Technical News Feature

The Removal of Organic Substances from Water with Nonvolatile Edible Solvents

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ABSTRACT

The use of nonvolatile, edible triglycerides for the removal of trace organic materials from water was investigated. All organic substances that were studied were readily removed from water by contact with triglycerides. Solvent extraction with liquid soybean oil reduced the concentrations of benzene and chloroform in water. A fixed bed filter of liquid soybean oil, hydrogenated palm oil and sand removed toluene and chloroform from water. Toluene was removed from water by adsorption with hydrogenated palm oil, a solid fat.

INTRODUCTION

The generally accepted method for the removal of trihalomethanes and other organic materials from water has been adsorption on the surface of activated carbon. Although activated carbon is satisfactory in many water purification situations, a reduction in the cost of the carbon and the expense of its surface regeneration would be desirable.

Moreover, it is possible that other processes may provide advantages in cost and effectiveness compared to carbon adsorption. An alternative to carbon adsorption could be extraction of water with an organic solvent. Solvents can effectively remove organic compounds from water, but trace amounts of the solvent may be distributed into the water. In addition, the volatility of most organic solvents limits their practicality. Solvent extraction might be feasible, however, with nonvolatile, nontoxic solvents that are insoluble in water. We report here a preliminary demonstration that triglyceride fats, nonvolatile foodstuffs, can perform as organic solvents or adsorbents and effectively remove organic compounds from water.

MATERIALS AND METHODS

The water used in all systems was from the deionized water tap at our laboratories. The partially hydrogenated soybean oil (liquid, iodine value 107), and completely hydrogenated palm oil (solid, iodine value 8) were bleached, deodorized, edible fats obtained from the Food Division of Procter & Gamble, Cincinnati, OH. The fatty acid composition of these materials is given in Table I. The Ottawa standard sand and reagent grade benzene, toluene and chloroform were obtained from MC/B, Norwood, OH.

Aqueous solutions were prepared by delivering the lipophile by micropipette to a known volume of water. Vigorous mixing provided dispersion and dissolution, and stepwise dilution gave the desired concentrations.

Two types of assays were used for water analysis. Benzene and toluene in water were analyzed by measurement of the ultraviolet (UV) absorbance of the aqueous phase (249 nm, benzene, and 260 nm, toluene) and comparison with absorbances of standard solutions. Chloroform was analyzed by gas chromatography (GC) by the James M. Montgomery Consulting Engineers, Pasadena, CA.

Three systems were used to demonstrate the reduction of organic material in water with triglycerides. The first of these used a liquid oil in a solvent extraction procedure. The second used an immobilized liquid oil in a fixed bed filter. The third system consisted of a fixed bed filter of a solid fat to remove the organic material by surface adsorption. All systems were at ambient temperature, 22-24 C.

System 1: Soybean Oil Layer on Stirred Water

A solution of the organic material in water (750-875 ml) was poured into each of 2 jars containing magnetic stirring bars. A layer (70-100 ml) of liquid soybean oil was gently poured onto the surface of water in one of the jars. After both jars were closed the water was stirred slowly with teflon-covered magnetic bars. The stirring rate was adjusted so that no visible oil droplets were allowed to form in the water. The area of the oil/water interface was ca. 90 cm^2. At intervals from 0-24 hr, aliquots were taken either by aspiration of the aqueous phase beneath the oil or by pipette from the jar containing only the aqueous solution of the lipophile.

System 2: Fixed Bed Filter

This system was a fixed bed of sand, solid hydrogenated palm oil and liquid soybean oil (5:5:1, v/v) that had been mixed with a spatula. About 100 ml of this mixture was placed in a separatory funnel and 20 ml of the aqueous solution (of lipophile) was poured through it and collected for analysis.

System 3: Fixed Bed, Solid Adsorbent

This system was a fixed bed filter similar to system 2. It consisted of 10 g of a single component, completely hydrogenated soybean oil, in a 125-ml separatory funnel. The aqueous solution (70 ppm toluene) was allowed to pass through the bed of granules of fat. These granules were irregular particles of dimensions of ca. 1 mm x 1 mm x 0.5 mm.

TABLE I

Composition of Fatty Acid Methyl Esters from Soybean Oil, Hydrogenated Palm Oil and Hydrogenated Soybean Oil (Weight %)

	Liquid soybean oil	Hydrogenated palm oil	Hydrogenated soybean oil
C14:0	0.3	1.0	Trace
C16:0	11.6	45.6	10.7
C16:1	--	--	0.2
C18:0	4.8	50.8	84.5
C18:1	47.1	0.6	4.3
C18:2	35.0	--	Trace

RESULTS AND DISCUSSION

System 1: Soybean Oil Layer on Stirred Water

Table II gives the results obtained for the removal of benzene and chloroform from water by this system. About 69% of the benzene and 77% of the chloroform were removed by this extraction process.

System 2: Fixed Bed Filter

Table III shows the change in concentration of toluene in water in 2 different solutions after a single pass through the sand-fat mixture. The removal of toluene was evident at both concentrations. The results for multiple passes of a chloroform solution are also given. Five passes through the filter removed nearly 80% of the chloroform. The decrease in the rate of removal with each pass reflects the reduction of chloroform in the aqueous phase as well as its uptake by the fat.

Since the systems with liquid soybean oil are solvent extraction processes, the "sink" for toxic lipophiles provided by dissolution in the oil is potentially larger than that provided by surface adsorption on activated carbon. Thus the extraction of organic materials by a triglyceride may surpass the 50% reduction that is sought with treatment by activated carbon (1).

System 3: Fixed Bed, Solid Adsorbent

Table IV shows the reduction of toluene in water caused by a single pass through a fixed bed filter of completely hydrogenated soybean oil. Almost 80% of the toluene was adsorbed by this high-melting fat. The reduction of toluene in water by the solid fat, completely hydrogenated soybean oil, suggests that such fats may provide a nontoxic adsorbent that could easily be separated from water.

The purpose of this study was to determine whether or not a triglyceride could remove lipophilic materials from water with systems that maintain a separation of the oil and water phases. All 3 organic substances examined were readily taken up from dilute aqueous solution by the oil phase. This water treatment concept is unique in that it employs the use of organic solvents or adsorbents that are edible and thus nontoxic. Paraffin and mineral oils may also meet this criterion of low toxicity.

The application of this concept to large-scale water treatment may be feasible. Clearly there remain unanswered questions about areas such as fat stability, microbial growth and cost analysis. In addition, the potential transfer of unchanged or hydrolyzed triglyceride to water might occur. The cost of regeneration of triglycerides by a steam deodorization process would need to be determined and compared to that of the reactivation of activated carbon in a furnace. The optimization of mixing and of separation of phases has been only briefly addressed in this study. The data presented here, however, suggest the potential use of nontoxic fats and oils in the removal of toxic lipophiles in water purification.

TABLE II

The Removal of Benzene or Chloroform from Water by Solvent Extraction with Liquid Soybean Oil

Time (hr)	Benzene concentration in water (ppm): Without soybean oil	With soybean oil
0	64	64
1	64	50
2	64	40
18	64	28
21.5	62	< 20

Time	$CHCl_3$ concentration in water (ppb): Without soybean oil	With soybean oil
24 hr	556	126

TABLE III

The Removal of Toluene or Chloroform from Water by a Fixed Bed Filter of Liquid Soybean Oil, Hydrogenated Palm Oil and Sand

	Toluene concentration in water (ppm): Before filtration	After single filtration
(Solution 1)	46	18
(Solution 2)	10	1

Number of passes through filter	Chloroform concentration in water (ppb)
0	949
1	454
3	276
5	200

TABLE IV

The Removal of Toluene from Water with a Solid Fat, Completely Hydrogenated Soybean Oil

Toluene concentration in water (ppm): Before filtration	After single filtration
70	15

REFERENCE

1. Preliminary Assessment of Suspected Carcinogens in Drinking Water, Report to Congress, USEPA, Washington, DC, 1974, p. 47-51.

[Received May 8, 1980]