented in this report with real radionuclides would help determine if a small fraction of cesium, strontium or cobalt do adhere to the infrastructure coupons, but could not be detected with the analytical techniques used in this study. Still, the results of this study suggest that the vast majority of the cesium, cobalt or strontium washed into a wastewater collection system would not persist on the infrastructure, with dissolved material traveling with the flow to a combined sewer outfall or wastewater treatment plant.

Bibliography

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