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Project Summary

Removal of Virus from Public Water Supplies

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Assays of concentrated raw Missouri River water for the presence of naturally occurring human enteroviruses resulted in the recovery of polioviruses, Coxsackie viruses, and ECHO viruses. Virus concentrations were found to be highest in the winter and spring, when river flows (and therefore the effects of dilution) were lowest. Statistically significant inverse correlations were found between virus recoveries and conventional microbiological indicators of water contamination (total coliform, fecal coliform, and standard plate counts).

An evaluation of the effectiveness of water treatment at a plant in Lexington, Missouri, indicated that presedimentation plus the addition of lime resulted in the reduction of virus levels. Concentrates derived from 1.9-m^3 (500-gal) samples of treated drinking water were assayed. No isolates were obtained from the 65 samples analyzed.

Batch disinfection studies were conducted using raw Missouri River water treated with chlorine, chloramine, chlorine dioxide, or ozone. Though virus levels were very low and data were limited, ozone and chlorine dioxide appeared to be most capable of inactivating viruses under the conditions employed.

Studies of the effectiveness of physical removal processes were conducted using water treatment pilot plants constructed of stainless steel and housed in a 12.2-m (40-ft) tractor-trailer. Because raw water viruses were present in insufficient numbers, bacteriophage-seeded studies were conducted. Results indicated that a virus reduction of one or two orders of magnitude was obtained by physical removal processes alone. A comparison of conventional treatment versus direct filtration indicated that comparable removal could be obtained by both processes, although conventional treatment was somewhat more consistent in performance. Reductions in other microbial indicators paralleled virus removals, indicating the effectiveness of the indicators as monitors of virus removals.

The final portion of the study was conducted by the Capital City Water Treatment Plant in Jefferson City, Missouri. Chlorine and chloramine were applied in parallel pilot-plant units for the disinfection of Missouri River water. Both disinfectants were capable of producing a finished water that met bacteriological standards. Chloramine, however, proved to be more stable than chlorine.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report order information at back).

Introduction

The efficiency of drinking water treatment processes for the removal and inactivation of viruses has been studied extensively. Because of the lack of methods for detection and enumeration of naturally occurring viruses at the levels at which they are present in most operating treatment plants, virus levels are usually increased by adding laboratory-propagated viruses. The adequacy of such studies for modelling or simulating actual water treatment conditions has frequently been questioned. In an attempt to conduct treatment efficiency studies using only naturally occurring viruses, an operating water treatment plant using poor quality source water was identified and used as the study site.

Preliminary studies indicated that the source water contained sufficient naturally occurring viruses to make the study feasible. Although virus levels were not consistently high throughout the course of the 3-year study, substantial information on the effects of water treatment unit processes on naturally occurring viruses and microbial indicator organisms was obtained.

Results

Longitudinal Studies of Virus in Missouri River Source Water

Throughout the study, naturally occurring human enteroviruses were found in Missouri River water at the Lexington, Missouri, water treatment plant intake. An average of 2.5 viruses were recovered in 216 samples of approximately 0.38 m^3 (100 gal) each. Polioviruses were most abundant (69%), followed by Coxsackie (11%) and ECHO viruses (5%). Of the total, only 10% of the virus particles were recovered on the 3- to 5-μm pore size prefilters, indicating that most of the recovered virus particles were not associated with the suspended sediment in Missouri River water.

Virus concentrations were found to average 10 plaque-forming units (pfu)/0.38 m^3 (100 gal) in the winter and spring of 1977, 1.5 pfu/0.38 m^3 (100 gal) in the summer and fall, and 5 pfu/0.38 m^3 (100 gal) in the winter and spring of 1978 (Figure 1). If the virus concentrations are normalized with respect to river flow, the virus flow in the Missouri River at Lexington appears to be more nearly constant throughout the year. But seasonal winter and spring virus flow peaks appear to persist.

Statistically significant inverse correlations were obtained between concentrations of virus and microbiological indicators (fecal coliform, total coliform, and standard plate counts). These results, coupled with winter and spring virus flow peaks, indicate that conventional microbial parameters may not always prove useful as quantitative indicators of virus contamination.

Field-Scale Studies of Virus Removal by Treatment Processes

Samples were taken of the presettled, lime-treated, and finished water at the Lexington, Missouri, water treatment plant over the period of December 2, 1976, to March 22, 1978. In 21 samples taken of presettled water, a total of 39 viruses were recovered. Seven viruses were recovered from 14 samples taken after adding lime to the raw water. Finally, no viruses were recovered from the 71 finished water samples (1.9 m^3 (500 gal)) collected.

The results from the survey of plant performance indicate that the overall water treatment process at Lexington, Missouri, is consistently effective in reducing viruses to below detectable limits. Moreover, preliminary treatment of raw Missouri River water with lime appeared to result in a measurable inactivation of the viruses present.

Chemical Disinfection for Virus Inactivation

Ozone and chlorine dioxide both showed potential for inactivating the human enteroviruses present in raw Missouri River water when sufficient dosage and time were provided. Chlorine and chloramine, however, appeared to be only marginally effective against viruses when applied to raw water. In general, the reduction of viruses to below detectable limits was accompanied by near-total destruction of fecal and total coliforms and by reductions in standard plate counts of two to three orders of magnitude. The comparatively low numbers of acid-fast bacteria and yeast found in raw Missouri River water appear to limit their use as indicator organisms.

Physical Removal of Virus Particles

As part of the study of the physical removal of virus-sized particles from Missouri River water, a mobile water treatment research facility was constructed. Twin water treatment pilot plants were built and mounted in a tractor-trailer. A separate, limited-edition internal report entitled *Construction Plans and Operations Manual for USEPA Mobile Water Treatment Facility* was prepared to provide subsequent operators of the pilot plant facility with design calculations, shop drawings, fabrication notes, and instructions for operation, maintenance, and safety.

For the physical removal studies, bacteriophage MS2 was seeded into raw Missouri River water as a surrogate for human enteroviruses to increase the number of virus particles present, to shorten the time between sampling and obtaining the experimental results, and to reduce costs.

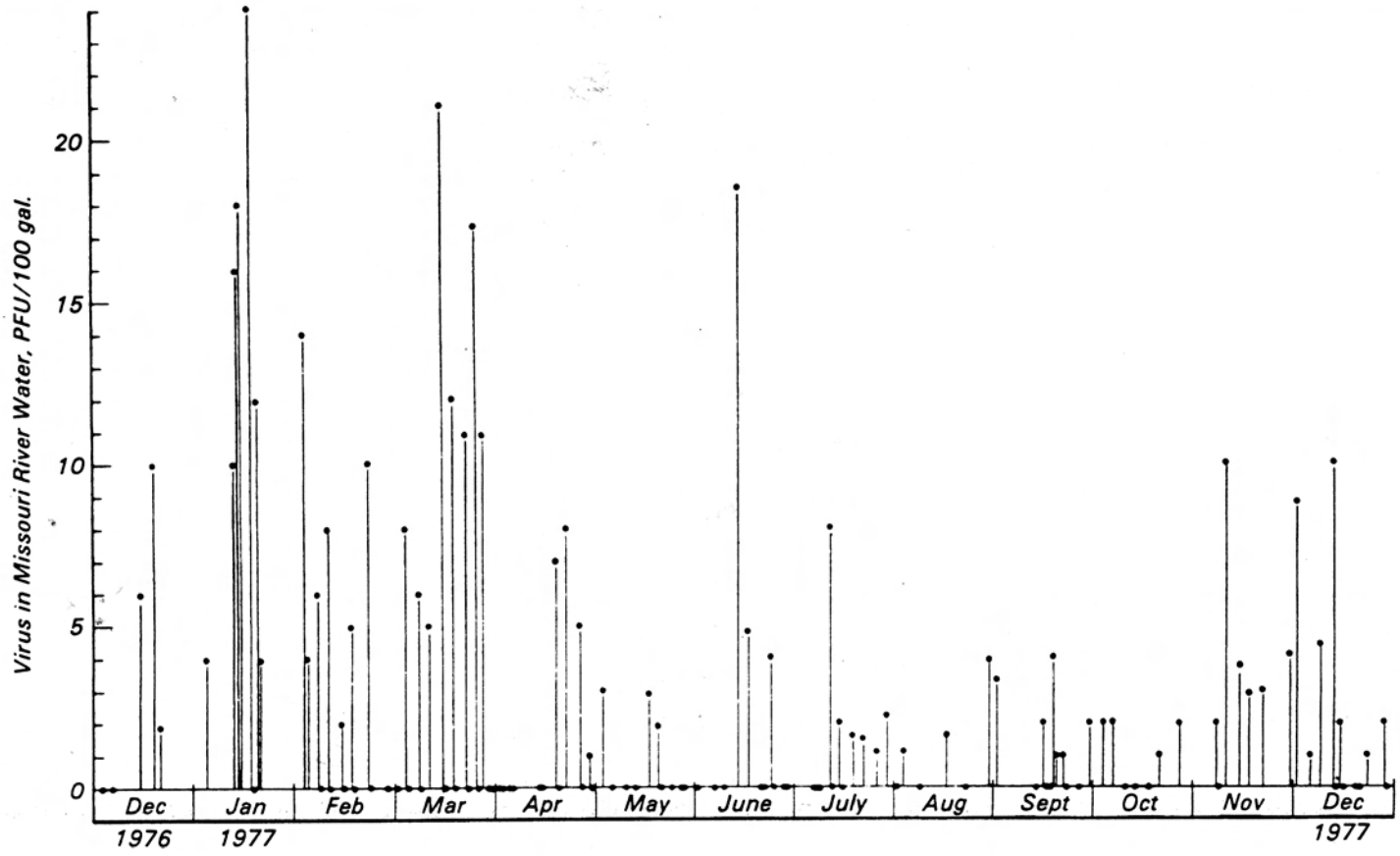
Coagulation with aluminum sulfate followed by sedimentation and dual-media filtration resulted in an overall removal of 93% of seeded bacteriophage. Comparable removals were obtained with respect to fecal and total coliforms, fecal streptococci, and standard plate count organisms.

In other studies on removal of naturally occurring MS2 bacteriophages, coagulation with a cationic polyelectrolyte followed by direct filtration resulted in an 87% removal of seeded MS2 bacteriophage.

With direct filtration, results were more erratic than those obtained with conventional treatment. Again, the removal of other indicator organisms paralleled the removal of MS2 bacteriophage.

Turbidity reductions reflected organism removals. Influent turbidities ranged from 19 to 180 NTU. Effluent turbidities ranged from 1 to 7 NTU for conventional treatment. Direct filtration produced turbidities in the range of 0.4 to 8.5 NTU, except for a single high value of 77 NTU. This turbidity breakthrough occurred during a period of high influent turbidity.

Overall, one- to two- order-of-magnitude removal of seeded virus and other microbial indicators of pollution was obtainable by both conventional water treatment and direct filtration under proper operating conditions. Direct filtration, however, was more subject to upset during periods of high influent turbidities.



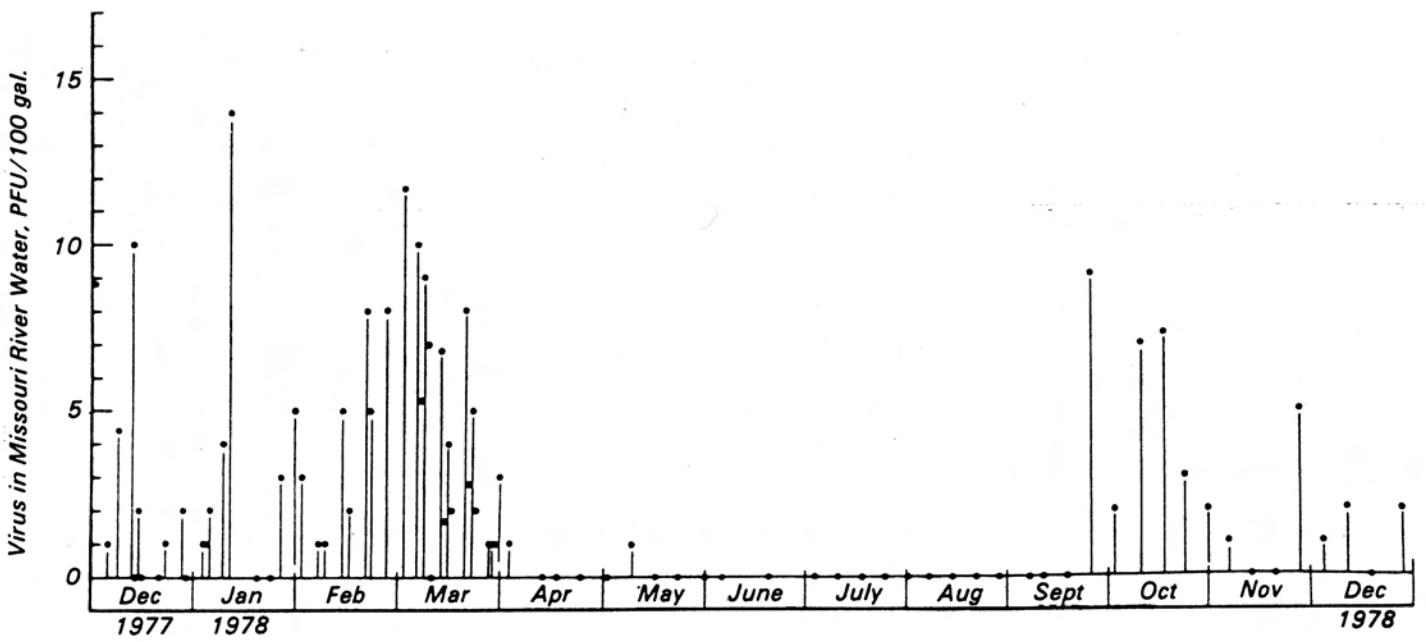


Figure 1. *Virus in raw Missouri River water, December 1976 through December 1978.*

Chlorine Versus Chloramine for Water Disinfection

Studies of organism removal and disinfection by chlorine and chloramine at Jefferson City, Missouri, began with a comparison of organism reductions with and without the addition of chlorine.

Aluminum sulfate coagulation and sedimentation removed 80% to 85% of the standard plate count organisms. With filtration, organism removal increased to 90%. Adding chlorine increased organism reductions to 99.9% or more.

The subsequent comparison of chlorine versus chloramine (each added before the rapid mix tank) indicated that both disinfectants were effective in attaining bacteriological drinking water standards. Moreover, chloramine produced an order of magnitude fewer trihalomethanes.

With the inclusion of GAC post-adsorbers in the pilot-plant operation at Jefferson City, Missouri, it was possible to observe the removal of trihalomethanes as well as the reduction in total organic carbon and substances that have trihalomethane-forming potential.

Comparable disinfection could be achieved with chlorine and chloramine, but effluent trihalomethanes were lower with chloramine than with the use of both chlorine and GAC.

Summary and Conclusions

The results of the virus removal studies indicate that both sedimentation processes using coagulants and various types of filtration processes usually remove more than 90% of the viruses present in the water. Results of the pilot- and field-scale studies tended to be similar to those of the laboratory-scale studies. Process control is the primary factor determining the efficiency of removal processes. The variability in removal efficiencies of the coagulation-flocculation and filtration processes points up the need for maintaining adequate disinfection in addition to the removal processes. The efficiency with which turbidity is removed by sedimentation and filtration generally indicates the efficiency of virus removal.

Other Reports Based on This Research

The following publications are based on research conducted under this grant and have been published or are in preparation.

Reach, Jr., C. D., Hemphill, L., Akin, E., and O'Connor, J. T. "Naturally-Occurring Human Enteroviruses in Missouri River Water." (In preparation; to be submitted to Water Research.)

Reach, Jr., C. D., Hoff, J. C., Logsdon, G., and O'Connor, J. T. "Chemical Inactivation and Physical Removal of Naturally-Occurring Human Enterovirus in Missouri River Water." (In preparation; to be submitted to Journal American Water Works Assoc.)

Reach, Jr., C. D., Hoff, J. C., Logsdon, G., and O'Connor, J. T. "Chlorine versus Chloramine for the Disinfection of Missouri River Water." (In preparation; to be submitted to Journal American Water Works Assoc.)

Reach, C. D., O'Connor, J. T., and Hamphill, L. "Virus and Bacterial Quality of Missouri River." Proc. Annual Meeting of American Water Works Association. Part I. pp. 519-529. 1979.

Reed, G. D., Reach, Jr., C. D., and O'Connor, J.T. "Trihalomethane Precursor Removal under Two Modes of Disinfection." Journal American Water Works Association (accepted for publication).

The full report was submitted in fulfillment of Grant No. R-804903-02 by the University of Missouri-Columbia under the sponsorship of the U.S. Environmental Protection Agency.

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***John C. Hoff** is the EPA Project Officer (see below).*

The complete report, entitled "Removal of Virus from Public Water Supplies," (Order No. PB 82-230 327; Cost: $15.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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