

Essential veterinary education in water-borne transmission of disease

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Summary

In this paper, the author reviews the reasons for the current interest in water-borne transmission of infectious agents in the veterinary curriculum. In addition, the paper provides short summaries of some of the major zoonotic outbreaks that have caused this new interest in water-borne diseases. Some curricular recommendations are made, including: basic training in modern methodologies in microbiology; a brief introduction to water and sewage treatment, with some discussion of pathogens in relation to the basic treatment processes of flocculation, sedimentation, filtration, disinfection, denitrification and phosphorus removal; and an introduction to the regulations being promulgated to reduce the pathogen loading of water on farms.

Keywords

Campylobacter – Centers for Disease Control and Prevention – Concentrated animal feeding operation – Cryptosporidium – Curriculum – Drinking water – Escherichia coli O157:H7 – Food and Drug Administration – Giardia – Leptospira – Manure – Outbreaks – Sewage – United States Department of Agriculture – United States Environmental Protection Agency – Zoonoses.

Introduction

In most veterinary curricula, the transmission of water-borne diseases has not routinely been covered within any particular framework. Historically, there have been lectures on food-borne and vector-borne animal diseases and some schools have offered specialty courses on zoonotic diseases which discuss diseases transmitted from domestic animals or wildlife reservoirs to people. Courses dealing with foreign animal diseases have often been routinely incorporated into curricula, and some schools have focused on diseases of the tropics. The fact that specific courses have not been developed does not mean that information on water-borne transmission of pathogens has not been presented. The matter has simply never been handled as a single topic within most curricula. When microbiologists discuss leptospirosis, they mention that the agent can persist in and be transmitted through water. When virologists discuss hepatitis E, they talk about water-borne transmission. When parasitologists discuss

Dracunculus insignis, there is an obvious discussion of water-borne transmission. However, discussing water as a specific source of transmission has been either taken for granted or ignored.

This lack of focus on water-borne transmission of pathogens has occurred for many reasons. The water purification industry, from the time of the installation of the first slow-sand filtration plant in Poughkeepsie, New York, in 1872, and the introduction of the chlorination of drinking water in the 1920s, has performed excellently in preventing water-borne disease in people and animals in the United States of America (USA). With the introduction of sterile technique, anaesthetics, antibiotics and anthelmintics, vaccines and modern diagnostics, etc., veterinary medicine no longer depended on improvements in disease control and animal husbandry practices to maintain the health of both livestock and companion animals/pets. This allowed the profession to worry less about preventing disease transmission and more about treating the individual animal that somehow became

infected in spite of all the preventive regimens in place. This may be construed as the profession being lulled into a sense of complacency, but that is not really the case. Things are markedly improved. The more common water-borne infections of people, e.g. cholera, typhoid fever, polio and hepatitis A, are basically gone from the developed world. In the case of animals, the most common diseases have historically not been considered as water-borne diseases. The introductory chapter of the 1988 edition of Hagan and Bruner's *Microbiology and infectious diseases of domestic animals* (18) is hard pressed to identify more than a few examples under the section on food and water transmission of pathogens.

The textbook of Hagan and Bruner cited above is an 'out-of-date' source in the sense that, only 20 years ago, the water-borne association of animal diseases was not a major consideration. Within the past 20 years or so that the author has taught at Cornell University, a student described how she grew up on a farm in New York State in a house without running water, where her mother would go out to the spring each morning to get water for the household before the cows were let out to drink. This is similar to what happens in much of the developing world. In addition, in developing countries, water is often contaminated with human-sourced pathogens that are serious threats to human health, and the cost-benefit ratio is such that it has not been sensible to worry about the risk of animal manure contamination of water until human faecal contamination is reduced. Thus, the issue of water-borne transmission of manure-associated pathogens is typically of concern in the developed, rather than the developing, world.

In recent years, there has been a clamour in the developed world to have veterinarians versed in water-borne disease and its prevention. So why now? Veterinary schools have existed in the USA for some 150 years, so what has changed over the last 10 or 15 years? Why the concern to increase awareness among veterinarians about water-borne disease? The simple answer is that people have recently been getting sick and, moreover, they were shocked at the fact that they were getting sick from their drinking water. Animals were considered to be, not always correctly, the source of the outbreaks. Since animals are under the care of veterinarians, veterinarians are charged with preventing these agents from moving from animals into people.

Important outbreaks that effected this change

Several important outbreaks of disease in humans have been unexpected because people thought they were protected. These outbreaks have involved bacterial and

protozoal infections for the most part, because most animal viruses transmitted in faeces have been considered, until recently, to be relatively host specific. The agents that have caused the most concern have been:

- *Giardia duodenalis*
- *Cryptosporidium parvum*
- *Campylobacter jejuni*
- *Escherichia coli* O157:H7
- *Leptospira interrogans*.

Some of the more important outbreaks in driving policy changes have been:

- giardiasis in Camas, Washington (USA), in 1979
- cryptosporidiosis in Wiltshire and Oxfordshire (United Kingdom [UK]) in 1989 and Milwaukee, Wisconsin (USA), in 1993
- enterohaemorrhagic *E. coli* in Burdine Township, Missouri (USA), in 1989 and Walkerton, Ontario (Canada), in 2003
- campylobacteriosis in Bennington, Vermont (USA), in 1978
- leptospirosis in Steel Tunnel Pond, Illinois (USA), in 1991.

These cases represent a few of the more important examples of outbreaks associated with these pathogens and are not meant to be a comprehensive listing of such outbreaks.

At the same time as these outbreaks occurred in humans, the attention of the public was also caught by the deaths of various sea mammals, due to pathogens that are usually associated with land animals. Thus, otters and other animals were found to have died from *Toxoplasma gondii*, *Sarcocystis neurona* and *Neospora caninum*. It is thought that the sea mammals were somehow infected via stages passed in the faeces of cats (*T. gondii*), opossums (*S. neurona*) or canids (*N. caninum*). Again, this was an unexpected turn of events.

Before summarising the outbreaks that have so highlighted the importance of being familiar with water-borne disease, it should be remembered that another water-associated environmental impact traceable to domestic animals was under scrutiny at the same time. Lakes, streams and estuaries were undergoing eutrophication, due to loading with nitrogen and phosphorus from farm run-off (and other agricultural and domestic sources). In 1997, outbreaks of the toxic dinoflagellate, *Pfiesteria piscicida*, in the Chesapeake Bay were associated with the run-off of poultry manure (1). The United States Environmental Protection Agency (EPA), under the auspices of the Clean

Water Act, realised that farms were becoming fewer and bigger and thus wanted such farms placed under increased regulation. In the end (2003), the EPA put in place the Concentrated Animal Feeding Operation (CAFO) rules, which include guidelines for minimising manure run-off from farms (19). Only nutrients were covered by the final CAFO rule, but pathogens were (and continue to be) a point of discussion. Domestic animals on farms are considered to be potential loading sources of many of the pathogens causing disease outbreaks in people.

The outbreaks

An outbreak of giardiasis in Camas, Washington, was important because it involved a source of filtered drinking water (2). Before this, it was basically believed that filtration protected people from such infection. There were problems at the plant that may have allowed the outbreak to have occurred in spite of the filtration barrier. Also, as with most giardiasis outbreaks, the source has never been adequately identified as being from animals or people. Cattle have often been blamed as the source, but this is coming under question with modern molecular methods of discrimination. In giardiasis, the epidemiologic evidence indicates high rates of infection from anthroponotic transmission, whereas genotyping and subtyping data point only to a potential role for zoonotic transmission, with little or no epidemiological support (22).

Two defining outbreaks of cryptosporidiosis occurred in Wiltshire and Oxfordshire, UK, and Milwaukee, USA. In the UK, there were 516 cases associated with three different water-treatment works and oocysts were found at these works and in the treated water (15). In Milwaukee, it is estimated that the outbreak involved some 400,000 people who drank tap water from a large filtration plant (11). Again, these outbreaks involved both treated water and some problems in water management; however, in the Milwaukee event, the finished water specifications never fell outside those required for drinking water at that time by the EPA. The oocyst source in the UK was never known, but the oocysts in the Milwaukee case, although initially blamed on cattle, were ultimately shown to be *Cryptosporidium hominis*, from a human source (23). Using various molecular typing methods on samples from cases around the world, it is now known that *C. parvum* from calves, lambs and kids can make its way into humans, with water being a significant source of infection (7, 8, 22). This transmission of the zoonotic forms occurs primarily in the rural areas of industrialised nations, including European countries, New Zealand, Canada and the USA (22).

Significant examples of enterohaemorrhagic *E. coli* outbreaks have occurred in Burdine Township, Missouri, USA, and Walkerton, Ontario, Canada. The organisms that

caused these outbreaks are typically found in cattle, which usually have no associated clinical signs. Both outbreaks took place in small communities, large percentages of the population developed bloody diarrhoea, and people died of the infections. In Missouri, it was determined that the cause of the spread was probably broken sewerage lines, but cattle were probably the original source of the infection (17). In the case of Walkerton, there was mismanagement at the water plant, but the source was identified as cattle manure that had been spread near one of the wells supplying the water (6). In these two cases, a pathogen from cattle manure contaminated the water, causing bloody diarrhoea and death.

In the case of *Campylobacter jejuni*, in Bennington, Vermont, USA, in 1978, some 3,000 people (19% of the Bennington population) developed diarrhoeal illness (21). As is often typical, the outbreak was probably caused by:

- rainfall increasing run-off and influent water turbidity at the treatment plant
- a construction crew working on the public water system at the same time
- potential back-siphoning of sewage into the drinking water lines.

In any event, *C. jejuni*, which is typically found in animals, including cattle, developed into an outbreak in an area where the watershed is surrounded by dairies. Sampling never revealed the agent in any animals in the area, but this does not exclude them as the potential source.

An outbreak of leptospirosis occurred in five boys who swam in a local swimming hole, Steel Tunnel Pond, in Illinois, USA (4). *Leptospira interrogans* serovar grippityphosa was isolated from two of the patients, the pond water, and animals around the pond. It was believed that a drought had concentrated the organisms within the pond to higher levels than typically occurred. The boys became ill, but were treated and recovered.

From the late 1980s, it was realised that river otters, sea otters, porpoises and seals were being infected with *Toxoplasma gondii*, *Sarcocystis neurona* and *Neospora caninum*, and other agents that are typically considered terrestrial and passed in the faeces of cats, opossums and dogs (3, 10, 14). In some cases, the infections were found to be lethal in the affected animals (14). The cause is rainwater run-off from the shoreline carrying the infectious oocysts into the food chain of these animals, which are exceptionally sensitive to the infection because they have been under no selective pressure for these infections in the past (13). Again, this is a noticeable loss of animal life involving animals with which many people have strong feelings of affinity.

Veterinarians have been placed in the midst of this flurry of activity involving the water-borne transmission of disease. They are directly responsible for animal health, and they are considered the guardians of human health in cases where animals may serve as the source of human infection. When outbreaks occur, veterinarians tending the 'offending' farms are consulted. These outbreaks have been due to pathogens from domestic animals or, based upon the best scientific information available at the time, were thought to be due to domestic animal sources. The development of the CAFO regulations and similar regulations in Europe were driven, in part, by pathogens, even though such pathogens were not covered by the final regulations (19). Animals in concentrated feeding operations are restricted from access to streams to protect watersheds. Unfortunately, the public often mistakenly equates a CAFO designation with being the equivalent of factory farming. This is a form of agriculture that is very strongly opposed by many people in the USA, European countries and other developed nations, and veterinarians are caught in the middle. Small-animal veterinarians must also be concerned with water-borne transmission, because dogs and cats are also affected. Some groups now want spay-and-release programmes discontinued because the pathogens from these hosts are being carried into streams and oceans, killing wildlife. Veterinarians are informed community leaders and are regularly looked to for guidance. Therefore, veterinarians need guidance in developing essential skills for leadership when they are required.

Essential coverage for water-borne disease transmission

The veterinary curriculum is already packed to near overflowing. However, it is important that veterinarians are properly positioned to protect their clients and patients where water issues are involved. The task is large. Others have pointed out how crucial it is to integrate molecular biology into the veterinary curriculum (16); and it should be remembered how rapidly the changes have come: knowledge of the structure of DNA is only 55 years old and polymerase chain reaction technology is only 25 years old. Veterinary students must be ready for the new processes that are coming their way and will be applied in their profession. At the same time, while students need to learn the essential principles of modern technology because it underlies their basic understanding of diagnostics, they also need to develop practical awareness of fundamental water and sewage treatment processes as these processes relate to clients and animal companion owners. Alongside these disciplines, they also need some knowledge of the relevant regulations and regulatory bodies, such as certain branches of the EPA and state equivalents, with which

veterinarians are, at present, often not familiar. Advances in science change world views and regulations, and these, in turn, will have an impact upon science and the interaction of peoples as communities.

In addition, veterinary students require training that will allow them to understand the myriad of modern approaches being applied to pathogens as part of the 'trace-back' methodologies that are undertaken when outbreaks occur. For example, the recent *E. coli* outbreak linked to bagged spinach was traced back, by lot numbers on the bar codes, to certain farms, and then the organisms themselves, along with their possible domestic and wild animal sources, were identified, using multiple locus tandem repeat analysis and pulsed-field gel electrophoresis, after digestion with XbaI and BlnI restriction enzymes (5). Students have to understand sufficient molecular biology to be able to comprehend the information that they are going to be sent by various agencies, such as:

- state diagnostic laboratories
- the United States Department of Agriculture (USDA)
- the Centers for Disease Control and Prevention (CDC)
- the Food and Drug Administration (FDA)
- the EPA.

Veterinarians are expected to understand the data that will be transmitted to them when their client or community is faced with an outbreak, and, if they do not, they will not help the client and will harm the profession. They must be prepared to keep up with new developments in the testing that is applied during outbreaks, which requires a fairly strong underpinning in immunodiagnostic and molecular methods. Things are not static, so they must also be ready for change; animal viruses were once not considered zoonotic but, with hepatitis E and the noroviruses, things have changed. Perhaps these viruses are indeed significant animal-sourced, water-transmitted viruses that can cause disease in people (9, 12).

Water and sewage treatment are usually within the realm of civil, sanitary or environmental engineers. Veterinarians do not take design courses but, as part of their public health training, they should have some introduction to the rudiments of water and sewage treatment plant design and the basic treatment elements of:

- flocculation
- sedimentation
- filtration
- disinfection
- denitrification
- phosphorus removal.

Many dairy and swine farmers are considering anaerobic digestion for methane production, but this stabilisation also inactivates many of the pathogens of concern in outbreaks. Members of the EPA have actually suggested that this should be required of all animal manures generated on farms for disinfection purposes alone, without considering the added benefit of energy production. Veterinary students should learn the rudiments of water and sewage treatment, and how, in turn, these are applied to manure treatment, which could probably be covered in one or two lectures. There are numerous methods for handling animal waste on farms of all sorts and all different scales, but this would be knowledge beyond the needs of a basic curriculum.

Students should have some introduction to the regulatory process and CAFO regulations that will have significant impacts upon their clients. They do not need to become watershed management experts, since this is already the professional role of many extension personnel, but they do need to have sufficient knowledge to be able to interact with these experts and their own communities in an intelligent and informed manner. Clients spend a lot of money on manure handling, fencing and buffer strip development for watershed management, and many communities will continue to demand tighter and tighter controls against manure or manure run-off entering waterways. Although pathogens are not covered by the current CAFO regulations, they are discussed in the 2008 US Government Accountabilities Office CAFO Report to Congressional Requesters (20), and are known to the general public. ■

Recommendations

The veterinary curriculum should contain, at a minimum, the following elements:

- basic training in modern methodologies of microbiology. This will give both large- and small-animal practitioners the tools to allow thoughtful consideration of the assays used in pathogen recognition, since such pathogens will directly affect the livelihoods of their clients and the well-being of their patients;
- an introduction to water and sewage treatment, with some discussion of pathogen reduction and how it is related to the basic treatment processes of flocculation, sedimentation, filtration, disinfection, denitrification and phosphorus removal;
- an introduction to the regulators, the regulatory community and the regulations being promulgated to reduce the pathogen loading of water, through pathogen reduction on farms, in treated manure and in farm run-off, through buffer strips and other management methods.

As can be seen, the major change being suggested is an increased awareness that water-borne disease transmission can have significant impacts on the veterinary profession and on the way in which that profession is viewed by its constituency, the public.

Les fondamentaux de l'enseignement vétérinaire sur les maladies à transmission hydrique

D.D. Bowman

Résumé

L'auteur analyse les raisons pour lesquelles l'étude de la transmission hydrique des agents pathogènes a repris depuis peu une place importante dans les programmes d'enseignement vétérinaire. En outre, il décrit brièvement des foyers majeurs de zoonoses d'origine hydrique dont la survenue peut expliquer le regain d'intérêt pour ce mode de transmission. Les aspects qui devraient figurer dans les programmes d'enseignement sont notamment : une présentation de base des méthodologies modernes de la microbiologie ; une initiation aux méthodes de traitement de l'eau et des eaux usées, avec un aperçu des

processus élémentaires de floculation, de sédimentation, de filtrage, de désinfection, de dénitrification et d'élimination du phosphore ; un aperçu des réglementations visant à réduire la charge en agents pathogènes des eaux utilisées dans les exploitations.

Mots-clés

Agence de protection de l'environnement des États-Unis d'Amérique – Campylobacter – Centers for Disease Control and Prevention – Cryptosporidium – Département de l'agriculture des États-Unis d'Amérique – Eau potable – Élevage intensif – Eaux usées – Enseignement vétérinaire – Escherichia coli O157:H7 – Food and Drug Administration – Foyer – Giardia – Leptospira – Transmission hydrique – Zoonose.

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Enseñanza veterinaria básica sobre la transmisión hídrica de enfermedades

D.D. Bowman

Resumen

El autor examina las causas de la atención que se presta actualmente en los planes de estudios de veterinaria a la transmisión hídrica de agentes infecciosos. Asimismo, se refiere brevemente a algunos de los grandes brotes zoonóticos que han motivado este nuevo interés por las enfermedades transmitidas por dicha vía. Acto seguido formula una serie de recomendaciones sobre los planes de estudios, entre ellas las siguientes: formación básica en métodos modernos de microbiología; breve introducción al agua y al tratamiento de aguas residuales, con el examen de algunos patógenos en relación con los procesos básicos de tratamiento: floculación, sedimentación, filtración, desinfección, desnitrificación y eliminación de fosfatos; y presentación de los reglamentos que se están promulgando para reducir la carga de patógenos en las aguas de explotaciones agrícolas.

Palabras clave

Administración Federal de Drogas y Alimentos – Agencia para la Protección del Medio Ambiente de los Estados Unidos – Agua de bebida – Aguas residuales – Brotes – Campylobacter – Centros de Control y Prevención de Enfermedades – Cryptosporidium – Departamento de Agricultura de los Estados Unidos – Escherichia coli, O157:H7 – Estudios de veterinaria – Ganadería intensiva – Giardia – Leptospira – Transmisión hídrica – Zoonosis.

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Research I am interested in infectious disease transmission dynamics, particularly at the interface of wildlife, domestic animals, and humans. My PhD research is focused on using mathematical models to better understand the dynamics of feline retroviruses in mountain lions. Publications. After the Flood: Water Quality and Health Considerations of the Post-Flood Conditions in Kasese, Uganda. ICOMOS International Conference April 24-27 2016, Minneapolis, Minnesota. Mahero M., D. Travis, K. Pelican, C. Robertson and D. Boulware. Awards CL Davis Foundation, Student Scholarship Award in Veterinary Pathology 2016 North Central Avian Disease Conference, B.S. Pomeroy Award 2016. Suwongsaksri, Napatsorn. Suwongsaksri, Napatsorn. People using contaminated tubewell water for drinking and haor water for cooking were infected with various water borne diseases such as diarrhoea, cholera, typhoid, liver diseases (Cirrhosis, Cancer), skin disease etc. Water quality, sanitation and hygienic conditions should be managed and monitored properly in haor area. Typhoid is among the most endemic diseases, and thus, of major public health concerns in tropical developing countries. In this study, we develop a deterministic compartmental mathematical model for assessing the effects of education campaigns, vaccination and treatment on controlling the transmission dynamics of typhoid fever in the community. Water borne diseases are viral, bacterial and parasitic diseases which use water as a common means of transmission. In this module we will discuss those water borne diseases in which the mode of entry of their etiologic agents into a susceptible host is oral 2.6. Epidemiology. Water borne diseases are major causes of morbidity and mortality world wide. In Ethiopia, since a large majority of the rural population obtain their water supplies from unprotected sources such as streams, ponds wells, etc, water borne diseases are one of the most significant public health problems. A person's health