

Virus survival in the environment

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Summary: Viruses pass into the environment from clinically ill or carrier hosts; although they do not replicate outside living animals or people, they are maintained and transported to susceptible hosts. Population concentrations and movement, both animal and human, have been steadily increasing in this century, enhancing transmission of respiratory and enteric viruses and compounding the difficulty of preventing environmental transmission.

Studies on environmental survival factors of viruses have been most definitive for polioviruses, foot and mouth disease viruses and Aujeszky's disease virus. In addition, heat resistance studies have been reported on adenoviruses, African swine fever virus and the Norwalk virus. Resistance to disinfectants has been studied for many viruses, including picornaviruses, papovaviruses, reoviruses and retroviruses. Survival of viruses in and on a variety of fomites has been studied for influenza viruses, paramyxoviruses, poxviruses and retroviruses. The subacute spongiform encephalopathy agents, under extensive current studies, are being found to have incredible stability in the environment.

KEYWORDS: Environment - Fomites - Inactivation - Resistance - Stability - Survival - Virus.

INTRODUCTION

In the triad of infectious disease transmission involving aetiological agents, susceptible hosts and the environment, the role of the environment is the most ambiguous. The environment receives, maintains or protects and transports aetiological agents to susceptible hosts. Viruses may enter the environment in enormous quantities from clinically ill or inapparent carrier hosts; when extant outside the hosts which support their replication, they are the least understood of infectious agents. The greatest prospects for disease control for the future, however, lie in environmental measures to halt or reduce transmission. Conversely, failure to break the chains of transmission will result from failure to protect the environment or to modify it beneficially.

The increase in respiratory disease transmission through population concentrations, in cities in the case of humans and in confinement production units in the case of animals, is the most striking example of disease prevalence. A greater contemporary awareness of the role played by the confined environment in increasing the transmission of some diseases while reducing that of others has prompted more serious study of the environment.

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This review of the survival of viruses in the environment attempts to consolidate data from reported studies. Further investigation of how numerous viruses survive in the environment is necessary. Current knowledge is fragmented and the fragments differ widely according to the infectious agents; this fact highlights the need for more comprehensive studies in the future.

This article discusses viral entry, survival and transport as they relate to any nonliving substances or living organisms which do not support viral replication. Viruses are considered by families and are ordered alphabetically. When more than one virus is discussed in a chapter, they are considered alphabetically in relation to the first virus mentioned in the chapter.

ADENOVIRIDAE

Thermal inactivation studies have been reported for adenovirus 12, reovirus 1 and herpes simplex virus in raw milk, sterilized homogenized milk, raw chocolate milk and raw ice cream mix, with minimum essential medium (MEM) as control suspending fluid (55, 57). From approximately 10,000 plaque-forming units (PFU) per ml of each suspending medium, inactivation curves at 40°C-60°C were asymptotic to the base line, indicating that small amounts of these viruses survived, even at the higher temperature. At 65°C, the inactivation curves approached first order reactions, indicating that temperatures near pasteurization standards were effective in inactivating these three viruses. In the same studies, influenza A and Newcastle disease viruses showed stability in raw and sterilized milk equivalent to that in MEM. Thermal inactivation of Maloney virus, Rauscher leukemia virus and Rous sarcoma virus assayed in mice showed Rous sarcoma to be the most resistant.

ARENAVIRIDAE

The hallmark of all rodent-borne arenaviruses is persistent infection in the rodent host in the presence of immunological response (38). Persistence is established in the natural host if virus transmission occurs *in utero* or shortly after birth. Most persistently infected rodents have permanent viruria and viremia. Viral persistence is a highly efficient means of virus perpetuation in most rodent offspring; it is also the most important source of contamination of the external environment and leads to transmission of infection.

HERPESVIRIDAE

Extensive studies have been published on assays of potentially contaminated fomites for both human and animal herpesviruses. Additional studies of virus survival on and in experimentally-contaminated fomites have been reported. In studies on the alphaherpesvirus, HSV2, assays of spa water failed to yield the virus (45). To

simulate the conditions of survival of HSV2 on plastic-coated benches and seats in spa facilities, HSV2 ($10^{4.2}$ CCID₅₀/0.5 ml) was placed on plastic surfaces in a humid atmosphere at 37°C-40°C. The virus was found to survive for up to 4.5 h under these conditions. The results of a study with HSV1 and HSV2 viruses demonstrated that HSV obtained directly from ulcerative or vesicular genital lesions was able to survive for several hours on fomites and hard surfaces and for several days on dry cotton gauze (35). HSV2 has been shown to survive for short periods outside the host; it is the opinion of some workers, however, that while the virus can persist on certain surfaces and porous items, such as towels, for relatively long periods of time, fomites are not particularly significant in transmission (22).

There has been considerable interest in environmental transmission of the betaherpesvirus, cytomegalovirus (CMV), among infants and personnel in medical facilities. During a four-month study, CMV was found in the urine of eight infants (54). Three of the isolates were found to be identical by restriction endonuclease analysis, which suggests that the three infants in question were infected with the same CMV strain. The evidence indicates that CMV was transmitted from one infant to the other two infants through unidentified fomites within the nursery. Samples from the immediate environment of these eight CMV-infected infants were obtained and submitted for virus assay in cell cultures (23). CMV was isolated from those objects which had come in direct contact with infected secretions, i.e. from six of eight oronasal suction bulbs, one feeding tube, four dry diapers in contact with genitalia, and from a pair of gloves worn by a nurse. While the conclusion was reached that CMV could be isolated for several hours after natural contamination, it was not determined that fomites were an important source of nosocomial CMV transmission. That personnel should wash their hands during patient care, however, was considered as essential.

Nosocomial transmission of CMV was investigated in a chronic care unit (CMV excretion prevalence 16%) and a neonatal unit (CMV excretion prevalence 0.7%) (19). In the chronic care unit, two infants were infected with homologous strains of CMV. No infants acquired CMV in the neonatal unit of the hospital, though seroconversion did occur in two nurses: CMV was isolated from diapers and from the hands of patients and personnel, but not from environmental surfaces.

In an epidemiological study of bovine herpes mammillitis (BHM) virus (27), pseudocowpox was confirmed in dual infections in nine of eleven BHM-positive milking herds. The pattern of BHM spread was not related to the incidence of pseudocowpox or to the order in which cows were milked. Meteorological data suggested that BHM occurred more frequently in those years conducive to the increase of large populations of insect vectors, and that the direction in which BHM spread to herds within a locality was related to the predominant wind direction.

Fomites were experimentally identified as a risk in the transmission of CMV (53). Urine and saliva inoculated with 1×10^4 PFU/ml of either a wild or laboratory strain of CMV could be recovered, at 37°C, for 48 h and 2 h, respectively.

Survival studies on Aujeszky's disease virus (ADV) in this unit have focused on experimental contamination of fomites and vehicles present in and around swine operations. Virus suspended in saliva, nasal-washing or saline-glucose control fluids

was assayed for survival on solid fomites kept moist at 25°C. What follows are the maximum times needed to reach 99.99% inactivation:

– control fluid (no fomite)	58 days
– steel	18 days
– concrete	4 days
– plastic	8 days
– rubber	7 days
– denim cloth	<1 day
– loam soil	7 days
– green grass	2 days
– shelled corn	36 days
– pelleted swine feed	3 days
– meat and bone meal	5 days
– alfalfa hay	<1 day
– straw bedding	4 days
– sawdust bedding	2 days
– swine faeces	2 days.

Mean survival time of ADV in contact with fomites in saliva suspension was 45% of virus in saline-glucose suspension; in nasal-washing suspension, the mean survival time was 30% of that for virus in saline-glucose suspension (52).

ADV suspended in liquid fomites at 25°C reached 99.99% inactivation at the following times (52):

– well water	7 days
– chlorinated water	2 days
– urine from swine on subtherapeutic medicated feed	14 days
– manure pit effluent	<1 day
– anaerobic lagoon effluent	2 days.

ADV in aerosol decayed logarithmically with half-lives of 17.4-36.1 min at 22°C and 27.3-43.6 min at 4°C, with longer survival times at 55% relative humidity than at 25% or 85% relative humidity (51).

ADV fed to houseflies (*Musca domestica*) could be recovered for as long as seven days in the internal organs but for only a short time from the body surfaces. The longest survival time for virus was obtained when 3-day-old flies were exposed (compared to survival in 5- to 13-day-old flies), and when exposed flies were kept at 10°C as compared to 20°C or 30°C (61). Virus placed on the feet of pigeons and

starlings could not be recovered, even when suspended in mucin, placed on washed surfaces of the toes and sampled promptly after exposure (M.A. Schoenbaum and G.W. Beran, unpublished data).

ADV mixed into 80% lean ground pork sausage, pH 5.85, could still be recovered after 14 days at 4°C storage and after 40 days at -20°C storage (E.C. Pirtle and T.A. Proescholdt, unpublished data).

IRIDOVIRIDAE

African swine fever virus (ASFV) is the only virus in the Iridoviridae family which is known to infect mammals. ASFV survives over a wide range of pH values and is particularly resistant to alkaline conditions. In the presence of protein, some infectious virus may survive for 7 days at pH 13.4 and for several hours below pH 4.0 (49).

NORWALK VIRUS

The Norwalk group of viruses is tentatively described as calici-like, but has not been definitely classified (32). In experiments, the Norwalk virus retained infectivity to volunteers producing gastroenteritis following exposure to pH 2.7 for 3 h at room temperature and after heating at 60°C for 3 min. Both the Norwalk and "W" (Wollan boarding school) agents were stable following treatment with 20% ether at 40°C for 18-24 h.

ORTHOMYXOVIRIDAE

Orthomyxoviruses, influenza A and B ($10^{3.5}$ and $10^{4.2}$ infectious doses/0.1 ml, respectively) were spread over stainless steel, plastic and absorbent material surfaces (30 to 50 mm) (4). These objects were subsequently sampled by rubbing with sterile swabs or "clean" fingers. Both influenza A and B viruses survived on hard surfaces for 24 to 48 h, but for less than 8 to 12 h on porous surfaces. The conclusion was therefore reached that, under conditions of heavy environmental contamination, the transmission of influenza virus by fomites may be possible.

PAPOVAVIRIDAE

Objects used in the treatment of patients with human papillomavirus (HPV) infections were tested for recovery of HPV-DNA (25). HPV-DNA was identified by hybridization on 8 of 16 (50%) surgical gloves, on 23 of 62 (37%) and 1 of 62 (1.6%)

biopsy forceps before and after sterilization in 30% tincture of Savlon for 30 min, and on 5 of 22 (23%) and 1 of 22 (4.5%) cryoprobe tips before and after cleaning with 90% ethanol for 1 min. Whether the HPV on fomites remained infectious was not evaluated; however, extreme caution on the part of patients and personnel was suggested.

PARAMYXOVIRIDAE

In studies on paramyxoviridae obtained from infants, a suspension of respiratory syncytial virus (RSV) containing approximately $10^{5.5}$ CCID₅₀/ml was used to contaminate Formica counter tops, cloth gowns, rubber gloves, paper facial tissues and hands (28). The virus was recovered from counter tops for as long as 6 h, from rubber gloves for 1.5 h, from cloth gowns and paper tissues for 30 to 45 min, and from skin for up to 20 min. Self-inoculation by contact with contaminated infant secretions was therefore considered a potential method of nosocomial transmission of RSV.

Dilutions of parainfluenza viruses (PIV), types 1, 2 and 3, were experimentally studied on nonabsorptive and absorptive surfaces (9). Virus was recovered for up to 10 h from nonabsorptive surfaces and for up to 4 h from absorptive surfaces. Interpretation of the results suggests that fomites should be considered as sources of PIV transmission inside and outside hospitals.

Newcastle disease virus was isolated from the carcasses of frozen poultry for over 730 days and from buried carcasses for 121 days (31).

Rinderpest virus was reported to inactivate rapidly outside the body (48) and to be most stable at pH 4.0-10.2 at 4°C. Infected meat stored in a chilled state between 2°C and 7°C was still infective after seven days.

PICORNAVIRIDAE

Extensive investigations have been conducted on the survival, under natural and experimental conditions, of several viruses belonging to the Picornaviridae family (small RNA viruses). Results of these picornavirus investigations are given herein.

The Mengo encephalomyocarditis virus, a picornavirus of the Cardivirus genus, was examined for survival at various temperatures (21). The virus suspended in saline at $1 \times 10^{6.6}$ infectious doses/ml was still detectable at titres of $\geq 10^2$ infectious doses/ml on the 25th day at 37°C, on the 102nd day at room temperature, and on the 117th day between 2°C and 10°C.

In studies in this unit, encephalomyocarditis virus (Florida strain) was mixed into 80% lean ground pork sausage, pH 5.85, held at 4°C and -20°C and assayed at regular intervals. By the 56th day, viral titres had decreased 99% in sausage stored at 4°C but not at all in sausage stored at -20°C (E.C. Pirtle and T.A. Proescholdt, unpublished data).

Foot and mouth disease (FMD) virus, a picornavirus of the genus Aphthovirus, has been widely studied for its strong environmental stability. Virus shed from infected mammary glands was incorporated into milk micelles and fat droplets, thus affording thermal resistance (7). A portion of the viral population was found viable in contaminated milk after pasteurization at 72°C for 15 seconds or after acidification to pH 4.6 (11). FMD virus has been recovered from cattle stalls 14 days after removal of infected cattle, from urine after 39 days, from soil after 28 days in autumn and after 3 days in summer, and from dry hay at 22°C after 20 weeks storage. Salting, curing and drying of hides of infected cattle has not been effective in inactivating the virus (15). Carcasses of infected animals at 4°C have reached a tissue pH ≤ 5.3 within a few days when chilled, thus inactivating FMD virus; however, virus has been recovered from bone marrow and lymph nodes after six months of refrigeration (1) and from swine blood after two months of refrigerated storage (15).

Numerous human pathogenic viruses exist among the enterovirus genus of the picornaviruses. Banker (3) has emphasized the detection of more than 100 different types of enteric viruses in drinking water, wastewater, sea water, as well as in soil, crops, foods and aerosols. Also emphasized was the possibility that viruses which are more resistant than indicator bacteria to conventional purification procedures, and which thus have greater potential for survival, may be contained in drinking water which meets bacteriological standards.

Three enteroviruses – polioviruses, echoviruses and coxsackieviruses – were used to contaminate soil and vegetables; their survival times, under various storage conditions, were then recorded (2). The concentration of the viruses employed varied from $1 \times 10^{4.5}$ to $1 \times 10^{5.5}$ CCID₅₀/ml. Depending on soil type, moisture content, pH and temperature, the viruses survived for 150 to 170 days in soil. When added to uncooked vegetables and stored under household conditions, the viruses survived for as long as 15 days.

Three of the numerous studies conducted on insects as possible survival hosts of enteroviruses are cited here. In one study (16), poliovirus types 1 and 3 were fed to two groups of blowflies (*Phoenicia sericata*) via sugar cubes contaminated with $10^{7.5}$ PFU/cube. The flies were then alternately incubated between 40°C and 4°C. Dead flies were removed and titrated for the polioviruses. Viruses were recovered from flies for 13 days (type 3) to 15 days (type 1). Virus titres decreased during the study period; this indicated that the virus did not replicate in the flies, and that mechanical means accounted for survival and potential spread.

In the second study (17), cockroaches (*Periplaneta americana*) were fed poliovirus type 3 at approximately $10^{6.5}$ PFU/roach. Virus survived in roaches for as long as 50 days with no evidence of virus multiplication; as in the blowfly study, the cockroaches were considered to be potential mechanical spreaders of the surviving poliovirus.

In studies conducted on the MF strain of swine enterovirus on the initial isolation farm, houseflies which had been in contact with the swine environment were collected and then assayed in nine pools of 25 flies each. The virus was recovered from all pools at mean concentrations between 19 and 186 CCID₅₀ per fly. Wash fluids from surfaces of the flies yielded a mean of 124 CCID₅₀ per fly, while a mean of 66 CCID₅₀ was obtained from ground tissues of the washed fly bodies. The authors concluded that contaminated houseflies could readily transport the virus between swine units. However, with regard to the widespread viral shedding in the environment by adult

swine and the widespread early infection of young pigs, flies did not seem to play any essential role in the maintenance of the endemic state of infection (60).

Poliovirus type 1 and coxsackieviruses, types B1 and B6, were added to foods at total concentrations of 1×10^5 or 1×10^6 CCID₅₀, then held at room temperature, 10°C and -20°C (37). The viruses were still viable after one week, one month and five months, respectively. Decomposition did not affect virus viability at room temperature and antibiotics controlled bacterial contaminants during laboratory assay.

In a study of the survival of coxsackievirus B2 experimentally inoculated on ground beef, a 75% recovery rate (7,000 PFU) was achieved by suspension, elution and inoculation of monkey kidney cell cultures (55). The same technique was used to recover naturally contaminating polioviruses and echoviruses from three of twelve purchases of market-purchased beef at levels between 1 and 195 PFU per 5 g. One loaf of beef yielded poliovirus type 1 and echovirus type 6, one yielded poliovirus type 2, and one yielded poliovirus types 1 and 3.

In a study on experimental contamination during the preparation of Thuringer sausage, approximately 85% of the coxsackievirus A9 (10^4 to 7.5×10^5 CCID₅₀) which was added to the sausage was lost during 24 h fermentation at 30°C (30). Additional heating of the prepared sausage at 49°C resulted in further progressive loss of virus; after 6 h at 49°C, however, an average of 1.1×10^3 CCID₅₀ of virus/g of sausage still remained of the initial 7.5×10^5 CCID₅₀/g. Despite the counts of spoilage bacteria which rose progressively, coxsackievirus A9 suspended in ground beef was found to survive, at levels considered as infectious, for up to eight days at both 23°C and 4°C.

So that parameters for virus isolation from environmental samples might be better defined, the effects of inoculum size and cell culture density on cytopathic effect (CPE) or plaque assay were assessed with poliovirus type 1 and Buffalo green monkey (BGM) cells (47). A linear relationship was obtained with an inoculum volume of 1.0 ml/25 cm². Depending on the sensitivity of the cell cultures, maximum titres were obtained when 25,000 to 75,000 cells/ml were incubated for six days before exposure to virus.

Survival of enterovirus 70 (EV70), the aetiologic virus of acute haemorrhagic conjunctivitis, was assayed at various temperatures (20°C to 35°C) and relative humidities (20, 50, 80 and 95%) (50). Ultrahigh relative humidity (95%) best protected EV70 from inactivation at 20°C, but the virus was least stable between 33°C and 35°C at this humidity level.

Human enterovirus 72, the aetiologic virus of human hepatitis A, has shown a relative stability which is typical of the majority of enteroviruses. Rapidly developing epidemics of hepatitis A have often followed faecal contamination of a single source, such as drinking water, food, or milk, with human enterovirus 72 (40, 42, 43, 58, 59).

A swine enterovirus was tested for stability to dimethyl ether, arsenilic acid, penicillin, dihydrostreptomycin, butyl parasept and oxytetracycline. It was also tested at pH values 5 to 9 and at incremental temperatures between 23°C and 70°C (5). No depression of infectivity titre was obtained with any of the chemicals or compounds tested. The virus was stable at pH values 5 to 9 at 4°C for 28 days, at 23°C for two weeks, and at 37°C for four days. It was inactivated within 30 min at 50°C; inactivation was immediate at 56°C and higher.

Swine enterovirus, which was excreted in large amounts in the faeces, was shown to survive in faeces at ambient temperatures for periods up to 27 days (20).

Swine vesicular disease virus (SVDV) has been isolated from infected faeces after 28 days (18). It was stable over a wide pH range (2 to 12) and survived at pH 5 to 10 at 4°C for long periods. SVDV has been isolated from infected premises for as long as eleven weeks after swine herd depopulation and disinfection of the premises. Only processes which involved heat treatment at or above 60°C for at least 30 min effectively inactivated SVDV. Contaminated meats, which had been imported and refrigerated, were found to remain dangerous almost indefinitely; for example, SVDV at -20°C yielded viable virus for 300 days.

Domestic sewage was found to contain about 500 enteric virus units/100 ml, while polluted surface water contained no more than one unit/100 ml (12). The ratio of enteric viral density to coliform bacterial density in human faeces was approximately 15 virus units for every 106 coliforms. The activated sludge process removed 90 to 98% of enteric viruses in raw sewage. Hypochlorous acid (HClO) was shown to be effective in inactivating viruses in water, with the rate depending on the virus, pH, temperature and contact time. Polioviruses, coxsackieviruses and hepatitis A viruses were more resistant to HClO than coliform or enteric pathogenic bacteria.

Coxsackieviruses in human stools were thermally inactivated at 55°C for 15 min or at 71.1°C for 15 seconds in water. Dairy products offered these viruses a measure of protection against thermal inactivation, but minimum conditions recommended for pasteurization (61.7°C for 30 min or 71.1°C for 15 seconds) proved adequate for inactivation of the faecal strains (34).

Surface sea water from the Mediterranean inactivated 10^3 CCID₅₀/ml of poliovirus type 1 in six to nine days (39). The sea water lost part of this virucidal activity after boiling, but Seitz filtration was found to have no such activity. Artificial sea water was less deleterious to the virus. It was therefore concluded that the virucidal activity was partly due to heat-labile substance(s) in sea water.

A study was conducted in the Philippines on the survival of enteroviruses in sea water alone, or in sea water containing oysters. In sea water alone, 99.99% of the decay in virus titre occurred for poliovirus type 1 in fourteen days and for poliovirus types 2 and 3 in seven days. The same percentage occurred for coxsackievirus B4 in three days, for coxsackieviruses A9, B1 and B6 in seven days, for coxsackieviruses B3 and B5 in fourteen days, for echoviruses 5 and 7 in seven days and for echoviruses 1, 12, 13, 17 and 20 in fourteen days. The same survival periods were recorded for poliovirus types 1-3 in sea water with living oysters; however, at three days the oysters were found to have concentrated poliovirus type 1 at titres of $10^{5.5}$ CCID₅₀/g of digestive tract and $10^{6.5}$ CCID₅₀/g of flesh compared to $10^{3.5}$ CCID₅₀/ml of sea water. At seven days, $\geq 99.9\%$ of the poliovirus type 1 was gone from the digestive tracts and tissues of the oysters; at fourteen days, virus levels in the oysters were at nearly the same levels as those found in their ambient sea water. Poliovirus types 2 and 3 were not taken up from the contaminated sea water by the oysters (G.W. Beran and J.C. Nakao, unpublished data).

In a flow-through sea water system, oysters were found to concentrate poliovirus type 1 at rates of 10 to 60 times the concentration of the virus in sea water. The oysters later cleansed themselves of virus in UV-treated fresh sea water. *E. coli* assayed as indicator showed that experimental conditions were optimal for the study (41).

The results of another study indicated that poliovirus added to ground beef may be more resistant to the levels of heat commonly employed when cooking if the meat contains fat levels approaching 30% (26).

In studies on the survival of virus during the manufacture of Cheddar cheese, 98% of poliovirus type 1, and nearly 100% of influenza A virus and vesicular stomatitis (VS) virus, were inactivated (13). Poliovirus persisted in cheese throughout the aging process, but was inactivated 10^6 -fold when milk which was to be made into cheese was given minimal prior heat treatment.

When suspended in water, milk or ice cream, poliovirus in faecal material from poliomyelitis patients was inactivated at pasteurization temperatures, 61.7°C for 30 min or 71.1°C for 15 seconds (33). Poliovirus in the spinal cords of infected monkeys suspended in the same media was also destroyed at pasteurization temperatures.

When cattle were inoculated in tongue epithelium with 10^5 bovine ID_{50} of foot and mouth disease virus (FMDV) (15), thyroid, adrenal and rumen yielded 1.2, 3.2 and $1.2 \log_{10}$ PFU, respectively, at eight days post inoculation. FMDV was recovered from bone marrow in titres of 1.2 to $1.5 \log_{10}$ PFU after seven months storage at 1°C to 4°C .

POXVIRIDAE

In studies involving one- to two-day-old chicks, avipox virus strain used as modified live virus (MLV) vaccine with 10^6 CCID₅₀/ml of drinking water proved more efficacious than 10^4 CCID₅₀/ml when administered either by drinking water or by aerosol (44). This was probably due to the better survival rate of avipox virus in the higher initial concentration of 10^6 CCID₅₀/ml.

The persistence of capripoxvirus in sheep flocks has been attributed in large part to the survival of infectious virions in skin scales which fall on pasture plants or the soil (24).

REOVIRIDAE

Reovirus type 1, influenza A, and parainfluenza 3 viruses survived for three days or less in low moisture processed food. However, poliovirus and echovirus 6 survived in such food for more than two weeks at room temperature and more than two months at 5°C (14).

In studies on the survival of rotaviruses, approximately 10^7 PFU of human rotavirus suspended in faecal matter were placed on disks of stainless steel, glass and plastic (36). Twenty-seven disinfectants were tested for ability to inactivate these viruses. Only nine of the twenty-seven formulations proved to be effective. The results indicated a relative resistance of human rotaviruses to a wide range of chemical disinfectants; they also emphasized the need to evaluate thoroughly the virucidal potential of formulations employed so as to prevent and control outbreaks of rotavirus diarrhoea in human patients.

It has been demonstrated that bluetongue is a noncontagious disease transmitted primarily by insects (46). The bluetongue virus has been shown to lose infectivity at pH 3.0, and lipid solvents to reduce infectivity approximately tenfold.

RETROVIRIDAE

The constantly increasing number of cases of human immunodeficiency virus (HIV) infections and the recognition of retroviral infections in animals has led to a search for effective methods to disinfect contaminated materials. Hypochlorite-releasing disinfectants have been evaluated against HIV (8). Sodium hypochlorite (NaOCl) and sodium dichloroisocyanurate (NaDCC) were tested by quantitative suspension. HIV suspensions of 10^4 to 10^5 syncytial forming units/ml were prepared in isotonic NaCl or NaCl plus 10% plasma. Results indicated that disinfection (10^3 - 10^4 reduction in 2 min) could be achieved using NaDCC and NaOCl at concentrations of 50 ppm and 2,500 ppm available chlorine (Av Cl₂) for virus in NaCl and NaCl plus plasma, respectively. Spilled blood required disinfection with high Av Cl₂ concentrations of NaDCC and NaOCl solutions of 5,000 ppm of blood to effect complete inactivation within 2 min.

RHABDOVIRIDAE

As rabies virus is transmitted by bites – unless accidentally injected under highly unusual conditions – and thus circumvents the need to survive in the environment, it is epidemiologically unimportant even when viable in the environment. The lipoprotein envelope and glycoprotein projections subject the virions to oxidative or ultraviolet light inactivation as well as to desiccation. Rare occurrences of aerosol transmission have involved high concentrations of virus through laboratory accidents or in caves where depleted oxygen levels, combined with a relative increase in virus-protecting nitrogen, allowed the accumulation of virus excreted by infected, cave-dwelling bats (6).

The vesiculovirus, vesicular stomatitis virus (VSV), is resistant to marked pH changes and is moderately resistant to heat and chemical inactivation (29). The virus remains infective for up to three weeks, depending on the medium in which it is suspended; frozen VSV has remained viable for several years.

SCRAPIE AGENT

The scrapie agent remains unclassified. Scrapie agent-infected brains from infected hamsters were ground, made into suspensions and centrifuged, after which the supernatant fluids were suspended in soil (10). The soil suspensions were placed into petri dishes and buried for three years. Of the 10^5 hamster infectious units thus interred, between 10^2 and 10^3 of infectious prions were recovered after three years in the soil.

PRIORITY AREAS FOR FURTHER STUDY

Further investigations of the viruses which enter the human and animal environments are needed, especially as soil and water receive increasing concentrations of these infectious agents. Determinations of the viability of viruses identified in the environment are important, as such viruses do not replicate. In the absence of applicable laboratory culture procedures, differentiating viable virions from degraded ones may be difficult. Nucleic acid hybridization is a promising method of detecting viral DNA.

Of specific importance are hepatitis A virus, the calici- and calici-like viruses (Norwalk, Ditchling or W, Cockle, Parramatta and Snow Mountain), astroviruses (Marin County), Sapporo and Otofuke agents, parvoviruses, coronaviruses and the enteric adenoviruses. Emerging in importance are the agents of subacute spongiform encephalopathies in humans and animals, the unique protein structures of which are being termed prions. These agents are highly resistant to any degradation or inactivation.

In the future, more emphasis needs to be placed on the survival of these viruses in specific environments where intimate human and animal contact exists. The movement of viruses over long distances in air, particularly in aerosols of different droplet sizes, in droplet nuclei and by adherence to dry particles, is a critical area which has yet to be adequately delineated. The survival of viruses in water remains a priority, while the survival of viruses in foods is emerging as a new priority. If properly developed, environmental virology will clearly be a significant discipline in the future.

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SURVIE DES VIRUS DANS L'ENVIRONNEMENT. — E.C. Pirtle et G.W. Beran.

Résumé: Les virus se transmettent dans l'environnement à partir de porteurs sains ou malades. Bien que leur réplication ne se produise que dans l'organisme des animaux ou des hommes, ils peuvent être transmis à des hôtes sensibles. L'augmentation régulière, depuis un siècle, des concentrations et des déplacements des populations tant animales qu'humaines, facilite la transmission des virus à tropisme respiratoire et entérique, et en rend la prévention plus complexe.

L'étude des facteurs liés à la survie des virus dans l'environnement a donné des résultats concluants dans le cas des poliovirus, des virus de la fièvre aphteuse et du virus de la maladie d'Aujeszky. La résistance à la chaleur des adénovirus, du virus de la peste porcine africaine et du virus de Norwalk a fait l'objet d'études dont les résultats sont également connus. La résistance aux désinfectants de nombreux virus, dont les picornavirus, les papovavirus, les réovirus et les rétrovirus, a été étudiée. La survie des virus sur ou dans divers vecteurs passifs a aussi été étudiée, en particulier pour les influenza virus, les paramyxovirus, les poxvirus et les rétrovirus. Les agents responsables des encéphalopathies spongiformes subaiguës font preuve d'une stabilité extraordinaire dans l'environnement, comme le démontrent des recherches en cours.

MOTS-CLÉS : Environnement - Inactivation - Résistance - Stabilité - Survie - Vecteurs passifs - Virus.

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SUPERVIVENCIA DE LOS VIRUS EN EL MEDIO AMBIENTE. — E.C. Pirtle y G.W. Beran.

Resumen: Los virus son transmitidos al medio ambiente por portadores sanos o enfermos. Aunque su replicación se produce únicamente en los organismos de los animales o del hombre, los virus pueden sobrevivir fuera de ellos y transmitirse a huéspedes sensibles. En el siglo presente, las concentraciones y los movimientos de poblaciones, tanto animales como humanas, han aumentado regularmente, favoreciendo así la transmisión de virus respiratorios y entéricos y haciendo más difícil su prevención.

Los estudios relativos a los factores de supervivencia de los virus en el medio ambiente han sido concluyentes para los poliovirus, los virus de la fiebre aftosa y el de la enfermedad de Aujeszky. También se tienen informes sobre estudios de la resistencia al calor de los adenovirus, del virus de la peste porcina africana y del virus de Norwalk. La resistencia a los desinfectantes se ha estudiado en numerosos virus, incluidos los picornavirus, papovavirus, reovirus y retrovirus. Así mismo, se ha investigado acerca de la supervivencia de los virus dentro o sobre diversas fomites, sobre todo en lo relativo a los influenzavirus, paramixovirus, poxvirus y retrovirus. Se están llevando a cabo estudios que demuestran una increíble estabilidad en el medio ambiente de los agentes responsables de las encefalopatías espongiiformes subagudas.

PALABRAS CLAVE: Estabilidad - Fomites - Inactivación - Medio ambiente - Resistencia - Supervivencia - Virus.

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