Public Health Concerns about Caliciviruses as Waterborne Contaminants

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Caliciviruses are disseminated by the fecal-oral route and are found in contaminated surface and ground waters. The US Environmental Protection Agency (EPA) is interested in preventing calicivirus contamination in treated waters used for consumption, and these viruses are on the EPA’s “contaminant candidate list” for regulatory consideration in drinking waters. These viruses also present a health threat for recreation and shellfish-growing waters. However, before EPA can make regulatory decisions regarding caliciviruses, significant information and technology needs must be established, including analytical methods for sampling, identifying, and quantifying the viruses; applicability of surrogates to determine their presence; efficacy of water and wastewater treatment or disinfection; waterborne occurrence levels and distribution; dose response; and the viruses’ effect(s) on health. Future drinking-water regulations may need to ensure that treatments are adequate to remove caliciviruses from source waters. For recreation and shellfish-growing waters, surrogate indicators and health criteria may need to be based upon establishing risks of exposure to caliciviruses.

Background

This article provides a general overview of concerns for caliciviruses in waters used for drinking, recreation, and shellfish growing and harvesting. The US Environmental Protection Agency (EPA) regulatory programs consider caliciviruses a health issue. Herein, we present specific questions and concerns to be addressed before the viruses can be controlled environmentally or through treatment. Because there are limited data on the occurrence of human calicivirus in the water environment, a number of assumptions or estimates are drawn from what is known about other enteric viruses.

In 1972, caliciviruses were characterized as viruses capable of causing gastrointestinal disease in humans [1]. The caliciviruses were divided into 5 groups on the basis of phylogenetic analysis [2]. However, the International Committee on Taxonomy of Viruses has more recently changed the calicivirus nomenclature to include 4 genera (Vesivirus, Lagovirus, “Norwalk-like viruses,” and “Sapporo-like viruses”), which are divided into 2 genogroups [3]. Hepatitis E viruses have been excluded from this nomenclature.

In humans, caliciviruses have been associated with the fecal-oral route of infection [1]. The estimated dose range to initiate infection by small round structured viruses (SRSVs, used herein as a synonym for Norwalk-like viruses) is 10–100 virus particles [3]. Federally sponsored studies have indicated that 10 polymerase chain reaction detection units of Norwalk virus produce infection in adult human volunteers and that pre-existing Norwalk serum IgG antibody may not be protective against reinfection (Moe C, University of North Carolina; personal communication).

There is significant direct epidemiologic evidence that the waterborne exposure route is important in the dissemination of caliciviruses to susceptible human hosts. Disease outbreaks have been associated with consumption of these viruses in drinking water and in contaminated shellfish [4–6]. There also is direct evidence of calicivirus outbreaks associated with recreational surface-water exposure [5], and it is likely that some portion of the nationwide incidence of acute gastrointestinal illness associated with swimming is caused by caliciviruses. While investigations have identified the association of caliciviruses with waterborne illness, there are a number of uncertainties and gaps in the data that must be resolved to determine how to control or eradicate these viruses from water and thus eliminate this route of infection as an important vector.

The available data suggest that human infectious caliciviruses are principally of human origin [2] and are generally seasonal, with a peak during the winter months (e.g., in the United Kingdom [7]). There is little evidence that nonhuman mammals or other animals are a significant source of these viruses with regard to anthropogenic transmission; thus, animals are probably not important as environmental sources for these contaminants. There have been instances of calicivirus transmission from the marine environment [8], but these cases were isolated, and the disease manifestation was dermal rather than enteric. Further studies on waterborne calicivirus may need to evaluate human fecal contamination sources, such as inadequately operated sewage treatment plants, combined sewer overflows (CSOs), storm sewers from urban and suburban areas, land application of biosolids (previously termed “sewage sludge”) not meeting...
final use and disposal requirements, and poorly maintained septic systems. These sources singly or in combination may contaminate a watershed and thus allow caliciviruses to reach drinking-water sources, recreational bathing beaches, and shellfish-growing areas.

Because of the lack of analytical methods that can readily detect, identify, and quantify caliciviruses in water, there are many unknowns regarding the nature and extent of the occurrence of these viruses in the water environment and their survival and distribution. There is a dearth of specific information regarding caliciviruses and the factors affecting them, including (1) the concentration of caliciviruses in sewage, (2) the efficacy of calicivirus removal by sewage treatment using physical removal and disinfection, (3) the inactivation of calicivirus through biosolid treatment processes, (4) the environmental fate and survival of caliciviruses (i.e., the effect of UV light; temperature; predation; physical or chemical constituents, including marine water; adsorption and sedimentation; and uptake by biota), (5) the treatment or attenuation of calicivirus in drinking water through physical removal and disinfection processes, and (6) the applicability of current microbial indicators to determine the occurrence, distribution, and treatability of caliciviruses.

Virus Monitoring versus the Use of Indicators to Determine the Risk from Caliciviruses

Monitoring to detect specific virus pathogens in drinking water and waters used for recreation and shellfish growing would provide the most realistic assessment of public health concerns. However, the costs and sophistication of analytical methods for most viral pathogens and the large sample-size requirements and amount of time needed to provide analytical results make the direct monitoring of pathogens impractical. For example, a typical approach for monitoring calicivirus occurrence would require 100- to 1000-L samples, with a subsequent final concentration to <100-mL for an assay. The analysis of these concentrated samples would either require genetic amplification for molecular probes or use of cell culture techniques or animal infection. Costs per sample would probably be in the range of $500–$1000, and the time to complete analysis in a typical laboratory could range from several days to several weeks.

Even if the fiscal resources to sample and analyze caliciviruses were available, there are significant technological constraints and concerns, including the following:

- The accuracy and precision of methods currently used for analyzing enteric viruses (collection, elution, concentration, and assay preparation) have not been established for caliciviruses.
- Reverse transcriptase–polymerase chain reaction (RT-PCR) methods do not adequately discriminate infectious or inactivated virus, and speciation needs further refinement.
- Sampling and final virus-concentration procedures also concentrate chemicals, such as humic and fulvic acids, that interfere with molecular identification procedures.
- Cell culture techniques for plaque or foci enumeration are not generally available for caliciviruses.
- Animal infection methods are not useful because of limited cross-species susceptibility.

The frequency of monitoring needed to adequately assess the occurrence of calicivirus could be a staggering burden. Recent experience has shown that the occurrence of pathogens in many recreational and shellfish-growing waters is sporadic and typically associated with rainfall events. Therefore, it is reasonable to anticipate that the EPA may need to continue to rely on the use of indicators or surrogates to identify specific pathogens or groups of similar pathogens before determining regulatory approaches to public health protection.

Indicator organisms have been used historically to estimate the waterborne occurrence of and the efficacy of water or wastewater treatment for various pathogens, including the enteric viruses (and presumably, caliciviruses). Total coliform organisms have been used in drinking water to determine treatment effectiveness and problems with water-distribution systems. This group (the total and fecal coliforms and *Escherichia coli*) has also been used as an indicator to determine the potential presence of fecal contamination in recreational and shellfish-growing waters. However, there has been increasing concern that the total and fecal coliform organisms are not adequate indicators of fecal contamination because they may have non-fecal origins and may proliferate under certain water and soil conditions. While not perfect in their ability to represent fecal contamination, *E. coli* and enterococci (a fecal species of the family *Streptococcaceae*) have been found to better reflect fecal contamination, especially for ground and surface waters. However, because the bacterial indicators have different sizes, structures, physiologies, susceptibilities to physical treatment and disinfection, and responses to environmental factors, they all may have inherent deficiencies for describing the occurrence, fate, and estimated risks for enteric viruses, including the caliciviruses.

Several alternative indicators are being examined as supplemental indicators or replacements for the current indicators in water. They are the coliphage (somatic and f+ phage groups) and *Clostridium perfringens* (or other sulfite-reducing *Clostridium* species). In the future, relative occurrence and die-off comparisons will be required to demonstrate the efficacy of these indicators to adequately represent the potential occurrence of caliciviruses as constituents of fecal contamination. Additional problems regarding the applicability of the present and proposed indicators in estimating virus contamination include the fact that (1) bacterial indicators other than *C. perfringens* may be more sensitive to water and wastewater treatment and dis-
infection than viruses, (2) bacterial indicators may have prolonged survival in tropical environments, and all but the Clostridium bacteria may grow in such environments, and (3) none of the indicators appear to show an unequivocal correlation with the occurrence of enteric virus in groundwaters.

The EPA’s Roles

The EPA Office of Water has a primary role in establishing regulations or guidance to control waterborne pathogens in drinking and recreational and shellfish-growing waters. The EPA determines the likelihood of specific pathogens presenting health concerns from waterborne exposure and the potential for their occurrence nationwide. After EPA determines the potential for significant health risks from the waterborne exposure scenarios likely to be encountered, it establishes watershed-management practices and water- and wastewater-treatment or -disinfection requirements to control primary pathogens in waters used for various purposes. The EPA has in place or is developing regulations, treatment requirements, and health criteria designed to protect drinking-water consumers and surface-water users against exposure to pathogenic viruses (such as calciviruses), protozoa, bacteria, and other waterborne pathogens.

Two different laws mandate the principal organizational approaches to protect the public against waterborne pathogens: the Safe Drinking Water Act (SDWA), which protects drinking waters originating from surface and groundwater sources, and the Clean Water Act (CWA), which regulates sewage treatment (e.g., the National Pollutant Discharge Elimination System [NPDES]) discharges and other point and non-point pollutant discharges. The CWA also provides criteria for states to adopt to protect users of recreational waters and regulations for shellfish-growing waters. In the future, the CWA regulations may also apply to pathogens that could contaminate fin fish.

SDWA and EPA Regulations

The SDWA was initially authorized by Congress in 1974 and was most recently reauthorized in 1996. The reauthorization significantly strengthened EPA’s ability to control pathogens in drinking water by increased protection through regulation. In addition to the existing Surface Water Treatment Rule (SWTR) and the Total Coliform Rule, which were promulgated in 1990, EPA is developing advanced rules that will further protect consumers from pathogens. These new or upcoming regulations to protect drinking waters against pathogens include the incremental improvement of the SWTR (enhanced SWTR) and the establishment of a groundwater rule. In addition, the SDWA reauthorization requires the EPA to develop a contaminant candidate list (CCL) by which additional pathogens (e.g., emerging or re-emerging pathogens) and chemical pollutants are identified and prioritized for the commitment of time and resources to address them. The determination of the need to regulate them is based upon their likely waterborne occurrence, drinking water treatability, human exposure potential, human dose response, and potential health effects. The most recent (1998) CCL includes calcicviruses, adenoviruses, echovirus, coxsackievirus, human infectious Microsporidia, Helicobacter pylori, Mycobacterium avium-intracellulare complex, and Aeromonas species.

The EPA’s regulatory philosophy in developing and promulgating SWTR to control pathogens in drinking waters has been to control the representative “worst-case” pathogens on the basis of the following factors: likely occurrence of the pathogens; potentially hazardous waterborne exposure levels; difficulty of treatment and disinfection; low dose response; and significant health effects. It has been assumed that if the worst pathogens (as determined on the basis of the above) are removed or inactivated, then others of less concern will also be accounted for. The protozoa Giardia lamblia historically has been identified as a worst-case challenge in drinking water from surface sources, as has Cryptosporidium parvum more recently. Cryptosporidium was chosen because it represents a significantly greater treatment and disinfection problem and because of the potentially greater health impacts to immunocompromised persons. The water-treatment control of pathogenic viruses has targeted enteroviruses, such as polio and hepatitis A virus, mainly because of their small size, which limits physical removal and resists disinfection. Altogether, application of these worst-case pathogens in treatment regulations has been successful in controlling epidemics of waterborne disease during the past decade. Most outbreaks have occurred because of treatment plant breakdowns or excessive but short-term pathogen-loading in treatment plant source waters caused by rainfall events or sewage spills, which overwhelm treatment capacities.

Today, typical technologies designed and used for pathogen reduction in drinking-water treatment include coagulation, settling, sand or multimedia filtration, and disinfection, which in combination, typically remove or inactivate substantial virus loads as well as pathogenic protozoan and bacterial contaminants. The EPA currently requires water-treatment systems to have a design capable of removing 99.99% (4-logs) of enteric viruses through the combination of physical removal (coagulation, settling, and filtration) and disinfection. The EPA is considering disinfection requirements to >4-log removal of viruses in systems that provide alternative physical barriers, such as microfiltration, in place of conventional coagulation, settling, and filtration.

Hurst [9], who reviewed several studies of water treatment for virus removal and combined the results for several different representative viruses, found that coagulation, sedimentation, and filtration each removed a median of 86.2% of the viruses. When postfiltration disinfection was added to these regimens, the median removal increased to ≈95.1%. Payment et al. [10] showed that the addition of prefiltration disinfection can pro-
Groundwater considerations. The presence of calicivirus in groundwaters is an important consideration since a number of outbreaks have been linked to these drinking-water sources (often from shallow wells and springs). Craun and Calderon [11] found 12 groundwater-associated outbreaks of gastroenteritis from 1971 to 1994. Little is known about the rate or process of translocation of this group of viruses from soil, but it can be assumed that they can migrate to groundwater from poorly functioning septic systems and contaminated surface waters, especially in alluvial soils, karst, and shale. It is not known if they behave similarly to the enterovirus group, for which the most data on the occurrence of viruses in groundwater have been established. Enteroviruses have the potential to translocate to groundwater, especially in shallow wells under the influence of contaminated surface water. In determining the movement of caliciviruses to groundwater, it is important to consider the hydraulic flow rate, the capacity of various types of soil to adsorb or trap viruses, the effects of pH and cation concentration on the effectiveness of virus adsorption in the soil column and on virus survival, and the impact of virus predation by microbial populations in surface soil.

When analytical methods are available, occurrence data for viruses in groundwater must be used to determine if the viruses are a significant threat to drinking-water sources and to establish the relationship or influence of contaminated surface water to groundwater contamination. In addition, it is important to verify whether the current and proposed microbial indicators can adequately detect potential occurrences of these viruses in the groundwater environment. In February 1999, the EPA held a workshop in which it was suggested that the most representative indicator monitoring approach for determining groundwater virus contamination would be the combination of enterococci or E. coli together with the somatic- or male-specific (or both) coliphage. At the workshop, a review of the results of a number of groundwater virus–indicator monitoring studies and associated studies revealed that none of these indicators alone was totally satisfactory in detecting the co-occurrence of enteric viruses.

CWA

The primary focus of the CWA, passed by Congress in 1972, is to ensure that US waters are fishable and swimmable, support aquatic ecosystems, and provide adequate sources of water for drinking. The major concerns for human enteric virus contamination other than drinking-water sources are recreational exposures and shellfish contamination. Because most human caliciviruses come from human sources, the major sources of surface water contamination are sewage treatment plants, CSOs, storm sewers, urban and agricultural runoff, and leakage from septic tanks.

The Health and Ecological Criteria Division (HECD) of the Office of Science and Technology in the EPA’s Office of Water has recently proposed the development of a strategy, research, and an implementation plan to use the CWA to reduce the
pathogen load in source waters, thus removing a portion of the burden placed on drinking-water utilities. The strategy would result in EPA issuance of microbial criteria and guidance for pathogens under the CWA. The strategy would be implemented in stages so that over a period of years, the HECD would issue criteria and implementation guidance for important classes of pathogens.

A key concept of this strategy would be to define classes of pathogens and incorporate features representative of a number of related pathogens. This relationship could be based upon phylogenetic characteristics; size; morphology; and environmental, treatment-resistance, or other characteristics. For example, Cryptosporidium or Giardia species could potentially represent the class of protozoan pathogens. The precise definition of “class” has not been determined and would require extensive consultation with the microbiology community, including the Centers for Disease Control.

There are two reasons to issue criteria for classes rather than individual pathogens. The first is that there are too many potential pathogens in source water to permit monitoring for all of them. Classification would allow states to monitor for 1 or 2 indicator organisms that represent a class of microbes of concern. The second reason is that it is not possible to predict which human or animal microbe will emerge as the next important human pathogen. Class criteria will allow the EPA and states to protect against these future risks. Under this scenario, viruses, such as calciviruses, could potentially be classified as a component of the enteric virus “class.”

**Treatment of sewage for calcivirus removal.** Secondary sewage treatment (required by most states) has played a major role in reducing the amount of fecal material entering US watersways. However, the associated virus removal is not complete, and the addition of disinfectants to the treated effluents may not totally eliminate viruses. In addition, high level of treatment and disinfection efficiency observed for many bacterial indicators may not translate to similar high levels of concurrent virus removal.

There are few data to support an assumption that the relative effectiveness of sewage treatment plant treatment for calciviruses would be significantly different for the other enteric viruses. It is assumed that physical removal and inactivation by disinfectants for these viruses would be of the same magnitude as the other enteric viruses. Estimates of enterovirus removal by secondary treatment and disinfection range from 1–2 orders of magnitude and depend somewhat on whether trickling filtration (lower removal) or activated sludge processes (higher removal) are used. Chlorination of sewage effluent may remove another 1–3 orders of magnitude of enteroviruses, depending on the dose, temperature, and contact time. Tertiary treatment techniques, which may be used where groundwater recharge or reuse are intended, have been shown to remove another 2–3 orders of magnitude of enterovirus. If sewage occurrence levels and secondary treatment effectiveness for calciviruses are similar to the other enteric viruses, then it can be expected that during routine treatment operations, low levels of calciviruses may enter effluent receiving waters.

A significant public health concern associated with sewage treatment arises from CSOs, which occur when there are meteorologic events that contribute significant runoff, which is collected into the sewage system and sent to sewage treatment plants. CSO events can partially or completely overwhelm (flood) the capacity of the treatment system to remove any viruses from raw sewage, as these events short-circuit treatment and diminish the capacity of the biologic system to capture, treat, and inactivate the viruses. While these events may occur infrequently, they may allow the release of significant quantities of enteric viruses over short time periods to the receiving streams. There is no evidence to suggest that calciviruses would not be found in receiving waters during CSO events if they are present in feces from the population served by the sewer system. Many systems that do not have CSOs may have their treatment capability adversely impacted during rainfall events due to storm water intrusion into the sewage collection system, which increases the volume of wastewater to the plant. This may especially occur where damaged or older leaky sewage collection system infrastructures are in place.

The other primary environmental or watershed sources of enteric viruses, including calciviruses, are from non-point sources, such as storm sewers, runoff from urban and suburban areas, and seepage or leachate from old or inadequately maintained septic systems. Again, the primary concern is the impact from rainfall events in which fecal contaminants are mobilized and reach receiving streams. In certain areas, the multiple contributions from these sources can be significant and may exceed virus contributions from point sources. The level of virus contribution from these sources during meteorologic events may be influenced by the following factors:

- Rainfall characteristics: Harder rainfall and longer duration increase mobilization.
- Soil type: Fine soils are prone to movement during rain and carry associated viruses.
- Grade of the land: Water on steeper land runs off more quickly and with more force.
- Distance traveled in the watershed to reach a receiving stream: Die-off and dilution may occur.
- Time period between meteorologic events: Longer periods allow more fecal accumulation.
- Ambient temperatures: Hot conditions expedite inactivation.
- Exposure to sunlight: UV light inactivates viruses.
- Drying conditions: Dry conditions dehydrate feces and inactivate virus.
- Vegetation: Grasses and root systems hold soil and virus.

Inadequately treated or improperly used sewage biosolids represent another potential source of viruses. Under the CWA,
the Code of Federal Regulations 40, part 503 regulations on biosolids require that viruses be treated to a level of no more than 1 pfu/4 g of dry biosolids if they are to be considered a class A biosolid. This grade of biosolid can be used as fertilizer or used in greenbelt areas where human activity is likely to occur. All enteric viruses are assumed to be effectively treated or used in greenbelt areas where human activity is likely to occur. All enteric viruses are assumed to be effectively treated by a number of processes that typically incorporate combinations of high temperature (>50°C), high pH (>11), extended holding time, and drying for prolonged periods (e.g., composting). There are no data on the occurrence of caliciviruses in biosolids or their treatability, but it may be assumed that they would be treated as effectively by these treatment conditions as the enteroviruses, for which treatment data are available. Class B sludges, which are not considered appropriate for human contact, only require the reduction (by treatment) of fecal coliforms to 2,000,000/g, and the expected total virus load is considered to present a potential human risk from direct exposure.

Protection of recreational waters. In 1986, the EPA issued an updated guide defining the appropriate microbiologic indicators for detecting fecal contamination. This guide provides associated health criteria to protect swimmers and other recreationists (e.g., water skiers, divers, surfers) against acute gastrointestinal illness disease from oral exposure due to head immersion in contaminated water. For fresh waters, the indicators are E. coli or enterococci, and the criteria provide acceptable 5-weekly sample geometric mean levels of 126 and 35 cfu/100 mL, respectively; in marine waters, enterococci may be used, and the acceptable criteria level is 33 cfu/100 mL. However, the current indicators and health criteria are not fully protective and theoretically allow 8 and 19 acute gastrointestinal illnesses (in fresh and marine waters, respectively)/1000 swimmers per day. The criteria are not protective against other types of disease risks of a more severe consequence or other swimmer exposure profiles.

Caliciviruses have been associated with some disease outbreaks from recreational exposure in open waters [5]. It is reasonable to expect the acute gastrointestinal illness findings to reflect some level of calicivirus infection to be occurring nationwide, especially given the low inoculum of virus required to cause infection. Because enteric viruses may be a significant component of acute gastrointestinal illnesses in swimmers, the EPA may need to assume that the caliciviruses are a component of that causality and the exposure risks that are to be characterized by the indicators.

A recent concern about beach monitoring to protect against pathogen exposure is the adequacy of the current recommended single weekly beach monitoring sample. The weekly beach samples are averaged (geometric mean) over 4 weeks to determine whether surrounding waters meet health-risk criteria. This approach may be deficient in that it does not consider the impacts of rainfall and the resulting CSO, storm water, and runoff conditions that allow pathogens to reach swimming areas. If the effectiveness of wastewater treatment plants (WWTPs) is degraded, then these events could introduce virus levels 2–5 orders of magnitude in excess of those found during stable flow conditions at the point where recreational use occurs. The EPA is conducting research on beach monitoring to provide improved future monitoring strategies that will consider local conditions and rainfall events. When developed, this new information on the importance of rainfall-event monitoring should provide improved guidance to local operators for establishing their local sampling protocols, beach closure criteria, and reopening criteria.

Better knowledge of calicivirus fate and transport in marine, estuarine, and fresh water would improve estimates of risks from sewage and other fecal contamination sources during rainfall events. Analytical methods that are accurate and precise would make it possible to evaluate the adsorption, settling, effects of predation, and physical or chemical impacts on survival of this group of viruses in recreational settings. It is assumed that their environmental behavior in recreational waters is similar to that of other enteric viruses.

Shellfish-growing waters. Prevention of virus and other pathogen contamination of economically important US shellfish-growing waters is managed through the control of sewage treatment plant discharges by NPDES permits whereby indicator bacteria numbers in the effluents are restricted. All WWTPs are required to obtain NPDES permits where beneficial water uses downstream may be impacted. Total and fecal coliform bacteria are used as tools to monitor the discharges from these point sources. Effluent sampling requirements may not consider the need for CSO or other rainfall-event monitoring from WWTPs when virus releases to receiving waters can be at their highest. Thus, during rainfall events, it is conceivable that gross virus contamination could travel downstream from sewage discharges to estuarine or ocean shellfish beds. Many of the same issues concerning indicators and monitoring requirements previously discussed for recreational waters are issues in shellfish waters.

During feeding in contaminated waters, shellfish may concentrate caliciviruses and other enteric viruses in their tissues. In fact, Norwalk virus and SRSVs have been incriminated in human gastrointestinal illness when contaminated raw shellfish have been consumed. For these viruses to attain human infectious levels in shellfish they were likely to have originated from sewage treatment plants or non-point sewage sources; it is unlikely that the caliciviruses are capable of replication in the shellfish or that they originate from animal fecal sources [3]. Norwalk viruses have been found to be poorly depurated from contaminated shellfish [12].

From a regulatory-control standpoint, it would be useful to have analytical methods (such as new indicators) that would differentiate human-derived fecal contamination from animal-derived contamination. This would allow for assessment of calicivirus risks on the basis of the types of fecal contamination
that may be present in a shellfish-growing area. Differentiation would also be useful in determining the sources of upstream pollution that represent risks to shellfish-growing areas for possible abatement.

Conclusions

Caliciviruses are an important group of human viruses that may be found in waters intended by humans for drinking, recreation, and shellfish growing. They represent potential hazards when there are human exposures to fecally contaminated waters. Their low infectious dose and nationwide occurrence in surface and groundwaters and their association with human illness make the caliciviruses an environmental health concern that cannot be ignored. While they may not be shed in fecal materials at numbers comparable to those of members of the Rotaviridae or other viruses, they are thought to be able to survive adverse environmental factors like many of the classical enteric viruses.

It is thought that the caliciviruses behave in a manner similar to the other classical enteric viruses with respect to treatment by conventional water and wastewater treatment and disinfection practices. However, scientists and public health officials currently are severely handicapped by the lack of appropriate methods to sample, detect, identify, and quantify these viruses in feces and various water media. Until adequate methods are available to establish calicivirus occurrence, treatability, and dose response, it will be difficult to fully determine the importance of these viruses or to establish treatment or abatement requirements to eliminate their occurrence and subsequent human exposure. Efforts to determine the need to regulate them will be conducted as part of the EPA’s CCL activities. Future regulatory programs will incorporate protective measures against caliciviruses if it is demonstrated that our current treatment and environmental control practices are not effective in controlling human exposures and preventing disease.

References