

Diseases from Animals, Poultry, and Fish

JAMES E. LESSENGER

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Poultry, animals, and fish raised and slaughtered for human consumption comprise a large and varied group of mammals, birds, reptiles, amphibians and fish. They may be raised in the wild or in small backyard farm plots for a family's own consumption. More commonly they are raised in small and medium farms and, in some countries, feedlots or ponds that are many hectares in size.

In the same way that contaminated food can infect those who consume the meat (see Chapter 2), agricultural workers can become ill from the animal or poultry that they raise. Many of the illnesses are the same, but some are intrinsic to the farm and not found in the contaminated product (1).

The emergence of new zoonotic diseases and the resurgence of old ones like tuberculosis and cholera, reflect changes in human ecology:

1. Rural-to-urban migration resulting in high-density peri-urban slums
2. Increasing long-distance mobility and trade
3. Social disruption of war and conflict
4. Changes in personal behavior
5. Human-induced global changes, including widespread forest clearance and climate changes (2).

Animals and birds are also raised and sold as pets. Rats, mice, parakeets, snakes, prairie dogs, iguanas, and other animals not normally consumed by humans are raised in kennels and kept in homes.

Means of Transmission

Workers in production agriculture may come in contact with animals and animal products in the course of their job tasks. Table 27.1 lists the circumstances of contact where disease can be transmitted from animals to humans.

TABLE 27.1. Means of transmission from animals to humans.

Animal bites
Animal secretions
Saliva
Semen
Vaginal secretions
Skin contact
Veterinary care
Procedures such as castration, dehorning
Pushing, pulling animals
Feeding the young
Carcass handling
Slaughter
Necroscopy
Eggs
Milk
Handling freshly cooked or uncooked meat or poultry products
Eating or drinking uncooked or unpasteurized products before or during processing
Manure
Urine
Feces
Veterinary treatment

Source: Data from Jemmi et al. (1), Spencer et al. (3), Dutkiewicz (4), Guan and Holley (5), and Weber and Rutala (6).

A key problem is the lack of foot protection so that the unprotected feet of workers come in contact with feces of the animals. The fecal-hand route of transmission is also critical. Perhaps the most insidious and difficult to control is the consumption of raw poultry and meat products by workers in farms and processing plants. Many people in agriculture are living on subsistence or below-subsistence wages and consume products off the processing lines. Many of these products are not fully processed and may contact pathogens that have not been killed through cooking or irradiation (see Chapter 2) (Table 27.1) (3,4).

The improper handling of manure is a major source of disease, including the use of manure on food crops, the discharge of manure into community water sources, and the spread of manure onto areas where children play. In Canada, an outbreak of *Escherichia coli* O157:H7 was traced to organic growers who contaminated their produce with cow manure containing *E. coli*. Also in Canada, an outbreak of *Citrobacter freundii* infections was associated with parsley originating from an organic garden in which pig manure was used. Other documented infections of humans from manure-contaminated foods includes *Listeria monocytogenes* in cabbage contaminated by sheep waste, *Cryptosporidium* spread by municipal water contaminated by cattle, *Salmonella hartford* in food prepared by contaminated water from a shallow well polluted with poultry manure, and *Pleisomonas shigelloides* infection associated with well-water contaminated by poultry manure (5).

Agricultural Workers at Risk

Workers, visitors, inspectors, veterinarians, and people who live on or adjacent to farms, ranches, feedlots, processing plants, and other agricultural endeavors are at risk for contracting diseases from animals, poultry, or fish. One needs only to follow the animals from the farm to the feedlots, slaughter house, processing and sorting lines, and packaging plants to appreciate the large number of people who are at risk due to contact with animals and animal products. Physicians and other health care professionals are also at risk as they visit farms and plants for inspections or orientations (6).

Prevention

Methods of preventing the transmission of infectious material from animals and poultry to agricultural workers mirror in many ways the safety techniques for protection from chemicals, trauma and other hazards (see Chapter 6). The methods are summarized in Table 27.2.

Key to the prevention of the transmission of animal disease to humans is the proper processing of food products. This includes proper cook times and temperatures, adequate refrigeration, and appropriate transportation, processing, and stocking in stores.

Personal protective equipment includes hats or head coverings and protective coats or uniforms that can be laundered and left at the plant or farm. Boots should also be cleaned and left at the farm or plant. Especially in poultry operations, protective particulate masks may be necessary. In some

TABLE 27.2. Methods for preventing the infection of agriculture workers from poultry or animals.

Proper food processing
Personal protective equipment (Chapter 6)
Masks, hats, coveralls, gloves
Protective physical barriers
Policies and procedures
Veterinary herd monitoring
Rapid culling
Public health monitoring for disease trends and epidemics
Medical monitoring
Immunizations (Chapter 25)
Education and training (Chapter 5)
Development of technologies to prevent transmission
Hygiene
Hand washing
Government regulations and monitoring (Chapter 4)
Supervision

Source: Data from Davies and Wray (7), Fone and Barker (8), Meslin (9), Gardner (10), and Richardson et al. (11).

situations, especially when handling urine or feces, protective gloves are important (see Chapter 6).

Protective physical barriers in farm, ranch, or plant design allow for the raising or processing of food products without actual contact of humans with the animals or products. Built-in barriers, changing rooms, boot baths, and hand-free handling techniques allow for the safe and efficient handling of food.

In British chicken hatcheries, an aggressive combination of egg sanitization and handling methods was successful in decreasing zoonotic infections and diseases spread through flocks. Procedures included:

1. Design changes in incubators
2. Whole building ventilation systems
3. Control of dust, fluff, and aerosol production
4. Disinfection of surfaces and equipment
5. Improved handling of wastes (7).

Policies and procedures to limit or prevent physical contact with animals, feces, or urine prevent transmission. Rules prohibiting the consumption of food products on farms and ranches or on production lines are especially important. Not only can the production food product be infectious to workers, but food brought in by workers can become contaminated, which mandates eating areas for workers away from the livestock (7).

Aggressive veterinary monitoring of livestock can detect early evidence of disease outbreaks in herds. Similarly, public health monitoring of disease in humans can detect and appropriately treat epidemics of food-borne disease in humans and trace the source to the food-processing breakdown that caused the disease. Hazard analysis of critical control points (HACCP) is crucial to the prevention of infections in herds. Low cost, ease of performance, and rapidity of results are the key criteria for the tests, and are sometimes more important than the performance characteristics of sensitivity, specificity, and reproducibility. Field test kits are available for bacterial, protozoa, antibiotic residue, and other parameters of animal health (8,9,10).

Medical monitoring can detect early disease and prevent its spread to other employees, the food product, and family members. Pre-placement medical monitoring can identify people who are susceptible to infection, for example people with diabetes or immune diseases. In parts of the world where bovine tuberculosis is common, TB skin test monitoring can detect early infections and allow early treatment (8,9).

Immunizations are expensive, unavailable in many parts of the world, and only recommended for areas of high infectivity or occupations of high risk such as veterinarians. Three critical immunizations are tetanus, rabies, and influenza (see Chapter 25). Vaccines against salmonella, shigella, and other pathogens are in development or testing.

Training and education in proper handling techniques are important. Proper ways of herding, handling, and caring for animals and poultry can prevent infection and the transmission of infectious material. See Chapter 5 for details of education and training.

Research and the development of new techniques to prevent transmission are critical. For example, airborne dust has been discovered to be a carrier of pathogens in broiler breeder pullets (chicken pens). The use of an electrostatic space charge system has decreased the particle concentration and, in the process, decreased the potential of disease transmission to other chickens and to poultry workers (11).

Hygiene, both in the person and in the workplace, is essential in preventing the transmission of disease. For example, in many German piggeries workers must shower and change clothing when they enter and leave the buildings. This technique prevents the infection of the pigs with outside pathogens, the transfer of pathogens from one piggery to another, and the transfer of pathogens to the home environment. Especially important are the cleaning of machinery and the timely cleaning of animal and poultry urine and feces. Not only can urine and feces be infectious but they can attract insects that can spread pathogens. As in medicine, the most important hygiene procedure is aggressive hand washing for all persons handling food products.

In Louisiana, for example, alligator farmers must wear rubber boots and waders to protect themselves from pathogens (but not from bites, which can go right through the protective ensembles). Each day, the pens must be flushed and hosed off to remove the wastes that could harbor pathogens dangerous to the alligator colonies and workers.

Governmental regulations and oversight are important in providing standardization and systemization of methods and procedures to reduce the risk of infection to agricultural workers. Good regulations and oversight are evidence-based and consistent with sound agricultural methods (see Chapter 4).

It is not enough to have rules, regulations, equipment and techniques to prevent the spread of pathogens from animals and poultry to workers. Fair and consistent supervision by knowledgeable managers is critical to see that the proper equipment and supplies are used and that handling and hygiene rules and regulations are carried out.

Mammalian-Borne Diseases

Game are mammals killed or captured in the field for human consumption or for their hides, including elk, boars, bison, and deer. Production animals include cattle, pigs, goats, sheep, horses, dogs, deer, and other animals grown in small to large farms and ranches for human consumption. Typically the animals are slaughtered and dressed in various cuts made from the different parts of the animal. In addition, many animals are raised and kept as pets.

Viral Diseases

Rabies

Rabies is a common viral infection in children who live in rural areas and in people who handle un-immunized mammalian animals. The prophylaxis for rabies is discussed in Chapter 31. With the exception of four cases where the disease was treated with intensive therapy, the disease is considered universally fatal. Therefore, immunizations and prophylaxis are critical.

Monkeypox in prairie dogs

During May and June 2003, the first cluster of human monkeypox cases in the United States was reported. Most patients with this febrile, vesicular rash illness presumably acquired the infection from prairie dogs. Monkeypox virus was demonstrated by using polymerase chain reaction in two prairie dogs in which pathologic studies showed necrotizing bronchopneumonia, conjunctivitis, and tongue ulceration. Immunohistochemical assays for orthopoxviruses demonstrated abundant viral antigens in surface epithelial cells of lesions in conjunctiva and tongue, with lesser amounts in adjacent macrophages, fibroblasts, and connective tissues. Viral antigens in the lung were abundant in bronchial epithelial cells, macrophages, and fibroblasts. Virus isolation and electron microscopy demonstrated active viral replication in lungs and tongue. Both respiratory and direct mucocutaneous exposures are potentially important routes of transmission of monkeypox virus among rodents and to humans. Prairie dogs can be studied for insights into transmission, pathogenesis, and vaccine and treatment trials, because they are susceptible to severe monkeypox infection (12).

Prion disease

Chronic wasting disease (CWD) in North American deer and elk has been associated with Creutzfeldt-Jakob disease (CJD) in 3 hunters who killed, prepared, and ate their own game. An absolute association was not established, but further monitoring is ongoing (see Chapter 29). Creutzfeldt-Jakob disease does not appear to be a problem with workers who raise cattle or dairy cows (13).

Bacterial Diseases

Champylobacter

Chlamydophila abortus is a well recognized pathogen causing abortions in cattle and goats. A recent report from Germany cites a case where a pregnant woman became infected from farm animals and aborted. This rare zoonotic infection underlines the insidious and widespread problem of zoonotic infections on farms (14,15).

Campylobacter jejuni and *C. coli* have recently become recognized as common bacterial causes of diarrhea. Infection can occur at any age. Sources of infection are typically mammalian and avian hosts. The usual incubation period of campylobacter enteritis is 2 to 5 days. Fever, diarrhea and abdominal pain are the most common clinical features. The stools frequently contain mucus and, a few days after the onset of symptoms, frank blood. Significant vomiting and dehydration are uncommon. A rapid presumptive laboratory diagnosis may be made during the acute phase of the illness by direct phase-contrast microscopy of stools. Isolation of the organism from stools requires culture in a selective medium containing antibiotics and incubation under reduced oxygen tension at 42°C. The organism persists in the stools of untreated patients for up to 7 weeks following the onset of symptoms. Erythromycin may produce a rapid clinical and bacteriologic cure and should be used to treat moderately to severely ill patients as well as patients with compromised host defenses (14).

Salmonella

Salmonellosis is one of the most important public health disease problems, affecting more people and animals than any other single disease in agriculture. In Canada, for example, there were 7,138 cases of food-borne salmonellosis in humans during 2003. The native habitat of members of the genus *Salmonella* is the intestinal tract of warm-blooded and many cold-blooded vertebrates. In humans, the incubation period is 6 to 48 hours and produces headache, malaise, nausea, fever, vomiting, abdominal pain, and diarrhea (with and without blood). *Salmonella* is also capable of invading the intestinal mucosa, entering the blood stream, and causing septicemia, shock, and death. The diagnosis is made through the clinical presentation and confirmation with blood and stool cultures and serology. Treatment is first started empirically pending culture results and then adjusted if necessary. Multi-drug resistant *S. typhimurium* bacteria have been documented to be present in milk after pasteurization (16,17).

Listeriosis

Listeria monocytogenes is a zoonotic food-borne pathogen that is responsible for 28% of food-related deaths in the United States annually and that is a major cause of food recalls worldwide. Agricultural exposure is through drinking unpasteurized milk or direct contact with the animal or manure. The disease pattern is similar to salmonella (18).

Tuberculosis

Tuberculosis (TB) continues to be a worldwide infectious problem for humans. While human-to-human infection is of greatest concern, one infected dairy herd can infect hundreds, if not thousands, of people.

Potentially, tuberculosis can infect any mammal, although production cattle, especially dairy cattle, are at greatest risk. Complicating efforts to combat the disease is the fact that deer, badgers, elk and other wild species have been found to harbor the mycobacterium. In England, badgers were found to be spreading the infection to herds of cattle. Also, in England and Ireland, herds of sheep were found to be infected. In New Zealand, wild brush tail possums (*Trichosurus vulpecula*) were discovered to be the main source of infection in livestock, including deer herds. In Tanzania, tuberculosis-infected herds were found more often in small, pastoral farms that have little veterinary monitoring, as opposed to the large, commercial enterprises (19–22).

In a Los Angeles zoo, TB was found in two Asian elephants, three Rocky Mountain goats, and one black rhinoceros. An investigation found no active cases of tuberculosis in humans; however, tuberculin skin-test conversions in humans were associated with training the elephants and attending an elephant necropsy (23).

Human-to-animal transmission of TB has been documented. In an exotic animal farm in Illinois, three elephants died of *Mycobacterium tuberculosis* and a fourth tested culture-positive. Twenty-two handlers were screened for TB; eleven had positive reactions to intradermal injection with purified protein derivative. One had a smear-negative, culture-positive active TB. DNA comparisons by IS6110 and TBN12 typing showed that the isolates from the four elephants and the handler with active TB were the same strain, thus documenting that the infection of the elephants came from the handler (24).

Mycobacterium (tuberculosis) can infect agricultural workers in a number of ways:

1. Human-to-human contact with co-workers through the inhalation of respiratory droplets
2. Drinking contaminated, unpasteurized milk
3. Direct contact with infected animals
4. Direct contact with the secretions of infected animals such as respiratory droplets, milk, manure, urine, semen, and vaginal secretions
5. Direct contact or inhalations of respiratory droplets during necropsy, slaughter, or processing of meat or dairy products (20–24).

The clinical presentation is that of weight-loss, night sweats, a chronic cough, and hemoptysis. Asymptomatic workers are typically discovered through public health surveys. Diagnosis is through the purified protein derivative (PPD) skin test, smears of respiratory secretions demonstrating acid-fast bodies, cultures of respiratory secretions and other body fluids, radiographs demonstrating caseating granulomas, and other typical findings. Treatment is by multidrug therapy, complicated by regional drug resistance patterns (20–24).

Protozoal Disease

Giardia infections have been associated with contaminated sewage and water in agricultural environments, producing gastroenteritis. In the Sierra foothills of California, cattle drink water contaminated by infected beavers. Beaver- and cattle-contaminated water is then consumed by unsuspecting tourists who develop crampy abdominal pain, fevers, and a profuse bloody diarrhea. The *Giardia* infections are easily treated with metronidazole (5).

Avian-Borne Diseases

Fowl are birds that grow in the wild. Nearly every bird found in the wild can be prepared for human consumption. Poultry are birds grown in farm environments for human consumption. Common poultry include: chickens, turkeys, ducks, pigeons, game hens, geese, doves, and peacocks.

Viral Diseases

Avian Influenza

Avian influenza A (H5N1) first infected humans in 1997, in Hong Kong. The virus was transmitted directly from birds to humans. Eighteen people were admitted to hospitals, and 6 died. In 2003, 2 cases of avian influenza A (H5N1) infection occurred among members of a Hong Kong family, 3 of whom had traveled to mainland China. One person died. How or where these 2 people became infected was not determined.

Influenza A has the potential to cross species and has been implicated in the 3 flu pandemics in the 20th century (1918, 1957 and 1968). Pandemics occur when 3 conditions are met:

1. The emergence of influenza A virus with a hemagglutinin subtype is completely different from that of strains circulating in humans for many preceding years.
2. There is a high proportion of susceptible people in the community (i.e., a population with low antibody titers to the new strain).
3. Efficient person-to-person transmissibility of the new virus is possible with accompanying human disease (25-27).

The reported signs and symptoms of avian influenza in humans include:

1. Typical flu-like symptoms such as fever, cough, sore throat, and muscle aches

2. Eye infections
3. Pneumonia
4. Acute respiratory distress syndrome (ARDS)
5. Multiple organ failure
6. Lymphopenia
7. Elevated liver enzyme levels
8. Abnormal clotting profiles.

Physicians are advised to isolate the patient, initiate droplet precautions, and contact their local medical officer for further discussions if an epidemiological link is suspected.

The World Health Organization (WHO) is moving to rapidly produce a new influenza vaccine capable of protecting people against the H5N1 strain of avian influenza A. Preliminary genetic tests conducted in CDC laboratories in Atlanta, London, and Hong Kong suggest that the H5N1 strain is resistant to amantadine and rimantadine but is believed to be susceptible to neuraminidase inhibitors.

The WHO has recommended urgent, rapid culling of infected and exposed bird populations to eliminate the reservoir of the H5N1 strain. In addition, WHO has discouraged the practice of marketing live poultry directly to consumers in areas currently experiencing outbreaks of avian influenza A (H5N1). Some countries have introduced trade restrictions to protect animal health. However, available data do not suggest that processed poultry products (i.e., refrigerated or frozen carcasses and products derived from them) or eggs from affected areas pose a public health risk. The virus is killed by cooking (25–27).

Newcastle Disease

Newcastle disease is caused by virulent strains of APMV. Death rates among naive bird populations can exceed 50%. The virus responsible for Newcastle disease has been known to cause conjunctivitis and upper respiratory infections in humans since the 1940s. The disease is self-limiting and does not have any permanent consequences (28).

West Nile Virus

In 2002, Wisconsin public health officials were notified of two cases of febrile illness in workers at a commercial turkey breeder farm. A high prevalence of West Nile virus antibody was found among workers and turkeys. An associated high incidence of febrile illness among farm workers also was observed. Possible non-mosquito transmission among birds and subsequent infection of humans was postulated, but the mode of transmission was unknown (29).

Bacterial Diseases

Avian tuberculosis was diagnosed in two mature rheas on different ratite farms over a 2-year period. Both birds died after weight loss and development of granulomas in the lungs of one bird and bilaterally in the cutis cranial to the shoulder in the other. Smears and cultures of the granulomas were positive for acid-fast bacilli and tuberculosis (30).

Psittacosis

Chlamydophila (Chlamydia) psittaci, *C. trachomatis*, and *C. pneumoniae* can be passed from birds of all species to humans. Wild pigeons and pheasants have been demonstrated to be a source. Wild birds in captivity, pets (usually cockatiels, parakeets, parrots, and macaws), and production animals can infect workers, and there are reports of customs and health inspection workers becoming infected. Infection is through contact with feces, urine, and oral secretions (31).

Mild infection produces a tracheobronchitis with flu-like symptoms of cough, congestion, myalgias, fatigue, and fever. In severe infections, untreated workers, and immunocompromised workers, pneumonia, sepsis, shock, and death can occur. Radiographs reveal a lobar infiltrate (31).

Diagnosis is by detection of the 16S rRNA gene of *C. Psittaci* in sputum with a PCR analysis, and a typical radiographic appearance and culture. Tetracyclines and erythromycin are effective for treatment. Prevention is through close monitoring and culling flocks and pet birds and personal protection equipment (32).

Campylobacter Jejuni

Raising poultry at home is common in low-income countries. Studies demonstrate that proximity to free-range domestic poultry increases children's risk of infection with diarrhea-causing organisms such as *Campylobacter jejuni*. Corralling might reduce the risk, but research on the socioeconomic acceptability of corralling is lacking. Many people report that home-grown poultry and eggs taste better and are more nutritious. They enjoy living around animals and want to teach their children about raising animals. To prevent theft, some residents shut their birds in provisional enclosures at night but allege that birds are healthier, happier, and produce better meat and eggs when let loose by day. Many rural peoples view bird feces in the house and yard as dirty, but few see a connection to illness. Residents consider chicks and ducklings more innocuous than adult birds and are more likely to allow them inside the house and permit children to play with them. Additional food and water costs with corralling are a significant obstacle for some. Adequate space and corral hygiene must also be addressed to make this intervention

viable. Developing a secure, acceptable, and affordable corral remains a challenge for rural populations (33,34).

Salmonellosis

Although approximately 95% of disease caused by non-typhoidal salmonella is transmitted by food-borne vehicles, four documented salmonella outbreaks in the 1990s have been traced to contact with young poultry. No environmental studies of source hatcheries were completed. A case-control study was performed by comparing culture-confirmed *Salmonella infantis* in Michigan residents, identified between May and July 1999, with two age- and neighborhood-matched controls. Eighty environmental and bird tissue samples were collected from an implicated hatchery; all salmonella isolates underwent pulsed-field gel electrophoresis (PFGE) analysis. The study included 19 case-patients sharing the same PFGE subtype and 37 matched controls. Within 5 days before illness onset, 74% of case-patients resided in households raising young poultry compared with 16% of controls (matched OR 19.5; 95% CI 2.9, 378.1). Eight hatchery samples yielded *S. infantis* with PFGE subtypes matching the patients' isolates. This investigation identified birds from a single hatchery as the source of human illness and confirmed the link by matching PFGE patterns from humans, birds and the hatchery environment. Subsequent public health interventions reduced, but did not eliminate, transmission of poultry-associated salmonellosis. Five additional PFGE-linked cases were identified in spring 2000, necessitating quarantine of the hatchery for depopulation, cleaning and disinfection (35).

Fish-Borne Diseases

Fish farming, or aquaculture, for fish and shellfish is becoming more common and more internationalized with every passing year. In the United States, more than half the seafood consumption is imported, much of it from fish farming. The world's seafood trade is very complex, and it is often difficult or impossible to determine where the seafood is raised or harvested. For example, the United States imports salmon from Switzerland and Panama though neither country is known for large salmon fisheries (36).

In general, farmed fish is as safe and nutritious as wild-caught species, but there are public health hazards associated with ignorance, abuse, and neglect of aquaculture technology. Numerous small fish ponds increase the shoreline of ponds causing higher densities of mosquito larvae and cercaria, which can increase the incidence and prevalence of lymphatic filariasis and schistosomiasis. Especially dangerous is the use of human waste draining to fertilize or create ponds. Technology abuse includes the misuse of therapeutic drugs, chemicals, fertilizers and natural fish habitat areas. Technology neglect includes the failure to pay attention to mosquito habitats and the concomitant increase in malaria, as well as the propagation of other organisms (36).

Human exposure can be through direct skin contact with fish or the consumption of contaminated fish or shellfish products or contaminated water. The main pathogens acquired topically from fish (through spine puncture or open wounds) are *Aeromonas hydrophila*, *Edwardsiella tarda*, *Erysipelothrix rhusiopathiae*, *Mycobacterium marinum*, *Streptococcus iniae*, *Vibrio vulnificus*, and *Vibrio damsela*. *S. iniae* has recently emerged as a public health hazard associated with aquaculture, and *M. marinum* often infects home aquarium hobbyists. Common zoonoses contracted through the consumption of contaminated products or water include salmonella, leptospirosis, yersiniosis, and tuberculosis (37).

Salmonella

Salmonellae species have been found associated with all of the poikilothermic vertebrate species studied, as well as the mollusks and crustaceans (38).

Leptospirosis

Leptospirosis does occur in the poikilothermic vertebrates, as evidenced by positive serological reactions and by the isolation of pathogenic leptospiral serovars. The finding of leptospirosis species in fish, mollusks and other aquatic species are of special importance in view of the increased worldwide interest in aquaculture farming. Since 1975, 24 of the 101 (23.7%) reported human cases of leptospirosis in Hawaii have been associated with aquaculture industries (taro farms, prawn farms and watercress farms) (39).

Yersiniosis

Species of *Yersinia* are a particular problem in fish and in people involved in fish farming. Workers who wade in fish ponds or drink drainage water are especially at risk. *Yersinia enterocolitica* has been demonstrated to be a causative agent in acute diarrhea illness in humans after workers become infected through the feces-hand-oral route (19).

Tuberculosis

Tuberculosis has also been reported in freshwater and marine fish species (piscine tuberculosis), especially in those grown on fish farms. *Mycobacterium marinum* and *M. celonae* have been demonstrated in fish farms (30).

Reptile-Borne Diseases

Turtles, lizards, snakes, green iguanas (*Iguana iguana*), alligators, and crocodiles are grown from eggs in farms for their hides and meat. Some species are also grown for sale as pets.

Salmonella infections in persons who had contact with reptiles usually cause gastroenteritis but can result in invasive illness, including septicemia and meningitis, especially in infants and immunocompromised persons. For decades, reptiles have been known to be a source for salmonellosis; however, numerous reptile owners remain unaware that reptile contact places them and other household members, including children, at greater risk for infection. (40)

Captive reptiles (such as iguanas) are routinely identified as reservoirs of Salmonella and the number of reports about reptile-associated salmonellosis is increasing. In Germany and Austria, salmonella was detected in 54.1% of fecal reptile samples cultured. The percentage of salmonella-positive samples was significantly lower in turtles as compared with lizards and snakes, as salmonella was only detected in one sample from a single turtle out of 38 turtles investigated. In all, 42 different salmonella serovars were found. All isolated salmonella belonged to the species *enterica*, predominantly to the subspecies I (n = 46) and IIIb (n = 30) but also to subspecies II (n = 3), IIIa (n = 6), and IV (n = 2). All isolates were sensitive to the antimicrobials examined. A significantly higher percentage of salmonella-positive reptiles was detected in the group of owners who purchased reptiles in comparison with pure breeders. The high percentage of salmonella in reptiles in the study confirms the risk for the transmission of the infection to humans (41).

Amphibian-Borne Diseases

Amphibians include frogs, toads, newts, and salamanders that are caught in the wild or grown on farms for use as food or as pets. Frogs are caught in the wild and grown in farms for their meat, primarily frog legs. Eating inadequately cooked frog legs can lead to an infection of *Alaria americana*, a trematode. Increasing evidence suggests that amphibians can pose risks for salmonellosis in humans (42).

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