



DEPARTMENT OF THE ARMY
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REPLY TO
ATTENTION OF

HSE-EW

1 FEB 1982

SUBJECT: Water Quality Information Paper No. 35

Volatile Organic Compounds in Potable Water Supplies

1. PURPOSE. The purpose of this information paper is to provide current information pertaining to the presence of volatile organic compounds (VOCs) in potable water supplies at Army installations, and to delineate promising treatment alternatives.
2. REFERENCE. See Inclosure 1 for a listing of references.
3. DESIGNATED VOLATILE ORGANIC COMPOUNDS. The most prevalent VOC contaminants observed in potable water are listed in Table 1:

Table 1. VOCs Commonly Found in Potable Water Supplies.

Trichloroethylene	Benzene
Tetrachloroethylene	Chlorobenzene
Carbon tetrachloride	Dichlorobenzene
1,1,1-trichloroethane	1,1-dichloroethylene
1,2-dichloroethane	Cis-1,2-dichloroethylene
Vinyl chloride	Trans-1,2-dichloroethylene
Methylene chloride	Trihalomethanes*

*Note. The components commonly associated with this grouping include chloroform, chlorodibromomethane, bromodichloromethane, and bromoform.

4. REGULATORY BACKGROUND.

a. As of 31 December 1981, there have been no enforceable regulatory guidelines established by the Federal government for VOCs, although research efforts have determined these compounds to be potential human carcinogens. A water quality criteria document, published in the 28 November 1980 Federal Register (Inclosure 1, reference 4), has served as the basic guideline by which health effects of VOC contamination can be judged. These criteria (Table 2) are based on accumulated data and scientific judgements on the relationship between pollutant concentrations and environmental and human health effects. This document lists threshold values for the individual components (listed in Table 2), as opposed to a single value assigned the total grouping of VOCs. As an example, an average man, who exists under normal conditions and ingests approximately 2 liters of water per day over a period of 70 years, has an increased chance of 1-in-100,000 (1 in 10^5) of contracting cancer if exposed to 27 $\mu\text{g}/\text{L}$ of trichloroethylene throughout

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his entire lifetime. Obviously, these figures are quite theoretical in nature. However, they do serve as some form of guidance should this form of contamination arise in a potable water supply.

Table 2. 28 November 1980 Federal Register-Water Quality Criteria*.

<u>Compound Grouping</u>	<u>1 in 10⁵ Health Criteria</u>
Trichloroethylene	27.0 µg/L
Tetrachloroethylene	8.0 µg/L
Carbon tetrachloride	4.0 µg/L
Vinyl chloride	20.0 µg/L
Dichloroethylene	0.33 µg/L
Chlorinated ethanes	9.4 µg/L
Benzene	6.6 µg/L
Chlorinated benzenes	7.2 µg/L

*Concerns only potable water consumption.

b. Additional guidance has been published in the form of "suggested no adverse response levels" (SNARLS) by the Environmental Protection Agency (EPA) for 3 compounds of concern (trichloroethylene, tetrachloroethylene and 1,1,1-trichloroethane). This information preceded the water quality criteria document, and involved not only the potential risk levels for carcinogenicity, but also for acute and chronic toxicity levels (Table 3). Information presented at recent public hearings indicate that an "advanced notice of proposed rule-making" (ANPRM) for 6 specific compounds will be released by early 1982. The specific VOCs to be addressed are trichloroethylene, tetrachloroethylene, carbon tetrachloride, 1,1,1-trichloroethane, 1,2-dichloroethane, and vinyl chloride. The ANPRM will be the first attempt to establish a definitive maximum contaminant level (MCL) for these materials. However, no indication has been given as to whether established limits will be for individual compounds, total VOCs, or both. Public comment and hearing stages, along with Agency (EPA) reevaluation and legal review, are among the steps necessary before actual MCLs will appear as promulgated regulations. Until that time, no binding legal limitation exists for VOCs in potable water supplies. The current stance maintained by a number of states where VOC contamination appears to be a problem (e.g., Michigan, Minnesota, and New Jersey) is that concentrations entering a distribution system must be at non-detectable limits (approximately 1 µg/L). Other states, such as New York, have established their own limitations based on accumulated data (i.e., a maximum allowable limit of 50 µg/L for any one organic contaminant and a total allowable limit of 100 µg/L for all such compounds). This situation (presence of VOC contaminants and lack of steadfast regulatory guidelines) directly impacts a number of CONUS Army installations, for it makes necessary the assembling of several distinct control, or treatment, strategies in order to meet the requirements established by the various regulatory agencies.

Table 3. EPA SNARLS for VOCs.

<u>Compound</u>	<u>Limit</u>	<u>Extent</u>	<u>Parameter</u>	<u>Published Date</u>
Trichloroethylene	2 mg/L	1 day	acute toxicity	26 Nov 79
	200 µg/L	7 days	acute toxicity	
	15-75 µg/L	---	chronic toxicity	
	4.5 µg/L	+1 in 10 ⁶	carcinogenic	
	45 µg/L	+1 in 10 ⁵	carcinogenic	
Tetrachloroethylene	2.3 mg/L	1 day	acute toxicity	6 Feb 80
	175 µg/L	10 days	acute toxicity	
	20 µg/L	---	chronic toxicity	
	3.5 µg/L	+1 in 10 ⁶	carcinogenic	
	35 µg/L	+1 in 10 ⁵	carcinogenic	
1,1,1-trichloro-ethane	300-500 µg/L	---	taste/odor	9 May 80
	1 µg/L	---	chronic toxicity	

c. Exceptions to this discussion, as it pertains to established regulations, involve the materials defined as trihalomethanes. An MCL of 100 µg/L for total trihalomethanes was promulgated and added to the National Interim Primary Drinking Water Regulations (44FR68624) on 29 November 1979. This group of compounds has, therefore, been previously approached and investigated separate and apart from the remainder of the VOCs, and will not be included in this discussion.

5. IMPLICATIONS TO ARMY INSTALLATIONS. Significant concentrations of VOCs have recently been identified in groundwater sources serving as the potable water supply at several Army facilities. Several of the installations among those identified as experiencing some form of VOC contamination are listed in Table 4. The presence of these contaminants is due, primarily, to past practices of uncontrolled disposal of spent industrial-type solvents and cleaning agents in the vicinity. These materials have leached, or have short-circuited by some means, down into the source aquifer. VOCs may be transferred to an aquifer and transported great distances because they are rather soluble and have little affinity for soil materials. Thus far, the installations known to be affected are, basically, located in areas where industrial activities and regional geology combine to allow relatively rapid percolation of contaminants into groundwater supplies.

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Table 4. Affected Army Installations and Maximum VOC Concentrations Observed.

Twin Cities Army Ammunition Plant	2000-10,000 µg/L
Tobyhanna Army Depot	20-35* µg/L
Anniston Army Depot	65,000 µg/L
ARRADCOM Activity	260**-3700*** µg/L

*-GAC treatment implemented once concentrations reached these levels.

**--noted in drinking water supplies.

***--noted in groundwater monitoring wells.

6. US ARMY ENVIRONMENTAL HYGIENE AGENCY INVOLVEMENT. The possibility of carcinogenesis and/or toxic reaction due to exposure to VOC-contaminated water supplies is of concern to the Army, which has initiated efforts to remedy existing and potential problem situations with the assistance of the US Army Environmental Hygiene Agency. The Agency has, to this point, made its services available to the involved installations for the purpose of reviewing alternative treatment technologies and manufacturer's proposals, as well as offering technical assistance in initiating pilot-scale investigations.

7. ALTERNATIVE TREATMENT TECHNOLOGIES FOR VOCs.

a. Several methodologies are currently available for treating VOC-contaminated water supplies, including various forms of carbon adsorption, resin absorption, and air stripping. All have been found to be rather successful in the removal of VOC materials, under certain circumstances. The key is to match up the proper treatment mechanism(s) with the characteristics of the water supply and contaminants in evidence at a particular site. Thus, the need for sound engineering judgement and thorough pilot-scale examinations is exhibited. Cost-effectiveness, as it relates to the scope of the project, is also an extremely important parameter which must be considered in the effort to institute remedial action.

b. Carbon adsorption is a familiar and effective means of treatment -- having many drinking water and wastewater applications. Intimate contact between the carbon and the raw water supply allows organic constituents to be adsorbed by the carbon. The carbon may be regenerated by exposure to extreme heat, once the active sites are exhausted. Removal values of 95 - 99% are typical. Activated carbon treatment may be employed in several ways: (1) as large granular activated carbon (GAC) units sized to handle all influent potable water to an installation or community, (2) package-type units which can be installed at individual buildings, under specific conditions, and (3) cartridge-type units which can be attached to individual fixtures. Inherent problems with the latter two alternatives have severely limited their wide-scale use, to this point. Packaged GAC units are commercially available, and have been quite successfully used for VOC removal at several military and

industrial installations (e.g., Tobyhanna Army Depot, Rocky Mountain Arsenal, Wertsmith AFB). However, relatively high costs associated with the implementation of GAC has limited its use, in some instances. According to EPA estimates (Inclosure 1, reference 14) the total investment required for a pressure carbon contactor capable of handling a flow of 1 MGD approaches \$110,000, at a minimum, excluding costs incurred by operation and maintenance (O&M). A breakdown of these charges are presented in Table 5. These figures neglect the presence of regeneration facilities, for an additional \$0.5 million would be necessary to site and construct a multiple hearth furnace for these purposes. Instead, a contractual agreement can generally be reached with the supplier/manufacturer to site and maintain a GAC unit, collect and regenerate carbon, and periodically monitor process efficiency. This method of implementation may be more feasible for a relatively small operation (less than 10 MGD). It would be necessary for tradeoffs, comparing system effectiveness to overall costs involved, to be made to determine if this treatment method should be employed.

Table 5. Costs of a 1-MGD Pressure Carbon Contactor for Water Treatment.

Construction and siting	\$82,000-\$100,000
Virgin Carbon (approx. 40,820 lb required)	\$26,000
O&M (energy, materials, labor)	\$58,000-\$75,000/yr.

c. Resin absorption involves the physical separation of the organic compounds from water by absorption to a complex synthetic polymer made specifically for these materials. Although it, too, is quite effective for VOC removal, it differs greatly from typical carbon adsorption. The units are more compact and can handle much higher hydraulic loading rates (as high as 6 GPM per square foot versus 1 GPM per square foot for activated carbon). Regeneration is more frequent, and is accomplished with low pressure steam and periodic exposure to an alcohol-wash. Difficulties with this system arise with the determination of the proper resin to use, the high costs of resinous materials (approximately 1.5 times that of GAC), and the handling and disposal of regeneration waste streams (the liquid waste stream contains high concentrations of VOC materials and may fit into the category of a hazardous waste material as established in the Resource Conservation and Recovery Act of 1980).

d. Air stripping is, gradually, proving to be the simplest and most cost-effective means of removing volatile organic compounds. Preliminary analyses of the air stripping process suggests that it may be considerably more economic, with respect to capital and O&M expenditures, than either GAC or resin absorption treatment. Air stripping has been utilized for many years in the chemical manufacturing industry, working with highly concentrated solutions. Such processes can be simplified somewhat to deal with dilute solutions of VOCs present in potable water supplies.

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(1) Many articles have been presented, throughout the last several years, describing the design and operation of GAC adsorption and resin absorption. Although the use of aeration in potable water treatment has been an accepted long-standing practice, the application of aeration towers for VOC removal is relatively recent. The basic operating principle of air stripping volatile substances involves two basic scientific premises (Inclosure 1, reference 5): (a) the kinetic theory of gases which states that molecules of a dissolved gas can readily move between gas and liquid phases, and (b) the empirical theory that these materials will move from a supersaturated to an undersaturated media. This being the case, water containing volatile contaminants in excess of its equilibrium level will release the contaminant to the exposed gas phase (air) from the liquid phase until equilibrium is approached. If the water comes in contact with a continuously replenished supply of fresh, contaminant-free air, it would follow that all of the contaminant will eventually be removed from solution. The objective of the design of air stripping equipment is to maximize the rate of this mass transfer at a reasonable cost.

(2) There are several available forms of aeration which may be employed in potable (or wastewater) treatment operations. The most prominent of these are diffused aeration, cross-flow towers and countercurrent packed towers. Diffused aeration achieves a maximum transfer surface area by decreasing effective bubble size, and is utilized primarily to increase the dissolution of a gas in water (i.e., oxygenation or ozonation). Cross-flow towers may have some future application in air stripping of organics, but have been basically designed and used as cooling towers in industry, to this point. The aeration apparatus with the greatest promise for removal of volatile organics remains the countercurrent packed-bed air-stripping columns. Untreated water is introduced at the top of the column and flows downward by gravitational action. Conversely, air enters at the bottom of the column and moves upward through a forced or induced draft. A synthetic packing material fills a majority of the column volume to provide an increased surface area over which transfer of the contaminants from liquid to gas phases may occur. Mass transfer rates (removal rates) are significantly increased when the depth of packing is increased, as this allows for a greater contact time.

(3) Within this air stripping scheme there are several factors which determine the rate at which a volatile compound may be removed from a contaminated water supply. An alteration of any one, or a combination, of these factors may significantly impair removal efficiency. The five most prominent items of importance are: (a) the air:water ratio, (b) contact time, (c) available area for mass transfer, (d) temperature of water and air, and (e) the physical chemistry of the contaminant. The first three factors can be controlled by proper design of the air stripping units, while special adjustments must be made to accommodate the final two factors, for they will differ with each specific water supply. Extensive research has shown that temperature has a dramatic effect on transfer rates. This parameter, in particular, must be adequately controlled and/or accounted for in unit design.

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(4) Air stripping may have wide-scale application in the realm of water treatment, for many of the priority pollutants (which include VOCs) are volatile to some degree and may be successfully stripped from the water. Although a number of high molecular weight organics cannot be efficiently removed, aeration is effective for many compounds which are not removed well by activated-carbon adsorption. Consequently, if additional treatment is necessary to handle highly contaminated waters, air stripping and GAC adsorption are excellent complementary processes which may be implemented. Used alone, air stripping employs no chemicals nor requires periodic regeneration, thus reducing overall costs even more. Also, removal efficiencies of 80 - 95% are commonly achieved with this treatment process. Costs of such units vary widely, depending upon location and local energy considerations. For a 1-MGD facility, \$40,000 - \$200,000 may be spent on the initial purchase of aeration towers (including packing material, support plates, blowers, etc.), with \$2,500 - \$10,000/yr necessary for operation and maintenance (Inclosure 1, reference 14 and direct interaction with consultants and manufacturers).

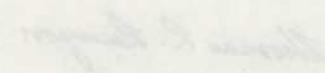
8. SUMMARY. The potential adverse health effects associated with VOC contamination of potable water supplies has created a degree of concern within the regulatory community. The US Army Environmental Hygiene Agency has been asked to become involved in the evaluation of problem extent and available treatment methodologies, due to the presence of these materials in groundwater aquifers serving several Army installations. The alternative treatment technologies include GAC adsorption, resin absorption and aeration. Certain design options of each of these processes have proven to be quite effective in removing VOCs from potable water (maximum removal efficiencies range between 90 - 99%). A site-specific analysis of these alternatives, and associated factors, must precede the implementation of a specific treatment scheme. Among the factors to be considered are an examination of the quantity and quality of the water supply, the types of contaminants present, other treatment processes currently employed, personnel available, and local energy and construction costs. Characteristics of an individual water supply and the applicability of one (or more) treatment schemes should be determined through careful bench-scale (laboratory) and on-site pilot-scale examination.

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(4) Air stripping may have wide-scale application in the realm of water treatment for many of the primary pollutants (which include VOCs) are volatile in some degree and may be successfully stripped from the water. Although a number of high molecular weight organics cannot be efficiently removed, attention is effective for many compounds which are not removed well by activated-carbon adsorption. Consequently, if additional treatment is necessary to handle highly concentrated water, air stripping and catalytic oxidation are excellent complementary processes which may be implemented. Used alone, air stripping employs no chemicals nor requires periodic regeneration, thus reducing overall costs even more. Also, removal efficiencies of 80 - 95% are commonly achieved with this treatment process. Loads of such water vary widely, depending upon location and local energy considerations. For a 1-MGD facility, \$40,000 - \$100,000 may be spent on the initial purchase of aeration towers (including packing material, support plates, blowers, etc.), with \$5,000 - \$10,000 per year for operation and maintenance (including I & E and direct interaction with consultants and manufacturers).

8. SUMMARY. The potential adverse health effects associated with VOC contamination of potable water supplies has created a degree of concern within the regulatory community. The US Army Environmental Hygiene Agency has been asked to become involved in the evaluation of proper extent and available treatment technologies, due to the presence of these materials in groundwater systems serving several Army installations. The alternative treatment technologies include GAC adsorption, resin absorption and oxidation. Certain design options of each of these processes have proven to be quite effective in removing VOCs from potable water (maximum removal efficiencies range between 80 - 95%). A site-specific analysis of these alternatives, and associated factors, must precede the implementation of a specific treatment scheme. Among the factors to be considered are an examination of the quantity and quality of the water supply, the types of contaminants present, other treatment processes currently employed, personnel available, and local energy and construction costs. Characterization of an individual water supply and the applicability of one (or more) treatment schemes should be determined through careful bench-scale (laboratory) and on-site pilot-scale examination.


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