Chemical Technology Division

**RESULTS OF SMALL-SCALE TESTS FOR REMOVING MERCURY
FROM ORNL PROCESS WASTEWATER**

P. A. Taylor and K. T. Klasson
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OAK RIDGE NATIONAL LABORATORY
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CONTENTS

LIST OF FIGURES	v
LIST OF TABLES	v
ABSTRACT	1
1. BACKGROUND	2
2. MATERIALS AND METHODS	3
2.1 Column Tests	3
2.2 Batch Precipitation Tests	5
2.3 Sampling and Filtration Tests	5
3. RESULTS	7
3.1 Column Tests	7
3.2 Batch Precipitation Tests	11
3.3 Sampling and Filtration Tests	12
3. CONCLUSIONS	14
4. REFERENCES	14

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1 Flow diagram for the Process Wastewater Treatment Complex facilities	2
2 Flow diagram of mercury test unit	4
3 Flow diagram of wastewater manholes sampled	6
4 Mercury effluent concentrations for sorbent tests in August 1997	8
5 Mercury effluent concentrations for sorbent tests in early 1998	9
6 Effect of chlorination on mercury removal by selected sorbents	10

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 Summary of mercury concentrations for the first pilot-scale test at PWTC-3608	7
2 Results for various treatments in batch precipitation tests	11
3 Average mercury concentrations and loadings at PWTC-3608 and PWTC-3544	12
4 Average mercury concentrations and loadings at process wastewater manholes	13

ABSTRACT

Oak Ridge National Laboratory (ORNL) received a new National Pollutant Discharge Elimination System (NPDES) Permit from the state of Tennessee in 1997. This permit reduced the limit for mercury in the effluent from the Process Wastewater Treatment Complex—Building 3608 (PWTC-3608) to 19 ppt for the monthly average, which is well below the current effluent concentration. The mercury limit is being appealed, so it is not currently being enforced, but experimental work is being done to determine if it is possible to meet this new limit. Various mercury sorbents were evaluated in small, continuous-flow columns. The first set of sorbent tests that were conducted at PWTC-3608 in August 1997 showed excellent mercury removal by the Forager Sponge, even at high flow rates. Subsequent tests, however, showed that the mercury removal efficiency of the sorbents varied considerably over time, probably as a result of changes in the form of the mercury in the wastewater. A significant portion of the mercury in PWTC-3608 water was bound to small particles during the later tests, which made the mercury less accessible to the sorbents. Chlorination of the water, which could convert the bound mercury to an ionic form, improved the performance of some of the sorbents.

Initial tests using various precipitation methods that could be incorporated into the existing equipment at PWTC-3608 appear promising, but additional studies will be needed before the costs and benefits of these processes can be determined.

Samples were obtained periodically from process wastewater manholes 157, 158, 171, 159, and 190, which collect flows from the central portion of ORNL. The results showed that the small wastewater flows from Buildings 4501 and 4505 (7 to 11 L/m), manholes 157 and 158 respectively, contain a large portion of the mercury that is present downstream at manhole 190, where the flow rate averaged 810 L/m.

1. BACKGROUND

Oak Ridge National Laboratory (ORNL) received a new National Pollutant Discharge Elimination System (NPDES) Permit from the state of Tennessee in 1997. This permit reduced the limit for mercury in the effluent from the Process Wastewater Treatment Complex—Building 3608 (PWTC-3608) to 19 ppt for the monthly average, which is well below the current effluent concentration. The mercury limit is being appealed, so it is not currently being enforced, but experimental work is being done to determine if it is possible to meet this new limit. Most of the influent to PWTC-3608 is collected in the nonmetals tank and is treated by filtration using dual-media columns, air stripping, and columns containing granular activated carbon (GAC) prior to discharge (see Fig. 1). Backwash water from the filtration and GAC columns, plus other metal-containing wastewaters, are collected in the metals tank and treated by precipitation, flocculation, and settling before being combined with the main wastewater flow at the filters. The activated-carbon columns at PWTC-3608 provide most of the mercury removal for the current flowsheet.

Fig. 1. Flow diagram for the Process Wastewater Treatment Complex facilities.

To improve the efficiency and reduce the cost of process wastewater treatment at ORNL, it is being proposed that PWTC-3608 be retrofitted with a zeolite system for removal of radioactive strontium (^{90}Sr) and cesium (^{137}Cs). The Process Wastewater Treatment Complex—Building 3544 (PWTC-3544), which currently treats radioactively contaminated wastewater by chemical precipitation (softening) and ion exchange to remove ^{90}Sr , would be shut down. This modification would eliminate 19,000 L of nitric acid regenerant solution annually from PWTC-3544, a mixed (hazardous and radioactive) waste, which represents 40% of the total annual volume of liquid radioactive waste concentrate generated at ORNL. PWTC-3608 has three GAC columns, two in service and one on standby. The retrofit would involve using two of these columns for treating ^{90}Sr and ^{137}Cs , using granular chabazite zeolite, which is a nonregenerable, inorganic sorbent with high selectivity for strontium and cesium. If only one of the GAC columns is used for treating PWTC-3608 wastewater, the quantity of mercury discharged to White Oak Creek will roughly double as compared with the current mercury discharges using two GAC columns in series. Therefore, the zeolite retrofit must include an additional process to improve mercury removal at PWTC-3608.

ORNL Waste Management and the Mixed Waste Focus Area (MWFA) of DOE's Office of Science and Technology have cofunded a series of small-scale mercury treatment tests at PWTC-3608. The MWFA funded tests of several sorbents to determine their mercury removal capabilities this year, while ORNL Waste Management funded earlier sorbent tests for mercury removal, various precipitation and sorption tests for mercury, mercury speciation analyses in the wastewater, and sampling to identify small wastewater streams with higher mercury concentrations for possible pretreatment studies.

2. MATERIALS AND METHODS

2.1 Column Tests

A portable test system was built with six glass columns (2.5 cm ID by 15 cm tall), six rotameters and valves to control the flow to each column, and a cartridge filter mounted on a plastic cart¹ (see Fig. 2). The cart was placed at PWTC-3608 and connected to a sample port for wastewater entering the GAC columns. Five sorbents can be tested simultaneously, while the sixth column is left empty as a control to check for mercury removal by the materials in the test system. Later, a 1-L mixing chamber was added prior to one of the columns, so that various pretreatments, such as mercury-binding polymers and chlorination, could be evaluated.

The first set of tests was conducted in August 1997. Five sorbents were tested: Ionac SR-3 (Sybron Chemicals, Inc., Birmingham, NJ); Keyle:X (SolmeteX Corp., Billerica, MA); Forager Sponge (Dynaphore, Inc., Richmond, VA); E-100-alpha-1 (ADA Technologies, Inc., Englewood, CO); and the GAC currently used at PWTC-3608, Cecarbon GAC-30 (Atochem, Inc., Tulsa, OK). About 60 mL of each sorbent was weighed and then placed in one of the columns. Each sorbent was tested at flow rates from 6 to 300 mL/min [0.1 to 5 bed volumes/min (BV/min)]. Each of the GAC columns at PWTC-3608 operates at a flow rate of about 0.1 BV/min. Samples were taken at each flow rate

Fig. 2. Flow diagram of mercury test unit.

after about 24 h of operation. These short-term tests were designed to determine the maximum flow rate that could be used with each sorbent to meet an effluent target but cannot determine how much water can be treated by the sorbents before breakthrough occurs. This type of test can identify the most promising sorbents, which can then be used in long-term tests to determine breakthrough curves.

Samples were analyzed for mercury by Frontier Geosciences, Inc. (Seattle, WA). The samples were oxidized with BrCl ; then an aliquot was analyzed by SnCl_2 reduction, dual gold amalgamation, and cold vapor atomic fluorescence detection.² A few samples were analyzed without using the BrCl in order to measure the chemically active (ionic and elemental) mercury, which would be readily accessible to the sorbents.

Another series of tests in the spring of 1998 used some of the sorbents listed above plus Ionac SR-4 (Sybron Chemicals, Inc., Birmingham, NJ), SIR-200 (ResinTech, Inc., Cherry Hill, NJ), and Self-Assembled Mercaptan on Mesoporous Silica (SAMMS), an experimental sorbent obtained from Pacific Northwest National Laboratory.³ The SAMMS material used in this test was the first engineered (bead) form that PNNL had produced from the SAMMS powder. The beads were larger than the other sorbents that were tested, which would reduce the sorption kinetics. New methods for making beads from the SAMMS powder are being investigated, and the best of these materials will be tested in the future. Three sorbents, GAC, Keyle:X, and SIR-200, were tested with and without chlorination of the wastewater to determine whether chlorine would oxidize the mercury to a more amenable form for the sorbents to remove. A mercury-binding chemical, trisodium trimercapto-s-triazine (TMT), was added prior to a column of GAC to determine if the TMT-mercury complex would be adsorbed more effectively by the GAC than the unreacted mercury.

2.2 Batch Precipitation Tests

A series of batch precipitation tests was performed on wastewater samples from the nonmetals tank at PWTC-3608. Various mercury-binding sorbents and complexing agents were tested, including diethyldithiocarbamate (DTC), SAMMS powder and TMT. Most of the batch tests used ferric chloride (1 mg/L as Fe) and 1 mg/L Betz-1100 (an anionic polyelectrolyte) as precipitation/flocculation agents. All of the samples were adjusted to a pH of about 8.0, using sodium hydroxide, and were then filtered through a 0.45- μ m-pore filter prior to analysis.

2.3 Sampling and Filtration Tests

The two largest individual sources of wastewater to PWTC-3608 are process water from manhole 190, where wastewater from the central part of ORNL is combined, and the effluent from PWTC-3544. Some of the pipelines carrying wastewater to PWTC-3544 are routed near known areas of mercury soil contamination, such as the areas south of Buildings 3503 and 3592, where contaminated inleakage might occur. The influent to PWTC-3544 was sampled to determine the amount of mercury entering PWTC-3544. Samples were also taken of wastewater entering PWTC-3608, as well as from various points inside PWTC-3608, to assess mercury removal by the treatment processes.

The Environmental Restoration Program has identified four main areas of mercury contamination at ORNL: Buildings 4501 and 4505, building 4508, an area south of Building 3503, and an area south of Building 3592. There are several sumps in Buildings 4501 and 4505 that discharge to PWTC-3608. Previous sampling of the water and sediment in these sumps has shown elevated levels of mercury, but the flow rate from these sumps is not known, so the mercury loading to PWTC-3608 is uncertain. There are no sumps in Buildings 4508, 3503, and 3592 that directly discharge to PWTC-3608, but there are process wastewater lines in these areas that could collect contaminated inleakage from the soil. The process waste lines from Buildings 3503 and 3592 discharge to PWTC-3544, rather than to PWTC-3608.

Samples were collected from the following process wastewater manholes: 157, 158, 171, 159, and 190 (see Fig. 3). Manhole 157 collects wastewater from Building 4501. Manhole 158 collects wastewater from Building 4505 plus the flow from manhole 157. Manhole 171, which collects the flow from Buildings 4500N and 4500S, has an automatic sampler and flowmeter installed at the manhole. The flow from manholes 171 and 158 combine at manhole 159, which also has an automatic sampler and flowmeter. By comparing the mercury concentrations and flow rates at manholes 171 and 159, it should be possible to determine the amounts of mercury coming from

Fig. 3. Flow diagram of wastewater manholes sampled.

Buildings 4501 and 4505 vs those from 4500N and 4500S. Manhole 190 contains the combined flows from manhole 159 and Building 4508. By comparing the flow rates and mercury concentrations at manholes 190 and 159, it should be possible to determine if Building 4508 contributes significant amounts of mercury.

Samples were collected from manholes 157, 158, and 190 by using a pump and a flexible suction line that was dropped down through the manhole grating and suspended in the middle of the flowing wastewater. The samples from manholes 157 and 158 occasionally contained visible suspended solids, so some of these samples were analyzed before and after filtration (0.45- μ m pore size). Samples from manholes 159 and 171 were collected using the permanently installed samplers to collect grab samples of the water. The flow rates at manholes 157 and 158 were visually estimated, while those from manholes 158, 171 and 190 were obtained from the flowmeters that automatically measure the flow using a calibrated weir.

A pilot-scale filtration test was conducted at manhole 158 to determine whether filtering the solids from the wastewater would significantly decrease the amount of mercury entering PWTC-3608. Prior to starting the filtration test, high-pressure water was used to remove most of the settled solids from the manhole and the downstream line. Sandbags were used to build a dike across part of the manhole. Water was pumped from upstream of the dike, through two filter cartridges in series, and then back to the downstream side of the dike. The goal was to filter all of the water entering manhole 158. The first filter cartridge had a pore size of 25 μ m; the second had a pore size of 1 μ m. Visual observation showed that some water was flowing through the walls of the manhole and entering downstream of the dike, but it is not known if there were any suspended solids in this water.

3. RESULTS

3.1 Column Tests

The first set of sorbent tests was conducted in August 1997. The mercury concentration in the feed to the test system varied considerably from day to day, ranging from 105 to 837 ng/L. The effluent from the test system cartridge filter (feed to the sorbent columns) varied from 107 to 682 ng/L, with the filter effluent concentration being higher than the influent on the first and last days of the test, as shown in Table 1. These results suggest that the filter can trap mercury during higher-concentration flows and then release it back into the water after the concentration decreases.

Table 1. Summary of mercury concentrations for the first pilot-scale test at PWTC-3608

Sample date	8/7/97	8/8/97	8/11/97	8/12/97	8/13/97
Flow rate (BV/min)	0.1	0.5	5.0	1.5	0.1
sample point:	Mercury concentration (ng/L or ppt ^a) at				
Filter influent	105	118	190	837	124
Filter effluent	177	107	183	682	165
Ionac SR-3 effluent	51.7	26.1	37.8	144	74.0
Forager Sponge effluent	23.4	10.0	19.3	54.5	35.5
Keyle:X effluent	158	26.1	35.7	114	73.6
ADA effluent	124	23.7	46.9	123	80.2
GAC effluent	142	27.3	52.6	115	86.9
Empty-column effluent	231	58.0	90.7	330	116

^a Parts per trillion.

Three of the sorbents (Keyle:X, GAC, and ADA) gave poor results on the first day, and all of them performed poorly on the last day, when the flow rate was the lowest (0.1 BV/min). These poor results are probably the result of the high mercury concentration in the water on the previous day. Mercury previously removed by the sorbents could have leached back into the water as the mercury concentration of the incoming stream decreased.

Figure 4 shows a graph of fractional breakthrough for each sorbent column (Hg concentration of sorbent column effluent/Hg concentration of empty-column effluent) plotted against the flow rate,

Fig. 4. Mercury effluent concentrations for sorbent tests in August 1997.

in bed volumes/minute, for the first 5 days. The Forager Sponge showed the best performance of all the sorbents tested, removing over 80% of the mercury from the water in most cases. Analyses of influent and effluent samples from the two full-scale GAC columns at PWTC-3608 showed that about 50% of the influent mercury was removed by each GAC column, giving a total mercury reduction of about 75% through both columns.

The concentrations of other heavy metals in the feed water to the test system were very low. Zinc was present at 0.06 mg/L, while arsenic, cadmium, chromium, iron, lead, nickel, and selenium were below detection limits. The concentration of zinc was below the detection limit of 0.02 mg/L for the effluent from each of the sorbent columns.

The next two sets of sorbent tests were conducted in early 1998. The first set used the Forager Sponge and SIR-200 sorbents, along with three columns of GAC. One of the GAC columns had 1 mg/L of trisodium trimercapto-s-triazine (TMT) added to the wastewater in the 1-L mixing chamber prior to the column, the second had no pretreatment, and the third contained GAC that had been soaked in a dilute TMT solution prior to being used. The mercury concentration in the feed to the test system varied from 69 to 146 ppt, with 58 to 106 ppt Hg in the filter effluent and 65 to 98 ppt Hg in the effluent from the empty column. The mercury concentration in the feed, which was generally lower than for the earlier test, did not change as drastically over time. The mercury concentration in the filter effluent was always slightly lower than that of the influent. The flow rate was varied from 0.1 to 7 BV/min. The performance of the Sponge in removing mercury from the wastewater was not nearly as efficient as in the earlier tests, especially at the higher flow rates, and the performance of the SIR-200 was only slightly better than that of the Sponge. Most of the results

are plotted in Fig. 5. The highest flow rates were omitted to make the graph easier to read, but very little mercury removal was achieved at the high flow rates. The mercury concentration in the effluent from the GAC column was consistently lower than that for the GAC column with TMT added to the water or GAC presoaked in TMT. These results suggest that the TMT forms complexes with the mercury in the wastewater, but the complex is not removed effectively by GAC.

Fig. 5. Mercury effluent results for sorbent tests in early 1998

In the second set of tests, which used GAC and SAMMS, the mercury concentration in the effluent from the empty column ranged from 70 to 212 ppt. The results for this set of tests are also shown in Fig. 5. All of the sorbents used in these tests showed very poor mercury removal at flow rates above 0.5 BV/min and exhibited a high variability in removal efficiencies at the lower flow rates. Such results suggest that a significant fraction of the mercury in the wastewater is in a form that is difficult to remove, possibly chemically complexed or bound to particulates.

Samples of PWTC-3608 wastewater were analyzed for chemically active (ionic and elemental) mercury to estimate the fraction of the mercury that was easily accessible to the sorbents. Samples were taken at different points in the treatment process at PWTC-3608, and some of the samples were filtered through 0.45- μ m- and 0.02- μ m-pore filters. (The 0.02- μ m filter will remove colloidal particles.) For the unfiltered samples, the chemically active mercury was only about 30 to 45% of the total mercury. As an example, the effluent from the air stripper on April 17, 1998, showed a total mercury concentration of 194 ppt unfiltered, 119 ppt after passage through a 0.45- μ m filter,

and 46 ppt after treatment with a 0.02- μ m filter. The active mercury in the same samples was determined to be 56, 53, and 29 ppt (29, 44, and 63%), respectively. These results suggest that a significant fraction of the mercury in the wastewater is associated with particulates. These types of measurements were not made during the first sorbent tests in August 1997, but the change in performance of the sorbents at different times is probably associated with changes in the fraction of total mercury that is in a chemically active form.

Three additional tests were performed in which the wastewater entering one column was chlorinated, while an adjacent column with the same sorbent received untreated wastewater. Chlorine should oxidize many mercury complexes and particle-bound mercury, converting the mercury to an ionic form that would be easily removed by the sorbents. The chlorine concentration in the treated water was about 3 mg/L, with a contact time of 10 to 100 min, depending on the flow rate. Three different sorbents — SIR-200, Keyle:X, and GAC — were tested each at a different time. In each case, the chlorine concentration in the effluent from the columns was below the detection limit of 0.2 mg/L. The results are shown in Figure 6. Chlorination of the wastewater greatly improved the performance of the Keyle:X sorbent but decreased the mercury removal efficiency of the SIR-200. Chlorination showed mixed results for the GAC, sorbent, improving mercury removal on some days while having no effect on other days. It appears that chlorination of the wastewater could improve mercury removal efficiency, but the long-term stability of the sorbents in the chlorinated water would be a concern. It is possible that the chlorine could react with the active sites of some of the sorbents and slowly destroy the sorbent materials.

Fig. 6. Effect of chlorination on mercury removal by selected sorbents.

3.2 Batch Precipitation Tests

The results of the batch precipitation tests are shown in Table 2. Two different samples of wastewater from the nonmetals tank at PWTC-3608 were tested and analyzed. The first sample, which was collected on May 4, 1998, was spiked with mercuric nitrate (9 ppb as Hg). The second sample of wastewater, collected on May 20, 1998, was used as received. The results show that precipitation/flocculation with Fe and Betz-1100, followed by filtration, removed only part of the mercury from the solutions. Most of the mercury-binding sorbents and complexing-agents tested were very successful in reducing the mercury concentration of the treated water. All of the treatments produced medium-sized floc particles that settled readily.

Precipitation/flocculation using iron and Betz-1100 with either trisodium trimercapto-s-triazine (TMT) or diethyldithiocarbamate (DTC) appears to be a promising method for reducing the mercury concentration of the PWTC-3608 effluent, but the mercury concentrations achieved for the treated wastewater were generally above the proposed NPDES limit. Treating all of the PWTC-3608 influent by precipitation and flocculation would increase the amount of sludge produced at the facility and, in turn, would increase the operational costs. Further testing would be needed before the costs and benefits of these processes could be determined.

Table 2. Results for various treatments in batch precipitation tests

Wastewater and treatment description	Mercury conc. (ppb)	Mercury removal (%)
Nonmetals tank sample 1 (spiked) — no treatment	7.6	0
Filtration only (0.45- μ m filter)	6.0	21.1
1 mg/L Fe; 1 mg/L Betz-1100	5.1	32.9
1 mg/L DTC; 1 mg/L Fe; 1 mg/L Betz-1100	0.95	87.5
10 mg/L DTC; 1 mg/L Fe; 1 mg/L Betz-1100	0.46	93.9
5.6 mg/L TMT; 1 mg/L Fe; 1 mg/L Betz-1100	0.81	89.3
11 mg/L TMT; 1 mg/L Fe; 1 mg/L Betz-1100	0.52	93.2
13 mg/L SAMMS; 1 mg/L Fe; 1 mg/L Betz-1100	0.17	7.8
Nonmetals tank sample 2 — no treatment	0.17	0
1 mg/L Betz-1100	0.11	35.3
10 mg/L DTC; 1 mg/L Betz-1100	0.054	68.2
10 mg/L DTC; 1 mg/L Fe, 1 mg/L Betz-1100	<0.01	>94

3.3 Sampling and Filtration Tests

A series of samples was taken the period February–March 1998 at various points within PWTC-3608 to determine the amount of mercury entering the facility, as well as the amount removed by each treatment process. Samples were also taken of the influent to PWTC-3544 during the same period. The results are shown in Table 3. The mercury concentration in the wastewater entering PWTC-3544 is higher than that for the PWTC-3608 influent (nonmetals tank), but most of this mercury would be removed in the PWTC-3544 softening process. The mercury concentration in the effluent from PWTC-3544 was not measured. Most of the mercury in PWTC-3608 metals tank would have originally been present in the nonmetals tank wastewater, but it was sorbed onto particulates in the water, removed by the dual-media filters, and then backwashed with the particulates into the metals tank. Most of this mercury would be removed in the sludge from the precipitation/flocculation process before the treated-metals wastewater joined the non-metals wastewater flow.

Table 3. Average mercury concentrations and loadings at PWTC-3608 and PWTC-3544

Sample location	Hg conc. (ppb)	Flow rate (L/m)	Hg loading (mg/day)
PWTC-3544 influent	0.47	450	307
PWTC-3608 metals tank	1.25	95	170
PWTC-3608 nonmetals tank	0.27	1230	480
PWTC-3608 filter effluent	0.14	1325	270
PWTC-3608 air-stripper effluent	0.11	1325	220
PWTC-3608 lead-GAC-column effluent	0.066	1325	126
PWTC-3608 lag-GAC-column effluent	0.039	1325	75

Samples were collected periodically from process wastewater manholes 157, 158, 171, 159, and 190 during the period February–April 1998; the results are shown in Table 4. The samples from manholes 157 and 158 frequently contained solids, and analyses of the samples with and without filtration indicated that most of the mercury in the water was associated with the solids. The results show that the small wastewater flows (7 to 11 L/m) from Buildings 4501 and 4505 (i.e., manholes 157 and 158, respectively), contain a large portion of the mercury that is present in the wastewater at manhole 190. The amount of mercury measured at manhole 158 was significantly higher than that at manholes 159 and 190, which indicates that the sampling activity at manhole 158 probably stirred up some solids that were not routinely moving through the manhole with the wastewater.

The amount of mercury measured at manhole 159 was somewhat higher than that at manhole 190, which again may indicate some disturbance of the flow by the sampling activity. No solids were visible in any of the samples from manholes 159, 171, and 190. Most of the volume of wastewater at manhole 190 comes through manhole 171, but the mercury concentration in this water was relatively low. The mercury concentration increased dramatically after the flow from manhole 158 joined the wastewater at manhole 159.

Table 4. Average mercury concentrations and loadings at process wastewater manholes

Sample location	Hg conc. (ppb)	Flow rate (L/m)	Hg loading (mg/day)
Manhole 157—unfiltered	35.3	7	384
Manhole 157—filtered	3.6	7	39
Manhole 158—unfiltered	49.2	11	803
Manhole 158—filtered	1.4	11	23
Manhole 171	0.19	340	92
Manhole 159	0.76	350	380
Manhole 190	0.25	810	291

The pilot-scale filtration system at manhole 158 removed about 60% of the mercury that was present in the wastewater. The mercury concentration in the untreated water averaged 7.6 ppb, and the effluent from the second (1- μ m-pore) filter averaged 2.7 ppb. The filtration system was operated for 6 days, and the filter cartridges needed to be changed every day to maintain flow through the system. The amount of mercury in the wastewater at manhole 190 did not change significantly while the filtration system was being operated. Part of the wastewater in manhole 158 was bypassing the filtration system by leaking through the wall of the manhole and possibly through or around the sandbag wall that was placed in the manhole. The bypass flow could have carried mercury-containing particulates that would have increased the mercury concentration in the wastewater routed to manhole 190.

4. CONCLUSIONS

The first set of sorbent tests that was conducted at PWTC-3608 in August 1997 showed very effective mercury removal by the Forager Sponge, even at high flow rates. Based on these results, it appeared feasible to maintain the mercury removal capabilities of PWTC-3608 by adding a layer of the Sponge to the one remaining GAC column, if two of the existing GAC columns were converted to zeolite usage. Later tests showed that the mercury removal efficiency of the sorbents varied considerably over time, probably associated with changes in the form of the mercury in the wastewater. A significant portion of the mercury in PWTC-3608 water was bound to small particles during the later tests, which made the mercury less accessible to the sorbents. Chlorination of the water, which could convert the bound mercury to an ionic form, improved the performance of some of the sorbents. The results to date do not show a clear method for consistently maintaining the mercury removal capabilities of PWTC-3608 if two of the existing GAC columns are converted to zeolite usage. Initial tests using various precipitation methods that could be incorporated into the existing equipment at PWTC-3608 appear promising, but additional studies will be needed before the costs and benefits of these processes can be determined.

Initial tests using various precipitation methods that could be incorporated into the existing equipment at PWTC-3608 appear promising, but more work will be needed before the costs and benefits of these processes can be determined.

Samples were collected periodically from process wastewater manholes 157, 158, 171, 159, and 190, which collect flows from the central portion of ORNL. The results show that the small wastewater flows (7 to 11 L/m) from Buildings 4501 and 4505 (i.e., manholes 157 and 158 respectively), contain a large portion of the mercury that is present downstream at manhole 190, where the flow rate averaged 810 L/m.

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