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Quantitative Studies on Fabrics as Disseminators of Viruses

V. Effect of Laundering on Poliovirus-Contaminated Fabrics

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The effects of laundering with both anionic and nonionic detergents in cold, warm, and hot water on poliovirus-contaminated cotton sheeting, cotton terry cloth, washable wool shirting, wool blanketing, dull nylon jersey, and dacron/cotton shirting were determined. The fabrics were exposed to virus by aerosolization and direct contact (pipette) in separate studies. Although the results varied with each factor used in the study, virus titers on all the fabrics were generally reduced considerably by the laundering process. When the fabrics were dried for 20 hr after laundering, an additional decline in virus titers was seen, often to below detectable levels. The type of detergent used made little difference in effect on virus titer reduction, but the hot wash water markedly reduced the detectable virus. Fabric type was not a major factor in the majority of the experiments, although virus tended to be eliminated more readily from the nylon jersey, and in warm water the virus persisted longer on wool blanketing material laundered in anionic detergent. Sterile fabrics of each type laundered with similar fabrics which contained virus often became contaminated by the virus during the laundering process. Virus titers ranging from undetectable to $10^{3.9}$ cell culture 50% infectious doses/ml were obtained from samples of the rinse water after warm- and cold-water laundering.

It has been established (6, 11–13) that certain viruses can persist for significant periods of time on fabrics typical of those used in clothing and household textiles. This suggests that such fabrics could play an important role in the dissemination of virus diseases. In the preceding report (15) this premise of fabrics as fomites was strengthened by the demonstration that viable polio and vaccinia virus remaining on fabrics after being dried were readily transferred to other fabrics during dry, random, tumbling contact. In some cases, significant titers of virus were transferred within 1 min after initiation of this contact. Reports by others (5, 7, 9, 10) also implicate fabrics as potential fomites for viruses. To further elucidate the problem of virus-contaminated fabrics, studies were undertaken to determine if such fabrics still contained viable virus after laundering under conditions typical of home use and whether virus dissemination could occur during such laundering processes. This report describes experiments using poliovirus-contaminated materials.

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MATERIALS AND METHODS

Virus. The MEF-1 strain of poliovirus, obtained in cell culture suspension from Parke, Davis & Co., Detroit, Mich., was used in this study. This virus was the same as that used in our previously reported work (15).

Fabrics. Cotton sheeting, cotton terry cloth, washable wool shirting, wool blanketing, dull nylon jersey, and dacron/cotton shirting were utilized. These fabrics were described fully in the preceding report (15). Prior to use in these studies, each fabric was laundered twice using the appropriate washing machine setting for each, in either anionic or nonionic detergent. Those fabrics laundered with anionic detergent were later used in the anionic detergent experiments, and those laundered in the nonionic detergent were used in the nonionic detergent experiments. After the preliminary laundering, all were then cut either into 35- by 105-cm strips or into ca. 5-cm diameter swatches. Sterilization was accomplished with ethylene oxide (12, 14).

Detergents. Two detergents, one anionic and the other nonionic, which were typical of those marketed for home use were employed for these studies. The ingredients of the anionic detergent were sodium linear alkylate sulfonate, nonionic surfactant (alkyl ethylene oxide condensate), sodium soap, sodium tripolyphosphate, sodium silicate, sodium sulfate, water, and minor miscellaneous chemicals not cited by the manufacturer. This product was produced especially for this study by the Proctor & Gamble Co., Cincinnati, Ohio. A low-sudsing detergent, it was used at a concentration of approximately 0.18% by volume of wash water. The nonionic detergent was obtained from the Lever Brothers Company, Edgewater, N.J. It contained, as major ingredients, nonionic detergent (synthetic alcohol-ethylene oxide condensate), sodium soap, sodium tripolyphosphate, cellulosic, sodium silicate and sodium sulfate, perfume, and optical dye. This detergent was used at a concentration of approximately 0.21% by volume of wash water.

Water hardness. Birmingham city water was used in all laundering experiments. It had an average calcium carbonate content of ca. 27 ppm.

Washing procedures. In each laundering experiment, each fabric was laundered in a standard automatic top-loading washing machine (no. 26W28900N, Sears, Roebuck and Co., Chicago, Ill.) using the wash, rinse, and spin-dry cycles appropriate to the particular fabric. For the cotton sheeting and terry cloth fabrics the "cottons, linens, white" cycle was used. The "permanent-press, white" cycle was used for the dacron/cotton shirting and the nylon jersey fabrics, and the "washable woolens and fragiles" cycle was used for the washable wool shirting and the wool blanketing. For all but the woolen fabrics, three wash temperatures were used in separate experiments. These were "cold," 21 to 27 C; "warm," 38 to 43 C; and "hot," 54 to 60 C. Only the cold and warm temperatures were used for laundering the woolen materials since washing in hot water is injurious to the fabrics. Approximately 44 liters of water was used to fill the washer tub in each experiment. After each complete use of the washing machine, the tub was thoroughly flushed with water at a temperature of ca. 64 C by running the machine at the "cottons, linens, white" setting a single time; preliminary bacterial tests indicated the efficacy of this procedure as a decontamination tool. In the event of possible contamination by aerosol as a result of laundering the contaminated fabric, the exterior of the machine was occasionally swabbed with 70% ethyl alcohol.

Determination of effect of laundering procedures. Fifteen swatches of each fabric were randomly attached to strips of the same fabric and exposed to virus by direct contact or aerosol. All were held for 16 hr in 35% relative humidity, when five swatches were detached and assayed for virus titer to serve as virus controls. The ten additional virus-containing swatches were placed in the washing machine. At the same time, five sterile swatches of the same fabric type attached to a sterile strip of the material were also placed in the machine, and sterile strips were added until a "standard" (by bulk) wash load was obtained. The fabrics were then laundered. Ten milliliters of the rinse water was removed near the end of the rinse cycle and assayed for content of viable virus. The swatches were removed from the fabric strips at the end of the spin cycle. Five were immediately assayed in HEp-2 cells as described previously (15) for content of viable virus. The remaining five swatches were held at 25 C in 35% relative humidity 20 hr before virus assay. The swatches, separated by sterile glass fiber screen, were placed five to a dish in elevated-lid plastic petri dishes (Falcon Plastic, Div. of B-D Laboratories, Inc., Los Angeles, Calif.) which in turn were held in insulated cabinets [40 by 40 by 22 inch (101.6 by 101.6 by 55.9 cm)] during this holding period. This method of humidity maintenance and swatch storage has been described in greater detail in previous reports (12). All the fabrics became essentially dry after a 20-hr storage under these conditions. Mean virus titers of each of the five swatches in each control and test group were determined; the effect of laundering was expressed as the reduction in virus titer on the test swatches as compared with the virus control swatches. The sterile swatches were employed to demonstrate if sterile materials would become contaminated if laundered with virus-containing fabrics. Cotton sheeting and wool blanketing exposed by direct contact to the virus were also laundered in the absence of detergent to serve as an additional control in the study.

RESULTS

An example of an individual experiment using pipetted poliovirus-contaminated wool blanketing laundered in warm water with nonionic detergent is shown in Table 1. The virus control swatches had a mean titer of $10^{5.3}$ cell culture 50% infectious doses/ml ($CCID_{50}$/ml) when tested after a holding period of 16 hr. Laundering the similar virus-contaminated swatches reduced the virus titer to $10^{1.7}$ $CCID_{50}$/ml, a titer reduction of $10^{3.6}$. After laundering, drying the contaminated swatches for 20 hr in 35% relative humidity further reduced the virus titer to $10^{0.6}$ $CCID_{50}$/ml, an additional virus reduction of $10^{1.1}$. Sterile, wool blanketing swatches which were laundered with the virus-containing fabrics apparently became contaminated with virus, having a mean titer of $10^{1.5}$ $CCID_{50}$/ml recovered from them immediately after laundering. The rinse water was similarly contaminated, having virus demonstrated with a titer of $10^{2.7}$ $CCID_{50}$/ml. The variation between titers of similar swatches in all experiments was usually less than ± 1 $\log_{10}$.

Experiments similar to the above were carried out with each fabric, detergent, method of virus exposure, and wash temperature. Tables 2 to 4 show the titers of the virus control swatches and the titer reduction resulting from washing and drying. The amounts of virus which were recoverable from the rinse water and the originally sterile fabrics are indicated in Tables 5 to 7. In

TABLE 1. *The effect of warm-water laundering (38 to 43 C) with nonionic detergent on the titer of poliovirus placed by direct contact on wool blanketing*

Identification of sample[a]	Swatch no.	Virus titer[b] ($CCID_{50}$/ml)	Mean virus titer ($CCID_{50}$/ml)
Virus control	1	$10^{5.0}$	
	2	$10^{5.9}$	
	3	$10^{4.9}$	$10^{5.3}$
	4	$10^{4.9}$	
	5	$10^{4.8}$	
Test-wet	6	$10^{1.2}$	
	7	$10^{1.9}$	
	8	$10^{1.2}$	$10^{1.7}$
	9	$10^{1.2}$	
	10	$10^{2.1}$	
Test-dry	11	$10^{0.4}$	
	12	$10^{0.8}$	
	13	$10^{0.4}$	$10^{0.6}$
	14	$10^{0.8}$	
	15	$10^{0.6}$	
"Sterile"-wet	16	$10^{1.0}$	
	17	$10^{1.6}$	
	18	$10^{1.9}$	$10^{1.5}$
	19	$10^{1.4}$	
	20	$10^{1.2}$	
Rinse water		$10^{2.7}$	$10^{2.7}$

[a] Virus control: fabric swatches which were exposed to virus, held 16 hr at 25 C in 35% relative humidity, and tested for virus titer. Test-wet: fabric swatches which were exposed to virus simultaneously with the virus controls, held under the same conditions as the virus controls, laundered, and tested immediately for virus titer. Test-dry: fabric swatches which were processed simultaneously with the test-wet swatches under the same conditions but allowed to dry in 35% relative humidity for 20 hr before being tested for virus titer. "Sterile"-wet: originally sterile fabric swatches which were laundered with the test-wet and test-dry swatches and then tested while still wet for virus which may have been transferred to them. Rinse water: ten milliliters of water removed from the washing machine near the end of the rinse cycle and assayed for virus titer.

[b] Concentration of virus in either the eluate medium after maceration of each swatch or in the rinse water. Expressed as mean $CCID_{50}$/ml of quintuplicate tests.

general, the virus titers were reduced considerably on the fabrics during the laundering process, but the sterile fabrics included in each experiment and the rinse water usually became contaminated with the virus in the process. When the test fabrics were then dried for 20 hr after laundering, an additional decline in virus titer occurred, often to the point that virus was no longer detectable.

Fabric type was apparently a less significant factor in these experiments than was observed earlier in the virus persistence studies, for the degree of virus reduction did not appear markedly different on the different materials. Two exceptions were noted. Virus tended to be eliminated more readily on the nylon jersey, particularly in warm and cold water; in warm water, virus seemed to persist longer on the wool blanketing material laundered in anionic detergent.

The method of virus exposure also influenced the results of the study. Laundering usually caused a greater virus titer reduction on fabrics which were exposed to virus by direct contact than on those exposed to the aerosolized virus, but the degree of virus transfer observed was not significantly influenced by the method of exposure.

Heat supplied by the wash water was one of the most important factors in eliminating viable poliovirus from the contaminated fabrics, as shown by the fact that virus reductions were marked in the hot-water experiments (Table 2), with little detectable virus remaining on the fabrics. Less differences were seen between the effects of warm and cold water, although a comparison of the data from the two studies (Tables 3 and 4) suggests that laundering in warm water was somewhat more effective than the use of cold water. In no hot water experiment (Table 5) was viable poliovirus recovered from the rinse water, and the amounts of virus detectable on the originally sterile fabrics were usually very low (less than $10^{1.0}$ $CCID_{50}$/ml).

Essentially no difference was seen in the two detergents in regard to their ability to eliminate viable virus from the fabrics (Tables 2 to 4), although the nonionic detergent appeared slightly more effective for the woolen materials at cold- and warm-water laundering temperatures. The detergent type used produced no marked differences in the amount of virus recoverable from the rinse water or from the originally sterile fabrics which had been laundered with the virus-containing materials (Tables 5 to 7). Laundering cotton sheeting in cold, warm, or hot water without detergent appeared to reduce the titer of the virus on the fabric as effectively as when the contaminated fabric was laundered with either of the detergents (Tables 2 to 4). Laundering the virus-contaminated wool blanket material in the detergents was more effective, however, than when the detergents were omitted (Tables 3 and 4).

The *p*H was apparently not a significant cause of the observed reductions in virus titer since in

TABLE 2. *Effect of hot-water laundering (54 to 60 C) of poliovirus-contaminated fabrics*

Fabric	Detergent	Mean virus titers ($CCID_{50}$/ml)					
		Direct contact exposure to virus			Aerosol exposure to virus		
		Virus control[a]	Test-wet[a]	Test-dry[a]	Virus control	Test-wet	Test-dry
Cotton sheeting	Anionic	$10^{6.2}$	$10^{0.6}$	$10^{0.5}$	$10^{5.0}$	$10^{0.4}$	$<10^{0.4}$
	Nonionic	$10^{4.0}$	$10^{0.5}$	$<10^{0.4}$	$10^{6.0}$	$10^{0.4}$	$<10^{0.4}$
Cotton terry cloth	Anionic	$10^{6.0}$	$10^{0.7}$	$10^{1.3}$	$10^{5.6}$	$10^{0.5}$	$10^{0.4}$
	Nonionic	$10^{6.0}$	$10^{0.8}$	$10^{0.6}$	$10^{5.8}$	$10^{0.4}$	$10^{0.9}$
Nylon jersey	Anionic	$10^{5.8}$	$10^{0.4}$	$10^{0.4}$	$10^{4.6}$	$10^{0.4}$	$10^{0.6}$
	Nonionic	$10^{6.1}$	$10^{0.8}$	$10^{0.4}$	$10^{5.1}$	$10^{0.6}$	$<10^{0.4}$
Dacron/cotton shirting	Anionic	$10^{5.5}$	$10^{0.6}$	$<10^{0.4}$	$10^{4.2}$	$10^{0.5}$	$<10^{0.4}$
	Nonionic	$10^{5.9}$	$10^{0.4}$	$<10^{0.4}$	$10^{1.1}$	$10^{0.5}$	$<10^{0.4}$
Cotton sheeting	None	$10^{5.8}$	$10^{0.4}$	$<10^{0.4}$			

[a] See the sample identification in footnote *a*, Table 1.

TABLE 3. *Effect of warm-water laundering (38 to 43 C) of poliovirus-contaminated fabrics*

Fabric	Detergent	Mean virus titers ($CCID_{50}$/ml)					
		Direct contact exposure to virus			Aerosol exposure to virus		
		Virus control[a]	Test-wet[a]	Test-dry[a]	Virus control	Test-wet	Test-dry
Cotton sheeting	Anionic	$10^{5.9}$	$10^{2.3}$	$10^{0.5}$	$10^{1.5}$	$10^{0.7}$	$10^{0.4}$
	Nonionic	$10^{6.4}$	$10^{2.6}$	$<10^{0.4}$	$10^{1.5}$	$10^{1.0}$	$<10^{0.4}$
Cotton terry cloth	Anionic	$10^{5.7}$	$10^{2.9}$	$<10^{0.4}$	$10^{4.8}$	$10^{2.2}$	$<10^{0.4}$
	Nonionic	$10^{5.8}$	$10^{2.7}$	$10^{0.6}$	$10^{4.9}$	$10^{2.2}$	$10^{0.4}$
Washable wool shirting	Anionic	$10^{5.6}$	$10^{2.8}$	$10^{0.8}$	$10^{3.2}$	$10^{1.4}$	$<10^{0.4}$
	Nonionic	$10^{6.1}$	$10^{1.2}$	$10^{0.4}$	$10^{4.8}$	$10^{0.7}$	$10^{0.4}$
Wool blanketing	Anionic	$10^{6.9}$	$10^{3.2}$	$10^{3.4}$	$10^{5.0}$	$10^{2.7}$	$10^{2.9}$
	Nonionic	$10^{5.3}$	$10^{1.7}$	$10^{0.6}$	$10^{5.7}$	$10^{1.3}$	$10^{0.4}$
Nylon jersey	Anionic	$10^{6.2}$	$10^{0.6}$	$<10^{0.4}$	$10^{5.5}$	$10^{0.4}$	$<10^{0.4}$
	Nonionic	$10^{6.0}$	$10^{0.6}$	$10^{0.5}$	$10^{2.6}$	$10^{0.9}$	$10^{0.5}$
Dacron/cotton shirting	Anionic	$10^{6.0}$	$10^{2.2}$	$<10^{0.4}$	$10^{3.8}$	$10^{2.5}$	$<10^{0.4}$
	Nonionic	$10^{5.9}$	$10^{3.8}$	$10^{1.3}$	$10^{3.7}$	$10^{1.1}$	$10^{1.4}$
Cotton sheeting	None	$10^{5.9}$	$10^{0.9}$	$10^{0.4}$			
Wool blanketing	None	$10^{5.9}$	$10^{4.2}$	$10^{0.5}$			

[a] See the sample identification in footnote *a*, Table 1.

all the experiments the *p*H was relatively similar. The *p*H of the wash water containing anionic detergent was 9.2 and that of the rinse water was 7.8; the *p*H of the wash water containing the nonionic detergent was 9.3 and that of the rinse water was 7.7. The eluates from the fabrics varied in *p*H from 7.1 to 7.7.

DISCUSSION

The actual effects of laundering on the virus cannot be accurately determined in a study of this nature, since the observed virus titer reduction could be a result of either simple elution of the virus from the fabric, or because the viable agent

TABLE 4. *Effect of cold-water laundering (21 to 27 C) of poliovirus-contaminated fabrics*

Fabric	Detergent	Mean virus titers (CCID50/ml)					
		Direct contact exposure to virus			Aerosol exposure to virus		
		Virus control[a]	Test-wet[a]	Test-dry[a]	Virus control	Test-wet	Test-dry
Cotton sheeting	Anionic	$10^{5.6}$	$10^{3.3}$	$<10^{0.4}$	$10^{3.9}$	$10^{1.1}$	$<10^{0.4}$
	Nonionic	$10^{5.9}$	$10^{3.6}$	$10^{0.6}$	$10^{4.5}$	$10^{4.7}$	$<10^{0.4}$
Cotton terry cloth	Anionic	$10^{6.4}$	$10^{4.2}$	$10^{0.8}$	$10^{2.4}$	$10^{1.6}$	$10^{0.7}$
	Nonionic	$10^{6.1}$	$10^{4.4}$	$<10^{0.9}$	$10^{3.9}$	$10^{1.7}$	$<10^{0.4}$
Washable wool shirting	Anionic	$10^{5.8}$	$10^{3.0}$	$10^{0.4}$	$10^{5.4}$	$10^{3.2}$	$10^{0.4}$
	Nonionic	$10^{5.8}$	$10^{2.5}$	$10^{0.5}$	$10^{3.8}$	$10^{0.5}$	$10^{0.4}$
Wool blanketing	Anionic	$10^{5.9}$	$10^{3.4}$	$10^{0.7}$	$10^{5.7}$	$10^{3.4}$	$10^{0.9}$
	Nonionic	$10^{5.7}$	$10^{2.0}$	$10^{0.7}$	$10^{5.7}$	$10^{2.0}$	$10^{0.4}$
Nylon jersey	Anionic	$10^{5.7}$	$10^{0.6}$	$<10^{0.4}$	$10^{2.0}$	$10^{0.4}$	$<10^{0.4}$
	Nonionic	$10^{6.0}$	$10^{0.4}$	$<10^{0.4}$	$10^{2.2}$	$10^{0.4}$	$<10^{0.4}$
Dacron/cotton shirting	Anionic	$10^{5.9}$	$10^{2.1}$	$10^{0.8}$	$10^{3.0}$	$10^{0.8}$	$10^{0.8}$
	Nonionic	$10^{6.2}$	$10^{2.1}$	$<10^{0.4}$	$10^{2.4}$	$10^{0.6}$	$<10^{0.4}$
Cotton sheeting	None	$10^{6.3}$	$10^{4.0}$	$10^{1.2}$			
Wool blanketing	None	$10^{5.8}$	$10^{5.1}$	$10^{0.6}$			

[a] See the sample identification in footnote *a*, Table 1.

TABLE 5. *Hot-water laundering (54 to 60 C) as a means of poliovirus dissemination: recovery of virus from rinse water[a] and from fabrics[b] laundered with contaminated material*

Fabric	Detergent	Recoverable virus titer[c]			
		Rinse water-direct contact experiment	Rinse water-aerosol experiment	Originally sterile fabric-direct contact experiment	Originally sterile fabric-aerosol experiment
Cotton sheeting	Anionic	—[d]	—	$10^{0.6}$	$10^{0.4}$
Cotton sheeting	Nonionic	—	—	$10^{1.4}$	$10^{2.1}$
Cotton terry cloth	Anionic	—	—	$10^{0.8}$	$10^{0.5}$
Cotton terry cloth	Nonionic	—	—	$10^{0.4}$	$10^{2.0}$
Nylon jersey	Anionic	—	—	$10^{0.5}$	$10^{0.4}$
Nylon jersey	Nonionic	—	—	$10^{0.6}$	—
Dacron/cotton shirting	Anionic	—	—	—	$10^{3.7}$
Dacron/cotton shirting	Nonionic	—	—	$10^{0.9}$	$10^{1.6}$

[a] Ten milliliters of water removed from the washing machine near the end of the rinse cycle.
[b] Originally sterile fabric swatches which were laundered with the test-wet and test-dry swatches of the same fabric (*see* Table 1).
[c] Concentration of virus in either the eluate medium after maceration of each swatch or in the rinse water. The titers for the originally sterile fabrics are expressed as the mean $CCID_{50}$/ml of five swatches.
[d] No virus demonstrated.

was being inactivated. To attempt to overcome the elution factor which existed because of the volume of wash and rinse water used, a relatively large quantity of virus was placed on the swatches and on the fabric strips to which the swatches were attached. The recovery of poliovirus from the rinse water in the experiments in which cold or warm water was used would suggest that the

TABLE 6. *Warm water laundering (38 to 43 C) as a means of poliovirus dissemination: recovery of virus from rinse water[a] and from fabrics[b] laundered with contaminated material*

Fabric	Detergent	Recoverable virus titer[c]			
		Rinse water-direct contact experiment	Rinse water-aerosol experiment	Originally sterile fabric-direct contact experiment	Originally sterile fabric-aerosol experiment
Cotton sheeting	Anionic	—[d]	—	$10^{0.6}$	$10^{0.9}$
Cotton sheeting	Nonionic	—	—	$10^{0.7}$	$10^{0.7}$
Cotton terry cloth	Anionic	$10^{1.2}$	—	$10^{1.5}$	$10^{0.9}$
Cotton terry cloth	Nonionic	$10^{1.1}$	$10^{.10}$	$10^{0.9}$	$10^{0.8}$
Washable wool shirting	Anionic	$10^{2.9}$	$10^{2.9}$	$10^{1.8}$	$10^{1.0}$
Washable wool shirting	Nonionic	$10^{2.4}$	$10^{2.2}$	$10^{0.6}$	$10^{0.6}$
Wool blanketing	Anionic	$10^{3.8}$	$10^{3.8}$	$10^{2.2}$	$10^{2.4}$
Wool blanketing	Nonionic	$10^{2.7}$	$10^{1.3}$	$10^{1.5}$	$10^{1.8}$
Nylon jersey	Anionic	—	—	$10^{1.5}$	$10^{0.4}$
Nylon jersey	Nonionic	—	—	$10^{0.6}$	$10^{0.6}$
Dacron/cotton shirting	Anionic	—	—	$10^{2.1}$	$10^{1.9}$
Dacron/cotton shirting	Nonionic	—	—	$10^{4.1}$	$10^{4.6}$

[a] Ten milliliters of water removed from the washing machine near the end of the rinse cycle.
[b] Originally sterile fabric swatches which were laundered with the test-wet and test-dry swatches of the same fabric (*see* Table 1).
[c] Concentration of virus in either the eluate medium after maceration of each swatch or in the rinse water. The titers for the originally sterile fabrics are expressed as the mean $CCID_{50}$/ml of five swatches.
[d] No virus demonstrated.

virus was indeed being physically removed from the fabric during the laundering process but was not being inactivated to a significant extent. The detergents, in lowering surface tension, would assist in this physical removal. Heat had a probable inactivating effect, since in the hot-water laundering experiments no virus was recoverable in the rinse water. Further evidence of this effect is provided by the observation that sterile fabrics which had been laundered in hot water usually had a lower virus content than similar fabrics laundered in warm or cold water. Dimmock (5) reported thermal inactivation of poliovirus could occur at temperatures as low as 20 C. Such inactivation at lower temperatures (below 44 C) required days, however, whereas at moderate temperatures (45 to 50 C) inactivation occurred in hours and at temperatures over 50 C, such as were used in the present hot-water laundering experiments, marked inactivation took place within 10 min. The inactivation which was observed at the higher temperatures was attributed by Dimmock to damage of the virus protein.

In all of our previously reported experiments (6, 11), poliovirus survived markedly longer on the woolen materials than on any other fabric type. In the present study less differences were seen in the degree of virus reduction on the various fabrics, but those differences in virus survival and transferral which were observed were probably a result of the fiber construction and possibly the weave of the cloth. Both factors were considered to be of significance in our previous virus persistence studies (6, 12).

The reduction in virus titer brought about by drying was considered highly significant. It is possible that these reductions were caused by alterations of the chemical structure of the virus or of the surroundings which made the virus more labile. Such alterations may have been caused by either the wash and rinse water or by the detergents, although the detergents, being surface-active agents, are the more probable suspects. This conclusion was substantiated to a degree in the experiments with the wool blanketing, since laundering this virus-containing fabric in water without detergent caused little loss of virus.

The primary purpose of the present study was to obtain quantitative information on the survival and dissemination of viruses from fabrics during home-type laundering. Such data would provide information regarding the potential health hazards involved with fabrics and the protective measures which could possibly be

TABLE 7. *Cold-water laundering (21 to 27 C) as a means of poliovirus dissemination: recovery of virus from rinse water[a] and from fabrics[b] laundered with contaminated material*

Fabric	Detergent	Recoverable virus titer[c]			
		Rinse water-direct contact experiment	Rinse water-aerosol experiment	Originally sterile fabric-direct contact experiment	Originally sterile fabric-aerosol experiment
Cotton sheeting	Anionic	—[d]	—	$10^{1.2}$	$10^{1.2}$
Cotton sheeting	Nonionic	—	—	$10^{0.9}$	$10^{0.9}$
Cotton terry cloth	Anionic	—	—	$10^{2.7}$	$10^{1.4}$
Cotton terry cloth	Nonionic	—	—	$10^{1.3}$	$10^{3.1}$
Washable wool shirting	Anionic	$10^{2.9}$	$10^{2.9}$	$10^{1.0}$	$10^{0.8}$
Washable wool shirting	Nonionic	$10^{1.0}$	$10^{1.4}$	$10^{0.4}$	$10^{0.9}$
Wool blanketing	Anionic	$10^{3.9}$	$10^{3.9}$	$10^{3.0}$	$10^{3.0}$
Wool blanketing	Nonionic	$10^{3.2}$	$10^{3.8}$	$10^{1.8}$	$10^{2.4}$
Nylon jersey	Anionic	—	—	$10^{0.4}$	$10^{0.4}$
Nylon jersey	Nonionic	—	—	$10^{0.6}$	$10^{0.4}$
Dacron/cotton shirting	Anionic	—	—	$10^{0.6}$	$10^{0.8}$
Dacron/cotton shirting	Nonionic	—	—	$10^{1.1}$	$10^{1.1}$

[a] Ten milliliters of water removed from the washing machine near the end of the rinse cycle.
[b] Originally sterile fabric swatches which were laundered with the test-wet and test-dry swatches of the same fabric (*see* Table 1).
[c] Concentration of virus in either the eluate medium after maceration of each swatch or in the rinse water. The titers for the originally sterile fabrics are expressed as the mean $CCID_{50}$/ml of five swatches.
[d] No virus demonstrated.

taken. Our earlier studies indicated that viruses could persist on various cotton and wool fabrics for sufficient periods of time for them to be potential fomites. In a recent report (15), both poliovirus and vaccinia virus were demonstrated to be readily transferred to other fabrics (and hence to potentially any object) by dry contact. The present study has shown that poliovirus transfer can also occur during a regular laundering process. Of equal importance was the demonstration of viable virus in the rinse water, implicating waste water from such laundering as another possible source of contamination. Community water as a virus fomite has been considered previously by others (1–3, 8).

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