A Review of Foodborne Bacterial and Parasitic Zoonoses in Vietnam

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Abstract: Vietnam has experienced unprecedented economic and social development in recent years, and the livestock sector is undergoing significant transformations. Although food animal production is still dominated by small-scale ‘backyard’ enterprises with mixed crop–livestock or livestock–aquatic systems, there is a trend towards more intensive and vertically integrated operations. Changes in animal production, processing and distribution networks for meat and animal products, and the shift from wet markets to supermarkets will undoubtedly impact food safety risks in Vietnam in unforeseen and complex ways. Here, we review the available published literature on bacterial and parasitic foodborne zoonoses (FBZ) in Vietnam. We report on clinical disease burden and pathogen prevalence in animal reservoirs for a number of important FBZ, and outline opportunities for future research.

Keywords: Vietnam, foodborne zoonoses, livestock, aquaculture, human–animal interface

INTRODUCTION

Foodborne zoonoses (FBZ) are human infections transmitted through ingested food and caused by pathogens whose natural reservoir is a vertebrate animal species (Hubalek 2003). In industrialized countries, ~20% people suffer annually from foodborne infections (Hall et al. 2005; Painter et al. 2013); the fraction attributable to zoonotic organisms is ~50% (Liu et al. 2004, 2006; Chen et al. 2010; EFSA 2012). In Vietnam, suspect outbreaks of foodborne disease are reported to the Vietnam Food Administration (VFA) (http://vfa.gov.vn). In 2011, 148 outbreaks were reported, with 38,915 cases, 3,663 hospitalizations and 27 deaths. In most cases, FBZ aetiologies remain undetermined, and the relative disease burden compared to other infectious diseases cannot be readily quantified.

Some characteristics of animal production and food consumption habits in Vietnam that may promote zoonotic disease transmission include: (1) high density of both human and animal populations living in close proximity; (2) a predominance of smallholder production systems with mixed species and little/no biosecurity; (3) the presence of abattoirs and wet markets operating with rudimentary hygiene, limited cold chain for distribution and low levels of meat inspection; (3) widespread consumption of raw/undercooked blood, meat, fish, organ tissues, raw leaf vegetables and wild animal products and (4) use of untreated wastewater and sewage for agriculture. For these reasons, Vietnam and South East Asia are often considered a hotspot for emerging infectious diseases (Coker et al. 2011). Indeed, the threat of emerging viral pathogens has
received significant international attention, while the burden of endemic (predominantly bacterial and parasitic) zoonoses remains largely neglected. Within the last two decades, Vietnam has undergone extraordinary development. Changes underway involve rapid urbanization, intensification of animal production, modernization of food marketing systems and changes in food consumption habits. These changes will undoubtedly have major impacts on human exposures to animal pathogens, and hence the overall risk of zoonotic disease transmission. Despite significant investments in improved disease surveillance systems, information on FBZ is not readily available, and veterinary services are chronically under-resourced. The objectives of this review paper are to highlight knowledge gaps on FBZ and suggest priorities and specific areas for future research.

**METHODS**

We reviewed the available published literature in English from Vietnam on bacterial and parasitic FBZ from 1991 until January 2013. We searched PubMed for articles on food and waterborne zoonotic pathogens listed by the UK Health Protection Agency (HPA 2013), plus: ‘yersiniosis’ and ‘Yersinia enterocolitica’, ‘Fasciola’, ‘fascioliasis’, ‘Angiostrongylus cantonensis’, ‘fishborne trematodes’ and ‘Paragonimus’. Each search term was used in combination with ‘Vietnam’ and ‘Viet Nam’. We also used the same search terms to identify relevant articles published in the following Vietnamese public health and veterinary journals: (1) Tạp chí phòng chống bệnh sốt rét và các bệnh ký sinh trùng (Journal of Prevention of Malaria and Parasitology); (2) Khoa học kỹ thuật thú y (Journal of Veterinary Medicine); (3) Y học thạch hành (Medical Practice); (4) Y học tp. HCM (Medicine in Ho Chi Minh City); (5) Tạp chí Y học dự phòng (Journal of Preventive Medicine). None of these journals is electronically indexed. Although the emergence of antimicrobial resistance (AMR) is of paramount importance to food safety and public health in Vietnam (Dyar et al. 2012; Lestari et al. 2012), we have chosen not to address AMR, as this topic merits an extensive review on its own. Similarly, due to space limitations, we have not covered viral FBZ. We document available data on diverse FBZ, including human clinical impact and prevalence/incidence data within animal reservoirs, with a specific focus on the current situation in Vietnam.

**BACTERIAL FBZ**

**Non-Typhoid Salmonella (NTS)**

Non-typhoidal *Salmonella* (NTS) infections are caused by serovars of *Salmonella enterica* other than (non zoonotic) *S. typhi* or *S. Paratyphi*. Most NTS serovars are presumed to be zoonotic and potentially pathogenic to humans. NTS infections are typically self-resolving gastroenteritis, although complications may occur in children (<5 years), elderly and immunodeficient patients (Pegues and Miller 2010). NTS may infect a wide range of animals (both domestic and wild), but the vast majority do not cause detectable pathology in the reservoir host.

In Vietnam, improvements in sanitation have resulted in dramatic reductions of typhoid over recent decades. In southern Vietnam, *S. typhi* cases reduced from 497 in 1994 to 34 in 2008, with a concurrent increase of invasive cases of NTS (from 9 to 24) (Nga et al. 2012). Studies on NTS in humans in Vietnam are summarized in Table 1. NTS prevalence in various farm animals (pre-slaughter) and in slaughter and retail facilities is summarized in Table 2. Detected levels in meat are high, suggesting widespread contamination during slaughtering/processing. Contaminated fish products likely reflect widespread use of animal/human sewage in aquaculture. Serovar or molecular data from animals and humans are limited, so it is difficult to establish the main sources of human infection. Epidemiological data suggests that person-to-person transmission plays a major role (Thompson et al. 2012). NTS carriage has been detected in ~5% of healthy adults (personal communication).

**Campylobacteriosis**

Globally, *Campylobacter* is the single most common human bacterial diarrhoeal pathogen, and together with NTS, account for ~90% of foodborne bacterial disease. In Vietnam, as in other countries, *C. jejuni* is the dominant species found in paediatric clinical cases (~85%) (Isenbarger et al. 2001), with the remainder due to *C. coli*.

Reported *Campylobacter* prevalence in Vietnamese poultry meat ranges from 28 to 31% (Ha and Pham 2006; Luu et al. 2006). A 2005–2006 investigation of *Campylobacter* spp. at slaughterpoints in five cities worldwide indicated lowest prevalence in Ho Chi Minh City (HCMC) (15.3%, vs. an overall prevalence of 65.5%); 74% were *C. lari*, 9% *C. coli*, 4% *C. jejuni* and 13% other species.
| Citation                          | Study date       | Study location | Sample size | Age      | Study type                              | NTS prevalence          | Other aetiologies and observations                                                                                                                                                                                                 |
|----------------------------------|------------------|----------------|-------------|----------|-----------------------------------------|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ngan et al. (1992)               | 1988–1989        | Hanoi          | 83 diarrhoea cases | <3 years | Hospital-based study                    | No cases detected        | 24% had ETEC isolated, 8% had EPEC, 5% rotavirus, 6% *Candida*, and 4% *Giardia lamblia*                                                                                                                                                   |
| Isenbarger et al. (2001)         | 1998–1999        | Red River Delta (3 communes) | 1,655 healthy children in longitudinal study; 2,160 diarrhoea cases; 203 controls | <5 years | Longitudinal (community), hospital-based case-control study | 0.8% cases, 1% controls | Diarrhoea incidence: 1.3 episodes/child/year. Only bacterial aetiologies investigated: Main aetiologies (cases vs. controls): *Campylobacter* spp. (6.8 vs. 3.8%), *Shigella* spp. (6.5 vs. 1.5%), ETEC (6.5 vs. 4.4%) |
| Bodhidatta et al. (2007)         | 2001             | Hanoi          | 291 diarrhoea cases; 291 controls | <5 years | Hospital-based case-control study       | 7% cases; 1% controls   | Main aetiologies (cases vs. controls): Rotavirus (31% vs. 3%); *Aeromonas* (15% vs. 8%); Astrovirus (12% vs. 1%); *Shigella* (9% and 1%); *Campylobacter* (4% and 0%); Adenovirus (4% vs. 1%) and ETEC (3.0% vs. 0%) |
| Nguyen et al. (2004); Vu Nguyen et al. (2006) | 2001–2002        | Hanoi          | 587 diarrhoea cases; 249 controls | <5 years | Hospital-based case-control study       | No cases detected        | Main aetiologies (cases vs. controls): Rotavirus (46.7 vs. 3.6%), EAEC (11.6% vs. 7.2%), EPEC (6.6 vs. 4.4%), ETEC (2.2 vs. 0.4%); *Shigella* spp. (4.8 vs. 0%); *Campylobacter* isolation not attempted |
| Khan et al. (2010)               | 2001–2003        | International study including hospital in Hue (central Vietnam) | 3611 febrile patients | 5 to 15 years | Hospital-based                              | No cases detected        | *S. typhi* detected in 18 cases (0.5%) in Hue; International study. Other sites in Pakistan, India, and Indonesia also included                                                                                                           |
| Hien et al. (2007)               | 2002–2004        | Hanoi; suburban area using wastewater for agriculture and aquaculture | 222 children enrolled in longitudinal study; 111 diarrhoea cases; 111 controls | <6 years | Longitudinal (community), hospital-based case-control study | 3.6% cases; 2.7% controls | Diarrhoea incidence: 0.63 episodes/child/year. Aetiologies (cases vs. controls): Rotavirus (17.1% vs. 4.5%), *Entamoeba histolytica* (15.3% vs. 4.5%), diarrhoeagenic *E. coli* (22.5 vs. 23.4%), *Shigella* spp. (6.0 vs. 0%), *Campylobacter* spp. (1.8 vs. 1.8%) |
Semi-industrial poultry slaughtering was associated with lower contamination than informal direct slaughter by sellers (Garin et al. 2012). In Vietnam, there are no published data on pre-slaughter (on-farm) prevalence or Campylobacter species diversity.

The relative contribution of Campylobacter and NTS to diarrhoea is not particularly high, and asymptomatic infections appear to be common (Table 1). Given the widespread prevalence of NTS and Campylobacter in food products, and the intense human–animal exposures for most rural Vietnamese, the low incidence of clinical disease may reflect high levels of population immunity.

**Listeriosis**

*Listeria monocytogenes* causes abortion and sepsis-like infection in humans, especially among immunocompromised individuals, neonates, pregnant women and the elderly. Clinical *L. monocytogenes* infection was confirmed in 2008–2009, among three patients with meningitis in Hanoi (Chau et al. 2010; Tran et al. 2010). Listeriosis has been linked to consumption of unpasteurised soft cheeses, processed meat and fish products. A study of fish and seafood products from Nha Trang Bay (central Vietnam) identified *L. monocytogenes* in 5.8% (Beleneva 2011).

There are no data on prevalence of *L. monocytogenes* in meat products in Vietnam, but studies in the region (Thailand) suggest a high prevalence of *L. monocytogenes* in raw meats, especially in those sold in supermarkets (Indrawattana et al. 2011). In Vietnam, meat is increasingly bought from supermarkets, especially in urban areas.

**Streptococcus suis**

*Streptococcus suis* is an emerging human infection in Vietnam. The clinical picture is typically severe, and may involve skin, respiratory, neurological, cardiovascular and gastrointestinal systems. The largest *S. suis* outbreak recorded occurred in China in 2005, with 215 confirmed cases among pig slaughterers (Yu et al. 2006). Aetiological studies in Vietnam of cerebrospinal fluid from >2,000 patients (1996–2010) with suspect CNS infection have identified *S. suis* serotype 2 in 8.9–33.6% diagnosed patients (Mai et al. 2008; Wertheim et al. 2009b; Ho Dang Trung et al. 2012), confirming *S. suis* as the most frequent cause of bacterial meningitis in adults. About 66% patients experienced hearing loss as a sequela (Mai et al. 2008). Serotype 2 accounts for 96% of human cases, but other

| Table 1. continued |
|--------------------|
| Citation | Study date | Study location | Sample size | Study type |
| Do et al. (2007) | 2002–2004 | Red River Delta | 636 healthy adults in longitudinal study; 163 cases and 163 controls | Longitudinal (community), hospital-based case-control study |
| | | | | 0.6% cases; 3.1% controls |
| Thompson et al. (2012) | 2009–2010 | HCMC | 1,419 diarrhoea cases | Hospital-based case-control study |
| | | | | < 5 years |
| | | | | 5.4% cases of which 58% were Group B |

| Other aetiologies and observations |
|-----------------------------------|
| Aetiologies (cases vs. controls): E. hystolitica (9.9 vs. 0%); diarrhoeagenic E. coli (13.5 vs. 9.8%); Shigella (3.1 vs. 1.2%); C. jejuni (0.6 vs. 0%); rotavirus (3.7 vs. 0.6%); Main independent risk factors: diarrhoeal contact (OR = 6.0) and living in a household with > 2 children (OR = 2.3) |
| Citation       | Study date | Study location       | Sampling site, species, sample type                                      | Sample size | NTS prevalence; additional observations                                                                 | NTS serovars                                                                 |
|----------------|------------|----------------------|--------------------------------------------------------------------------|-------------|----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Tran et al. (2004) 2000 | Mekong Delta (6 provinces) | Animals in farms: pigs (faeces), chickens and ducks (caecal samples) | 439 pigs, 302 chickens, 357 ducks                                      | Prevalence in pig, chicken and duck samples was 5.2, 7.9, and 8.7%, respectively. Higher prevalence on small-scale farms than industrial farms | Most common serovars: S. Javiana and S. Derby (pigs); S. Emek and S. Javiana (chickens); S. typhimurium and S. Weltvreden (ducks) |
| Vo et al. (2006) 2004 | South Vietnam (13 provinces) | Pigs, cattle, chickens, ducks (carcasses, faeces, meat) at farms and abattoirs; Human (faeces) | Pigs (534), Cattle (390), Chickens (257), Ducks (34) | Prevalence in pigs, cattle, chicken and duck samples: 49.4, 27.4, 38.5, 20.5%, respectively. | Most common serovars: S. typhimurium and S. Anatun (pigs); S. Emek and S. Blockley (poultry); S. Anatum, S. Weltvreden, and S. Lexington (15.9%) (cattle) |
| Hong et al. (2006) 2004 | Central Vietnam | Pigs on smallholder farms (faeces) | 100 farms; 90 piglets with diarrhoea, 63 piglets without diarrhoea | No difference in prevalence of NTS in piglets with and without diarrhoea (10 and 11% positive, respectively) |                                                                                  |
| Phan et al. (2005) 2000–2001 | Mekong Delta | Fresh meat and shrimps from the market | 718 samples of meat (pork, duck, beef, chicken) and shrimps | 70% (pork); 49% (beef); 24% (shrimps); 22% (duck); 21% (chicken) | Most common serovars: S. Derby, S. Weltvreden, and S. London (pork); S. Weltvreden, S. London, S. Dessau (beef); S. Emek, S. typhimurium, S. Dessau (chicken); S. Lexington, S. Derby, and S. Dessau (duck); S. Dessau, S. Weltvreden and S. Tennessee (shrimps) |
| Citation          | Study date    | Study location | Sampling site, species, sample type            | Sample size | NTS prevalence; additional observations                                                                 | NTS serovars                                                                 |
|------------------|---------------|----------------|-----------------------------------------------|-------------|----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Van et al. (2007)| Unknown       | HCMC           | Fresh meat market samples                     | 130 samples | 64% (pork); 62% (beef); 18% (chicken).                                                                    |                                                                            |
| Ha and Pham (2006)| 2003–2004    | Hanoi          | Meat samples from factory, schools, hospital canteens | 177 meat samples | 8.3% poultry meat; 1.2% other meat                                                                       |                                                                            |
| Thai et al. (2012)| 2007–2008    | Northern Vietnam | Retail supermarkets                           | 586 meat samples | 39.6% (pork); 42.9% (chicken)                                                                          | Most common serovars: S. Emek, S. Infantis, S. Blockey, and S. Anatum (chicken); S. Anatum, S. Derby, S. typhimurium and S. Infantis (pork) |
| Le Bas et al. (2006)| Unknown    | Hanoi          | 15 pig slaughterpoints (faeces, carcass swabs) | 117 faeces (caeca) and 46 carcass swabs | 52% (faeces) and 96% (carcass swabs)                                                                    |                                                                            |
| Ellerbroek et al. (2010)| Unknown | Hanoi           | 6 pig slaughterpoints (lymph nodes)            | 178 lymph nodes | Prevalence from backyard small-scale farms (43%) versus intensive farms (29%)                          | S. Derby (50%); S. typhimurium (27%). Most S. typhimurium isolates were phage type DT22 |
| Ta et al. (2012)  | Unknown       | Six provinces (different regions) | Wet markets and supermarkets (chicken carcasses) | 1,000 carcasses | 46%; no significant difference between study sites, temperature at retail, or wet markets versus supermarkets |                                                                            |
serotypes (i.e. 16, 14) have also occurred (Nghia et al. 2008). A case–control study identified the following risk factors: (1) eating undercooked pig blood/intestine; (2) occupation related to pigs; and (3) exposure to pigs while having skin injuries (Nghia et al. 2011). Due to poorly regulated marketing systems, ill pigs may enter the food chain, thus posing a significant risk to both slaughterhouse workers and consumers. Consumption of pig blood, intestines and organ meats is common in Vietnam (Wertheim et al. 2009a).

Streptococcus suis carriage rates of 41% ($n = 542$) have been identified in healthy Vietnamese pigs. Serotype 2 appears to be dominant (14%), followed by serotypes 3, 21, 21 and 16 (Ngo et al. 2011). High numbers of pigs infected with Porcine Respiratory Reproductive Syndrome (PRRS) virus have tested positive for $S. suis$ in blood, indicating concurrent viraemic and bacteraemic infections (Hoa et al. 2013).

Leptospirosis

Leptospirosis is caused by several pathogenic species within the genus Leptospira. Humans become infected through cuts, skin abrasions or by drinking contaminated water. Symptoms can range from mild, influenza-like illness to severe infection with renal and hepatic failure, pulmonary distress and death (Adler and de la Pena Moctezuma 2010).

Studies of acute jaundice in Hanoi and HCMC from 1993 to 1997 ($n = 550$ patients) reported 8 and 2% leptospirosis, respectively. The most commonly identified serovars were Seramanga and Bataviae (Laras et al. 2002). A serosurvey in the Mekong Delta reported high seropositivity (21%) among 36–45 year olds, with detection of Bataviae (21.7%), Panama (15.2%), Icterohaemorrhagiae (13.7%), and Australis (8.7%). In that study, walking barefoot was a significant risk factor for seropositivity, but not contact with animals (Van et al. 1998). A 2003 survey of children ($n = 961$) in southern Vietnam identified anti-Leptospira IgG in 12.8%, a 1.5:1 male: female ratio of seropositivity, and significant association with swimming in rivers. Based on IgG seroconversion, a 0.99% annual incidence was estimated (Thai et al. 2006).

Leptospiras have a broad range of animal reservoirs. Most studies in Vietnam have focused on pigs due to their impact on swine reproduction. In the Mekong Delta, Bratislava, Icterohaemorrhagiae, Autumnalis, Grippotyphosa and Pomona are the most common serovars, with higher prevalence in small-scale farms compared to large holdings (Boqvist et al. 2002a, b). In general, there appears to be little overlap between serovars in pigs and humans; however, there is a paucity of surveillance data on which to judge exposures and epidemiological associations. The diffuse clinical picture and lack of straightforward diagnostics for leptospirosis (Wagenaar et al. 2004; Smythe et al. 2009) hamper adequate case reporting from Vietnam.

Parasitic FBZ

Toxoplasmosis

Toxoplasmosis is caused by the larval stage of the protozoan Toxoplasma gondii. Humans become infected by ingesting cysts (from undercooked meat/viscera), or oocysts released from the definitive host (the domestic cat) that contaminate food, water or the environment. Clinical signs range from mild to severe due to invasion of muscle, brain and eyes. Congenital toxoplasmosis occurs due to primary maternal infection during gestation (Montoya et al. 2010).

In Vietnam, a number of $T. gondii$ serosurveys have been conducted (Table 3). Human seroprevalence is not particularly high (1–24%); in animals it ranges from low/medium (3% buffalo, 10% cattle) to high (23% pigs; 29% poultry; 50% domestic dogs). There are no published data on prevalence in domestic cats. Pigs are likely to play a major role in $T. gondii$ infection, since pork is the most commonly consumed meat. In Thailand, a high prevalence in stray dogs has also been reported (Jittapalapong et al. 2007). Domestic dogs may also be relevant to transmission, since stray dogs are often imported from Thailand to supply dog meat restaurants. In southeast Asia, culinary habits (e.g. eating undercooked meat) and low water quality may be a more significant risk factor for $T. gondii$ than cat ownership (Nissapatorn et al. 2003).

Cryptosporidiosis

Cryptosporidiosis is caused by protozoa of the genus Cryptosporidium. Of ~20 Cryptosporidium species, seven are zoonotic (Fayer 2004), the most common one being C. parvum bovine genotype 2. Transmission is through ingested contaminated water and vegetables, although person-to-person transmission has been also documented. Most outbreaks have been attributed to $C. parvum$ and linked to a waterborne source (Clinton White 2010). Studies in Vietnam have not found evidence of Cryptos-
| Citation           | Study date | Study location                                      | Species | Details                                                      | Sample size | Overall prevalence; additional observations |
|--------------------|------------|-----------------------------------------------------|---------|--------------------------------------------------------------|-------------|-----------------------------------------------|
| Sery et al. (1988) | 1984       | Suburban Hanoi and Hoa Binh (northern mountain region) | Human   | Healthy individuals, all ages                                | 259 (140 from Hanoi, 119 from Hoa Binh) | 24.3% (Hoa Binh); 15.7% (sub-urban Hanoi); Higher prevalence in early childhood than middle age. |
| Huong et al. (1998)| 1995       | Near HCMC                                           | Cattle, buffalo | Cross-bred Frisian-Zebu cattle | 200 of each species | 10.5% (cattle) and 3% (buffalo) |
| Dubey et al. (2008)| 2003       | Mekong Delta (6 provinces) (and 6 other countries: Ghana, Indonesia, Poland and Italy) | Chickens | From 38 different farms                                     | 330         | 24.2% seropositive by MAT                     |
| Huong and Dubey (2007) | 2003–2005 | Southern Vietnam (Dong Nai, Tien Giang provinces) | Pigs    |                                                              | 587         | 27.2% seropositive in market weight pigs (6 months). Prevalence higher in older pigs |
| Dubey et al. (2007) | 2006       | Mekong Delta (7 provinces)                          | Domestic dogs |                                                              | 42          | 50% seropositive; experimental infections of naive cats with tissues from 8 dogs with high titres demonstrated transmission in 100% cases; high genetic similarity between T. gondii isolates from Vietnam and South America |
| Udonsom et al. (2008) | 2007      | Three provinces: Nghe An and Lao Cai (north) and Tien Giang (Mekong Delta) | Humans Rural |                                                              | 650         | Overall prevalence 4.2%; Highest in Nghe An (6.4%), followed by Lao Cai (4.7%) and Tien Giang (1.1%) |
poridium clinical disease among children with diarrhoea (Uga et al. 2005; Bodhidatta et al. 2007).

Cattle are thought to be the most common source of C. parvum genotype 2, although infection of pigs has also been described (Jenkins et al. 2010). A study of 266 cattle in three central provinces found 33.5% C. parvum positive (Nguyen et al. 2007a). Another study from the Red River Delta failed to detect Cryptosporidium among 68 healthy calves, but found 50% positive for Giardia (Geurden et al. 2008). A Cryptosporidium prevalence of 18% among diarrheic pigs of central Vietnam was reported (Nguyen et al. 2012), however, speciation was not performed, thus the implications for zoonotic transmission were unclear. C. parvum has been detected in farmed fish from southern Vietnam in association with wastewater used in aquaculture (Gibson-Kueh et al. 2011).

Giardiasis

Giardia lamblia is a protozoan cause of diarrhoea found in soil, food, and water contaminated with faeces from infected humans or animals. G. lamblia has a very broad host range, and some subtypes/species are zoonotic. Recent molecular analysis of specific genetic assemblages suggests a high degree of host-specificity, with limited potential to infect humans (Xiao and Fayer 2008). A study on children less than 3 years old with severe diarrhoea in Hanoi identified G. lamblia among 2.4% (Ngan et al. 1992). Healthy people (N = 2,522) in north-western Vietnam had a surprisingly high prevalence (4.1%) (Verle et al. 2003). A study in calves less than 3 months old showed that Giardia spp. were the most prevalent parasites (50%); further characterization of 17 isolates indicated that all were non-zoonotic G. duodenalis (Geurden et al. 2008). Both Giardia and Cryptosporidium represent a challenge to safe drinking and recreational water supplies, due to their resistance to chlorine and environmental persistence.

Taeniasis/Cysticercosis

Taeniasis and cysticercosis are distinct disease entities caused by different life stages of Taenia spp. Taeniasis refers to human enteric infection with the adult tapeworm, after ingestion of taenid cysts (cysticerci) present in undercooked beef (T. saginata) and pork (T. solium and T. asiatica). Cysticercosis are infections caused by ingestion of taenid eggs. Over the past decades, incidence of cysticercosis has decreased substantially worldwide owing to improved animal husbandry, sanitation and better meat inspection (Sotelo 2003).

Studies on taeniasis and cysticercosis in humans are shown in Table 4. During the 1990s, approximately 100–150 patients with neurocysticercosis were annually referred to Hanoi hospitals (Ky and Van Chap 2000). In addition, serosurveys published in Vietnamese suggest a large variation in prevalence among adults (0.2–7.2%) (Willingham et al. 2003). Pig infections with cysticerci may result in reduced carcass value or full condemnation. A 1989–1992 study of meat carcasses in Hanoi indicated low prevalence (<0.1%). A 1999–2000 swine serosurvey indicated ~10% prevalence of cysticerci; however, cysts were T. hydatigena, for which the domestic dog is the final host (Dorny et al. 2004). Taenid eggs and T. solium cysts have been found in vegetables and dog meat sold in Hanoi (Uga et al. 2009; Willingham et al. 2010). Eating raw/pickled pork (i.e. ‘nem chua’) may be a major risk factor, as well as agricultural use of human wastewater as fertilizer (Dorny et al. 2004). To date, T. asiatica has not been reported from pigs in Vietnam, suggesting there may be other non-porcine intermediate hosts (Dorny et al. 2007). It is not yet clear whether T. asiatica causes cysticercosis (Galan-Puchades and Fuentes 2009). The presence of both T. saginata and T. asiatica in Vietnam may limit transmission of the more serious T. solium infection due to cross-protection (Conlan et al. 2009).

Trichinlosis

Trichinlosis is caused by ingestion of encysted larvae of the genus Trichinella, predominantly from contaminated pork. T. spiralis is the most common species, found in pigs, wild boars and other species (Pozio et al. 2009). In humans, the clinical spectrum ranges from mild fever to myalgia and fulminating fatal disease. Like cysticercosis, the incidence of Trichinlosis has been decreasing worldwide over the last century. Data on Trichinella from Vietnam are limited to a few reports of sporadic outbreaks (~25 cases each) reported since 1970 in remote northern provinces (Dien Bien, Yen Bai and Son La), all traced back to consumption of undercooked/fermented pork (Taylor et al. 2009). A 2008–2009 serosurvey for T. spiralis in 1,035 free-roaming pigs reported age-dependent increases in seroprevalence, with overall seropositivity of 20%, and Trichinella larvae in 14.5% (Thi et al. 2010).
### Table 4. Published surveys of Taeniasis/Cysticercosis in humans in Vietnam.

| Citation            | Study date | Study location | Type of study | Details | Sample size | Overall prevalence; additional observations |
|---------------------|------------|----------------|---------------|---------|-------------|---------------------------------------------|
| Erhart et al. (2002)| 1999       | Bac Ninh (Red River Delta) | Survey using serum cysticercosis prevalence | Healthy individuals, all ages | 210 | 5.7%; 5/12 seropositive individuals reported history of epilepsy. |
| Verle et al. (2003) | 1999       | Hoa Binh (north-western Vietnam) | Survey of gastrointestinal helminth infection | 6 ethnic groups | 526 households (2,522 samples) | Taenia eggs detected in 0.1% stool samples. One person had subcutaneous nodules that were diagnosed as cysticercosis by biopsy. |
| Somers et al. (2007)| 2002–2003  | Northern Vietnam (14 provinces) | Hospital-based | Patients | 65 patients from 14 hospitals | 55.4% specimens identified as *T. asiatica*; 38.5% *T. saginata* and 6.2% *T. solium* tested by mitochondrial 12S rDNA by PCR. |
| Somers et al. (2006)| 2003–2004  | Bac Kan (far northern province); Ha Tinh (central Vietnam); Hai Duong (Red River Delta) | Survey using serum (prevalence of cysticercosis) and faeces (prevalence of taeniasis) | Healthy individuals from 3 areas: 1. Bac Kan (rural, mountainous) 2. Ha Tinh (rural, coastal) 3. Hai Duong (peri-urban, coastal) | 303 (mountainous region); 179 (rural coastal region); 229 (peri-urban, coastal region) | Study investigating helminth infections. 5.3% (Bac Kan); 0.6% (Ha Tinh); 0% (Hai Duong). |
**Fascioliasis**

Fascioliasis is caused by liver flukes of two species, *Fasciola hepatica* and *F. gigantica*. Humans become infected through ingestion of water or freshwater plants with adherent metacercaria (Mas-Coma 2005; Ashrafi et al. 2006) or juvenile forms (Taira et al. 1997). The parasite requires replication in *Lymnea* snails as intermediate hosts.

In Vietnam, fascioliasis has been increasingly diagnosed since the 1990s, mostly in ruminant-producing areas during the rainy season (De et al. 2003) (Table 5). Aberrant clinical forms (cutaneous fascioliasis) have been reported in association with *F. gigantica* (Xuan et al. 2005; Le et al. 2007). A hybrid of *F. hepatica* and *F. gigantica* has been reported from humans, cattle (Le et al. 2008) and goats (Nguyen et al. 2009). Parasite burdens are likely to have economic repercussions for livestock production.

It is unclear whether increasing case numbers of fascioliasis represent disease emergence or improved laboratory diagnostics and reporting. Changes in environmental factors and/or livestock production (i.e. increasing stocking densities, use of cattle faeces as fertilizer) may contribute to transmission (Tran et al. 2001b; De et al. 2003).

**Fish-Borne Zoonotic Trematodes (FZT)**

FZT comprise a large group of flukes of the families *Heterophyidae*, *Echinostomatidae* and *Opisthorchiidae* (Chai et al. 2005). Adult liver flukes live in the biliary tract of a range of vertebrates. Eggs are released in the environment; the miracidium penetrates freshwater snail tissues, where it develops into free-swimming cercariae that infect cyprinid freshwater fish. Within the fish host, parasites invade muscle and transform into metacercariae that are infectious for humans. Although most human FZT infections are subclinical, *Clonorchis sinensis* and *Opistorchis verrini* may cause chronic liver infection, pancreatitis, cholangitis and cancer (Choi et al. 2006; Mayer and Fried 2007). *C. sinensis* is widely distributed in East Asia and is endemic to the Red River Delta, whereas *O. viverrini* is present in Laos, Cambodia, Thailand and southern Vietnam.

Approximately, one million people are infected with FZT in Vietnam (Kino et al. 1998). Overall, low to moderate levels of FZT are found within healthy individuals. Epidemiological studies indicate significant geographic variability, associations with culinary habits, and widespread infection of diverse animal species (Table 6). During 2009–2010, an intervention study in 18 fish nurseries introduced snail control by pond draining and treatment of humans and domestic cats. Examination of ~15,000 fish after 9 weeks of intervention indicated moderate success in reducing fish infection rates with FZT (Hedegaard Clausen et al. 2012). Given that human, pig and poultry excreta are commonly used as fish feed, and that snails and fish are fed to poultry, it is likely that multiple vertebrate species play a role in maintaining FZT transmission. There are strong economic and trade incentives to reduce transmission to promote successful development of aquaculture exports.

**Paragonimiasis**

Paragonimiasis is a lower respiratory tract infection caused by lung *Paragonimus* flukes. Humans become infected through consumption of infective metacercariae from raw or undercooked crustaceans. Eggs are voided by infected people in sputum or faeces; in the environment, the parasite goes through several stages involving snails and then crayfish or crabs as hosts. Symptoms are sometimes mistaken with chronic tuberculosis (Vijayan 2009). Clinical cases in Vietnam have been documented from mountainous regions, linked to consumption of infected crabs (Table 7). Vietnamese domestic dogs and pigs infected with *Paragonimus* have been reported (Queuche et al. 1997). Species identified from Vietnam include *P. heterotremus*, *P. vietnamiensis*, *P. proliferus* (northern mountainous areas) and *P. westermani* (central Vietnam) (Doanh et al. 2007, 2008, 2009). In spite of mass screening, treatment and education programmes, paragonimiasis remains a problem in a limited number of areas of the country.

**Gnathostomiasis**

Gnathostomiasis occurs wherever consumption of raw fish is common. Human infections are acquired by ingestion of advanced third stage larvae (AL3) of *Gnathostoma* spp. present in fish species. Humans are paratenic hosts; the larvae commonly migrate through subcutaneous tissues, visceral organs and the central nervous system. *G. spinigerum* is the most common species in Southeast Asia, usually found in swamp eels (*Monopterus albus*) (Waikagul and Diaz Camacho 2007).

Until 1998 only three cases of *G. spinigerum* had been documented in Vietnam; however, introduction of serological tests since then led to hundreds of cases since. A study indicated that 63.8% had cutaneous and 14.7% had...
## Table 5. Published surveys of *Fasciola* spp. in humans and ruminants in Vietnam.

| Citation          | Study date   | Study location                        | Species | Sample collections                                                                 | Sample size | Overall prevalence; additional observations                                                                 |
|-------------------|--------------|---------------------------------------|---------|-------------------------------------------------------------------------------------|-------------|-------------------------------------------------------------------------------------------------------------|
| Tran et al. (2001a, b) | 1997–2000 | Hospitals in central and southern Vietnam | Humans  | Stools from hospitalized patients with confirmed *Fasciola* infection                | 500         | Largest number of cases from central provinces of Khanh Hoa, Binh Dinh and Quang Nga; prevalence per site per year unknown |
| Verle et al. (2003)   | 1999        | Hoa Binh (north-western Vietnam)       | Humans  | Stools from healthy community cohorts (6 ethnic groups)                              | 2,522 from 526 households | No *Fasciola* eggs detected                                                                                   |
| Holland et al. (2000) | 1999–2000 | Hanoi province (northern Vietnam)      | Cattle  | Faeces                                                                              | 119         | 22% *Fasciola* egg-positive; positives only among animals > 3 months; no evidence of seasonality              |
| Linh et al. (2003)    | 2000–2002   | Hanoi province (northern Vietnam)      | Cattle/buffalo | Faeces and livers (30 cattle, 2 water buffalo)                                      | 30 cattle, 2 water buffalo | 62% *Fasciola* egg-positive, and 100% positive for worms in liver tissue                                        |
| Anderson et al. (1999)| 2002       | Hanoi city (northern Vietnam)          | Cattle  | Faeces and livers                                                                    | 92          | 78.3% cattle had *Fasciola* in liver. Positive correlation between age of cattle and number of liver flukes     |
| Suzuki et al. (2006)  | 2002–2003   | Hanoi province (northern Vietnam)      | Cattle  | 99 smallholder dairy farms; 4 time points; faeces                                    | 263 cattle  | 10% *Fasciola* egg-positive in June; 26% egg-positive in March; significant association between poor reproductive performance and *Fasciola* infestation |
| Uga et al. (2005)     | 2003–2004   | Suburban Hanoi (northern Vietnam)      | Humans  | Stools from adolescents (14–15 years)                                               | 116         | 1% *Fasciola* egg-positive. The most frequently detected helminths were: *Trichuris trichiura* (67%), *Ascaris lumbricoides* (34%) and hookworm (3%) |
| Geurden et al. (2008) | 2006        | Red River Delta (5 provinces)          | Cattle  | Faeces                                                                              | 334 cattle  | 28% *Fasciola* egg-positive (3-24 moths); 39% prevalence in cattle > 2 years                                 |
| Nguyen et al. (2011)  | 2008        | Binh Dinh (central Vietnam)            | Cattle  | Faeces and sera                                                                      | 825 cattle  | 54.9% *Fasciola* egg-positive and 72.2% *Fasciola* seropositive                                            |
Table 6. Published surveys of foodborne trematode zoonoses (FTZ) in humans and animals in Vietnam.

| Citation       | Study date | Study location          | Sample collections                  | Sample size | Overall prevalence; additional observations |
|----------------|------------|-------------------------|-------------------------------------|-------------|---------------------------------------------|
| Phan et al. (2011) | Unknown    | Nam Dinh province (Red River Delta) | Faeces of farming household members | 180         | 32.2% FTZ egg-positive; 8% did not report eating raw fish; OR = 2.3 for consuming raw fish (vs. no consumption); OR = 3.6 for eating raw fish in restaurants vs. eating raw fish at home |
| De (2004)      | 1976–2002  | 15 provinces all over the country | Healthy individuals, domestic dogs and cats | ~30,000  | Overall 21% FTZ egg-positive for C. sinensis/O. viverrini. Highest in Nam Dinh (37.5%) and lowest in Thai Binh (0.2%). Prevalence 3 times higher among men. Peak in 40-50 years. Prevalence in dogs (28.6%) and 64.2% in cats. 7/10 species of fresh water fish infected with metacercaria |
| Kino et al. (1998) | 1997      | Ninh Binh province (Red River Delta) | Faeces from healthy individuals; tissues of farmed fish | 306         | 13.7% FTZ egg-positive for C. sinensis; Males higher prevalence than females (23 vs. 1.5%); prevalence increase with age; prevalence of metacercaria in silver carp > 56%; prevalence of cercaria among Melanoides tuberculatus snails (13%) |
| Dang et al. (2008) | 1999/2000  | Ninh Binh province (Red River Delta) | Faeces from healthy individuals | 1,115       | 26.1% FTZ egg-positive; males higher prevalence than females; All adult parasites recovered were C. sinensis; association between FTZ positivity and consumption of raw fish |
| Olsen et al. (2006) | 2004      | Nghe An (north-central Vietnam) | Faeces of fish farmers | 964         | 0.6% FTZ egg-positive for FTZ; 0.7% for Fasciolopsis buski; infection prevalences of Ascaris lumbricoides, Trichuris trichiura and hookworm were 34.8, 50.7 and 51.3%, respectively |
| Citation            | Study date | Study location                  | Sample collections                                                                 | Sample size         | Overall prevalence; additional observations                                                                 |
|---------------------|------------|---------------------------------|------------------------------------------------------------------------------------|---------------------|-----------------------------------------------------------------------------------------------------------|
| Trung et al. (2007) | 2005       | Nam Dinh province (Red River Delta) | Faeces of healthy individuals; positive individuals examined for adult parasites after treatment with praziquantel | 615 (33 examined twice) | 65% FZT egg-positive; Among treated and re-examined patients: 51% positive with C. sinensis. Other species identified were *Haplorchis pumilio* (100%); *H. taichui* (70%); *H. yokogawai* (3%); *Stellantchasmus falcatus* (6%); *Fasciolicus buki* (3%) |
| Chi et al. (2008)   | 2005       | North-central Vietnam           | Tissues of tilapia and 6 carp species from 53 fish farms                            | 716                 | 12–61% FZT metacercaria positive species included FZT *H. pumilio*, *H. taichui*, *H. yokogawai*, *Centrocestus formosanus*, *S. falcatus* and *Echinochasmus japonicus*; similar prevalence in nursery and grow-out ponds |
| Lan-Anh et al. (2009)| 2005      | Nghe An (north-central Vietnam) | Faeces of terrestrial farm species                                                 | 35 domestic cats, 80 domestic dogs, and 114 pigs     | 48% egg FZT positive (cats); 35% (dogs); 14% (pigs) |
| Nguyen et al. (2007a, b) | 2005–2006 | Nghe An (north-central Vietnam) | Tissues of tilapia and carp fish reared on wastewater-fed ponds                    | 1,200               | Overall ~4.8% FTZ metacercaria positive (higher in warmer months). All metacercariae recovered were of the family Heterophyidae. Tilapia and 3 species of carp were infected |
| Thu et al. (2007)   | 2005–2006 | Mekong Delta                    | Tissues of catfish and snakehead fish                                              | 852                 | 31% FZT metacercaria positive; 10% positive for zoonotic species, including *O. viverrini* (1.9%), *H. pumilio* (2.8%) and *Procercovum* spp. (5.6%) |
| Anh et al. (2010)   | 2009       | Nam Dinh province (Red River Delta) | Liver tissues from poultry from 60 fish farms                                      | 50 (chickens); 50 (ducks) | Identified *Centrocestus formosanus* and *Echinochasmus cinetorchis* |
| De and Le (2011)    | 2009/2010  | Nam Dinh (Red River Delta)      | Faeces of healthy individuals; positive individuals examined for adult parasites after treatment with praziquantel | 405 (10 examined twice) | 32.2% FZT egg-positive; 29.3% in males and 16.0% in females. 385 adult flukes from 10 patients identified: *C. sinensis* (14.6%), *Haplorchis taichui* (32.3%), *Haplorchis pumilio* (52.08%) and *Centrocestus formosanus* (1.0%) |
| Citation               | Study date | Study location                  | Sample collections                                                                 | Sample size                                      | Overall prevalence; additional observations                                                                 |
|-----------------------|------------|----------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| Queuche et al. (1997) | 1993       | Lai Chau (northern Vietnam)      | Sputum of patients with pulmonary disease; faeces of healthy people                  | 155 patients; 225 healthy; 125 children 8–18 years; 16 domestic dogs; 15 pigs | 28% of patients had eggs in sputum; Mean age 11 years; 2 of 155 patients had CNS symptoms; 5% healthy people were egg-positive; associations with consuming freshwater crabs; 5/16 dogs and 2/15 pigs tested positive for adult lung flukes |
| Vien et al. (1997)    | 1994/1995  | Lai Chau (northern Vietnam)      | Sputum of chronic respiratory disease patients                                        | 44                                               | 2 of 44 with CNS symptoms; 100% of cases egg-positive; most cases had eaten insufficiently roasted crabs         |
| Doanh et al. (2011)   | Unknown    | Three provinces: Lai Chau, Yen Bai (north) and Quan Tri (central) | Sputum of healthy patients                                                         | 590                                              | 12, 4 and 0% seropositive from Lai Chau, Yen Bain and Quan Tri, respectively; sequences from eggs from sputum of six individuals identified *Paragonimus heterotremus* |
visceral manifestations (Xuan et al. 2004). Severe eye infection due to *G. spinigerum* was reported in the Mekong Delta (Xuan et al. 2002). Market surveys of eels (*n* = 1,081) in HCMC identified *G. spinigerum* AL3 in 0.11% (Le and Rojekittikhun 2000). Prevalence was higher in wild-caught eels and at the end of the rainy season (Sieu et al. 2009).

**Other FBZ Reported in the Vietnamese Literature**

Between 2006 and 2011, 413 human cases and three anthrax deaths were reported in northern Vietnam. All had a history of slaughtering/eating dead ruminants (Tran and Pham 2012). Studies on suspect cases of *Toxocara canis* using serology confirmed 83 visceral and 33 ocular infections (Tran et al. 2001a; Le et al. 2012). A 2004 serological study of 1,201 dairy cattle in HCMC reported negative results for *M. bovis* (ELISA) and *Brucella* spp. (Nguyen et al. 2006).

**DISCUSSION**

Our review of 95 publications reveals the highly diverse range of endemic pathogens associated with FBZ in Vietnam. Although a systematic ranking of disease burden associated with FBZ is not possible at this time, the pathogens fall largely into three groups: (1) pathogens that are relatively more common as causes of clinical disease in Vietnam than in developed temperate-zone countries; (2) pathogens known to be present in Vietnam that are not responsible for a particularly high disease burden; and (3) FBZ which may be fairly common, but for which the dearth of either research or surveillance data in Vietnam prohibits making any valid assessments of relative burden.

In the interest of maximizing development impacts and pursuing a One Health research agenda, there are clear imperatives to prioritize research on zoonoses within group 1 that also cause significant production losses and incur the highest economic costs to farmers. We suggest that *Streptococcus suis*, *Leptospira*, *Fasciola* and fish-borne trematode infections meet these criteria, and that a better understanding of the transmission ecology of these pathogens within smallholder production systems could readily generate improved control options with benefits to both human and animal health. In contrast, *Campylobacter* and NTS belong to the second category of FBZ, for which the clinical disease does not appear to rank particularly high; although elsewhere in the world *Campylobacter* and NTS are dominant causes of foodborne diarrhoea, and are the focus of intense multinational control efforts. The influence of human–animal contact rates and human population immunity to *Campylobacter* and NTS merits further research, since future changing patterns of exposure may drive a shift in the age-related incidence of infection. Unfortunately, the majority of pathogens fall within category 3, for which data sources are entirely inadequate to estimate burden.

Potential impacts of ongoing urbanization and economic development on FBZ in Vietnam are summarized in Table 8, alongside suggested areas for further research and improved surveillance. Surveillance of FBZ remains one of the weakest aspects of the health systems in Vietnam. In most cases, hospitals do not carry out routine diagnosis of most bacterial and parasitic FBZ. Serious diseases such as leptospirosis and toxoplasmosis are often not adequately diagnosed and reported.

The pace of industrialization of Vietnam’s farming systems varies by sector and region. The trend is towards increasing farm sizes with higher stocking densities and modern management (all-in all-out systems, synchronized breeding, etc.). In the last decade, central decisions made at the Ministry of Agriculture and Rural Development and the Department of Livestock Production to promote restructuring of the poultry sector was viewed as a way to improve control of highly pathogenic avian influenza (HPAI). Although consolidation undoubtedly provides many more opportunities for increased biosecurity at the farm level, it may also increase vulnerabilities to dissemination of pathogens across the food chain. Changes in pathogen exposure, increased stress and breed and management factors may alter herd/flock immunity and pathogen population dynamics. The risk of pathogen emergence in modern versus traditional production systems has received some attention, but largely in relation to viruses (Drew 2011; Graham et al. 2008). It remains to be seen whether knowledge gained on drivers of viral emergence can be generalized to bacterial and parasitic FBZ.

In spite of government efforts to promote consolidation, smallholder mixed crop–livestock production remains dominant in Vietnam. Use of animal/human excreta and feed leftovers is common, especially within the ‘VAC system’ (Vuon = garden, Ao = pond and Chuong = pig pen) (Pham Duc et al. 2011). Such integrated systems provide efficient nutrient recycling, but also may promote transmission of parasites whose life cycles involve invertebrates.
Table 8. Summary of main challenges and suggested priority research areas on FBZ in Vietnam.

| Foodborne pathogen | Data on prevalence/incidence in humans | Data on animal reservoir | Challenges for Vietnam | Suggested areas of research |
|--------------------|--------------------------------------|--------------------------|------------------------|---------------------------|
| Non-typhoidal *Salmonella* (NTS) infection | Responsible for ~0–7% of diarrhoea in < 5 year children; limited data on serovar distribution in humans. High levels of NTS carriage among adults; some evidence for person-to-person transmission among children. | High prevalence and variability of serovars in poultry, pigs, fish/seafood and meat products | Meeting export targets of meat products will require improved control of NTS in fish, pigs and poultry | Attribution studies in humans; impact of urbanization and backyard farming on human immunity; Antimicrobial resistance; NTS diversity within backyard versus industrialized production systems |
| *Campylobacter* spp. infection | Responsible for 4–40% of diarrhoeal cases in < 5 year children (Red River Delta) | Very high prevalence in chicken carcases and meat products | High levels of multi-resistance including ciprofloxacin resistance | Risk factors and attribution studies among clinical cases; prevalence and genetic diversity in backyard versus industrialized production systems, and along processing/retailing market chains; impact of urbanization and backyard farming on human immunity |
| *Streptococcus suis* infection | Most common cause of adult bacterial meningitis; majority of cases caused by *S. suis* serotype 2; approximately 5–43 confirmed cases per year in Vietnam | High (> 40%) carriage in upper respiratory tract (tonsils) of market weight swine; predominance of *S. suis* 2; epidemiological interactions with viral infections (e.g., PRRSv) | Improved control over illegal marketing of ill pigs; hygiene and health quality standards in slaughter/processing facilities | Estimation of burden of disease using combined indicators for human morbidity/mortality and economic losses to swine sector; risk factors for pig colonization; development of porcine vaccines and novel diagnostic tools for herd management and risk mitigation |
| Listeriosis | Three clinical case reported from north Vietnam with meningitis in 2008/2009 | No data | Possible increased incidence in coming years, due to greater consumption of packed food items including soft cheeses, meat and fish | Consumer perceptions of risk, health and safety in relation to highly processed foods; enhanced surveillance among high risk groups; investigation in food processing plants |
| **Table 8. continued** |
|------------------------|
| **Foodborne pathogen** | **Data on prevalence/incidence in humans** | **Data on animal reservoir** | **Challenges for Vietnam** | **Suggested areas of research** |
| Toxoplasmosis | No published data on human clinical cases. Seroprevalence in humans ranging between 1.1 and 6.4%. Higher (7.7–11%) among pregnant women and drug users in some | Very high prevalence in domestic dogs and pigs (>50%); lower in cattle and buffalo (3–10%) | Unknown risks due to poor understanding of principle zoonotic reservoir | Enhanced surveillance among pregnant women and neonates to estimate burden of disease; prevalence of oocysts in cats, dogs, dog meat and treated and untreated wastewater |
| Cryptosporidiosis | No published data on human clinical cases. At least two studies of paediatric diarrhoea failed to identify *Cryptosporidium* | High prevalence of *C. parvum* and *C. andersoni* in cattle; *Cryptosporidium* spp. oocysts found in pigs and farmed fish but not speciated | Risks associated with uncontrolled urbanization, peri-urban agriculture, waste water treatment and climate change | Etiological and syndromic studies of enteric disease in humans and animals; development of informal networks for reporting and investigating suspect foodborne outbreaks |
| Giardiasis | No published data on human clinical cases. 4% carriage of *G. lamblia* among healthy subjects in north Vietnam | 50% of calves near Hanoi found positive by faecal microscopy; however, dominant species may be non-zoonotic *G. duodenalis* | Risks associated with uncontrolled urbanization, peri-urban agriculture, waste water treatment and climate change | Etiological and syndromic studies of enteric disease; species diversity in farm animals and farmed ‘wild’ exotic species; risk factor studies; detection of oocysts in vegetables, treated and untreated wastewater |
| Taeniasis/ cysticercosis | In the late 1990s, approximately 100–150 cases/year with cerebral cysticercosis in northern Vietnam. Human surveys (2003/2004) using stool egg counts suggest low level prevalence of (0.2–7.2%). Likely to be circumscribed to certain areas in Vietnam | Multiple species identified from pigs and domestic dogs, including *T. solium*, *T. saginata asiatica* | Probable future reductions in prevalence/incidence due to changes in swine production | Seroepidemiological and clinical studies. Identify host species of *T. s. asiatica*; studies investigating prevalence of *Taenia* eggs in the environment |
| Foodborne pathogen          | Data on prevalence/incidence in humans                                                                 | Data on animal reservoir                                                                 | Challenges for Vietnam                                                                 | Suggested areas of research                                                                 |
|----------------------------|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Fascioliasis               | > 1,000 patients/year reported in central provinces, especially Quang Nai; seroprevalence ~8% in some areas; diagnostic case reports increasing | Hyper-endemic in ruminants of central provinces (> 70% in adult cattle); high level species diversity; hybrid species identified (F. gigantica and F. hepatica) | Risks associated with changes in forage production for beef and dairy cattle             | Detection of metacercariae in leaf vegetables; ecologic determinants of disease transmission; risk assessment; development of novel indicators to estimate combined disease burden in humans and animals |
| Leptospirosis              | Highly seroprevalence in southern Vietnam suggesting endemcity. Responsible for 2–8% cases of acute jaundice. Main serovars identified Seramanga and Bataviae | Hyper-endemic in pigs in the Mekong Delta                                                | Very common in kidneys in fattening pigs. Main serovars Bratislava, Iterohaemorrhagiae, Automnalis and Pomona | Estimate burden of infection by targeting patients with suspect hepatic and haemorrhagic syndromes. Investigate main reservoirs of infection including rats, pigs, dogs and cattle |
| Trichinellosis             | Decreasing incidence in recent years; small outbreaks in northwest                                      | Seroprevalence in swine ~14–20% in some areas                                             | Probable future reductions in prevalence/incidence due to changes in swine production | Role of rodents in transmission; risks associated with specific culinary practice          |
| Fishborne zoonotic trematode (FZT) infection | High rates of asymptomatic carriage in humans living in Red River Delta provinces (> 75%) | High species diversity including both pathogenic and non-pathogenic flukes of multiple genera | Risks associated with expansion of aquaculture industry, waste water treatment and climate change | Enhanced surveillance to estimate disease burden; detection of FZT in fish; risk assessment; intervention studies; ecologic determinants of disease transmission |
VAC systems are now less common in Vietnam than a few decades ago, due to alternatives for use of animal excreta (i.e. biogas) as well as increasing constraints on land use and increased land costs. Government programmes and development projects aimed at improving sanitation have resulted in safer human waste disposal. Where human excreta are used as fertilizer, a minimum of 6-month retention period is recommended to ensure pathogen inactivation. The level of compliance with this norm is not known, although some data suggests good adherence (Phuc et al. 2006). VAC systems are of course particularly vulnerable to fish-borne trematode infections, whereas industrial aquaculture operations provide increased investments in infrastructure for both quality and safety control, through the use of commercial laboratories for pathogen screening and chemical pest control of invertebrates. In the swine sector, investments in housing and improved nutrition are expected to reduce the burden of parasitic diseases such as taeniasis/cysticercosis and trichinellosis. Intensified bovine and dairy production may increase the risk of introducing cattle-associated FBZ such as bovine tuberculosis and brucellosis. Finally, for target organisms that are particularly associated with processed animal foods, such as listeriosis, increased consumption of processed food items such as soft cheeses, sausages and pates may result in increased incidence unless production of these commodities is adequately regulated.

In Vietnam, per capita ingestion of animal protein has steadily increased over the last few years (Thang and Popkin 2004) and in urban areas, the consumption of chilled, frozen and processed meat is rapidly increasing (Anon. 2011). Modern retail outlets (supermarkets, convenience stores, etc.) now account for >15% of total food distribution (Cadilhon et al. 2006), and fast-food restaurants are rapidly proliferating. Consumption of wild-animal meat has also been increasing among wealthy sectors of the population; these ‘exotic’ products pose novel and unforeseen food safety risks (Drury 2011).

In the past, regulation of food safety in Vietnam has been hampered by highly decentralized authority for monitoring value chains. A Food Safety Law (No. 55/ QH12/2010) seeks to impact quality control of slaughter and processing facilities within food distribution networks, in part through clarifying new standards and regulatory policies. Examples include the development of certification systems for good food production and slaughtering practices, increase traceability and strengthening of penalties for marketing uncertified animals. Better control of food chains is likely to improve control of diseases associated with unregulated marketing (i.e. S. suis). In addition, measures such as zoning regulations on the proximity of production units close to open waterways or urban centres have been introduced. Although the impetus for many of these reforms is driven by the threat of avian influenza pandemics, the measures will likely have an impact both on disease transmission and cultural practices. Efforts to expand export markets of agricultural commodities are also providing an incentive to improve quality controls and laboratory testing; these developments are likely to be driven by the private sector and will target organisms such as NTS to meet international regulatory standards.

In summary, the rapid intensification of animal food production systems and urbanization in Vietnam will undoubtedly change the landscape of food safety risks, introducing both new opportunities for control and prevention, as well as new vulnerabilities for the spread of disease. Within this context, the key for understanding and monitoring changes will be a strengthened infrastructure for surveillance, both of human clinical disease and within the veterinary community.

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