Asbestos in water: mining and processing effluent treatment

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The relatively recent discovery of asbestos fibers in water[1,2] has given rise to concern about the possible health hazards associated with ingestion of the mineral.[3] Medical authorities are still divided on the effects of orally consumed asbestos and, because of the nature of the problems, are likely to remain so for some time.

Asbestos is a generic term that applies to a number of hydrated mineral silicates. Chrysotile, a fibrous form of serpentine that accounts for 95 percent of the world's asbestos consumption, is the most common form found in the aquatic environment, although a relatively large amount of cummingtonite (a member of the amphibole group) is present in Lake Superior as a result of the mining operations in that area.

The background level of asbestos in Canadian and northern U. S. surface waters varies between 10^5 and 10^7 fibers/l but there are some localities, notably in the vicinity of asbestos or iron ore mines, in which the level is between 10^9 to 10^{12} fibers/l. In most of these cases the abnormally high levels can readily be attributed to direct contamination from mine or processing plant effluent water. Although it is impossible to eliminate asbestos from the aquatic environment, because of natural leaching and widespread industrial applications, the direct contamination of specific waterways can and should be prevented.

Treatment methods for reducing asbestos levels in potable water to less than 10^5 fibers/l have recently been developed based on alum or ferric chloride coagulation with polyelectrolyte.[4] The purpose of this paper is to present data to indicate that simple, low cost treatment methods based on sedimentation and filtration will effectively remove most of the suspended asbestos found in mining and asbestos processing plant effluents. In addition, these methods do not produce such large volumes of asbestos laden sludge as chemical coagulation methods.

EXPERIMENTAL METHOD

Initial experiments were carried out using synthetic asbestos suspensions containing approximately the same concentration and size distribution as typical asbestos mine effluents. Results were then substantiated with effluent water collected from specific asbestos mines.

Asbestos suspensions were prepared by blending at approximately 5000 rpm 10 mg commercial chrysotile asbestos fiber in 100 ml distilled water for 30 min. Five such batches were then combined, diluted to 1 l with water (1:2 dilution) and sonicated at 150 w, 20 kHz for 30 min. This resulted in a suspension containing on the order of 10^{12} fibers/l, with 80 percent of the fibers <2 μm in length. The distribution of fiber sizes is shown in Figure 1.

Accurate fiber counts were carried out using a transmission electron microscope, TEM,

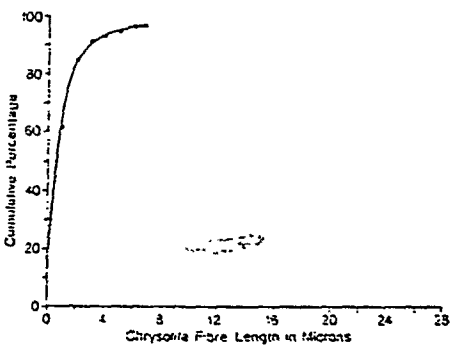
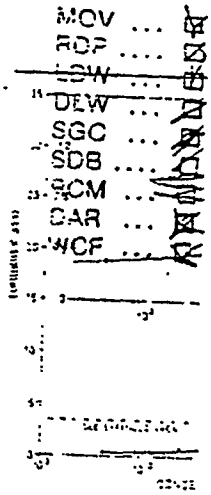


FIGURE 1. Fiber size distribution of synthetic chrysotile suspension. (Fiber size expressed as a function of cumulative percent of fibers larger than a given size.)



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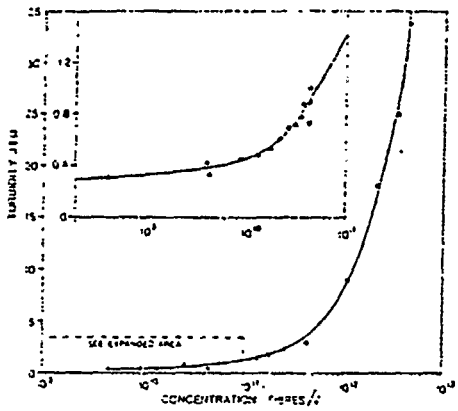

FIGURE 2. Variation of turbidity with concentration for synthetic asbestos suspensions. (Turbidity of distilled water used in preparation of suspension 0.26 JTU.)

by a procedure described by Durham and Pang.[3] In order to eliminate some of the lengthy TEM counts on the synthetic suspensions, a turbidity-fiber concentration relationship was established. This relationship is shown in Figure 2 and was used to convert the turbidity of synthetic suspensions into approximate fiber concentrations when working in the 5×10^{10} to 5×10^{12} fibers/l range. For accurate analyses in this range and for all other measurements, the TEM was always used.

Sedimentation rates were determined by allowing suspensions to settle in graduated cylinders for predetermined times and either noting the settling rate of the visible asbestos or measuring the turbidity as a function of depth. A small scale, flow-through sedimentation unit was built to evaluate sedimentation characteristics under continually operating conditions. The unit is shown schematically in Figure 3. The capacity of each sedimentation tank was 4 l and the flow rate through the system was regulated at approximately 1.5 l/h. Sand filters consisted of 60 mm 0.81 to 1.3 mm sand (bottom), 120 mm 0.61 to 0.80 mm sand (middle) and 140 mm 0.45 to 0.55 mm sand (top). The mixed media filters were of similar composition except that an additional 120 mm layer of 1.5 mm anthracite coal was added above the sand. The flow rate through these columns was regulated to 0.9 l/m²·s (1.1 gal/min/sq ft).

The diatomite filters were prepared by applying a pre-coat of Diatomite onto a cylindrical support at the rate of 4.5 g/100 cm² of filter surface. The flow rate through this unit was regulated at approximately 0.3 l/100 cm² of filter area.

RESULTS AND DISCUSSION

One of the simplest methods for treating effluents containing high concentrations of asbestos is sedimentation, since suspensions containing $>5 \times 10^{10}$ fibers/l settle readily on standing. Figure 4 shows the settling characteristics as a function of time for the visible asbestos in a suspension containing 4×10^{12} fibers/l. The fibers tended to flocculate and settle rapidly until the sediment volume was reduced to about 20 percent of the total volume. Further reduction in the sediment volume was then extremely slow (19 percent after 24 h). The fiber concentration of the settled water was 5×10^{11} fibers/l after 1 h and 1×10^{11} fibers/l after 24 h.

The addition of small amounts of diatomite to the suspensions prior to settling resulted in a significant reduction in final sediment volume. The results are summarized in Table I. The addition of more than 0.3 g/l diatomite resulted in a 50 to 75 percent reduction in sediment volume. The diatomite/asbestos suspensions were not only more compact than the pure asbestos suspensions, but much less disturbed by slight to moderate turbulence. This results partly from weighting by the larger diatomite particles and partly from surface charge neutralization.

Very similar sedimentation results were obtained from the flow-through unit illustrated in Figure 3. The effect of continuous sedimentation is shown in Figure 5 for a suspension

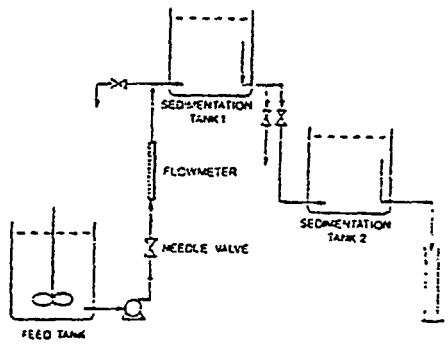

FIGURE 3. Flow diagram of flow-through sedimentation unit.

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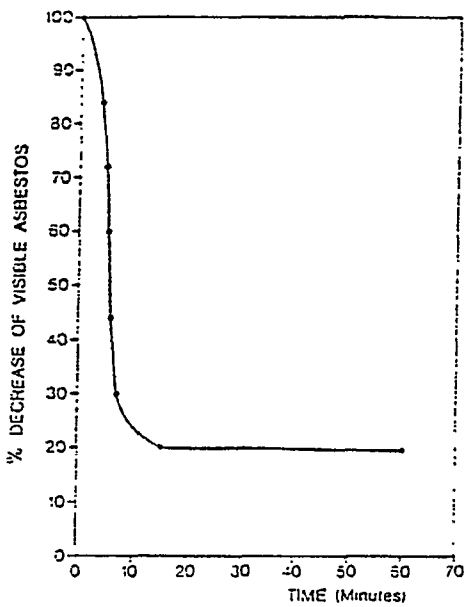

FIGURE 4. Sedimentation behavior of an asbestos suspension containing 4×10^{12} fibers/l.

containing 4×10^{12} fiber/l [turbidity 25 Jackson Turbidity Units (JTU)]. Turbidity was monitored rather than fiber counts purely for convenience. From Figure 2, turbidities of 2 to 4 JTU correspond to fiber concentrations of between 2×10^{11} and 5×10^{11} fibers/l. The continuous, slow addition of a diatomite suspension (0.5 g diatomite/l asbestos suspension) lowered the fiber concentration by a further factor of 10.

Having achieved a substantial decrease in fiber concentration, the next logical step was to filter the sedimentation tank effluent. The effect of mixed media filtration is illustrated

TABLE I. Effect of Diatomite Addition on Sediment Volume.

Diatomite Addition (g/l)	0	0.1	0.3	0.6	1.0
Sediment Volume* after 30 min	20%	20%	9%	6%	5%
Sediment Volume* after 15 h	21%	16%	9%	6%	6%

* Volumes are expressed as percentage of original suspension volume.

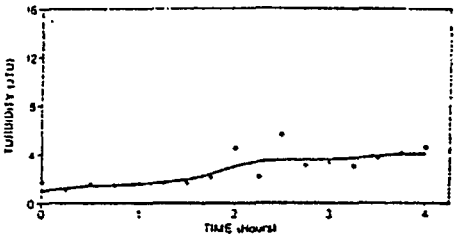

FIGURE 5. Effluent turbidity from the flow-through sedimentation unit. Before settling, turbidity was 25 JTU and fiber concentration was 4×10^{12} fibers/l.

in Table II. We observed a reduction of about 100-fold in the fiber concentration with the high concentration suspensions and this gradually decreased to 40 in the 10^3 to 10^5 range. From our potable water treatment work[4] we found that at concentrations of 10^6 fibers/l mixed media filtration reduced the concentration by a factor of ten.

Diatomite filtration was also investigated because these filters have been found to be quite effective in removing asbestos from potable water[4-6]. The fiber concentration of effluents containing 10^9 to 10^{11} fibers/l was reduced by a factor of about 10^2 with diatomite. Coated diatomite (that is, diotomite coated with aluminum hydroxide by a method reported from Johns-Manville[3]) was even more effective and reduced the concentration from 10^9 to $<10^3$ fibers/l.

In summary, the initial results obtained on synthetic suspensions indicated that with a concentration of 4×10^{12} fibers/l, which is as high as any case histories that have come to our attention, sedimentation followed by mixed media filtration will reduce the fiber content to 10^9/fiber/l and sedimentation followed by

TABLE II. Filtrate Quality for Different Initial Concentrations of Asbestos.

Initial Suspension Concentration (fibers/l)	Filtrate Concentration (fibers/l)
4×10^{12}	4×10^{10}
4×10^{11}	1×10^{9}
4×10^{10}	4×10^{8}
4×10^{9}	1×10^{8}

* Filter was dual media with 25 mm anthracite coal and 320 mm graded sand

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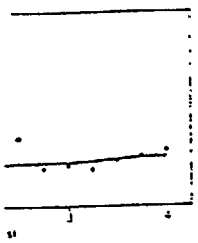

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TREATMENT OF WATERS FROM SPECIFIC LOCATIONS

Having illustrated the effectiveness of these treatment methods on synthetic suspensions, the remainder of the paper will be concerned with treating water from specific site locations. The three sites chosen were Asbestos, Quebec, Baie Verte, Newfoundland, and the Johns-Manville plant, Toronto.

Johns-Manville. This is an asbestos-cement processing plant that produces an effluent high in both asbestos and cement. This water could not be run through the sedimentation unit because the abrasive cement particles rapidly destroyed the pump bearing. Consequently, all tests were done on static batches of water. The results of both the sedimentation and filtration are shown in Table III.

Sedimentation quickly removed most of the cement particles but had little effect on the asbestos content. This was to be expected as earlier experiments had shown that sedimentation had little effect on suspensions containing $<10^{10}$ fibers/l. Mixed media filtration of the settled water, however, reduced the concentration to 3×10^7 fibers/l, indicating that sedimentation followed by filtration would produce an effluent relatively low in both turbidity and asbestos.

Asbestos. The water that was collected at Asbestos, Quebec contained 10^9 fibers/l, so it was filtered directly. Mixed media filtration reduced the asbestos content by a factor of 30 while diatomite reduced the concentration to 10^6 and 10^5 fibers/l for uncoated and coated respectively. The results are shown in Table IV.

Baie Vert. This mine drainage water contained between 10^9 and 10^{11} fibers/l. Water containing 10^{11} fibers/l was treated by sedimentation in the continuous flow unit followed by filtration; that in the 10^9 range was filtered directly. The results are summarized in Table V.

TABLE III. Asbestos-Cement Processing Plant.

	Turbidity (JTU)	Fiber Count (Fibers/l)
Raw Water	620	5×10^9
24 h settled	1.0	9.3×10^8
24 h settled + Sand Filter	0.38	3.2×10^7

TABLE IV. Asbestos Mine, Asbestos, Quebec.

	Fiber Concentration (Fibers/l)
Raw Water	1×10^9
Mixed Media Filter	3×10^7
Diatomaceous Earth Filter Uncoated	3×10^6
Diatomaceous Earth Filter Coated	8×10^4

TABLE V. Asbestos Mine, Baie Verte, Newfoundland.

	Fiber Concentration (Fibers/l)	
	Sample 1	Sample 2
Raw Water	1×10^{11}	1×10^9
Sedimentation	1×10^{10}	1×10^9
Sedimentation + Dual Media Filtration	1×10^9	1×10^8
Sedimentation + Diatomite Filtration (uncoated)		2×10^5
Sedimentation + Diatomite Filtration (Alum coated)		$<10^4$

CONCLUSIONS

We have demonstrated that sedimentation followed by mixed media filtration is very effective for removing most of the asbestos from mine and processing plant effluent. In the case of effluents containing 10^9 fibers/l or less, sedimentation (in either continuous or batch processes) is ineffective; these waters should be filtered directly. Diatomite filters are even more effective than mixed media filters but it could be argued that they are too effective for waste stream treatment. However, diatomite filters could prove useful in small mining communities for treatment of potable water. Usually these small communities have only one local stream which must serve as both the source of drinking water and the effluent discharge stream.

Disposal of the asbestos laden sediments and treatment of filter back-wash water have not been considered in this investigation. In mining areas, waste disposal would not present a major problem as the removed asbestos could be returned to a unused part of the mine. Asbestos processing plants, however, are often

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located in urban areas and there the problem of waste disposal is much more serious. Further studies on asbestos waste disposal in these areas are urgently needed.

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Authors. John Lawrence and H. Walter Zimmermann are, respectively, Research Scientist and Technologist in the Water Chemistry Section, Canada Centre for Inland Waters, Burlington, Ontario, Canada.

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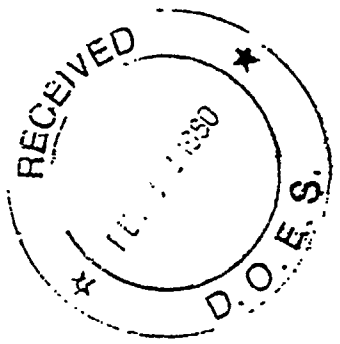
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