

Emerging global food pathogens and its public health implication: A review.

Patógenos alimentarios emergentes en el mundo y su implicación para la salud pública: una revisión.

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ABSTRACT

The epidemiology of food borne disease is changing. New pathogens have emerged, and some have spread worldwide. The broad spectrum of food borne infections has changed dramatically over time, as well-established pathogens have been controlled or eliminated, and new ones have emerged. Food pathogens have been a cause of a large number of diseases worldwide and more so in developing countries. This has a major economic impact. The burden of food borne disease remains substantial. Most of these illnesses are not accounted for by known pathogens, so must remain to be discovered. Among the known food borne pathogens, those more recently identified predominate, suggesting that as more and more is learned about pathogens, and they come under control. In addition to the emergence or recognition of new pathogens, other trends include global pandemics of some food borne pathogens, the emergence of antimicrobial resistance, the identification of pathogens that are highly opportunistic, affecting only the most high-risk sub populations, and the increasing identification of large and dispersed outbreaks. Outbreak investigations and case-control studies of sporadic cases can identify sources of infection and guide the development of specific prevention strategies. Better understanding of how pathogens persist in animal reservoirs is also critical to successful long-term prevention. In the past, the central challenge of foodborne disease lay in preventing the contamination of human food with sewage or animal manure. In the future, prevention of foodborne disease will increasingly depend on controlling contamination of feed and water consumed by the animals themselves.

Key words: Food, Emergence, Foodborne and Waterborne pathogens and Zoonoses.

RESUMEN

La epidemiología de las enfermedades transmitidas por los alimentos está cambiando. Han surgido nuevos patógenos y algunos se han extendido por todo el mundo. El amplio espectro de infecciones transmitidas por alimentos ha cambiado drásticamente con el tiempo, ya que los patógenos bien establecidos se han controlado o eliminado, y han surgido otros nuevos. Los patógenos alimentarios han sido la causa de un gran número de enfermedades en todo el mundo y más aún en los países en desarrollo. Esto tiene un gran impacto económico. La carga de las enfermedades transmitidas por los alimentos sigue siendo sustancial. La mayoría de estas enfermedades no son contabilizadas por patógenos conocidos, por lo que debe permanecer por descubrir. Entre los patógenos conocidos transmitidos por los alimentos, predominan los identificados más recientemente, lo que sugiere que a medida que se aprende más y más sobre los patógenos, se controlan. Además del surgimiento o reconocimiento de nuevos patógenos, otras tendencias incluyen pandemias globales de algunos patógenos transmitidos por los alimentos, la aparición de resistencia a los antimicrobianos, la identificación de patógenos que son altamente oportunistas, que afectan solo a las subpoblaciones de mayor riesgo, y el aumento de identificación de brotes grandes y dispersos. Las investigaciones de brotes y los estudios de casos y controles de casos esporádicos pueden identificar las fuentes de infección y guiar el desarrollo de estrategias de prevención específicas. Una mejor comprensión de cómo persisten los patógenos en los reservorios animales también es fundamental para la prevención exitosa a largo plazo. En el pasado, el desafío central de las enfermedades transmitidas por los alimentos consistía en prevenir la contaminación de los alimentos humanos con aguas residuales o estiércol animal. En el futuro, la prevención de las enfermedades transmitidas por los alimentos dependerá cada vez más del control de la contaminación de los alimentos y el agua que consumen los propios animales.

Palabras clave: Alimentación, emergencia, intoxicación alimentaria y zoonosis.

INTRODUCTION

Infections caused by microbes that contaminate the food supply are a frequent reminder of the complex food web that links us with animal, plant, and microbial populations around the world. While all are at risk, the consequences are the most severe in the vulnerable populations of the very young, pregnant women, elderly, and those with compromised immune systems. Emerging pathogens are those that have appeared in a human population for the first time, or have occurred previously but are increasing in incidence or expanding into areas where they have not previously been reported, usually over the last 20 years (World Health Organization (WHO), 2003). Re-

emerging pathogens are those whose incidence is increasing as a result of long-term changes in their underlying epidemiology (Woolhouse, 2002). By these criteria, 175 species of infectious agent from 96 different genera are classified as emerging pathogens. Of this group, 75% are zoonotic species sustained in animal reservoirs and contaminate our food supply because they are present in the flesh, milk, or eggs in the living animal, or because they are in the excreta of infected animals that subsequently contaminate the foods we eat. Improved methods of surveillance, epidemiological studies and -the continuous development of more advanced methods of diagnosis have made it possible to detect new pathogenic species of micro-organism or to associate a known micro-organism with a new or atypical set of disease symptoms. Furthermore, the agents of several diseases that were thought to have been controlled are re-emerging as a result of adaptive changes in the pathogen, changes to the immunological status of the host, or environmental, demographic and socio-economic changes. Each of these pathogens represents a public health problem. Of the many pathogens that can contaminate food, some, like *norovirus* and *Salmonella* serotype *Typhi*, are sustained in human reservoirs and contaminate the food supply via the excreta of infected humans (Tauxe, 2005).

The specific objective of this work is to review the emerging global food pathogens and its public health implications. Other objectives are; to review the emerging global pathogens and the types, to assess the pathogens that cause infectious diseases, to review emerging food borne, water borne pathogens and their transmissibility and to find out their public health implications and make recommendations.

PATHOGENS

A pathogen in the oldest and broadest sense is anything that can produce disease and cause illness to its host (Casadevall and Pirofski, 2014). Typically the term is used to describe an infectious agent such as virus, bacterium, prion, fungus, viroid or parasite that causes disease in its host. The host may be an animal, plant, a fungus or even another microorganism. Pathogens are highly abundant, for they can just live anywhere. Some thrive in heat, while others prefer the cold. Some types need oxygen or a host, while others do not.

- Pathogens that cause infectious diseases are often grouped into different types (Health Blurb, 2015)

Route of transmission is one way a pathogen is typed. These are some of various means and a sampling of the different types of related pathogens or diseases:

- Another person ~ STDs
- Blood borne ~ hepatitis B virus, HIV
- Waterborne ~ *rotavirus*, *cholera*, *adeno -viruses*, *entero -viruses*, *shigella*, *giardia*
- Zoonotic ~ rabies, cat scratch disease, *dermatophytosis*, *brucellosis*, *leptospirosis*
- Foodborne ~ *campylobacter*, *botulism*, *E. coli*, *listeria*, *shigella*, *norovirus*, *toxoplasmosis*, *salmonella*
- Airborne ~ parvovirus B19, rhinovirus, coxsackievirus, coronavirus, parainfluenza, respiratory syncytial virus
- Vector-borne (fleas, ticks, flies, mosquitoes) ~ Lyme disease, dengue, yellow fever, plague, tularemia, malaria, Chagas disease, Rocky Mountain Spotted Fever

Most infections fall into three major types:

*Acute

*Latent

*Chronic

A special pathogen is a highly infectious type that causes a severe disease and because of their nature requires special handling. A couple of the different types of diseases that are considered special are:

- * Severe acute respiratory syndrome (SARS)
- * Lassa fever
- * Ebola hemorrhagic fever
- * Nipah virus encephalitis
- * Hantavirus pulmonary syndrome

Evidence is emerging that there are links with different types of pathogens to:

- * Coronary artery disease (CAD)
- * Diabetes
- * Some cancers
- * Multiple sclerosis
- * Various chronic lung diseases

The body has an arsenal of natural defenses to pathogens. For instance, the immune system produces different types of cells, such as leukocytes, neutrophils and antibodies for immunity that can fight off germs. Fever, coughing and sneezing are also measures used to rid a pathogen as well (Health Blurb, 2015).

New foodborne pathogens have emerged. Among the first of these were infections caused by nontyphoid strains of *Salmonella*, which have increased decade by decade since World War II as reported by Tauxe, (1997). In the last 20 years, other infectious agents have been either newly described or newly associated with foodborne transmission. *Vibrio vulnificus*, *Escherichia coli* O157: H7, and *Cyclospora cayetanensis* are examples of newly described pathogens that often are foodborne. *V. vulnificus* was identified in the bloodstream of persons with underlying liver disease who had fulminant infections after eating raw oysters or being exposed to seawater; this organism lives in the sea and can be a natural summertime commensal organism in shellfish (Blake *et. al.*, 1979). *E. coli* O157:H7 was first identified as a pathogen in 1982 in an outbreak of bloody diarrhea traced to hamburgers from a fast-food chain (Wendel *et. al.* 2009); it

was subsequently shown to have a reservoir in healthy cattle (Martin *et. al.*, 1986). *Cyclospora*, known previously as a cyanobacteria like organism, received its current taxonomic designation in 1992 and emerged as a foodborne pathogen in outbreaks traced to imported Guatemalan raspberries in 1996 (Ortega, *et. al.*, 1993; Herwaldt and Ackers, 1997). The similarity of *Cyclospora* to *Eimeria* coccidian pathogens of birds suggests an avian reservoir. Some known pathogens have only recently been shown to be predominantly foodborne. For example, *Listeria monocytogenes* was long known as a cause of meningitis and other invasive infections in immunocompromised hosts. How these hosts became infected remained unknown until a series of investigations identified food as the most common source (Jackson and Wenger, 1993). Similarly, *Campylobacter jejuni* was known as a rare opportunistic bloodstream infection until veterinary diagnostic methods used on specimens from humans showed it was a common cause of diarrheal illness (Dekeyser, *et. al.*, 1972). Virtually all have an animal reservoir from which they spread to humans; that is, they are foodborne zoonoses. In marked contrast to many established zoonoses, these new zoonoses do not often cause illness in the infected host animal. The chicken with lifelong ovarian infection with *Salmonella* serotype *enteritidis*, the calf carrying *E. coli* 0157:H7, and the oyster carrying Norwalk virus or *V. vulnificus* appear healthy; therefore, public health concerns must now include apparently healthy animals. Limited existing research on how animals acquire and transmit emerging pathogens among themselves often implicates contaminated fodder and water; therefore, public health concerns must now include the safety of what food animals themselves eat and drink. For reasons that remain unclear, these pathogens can rapidly spread globally. For example, *Y. enterocolitica* spread globally among pigs in the 1970s (World Health Organization (WHO), 1976); *Salmonella* serotype *enteritidis* appeared simultaneously around the world in the 1980s (Rodrigue *et. al.*, 1990) and *Salmonella typhimurium* Definitive Type (DT) 104 is now appearing in North America, Europe, and perhaps elsewhere (Centers for Disease Control and Prevention (CDC), 1996); therefore, public health concerns must now include events happening around the world, as harbingers of what may appear here.

Many emerging zoonotic pathogens are becoming increasingly resistant to antimicrobial agents, largely because of the widespread use of antibiotics in the animal reservoir. For example, *Campylobacter* isolated from human patients in Europe is now increasingly resistant to fluoroquinolones, after these agents were introduced for use in animals (Endt *et. al.*, 1991). *Salmonellae* have become increasingly resistant to a variety of antimicrobial agents; therefore, public health concerns must include the patterns of antimicrobial use in agriculture as well as in human medicine. According to Cieslak *et al.*, (1997), the foods contaminated with emerging pathogens usually look, smell, and taste normal, and the pathogen often survives traditional preparation techniques: *E. coli*

0157:H7 in meat can survive the gentle heating that a rare hamburger gets; *Salmonella enteritidis* in eggs survives in an omelette (Humphrey *et. al.*, 1989); and Norwalk virus in oysters survives gentle steaming (Kirkland *et. al.*, 1996).. Following standard and traditional recipes can cause illness and outbreaks. Contamination with the new foodborne zoonoses eludes traditional food inspection, which relies on visual identification of foodborne hazards. These pathogens demand new control strategies, which would minimize the likelihood of contamination in the first place. The rate at which new pathogens have been identified suggests that many more remain to be discovered. Many of the foodborne infections of the future are likely to arise from the animal reservoirs from which we draw our food supply.

Emerging food borne pathogens

❖ Major etiological agents of infectious diseases identified since 1972 (Desselberger, 2000).

Year	Agent	Disease
1972	Small round structured viruses	Diarrhoea
1973	Rotaviruses	Infantile diarrhea
1975	Astroviruses	Diarrhoea
1975	Parvovirus B19	Aplastic crisis in chronic haemolytic anaemia
1976	<i>Cryptosporidium parvum</i>	Acute enterocolitis
1977	Ebola virus	Ebola haemorrhagic fever
1977	<i>Legionella pneumophila</i>	Legionnaires' disease
1977	Hantaan virus	Haemorrhagic fever with renal syndrome
1977	<i>Campylobacter spp.</i>	Diarrhoea
1980	Human T-cell lymphotropic virus-1 (HTLV-1)	Adult T-cell leukaemia/ HTLV-1 associate myelopathy
1982	HTLV-2	Hairy T-cell leukaemia
1982	<i>Borrelia burgdorferi</i>	Lyme disease
1983	HIV-1, HIV-2	Acquired immunodeficiency syndrome
1983	<i>Escherichia coli</i> O157:H7	Haemorrhagic colitis; haemolytic uremic syndrome
1983	<i>Helicobacter pylori</i>	Gastritis, gastric ulcers, increased risk of gastric cancer
1988	Human herpesvirus-6	Exanthema subitum
1989	<i>Ehrlichia spp.</i>	Human ehrlichiosis
1989	Hepatitis C virus	Parenterally transmitted non-A, non-B hepatitis
1990	Human herpesvirus-7	Exanthema subitum
1990	Hepatitis E virus	Enterically transmitted non-A, non-B hepatitis
1991	Hepatitis F virus	Severe non-A, non-B hepatitis
1992	<i>Vibrio cholerae</i> O139:H7	New strain associated with epidemic cholera
1992	<i>Bartonella henselae</i>	CAT-scratch disease, bacillary angiomatosis
1993	Sin nombre virus	Hantavirus pulmonary syndrome
1993	Hepatitis G virus	Non A-C hepatitis
1994	Sabia virus	Brazilian haemorrhagic fever
1994	Human herpesvirus-8	Kaposi's sarcoma
1995	Hendravirus	Castleman's disease
1996	Prion (BSE)	Meningitis, encephalitis
1997	Influenza A virus	New variant Creutzfeldt-Jakob disease
1997	Transfusion-transmitted virus	
1997	Enterovirus 71	Epidemic encephalitis
1998	Nipah virus	Meningitis, encephalitis
1999	Influenza A virus	Influenza (Hong Kong)
1999	West Nile-like virus	Encephalitis (New York)

New Food Vehicles of Transmission: along with new pathogens, an array of new food vehicles of transmission has been implicated in recent years. Traditionally, the food implicated in a foodborne outbreak was undercooked meat, poultry or seafood, or unpasteurized milk. Now, additional foods previously thought safe are considered hazardous. For example, for centuries, the internal contents of an egg were presumed safe to eat raw. However, epidemic *Salmonella enteritidis* infection among egg-laying flocks indicates that intact eggs may have internal contamination with this *Salmonella* serotype. Many outbreaks are caused by contaminated shell eggs, including eggs used in such traditional recipes as eggnog and Caesar salad, lightly cooked eggs in omelettes and French toast, and even foods one would presume thoroughly cooked, such as lasagna and meringue pie (St. Louis *et. al.*, 1988; Mishu *et. al.*, 1994). *E. coli* 0157:H7 has caused illness through an ever-broadening spectrum of foods, beyond the beef and raw milk that are directly related to the bovine reservoir. In 1992, an outbreak caused by apple cider showed that this organism could be transmitted through a food with a pH level of less than 4.0, possibly after contact of fresh produce with manure (Besser *et. al.*, 1993). Norwalk-like viruses, which appear to have a human reservoir, have contaminated oysters harvested from pristine waters by oyster catchers who did not use toilets with holding tanks on their boats and were themselves the likely source of the virus (Kohn *et al.* 1995; Herwaldt and Ackers, 1997).

The new food vehicles of disease share several features. Contamination typically occurs early in the production process, rather than just before consumption. Because of consumer demand and the global food market, ingredients from many countries may be combined in a single dish, which makes the specific source of contamination difficult to trace. These foods have fewer barriers to microbial growth, such as salt, sugar, or preservatives; therefore, simple transgressions can make the food unsafe. Because the food has a short shelf life, it may often be gone by the time the outbreak is recognized; therefore, efforts to prevent contamination at the source are very important. An increasing, though still limited, proportion of reported foodborne outbreaks are being traced to fresh produce (Tauxe *et. al.*, 1997). A series of outbreaks recently investigated by the Centers for Disease Control and Prevention (CDC) has linked a variety of pathogens to fresh fruits and vegetables harvested in the United States and elsewhere. The investigations have often been triggered by detection of more cases than expected of a rare serotype of *Salmonella* or *Shigella* or by diagnosis of a rare infection like *Cyclosporiasis*. Outbreaks caused by common serotypes are more likely to be missed. Various possible points of contamination have been identified during these investigations, including contamination during production and harvest, initial processing and packing, distribution, and final processing. For example, fresh or inadequately composted manure

is used sometimes, although *E. coli* 0157:H7 has been shown to survive for up to 70 days in bovine feces (Wang *et. al.*, 1996):

Emerging waterborne pathogens: developments in our understanding of the relationships between water and human health have been characterized by the periodic recognition of previously unknown pathogens or of the water-related significance of recognized pathogens. According to World Health Organization (WHO, 1997a), several studies have confirmed that water-related diseases not only remain a leading cause of morbidity and mortality worldwide, but that the spectrum of disease is expanding and the incidence of many water-related microbial diseases is increasing. Since 1970, several species of micro-organism from human and animal faeces and from environmental sources, including water, have been confirmed as pathogens. Examples include *Cryptosporidium*, *Legionella*, *Escherichia coli* 0157 (*E. coli* 0157), rotavirus, hepatitis E virus and norovirus (formerly Norwalk virus). Furthermore, the importance of water in the transmission of recognized pathogens is being continually assessed as new tools become available through advances in science, technology and epidemiology. *Helicobacter pylori* (*H. pylori*) are an example of a recently emerged pathogen that may be transmitted through water. Untreated or contaminated water seems to be a particularly likely source of contamination (WHO, 1997a). Water used for spraying, washing, and maintaining the appearance of produce must be microbiologically safe. After two large outbreaks of salmonellosis were traced to imported cantaloupe, the melon industry considered a "Melon Safety Plan," focusing particularly on the chlorination of water used to wash melons and to make ice for shipping them. World Health Organisation (WHO, 1997a) went on to say that, although the extent to which the plan was implemented is unknown, no further large outbreaks have occurred. After two large outbreaks of salmonellosis were traced to a single tomato packer in the Southeast, an automated chlorination system was developed for the packing plant wash tank. Because tomatoes absorb water (and associated bacteria) if washed in water colder than they are, particular attention was also focused on the temperature of the water bath (Zhuang *et.al.*, 1995; Rushing *et al.*, 1996).

Pathogenic mycobacteria in water: previously unrecognized or under-appreciated pathogens continue to be recognized to be associated with the waterborne route and as being of public health significance. *Mycobacterium avium* complex has been a leading cause of death amongst HIV positive populations. Recently, incidence of two of the three diseases associated with MAC (pulmonary MAC and lymphadenitis) (WHO, 1997a) appears to be increasing. There is also evidence of the role that drinking-water plays in the development of MAC-related illness. This book provide information on the *Mycobacterium avium* complex and other pathogenic mycobacteria in water.

Potential drivers of the emergence and re-emergence of pathogens in water (WHO, 1997a) - New environments:

- Climate shifts/deforestation
- Water resources development projects (dams and irrigation)
- Water-cooled air conditioning plants
- Changing industrial and agricultural practices (eg intensive livestock rearing)
- Piped water systems and their inadequate design and operation
- An increasing number of humanitarian emergencies

Changes in human behaviour and vulnerability:

- Human circulation and the accessibility and rapidity of transport worldwide
- Demographic changes
- Increasing size of high risk populations
- Deliberate and accidental release of pathogens to water
- Increasing number of humanitarian emergencies

New technologies:

- Water resources development projects (dams and irrigation)
- Water-cooled air conditioning plants
- Changing industrial and agricultural practices
- Waterborne sewage and sewage treatment alternatives

Scientific advances:

- Inappropriate, excessive use of antibiotics anti-parasitic drugs and public health insecticides
- Changing industrial and agricultural practices
- Improved methods of detection and analysis
- Inappropriate use of new generation insecticides.

A New Outbreak Scenario and Transmissibility: because of changes in the way food is produced and distributed, a new kind of outbreak has appeared. The traditional foodborne outbreak scenario often follows a church supper, family picnic, wedding reception, or other social activities (Tauxe and Hughes, 1996).

Overall, most zoonotic pathogens are either not transmissible (directly or indirectly) between humans at all (i.e., humans are a dead-end host) or are only minimally transmissible. Examples include rabies virus, Rift Valley fever virus, and *Borrelia burgdorferi* (the agent of Lyme disease). A small minority ($\approx 10\%$) of pathogen species that are technically zoonotic are, in fact, spread almost exclusively from person to person (e.g., *Mycobacterium tuberculosis* or measles virus) or can do so once successfully introduced from a nonhuman source (e.g., some strains of influenza A, *Yersinia pestis*, or severe acute respiratory syndrome (SARS) coronavirus) (Woolhouse and Gowtage-Sequeria, 2005). However, a substantial minority of zoonotic pathogens

(about 25%, i.e., 200 species) is capable of some person-to-person transmission but do not persist without repeated re-introductions from a nonhuman reservoir (e.g., *E. coli* O157, *Trypanosoma brucei rhodesiense*, or *Ebola virus*). This pattern is fairly consistent across the major pathogen groups.

Some top common emerging food borne pathogens: some emerging food borne pathogens are highlighted below according to (Centers for Disease Control and Prevention (CDC), 2014; D e V e n t e r, 2000).

Pathogen: *Campylobacter jejuni*: A bacterium that's the most common bacterial cause of diarrhea in the U.S.

Basics: Must-Know: Children under age 1 have the highest rate of *Campylobacter* infections. Unborn babies and infants are more susceptible on first exposure to this bacterium. In addition, there's a low threshold for seeking medical care for infants.

Sources: Raw milk, untreated water, raw and undercooked meat, poultry, or shellfish

Symptoms: Diarrhea (sometimes bloody), stomach cramps, fever, muscle pain, headache, and nausea.

Incubation: Generally 2 to 5 days after eating contaminated food

Duration: 2 to 10 days

Pathogen: *Clostridium botulinum*: A bacterium that can be found in moist, low-acid food. It produces a toxin that causes botulism, a disease that causes muscle paralysis.

Basics: Must-Know: Don't feed a baby honey - at least for the first year.

Source: Honey can contain *Clostridium botulinum* spores. Infant botulism is caused by consuming these spores, which then grow in the intestines and release toxin. Home-canned and prepared foods, vacuum-packed and tightly wrapped food, meat products, seafood, and herbal cooking oils

Symptoms: Dry mouth, double vision followed by nausea, vomiting, and diarrhea. Later, constipation, weakness, muscle paralysis, and breathing problems may develop. Botulism can be fatal. It's important to get immediate medical help.

Incubation: 12 to 72 hours after eating contaminated food (in infants 3 to 30 days)

Duration: Recovery can take from between 1 week to a full year.

Pathogen: *Clostridium perfringens*; A bacterium that produces heat-stable spores, which can grow in foods that are undercooked or left out at room temperature.

Source: Meat and meat products

Symptoms: Abdominal pain, diarrhea, and sometimes nausea and vomiting.

Incubation: 8 to 16 hours after eating contaminated food

Duration: Usually 1 day or less

Pathogenic *Escherichia coli* (*E. coli*): A group of bacteria that can produce a variety of deadly toxins.

Source: Meat (undercooked or raw hamburger), uncooked produce, raw milk, unpasteurized juice, and contaminated water

Symptom: Severe stomach cramps, bloody diarrhea, and nausea. It can also manifest as non-bloody diarrhea or be symptomless.

Basic: Must-Know: *E.coli* 0157:H7 can cause permanent kidney damage which can lead to death in young children.

Incubation: Usually 3 to 4 days after ingestion, but may occur from 1 to 10 days after eating contaminated food.

Duration: 5 to 10 days

Pathogen: *Listeria monocytogenes*: A bacterium that can grow slowly at refrigerator temperatures.

Basic: Must-Know: *Listeria* can cause serious illness or death in pregnant women, fetuses, and newborns.

Source: Refrigerated, ready-to-eat foods (meat, poultry, seafood, and dairy - unpasteurized milk and milk products or foods made with unpasteurized milk).

Symptom: Fever, headache, fatigue, Muscle aches, nausea, vomiting, diarrhea, meningitis, and miscarriages.

Incubation: 9 to 48 hours after ingestion, but may occur up to 6 weeks after eating contaminated food.

Variable *Norovirus* (Norwalk-like Virus): A virus that's becoming a health threat. It may account for a large percent of non-bacterial foodborne illnesses.

Source: Raw oysters, shellfish, cole slaw, salads, baked goods, frosting, contaminated water, and ice. It can also spread via person-to-person.

Symptom: Diarrhea, nausea, vomiting, stomach cramps, headache, and fever.

Incubation: 24 to 48 hours after ingestion, but can appear as early as 12 hours after exposure.

Duration: 1 to 3 days

Pathogen: *Salmonella enteritidis*: A bacterium that can infect the ovaries of healthy-appearing hens and internally infect eggs before the eggs are laid.

Source: Raw and under cooked eggs, raw meat, poultry, seafood, raw milk, dairy products, and produce.

Symptom: Diarrhea, fever, vomiting, headache, nausea, and stomach cramps

Basic: Must-Know: Symptoms can be more severe in people in at-risk groups, such as pregnant women.

Incubation: 12 to 72 hours after eating contaminated food

Duration: 4 to 7 days

Pathogen: *Salmonella typhimurium*: Some strains of this bacterium, such as DT104, are resistant to several antibiotics.

Source: Raw meat, poultry, seafood, raw milk, dairy products, and produce

Symptom: Diarrhea, fever, vomiting, headache, nausea, and stomach cramps

Basic: Must-Know: Symptoms can be more severe in people in the at-risk groups, such as pregnant women.

Incubation: 12 to 72 hours after eating contaminated food

Duration: 4 to 7 days

Pathogen: *Shigella*: A bacterium that's easily passed from person-to-person via food, as a result of poor hygiene, especially poor hand washing. Only humans carry this bacterium.

Source: Salads, milk and dairy products, raw oysters, ground beef, poultry, and unclean water

Symptom: Diarrhea, fever, stomach cramps, vomiting, and bloody stools

Incubation: 1 to 2 days after eating contaminated food

Duration: 5 to 7 days

Pathogen: *Staphylococcus aureus*: This bacterium is carried on the skin and in the nasal passages of humans. It's transferred to food by a person, as a result of poor hygiene, especially poor hand washing. When it grows in food, it makes a toxin that causes illness.

Source: Dairy products, salads, cream-filled pastries and other desserts, high-protein foods (cooked ham, raw meat and poultry), and humans (skin, infected cuts, pimples, noses, and throats)

Symptom: Nausea, stomach cramps, vomiting, and diarrhea

Incubation: Usually rapid - within 1 to 6 hours after eating contaminated food

Duration: 24 to 48 hours

Pathogen: *Vibrio cholera*: A bacterium that occurs naturally in estuarine environments (where fresh water from rivers mix with salt water from oceans).

Basic: It causes cholera, a disease that can cause death if untreated.

Source: Raw and under cooked seafood or other contaminated food and water.

Symptom: Often absent or mild. Some people develop severe diarrhea, vomiting, and leg cramps. Loss of body fluids can lead to dehydration and shock. Without treatment, death can occur within hours.

Incubation: 6 hours to 5 days after eating contaminated food

Duration: 3 to 7 days

Pathogen: *Vibrio parahaemolyticus*: A bacterium that lives in saltwater and causes gastrointestinal illness in people.

Source: Raw or undercooked fish and shellfish

Symptom: Diarrhea, stomach cramps, nausea, vomiting, headache, fever, and chills

Incubation: 4 to 96 hours after eating contaminated food

Duration: 2 to 5 days

Pathogen: *Vibrio vulnificus*: A bacterium that lives in warm seawater. It can cause infection in people who eat contaminated seafood or have an open wound exposed to seawater.

Source: Raw fish and shellfish, especially raw oysters

Symptom: Diarrhea, stomach pain, nausea, vomiting, fever, and sudden chills. Some victims develop sores on their legs that resemble blisters.

Incubation: 1 to 7 days after eating contaminated food or exposure to organism

Duration: 2 to 8 days

Pathogen: *Yersinia enterocolitica*: A bacterium that causes *yersiniosis*, a disease characterized by diarrhea and/or vomiting.

Source: Raw meat and seafood, dairy products, produce, and untreated water

Symptom: Fever, diarrhea, vomiting, and stomach pain

Basic: Must-Know: Symptoms may be severe for children.

Incubation: 1 to 2 days after eating contaminated food

Duration: 1 to 3 weeks

Detection of food pathogens: the detection and enumeration of pathogens in food and on surfaces that come into contact with food are an important component of any integrated program to ensure the safety of foods throughout the food supply chain. Traditional methods of detecting food borne pathogenic bacteria are often time-consuming because of the need for growth in culture media, followed by isolation, biochemical and/or serological identification, and in some cases, sub specific characterization. Advances in technology have made detection and identification faster, more sensitive, more specific, and more convenient than traditional assays. These new methods include for the most part antibody and DNA-based tests, and modifications of conventional tests made to speed up analysis and reduce handling. With few exceptions, almost all assays used to detect specific pathogens in foods are qualitative assays, as they still lack sufficient sensitivity for direct testing and require some growth in an enrichment medium before analysis. The possibilities of combining different rapid methods, including improved technologies for separation and concentration of specific bacteria, and for DNA extraction and purification, will facilitate the direct detection of pathogens in food (CDC, 2014).

Public health implications of emerging and re-emerging pathogens and Zoonoses.: direct implications are defined as the consequences for human health in terms of morbidity and mortality. Indirect implications are defined as the effect of the influence of emerging zoonotic disease on two groups of people, namely: health professionals and the general public (CDC, 2014). Professional assessment of the importance of these diseases influences public health practices and structures, the identification of themes for research and allocation of resources at both national and international levels. The perception of the general public regarding the risks involved considerably influences policy-making in the health field.

Extensive outbreaks of zoonotic disease are not uncommon, especially as the disease is often not recognised as zoonotic at the outset and may spread undetected for some time. However, in many instances, the direct impact on health of these new, emerging or re-emerging zoonoses has been small compared to that of other infectious diseases affecting humans. To illustrate the tremendous indirect impact of emerging zoonotic diseases on public health policy and structures and on public perception of

health risks, the researchers provide a number of examples, including that of the Ebola virus, avian influenza, monkey pox and *bovine spongiform encephalopathy* (CDC, 2014). These diseases have contributed to the definition of new paradigms, especially relating to food safety policies and more generally to the protection of public health. Concentrated animal production has parallels with human urbanization, like the challenge of providing water, food, and fecal disposal for thousands of individuals every day. Just as the spread of many infections in human cities depends critically on treating the drinking water, and collecting sewage and keeping it out of the food and water supplies, and immunizing ourselves against many infections, so will the health of animals raised in virtual cities depend on attention to the safety of their water and food supplies, coupled with selective immunization. Zoonoses are diseases which occur primarily in animals but are occasionally transmitted to people (Plague, Lyme disease, and Rocky Mountain spotted fever). Many new, emerging and re-emerging diseases of humans are caused by pathogens which originate from animals or products of animal origin. However, in many instances, the direct impact on health of these new, emerging or re-emerging zoonoses has been small compared to that of other infectious diseases affecting humans. Subsequent epidemiologic investigations implicated poultry and raw milk as the most common sources of sporadic cases and outbreaks, respectively (Tauxe *et al.*, 1997). *Yersinia enterocolitica*, rare in the United States but a common cause of diarrheal illness and pseudoappendicitis in northern Europe and elsewhere, is now known to be most frequently associated with undercooked pork (Tauxe *et al.*, 1997). The epidemiology of food borne disease is changing. New pathogens have emerged, and some have spread worldwide. Many, including *Salmonella*, *Escherichia coli* 0157:H7, *Campylobacter*, and *Yersinia enterocolitica*, have reservoirs in healthy food animals, from which they spread to an increasing variety of foods. These pathogens cause millions of cases of sporadic illness and chronic complications, as well as large and challenging outbreaks over many states and nations.

An updated literature survey identified 1,407 recognized species of human pathogen, 58% of which are zoonotic. Of the total, 177 are regarded as emerging or reemerging zoonotic pathogens are twice as likely to be in this category as are non zoonotic pathogens. Emerging and reemerging pathogens are not strongly associated with particular types of nonhuman hosts, but they are most likely to have the broadest host ranges. Emerging and reemerging zoonoses are associated with a wide range of drivers, but changes in land use and agriculture and demographic and societal changes are most commonly cited. However, although zoonotic pathogens do represent the most likely source of emerging and reemerging infectious disease, only a small minority have proved capable of causing major epidemics in the human population. However, a recent, comprehensive literature survey of human pathogens listed >1,400 different species,

more than half known to be zoonotic, i.e., able to infect other host species. The survey data showed that those pathogens regarded as emerging and reemerging were more likely to be zoonotic than those that are not, confirming an association between these characteristics which had long been suspected, but which could not be formally demonstrated without denominator data as well as numerator data. A wide variety of animal species, both domestic and wild, act as reservoirs for these pathogens, which may be viruses, bacteria or parasites. Some pathogens persist in the environment, or in multiple hosts, and can contaminate the foods we eat via pathways that reflect the variety of ecosystems that make up our food supply. An increasing number of microbes have been recognized that can cause serious illness in humans, but rarely cause illness in the animals that carry them. The presence of these microbes is thus not apparent to the rancher or farmer, and the animal appears entirely healthy on inspection at slaughter; addressing these microbes requires a different prevention paradigm based on reducing levels of microbial contamination throughout the food chain. This effort starts on the farm or ranch where animals are raised, with attention to fodder, water, and biosecurity there. An early success was the virtual elimination of the parasite *Trichinella* from the nation's swineherds, and the prevention of pork-related trichinosis in people, through attention to the fodder fed to pigs (Schantz, 1983)). Recent outbreaks show that plants can also be contaminated with human pathogens on the farm, through manures, water, and wild animal incursions (Lynch *et. al.*, 2009). The need to reduce and prevent contamination continues through harvest and slaughter, subsequent processing, and the food preparation steps in the final kitchen. Indeed, reducing the number of food borne infections by making food safer is the result of efforts by many partners in the food safety system.

As conclusion, humans are affected by an impressive diversity of pathogens; 1,407 pathogenic species of viruses, bacteria, fungi, protozoa, and helminths are currently recognized. Of this total, 177 (13%) pathogen species are considered emerging or reemerging. This number must be viewed with some caution, given that these terms are still used somewhat subjectively. More rigorous definitions of emerging and reemerging pathogens have been proposed (Woolhouse and Dye, 2001; Institute of Medicine, 2003; World Organization for Animal Health, 2005), but these are difficult to apply universally because they require long-term data on distributions and incidences which are available for only a small subset of infectious diseases (e.g malaria) (World Organization for Animal Health; 2005) and tuberculosis (Hay *et. al.*, 2004). Moreover, the counts of emerging and reemerging pathogen species reported are subject to ascertainment bias. Despite these caveats, there are suggestions that pathogens associated with emerging and reemerging diseases share some common features. First, emerging and reemerging pathogens are disproportionately viruses, although they are not disproportionately

different kinds of viruses. Numerically, RNA viruses dominate, comprising 37% of all emerging and reemerging pathogens. RNA viruses are also prominent among the subset of emerging pathogens that have apparently entered the human population only in the past few decades, such as HIV or the SARS coronavirus (Burke,1998; Corbett *et al.*, 2003).

A possible explanation for this observation is that much higher nucleotide substitution rates for RNA viruses permit more rapid adaptation, greatly increasing the chances of successfully invading a new host population (Burke,1998; Corbett *et al.*, 2003). Second, emerging and reemerging pathogens are not strongly associated with particular nonhuman host types, although emerging and reemerging pathogens more often are those with broad host ranges that often encompass several mammalian orders and even non mammals. This pattern is consistent across the major pathogen groups. The determinants of host range in general remain poorly understood, but among viruses for which the cell receptor is known, an association exists between host range and whether the receptor is phylogenetically conserved (as measured by the homology of the human and mouse amino acid sequences) (Woolhouse, 2002). Emerging and reemerging pathogens have been likened to weeds (Dictionary.com, 2015), and that the associations reported above are likely reflecting underlying "weediness," that is, a degree of biologic flexibility that makes certain pathogens adept at taking advantage of new epidemiologic opportunities. This characteristic seems to be reflected in the broad range of drivers of the emergence or reemergence of pathogens, ranging from changes in land use and agriculture, through hospitalization to international travel. Although some drivers are numerically more important than others, the overall impression is that pathogens are exploiting almost any Host Range and Emerging and Reemerging Pathogens Emerging Infectious Diseases.

Recent epidemics of emerging diseases have served as a reminder of the existence of infectious diseases and of the capacity of these diseases to occur unexpectedly in new locations and animal species. Therefore, an important point that needs to be stressed here is that the search for better detection methods of pathogens cannot be stopped at one point. This will be an area of research and newer experiment will be evolving to make the detection systems rapid, sensitive, specific and cost-effective to the maximum extent.

RECOMMENDATIONS.

More rigorous definitions of emerging and reemerging have been proposed (Burke,1998; Corbett *et al.*, 2003; Hay *et. al.*, 2004), but these are difficult to apply universally because they require long-term data on distributions and incidences which

are available for only a small subset of infectious diseases (e.g., malaria (Woolhouse *et.al.*, 2005) and tuberculosis (Dobson and Foufopoulos, 2001).

The need for greater international co-operation, better local, regional and global networks for communicable disease surveillance and pandemic planning.

The examples described so far emphasize the importance of inter-sectorial collaboration for disease containment, and of independence of sectorial interests and transparency when managing certain health risks.

There is the need for health vigilance in the sectors responsible to be able to reduce these pathogens to the barest minimum.

Finally, the awareness campaign to enlighten the populace on how to avoid these pathogens should be increased.

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