VIRUS FATE IN GROUNDWATER

by

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INTRODUCTION

Groundwater traditionally has been considered to be safe for consumption without treatment. Currently, however, groundwater accounts for about 50% of the documented waterborne illness in the United States (Craun, 1979). Of these, over 65% have a probable viral etiology. A total of 50 waterborne outbreaks occurred during 1980, increasing the annual average of outbreaks to 39 for the five-year period from 1976-1980. This represents more than 50% increase over the 1971-1975 average of 24. The five-year averages have steadily increased from an annual average of ten during 1951-1955. Before that period, the trend was declining (Lippy, 1981).

It should be emphasized that reporting of waterborne disease outbreaks, particularly in individual systems, is notoriously poor. Given the difficulty of performing epidemiologic studies and inadequacy of waterborne disease reporting, evidence for potential health problems related with land application of wastewater will often rest on our ability to assess the fate of human pathogens in the environment.

More than 110 different virus types may be present in raw sewage including polioviruses, echoviruses, coxsackieviruses, rotaviruses, hepatitis virus, adenoviruses, calciviruses, etc. The list of pathogenic human enteric viruses has continued to grow during the last decade. Rotaviruses are now recognized as a major cause of childhood gastroenteritis, sometimes resulting in dehydration and death in infants. Rotaviruses also cause diarrhea in adults and several waterborne outbreaks have been documented recently (Sutmoller et al., 1982). The Norwalk viral agent has been demonstrated to be the cause of numerous water and foodborne outbreaks of epidemic viral gastroenteritis (Kaplan et al., 1982; Gunn et al., 1982).

In most of the groundwater waterborne disease outbreaks, underground migration of septic tank effluent was believed to be the probable cause. But, viruses may also find their way into groundwater from the intentional land application of domestic sewage for purposes of crop irrigation or groundwater recharge. Viruses also occur in solid household domestic wastes because of the widespread use of disposable diapers and, thus, find their way into landfills. Viruses have been detected in groundwater beneath land application sites where sewage was being applied and near domestic landfill sites (keswick and Gerba, 1980). Viruses were detected at depths as great as 46m and at distances as great as 900m at some sites. An understanding of factors that control virus migration through the subsurface is necessary for the management of septic tanks, landfills and wastewater land treatment systems.

SURVIVAL OF VIRUSES IN THE SUBSURFACE

The fate of pathogenic bacteria and viruses in the subsurface will be determined by their survival and their retention by soil particles. Both survival and retention are now believed to be largely determined by climate, nature of the soil and nature of the microorganism. Climate will control two important factors in determining viral and bacterial survival: temperature and rainfall. The survival of microorganisms is greatly prolonged at low temperature; below 4°C they can survive for months or even years (Gerba et al., 1975). At higher temperatures, inactivation or die-off is fairly rapid. In the case of bacteria, and probably viruses, the die-off rate is approximately doubled with each 10°C rise in temperature between 5°C and 30°C (Reddy et al., 1981). Above 30°C, temperature is probably the dominant factor determining virus survival time. While the survival of human pathogenic enteric viruses in soil has previously been studied, almost no information on the survival of viruses in groundwater exists. Hurst et al. (1980) concluded that temperature and adsorption appear to be the most important factors affecting virus survival in soils. Factors controling virus survival in groundwater have yet to be determined.

MIGRATION OF VIRUSES IN THE SUBSURFACE

Rainfall mobilizes previously retained bacteria and viruses and greatly promotes their transport in groundwater. Several studies have shown that the greatest degree of drinking water well contamination occurs after periods of heavy rainfall (Dewalle et al., 1980; Lewis et al., 1980).

The nature of the soil will also play a major role in determining survival and retention. Soil properties influence moisture-holding capacity, pH and organic matter - all of which will control the survival of bacteria and virus in the soil. Other soil properties such as particle size, cation exchange capacity and clay content will influence retention. Factors that may influence virus movement through the subsurface are shown in Table 1.

TABLE 1. Factors that may influence virus movement through the subsurface

Factor	Comments
Soil Type	Fine-textured soils retain viruses more effectively than light-textured soils.
pH	Generally, adsorption increases when pH decreases.
Cations	Adsorption increases in the presence of cations. Rainwater may desorb viruses from soil due to its low conductivity.
Soluble Organics	Can compete with viruses for adsorption sites. No significant competition at concentrations found in wastewater effluents. Humic and fulvic acid reduce virus adsorption to soils.
Virus Type	Adsorption to soils varies with virus type and strain.
Flow Rate	The higher the flow rate, the lower adsorption of virus to soils.
Saturated vs. unsaturated flow	Virus movement is less under unsaturated flow conditions.

Retention of viruses by soil is, of course, a paramount consideration in protecting groundwater from contamination. Filtration plays a major role in bacterial removal, although adsorption is also involved. Virus removal is believed to be almost totally dependent on adsorption (Keswick and Gerba, 1980). The nature of the soil probably plays a major role in determining the degree of virus adsorption. Generally, soils containing clays are more effective in retaining viruses. Understanding the physical-chemical properties of the soil as related to virus adsorption has been seen as an aid in understanding the potential for groundwater contamination. Virus adsorption to soils is believed to be largely governed by electrostatic double-layer interactions and Van der Waal's forces (Murray and Parks, 1980). More recent work indicates that hydrophobic interactions may also play a role (Farrah et al., 1981).

A number of studies evaluating virus adsorption to soils using batch reactors have been conducted (Goyal and Gerba, 1979). In these studies, a given amount of soil was mixed with virus suspended in a solution and adsorption determined after a given period of time. The results of such studies indicate that virus adsorption is related to cation exchange capacity, pH, surface area and organic matter, but firm predictive correlations between virus adsorption and these factors have not been well established.

Establishment of predictive relationships between soil factors and virus adsorption is further complicated by genetic variability among different types and strains of viruses. The isoelectric point of viruses varies among strains and types of viruses, and this has been shown to effect virus adsorption to the surfaces of charge modified glass beads (Zerda et al., 1981). Recently, we have been conducting studies on the removal of different viruses by soil columns. These studies indicate that the retention of viruses by a given soil can vary markedly as shown in Table 2.

Table 2. Removal of Poliovirus type 1 and coliphage f2 by Pomello fine sand*

Column Depth (cm)	Percentage of Virus Remaining	
	Poliovirus 1	f2
0	100	100
2	41	109
27	13	102
67	2	98
87	1	101

*Suspended in secondarily treated sewage and passed through a 2 cm diameter column at a flow rate of 120-194 cm/day. Initial virus concentration was approximately 10^5 plaque forming units/ml.

The results of these column studies indicate that some viruses will have a greater potential for contamination than others. Differences in adsorption among viruses may be due to variations in configuration of proteins in the outer capsid of the virus, which affects the net charge on the virus. This affects the electrostatic potential between virus and soil, which, in turn, affects the degree of interaction between the two particles. Thus, it appears that no one virus can be used as the sole model for determining the adsorptive behavior of viruses to soils and that no single virus can be used as the model for determining viral adsorptive capacity of all soil types.

From the foregoing discussion, it is apparent that many factors control the removal and persistence of pathogenic enteric viruses during the movement of wastewater through the soil. Additional research in this area is needed to further define processes involved in the survival and transport of viruses in the subsurface.

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