Bangl. J. Vet. Med. (2011). 9 (2): 95 - 120

PUBLIC HEALTH THREAT CAUSED BY ZOONOTIC DISEASES IN BANGLADESH

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ABSTRACT

Diseases and infections shared between animals and humans are mainly called zoonotic diseases which may be categorized as emerging, reemerging and neglected. All types of these diseases occur throughout the world including Bangladesh. The results on the prevalence and effects of zoonotic diseases in humans and animals of Bangladesh are analyzed from the published literatures and presented in this report. It appears from the literature that there are about 1415 human pathogens of which 61% are zoonotic and nearly half of all human pathogens can be classified as emerging, of which 75% of these are caused by zoonotic pathogens. The major zoonotic bacterial diseases recorded in Bangladesh are Anthrax, Tuberculosis, Brucellosis, Salmonellosis, Campylobacteriosis and Leptospirosis, of which only Anthrax has been reported as clinical outbreaks form in both the humans and cattle. During the period 2009 to 2012, anthrax caused death of hundreds of cattle and more than 650 cases of cutaneous anthrax in humans including fatalities in two humans associated with anthrax. The major reported viral zoonotic diseases in Bangladesh include Avian influenza, Rabies, Nipah virus infection, Japanese encephalitis, Rotavirus and Dengue fever. Avian influenza caused by highly pathogenic H5N1 in humans and poultry in Bangladesh and about six humans affected with H5N1 but all of them have recovered. Since 27 March 2007 when Avian influenza was reported to have occurred for the first time in Bangladesh, this virus spread in 51 out of 64 districts with more than 480 outbreaks, culled more than two million poultry birds and cost Tk. 55 billion (US $ 757.9 million) in Bangladesh. Rabies is considered as a priority zoonosis in Bangladesh and it is mainly transmitted to humans and food animals mainly through dog bite nearly 100,000 people and at least 2000 died of rabies in 2009 in Bangladesh. Nipah virus infection is an important emerging infectious disease has been recognized since 2001 in Bangladesh and up to February 2011, 173 humans cases have been identified, of which 110 (63.58%) died. Japanese encephalitis (JE) is a vector borne zoonotic disease, first recognized in Bangladesh since an outbreak in 1977 and 12.38% encephalitis patients had JE virus infection which was associated with mortality, physical disability and cognitive difficulties. Rotavirus is a worldwide distributed zoonotic disease affecting mammals and birds and it has been reported from Bangladesh in humans (23.75%), animals (12 to 43.78%) and broiler birds (13.15%) associated with diarrheic syndrome. Dengue fever was first reported in Bangladesh in 1964 and outbreak that began in 2000 predominantly caused by DENV-3 in which 5551 cases recovered and 93 Dengue related deaths were reported. The dermatomycosis has been reported in 9.3% cattle, 18.6% goats and 25.2% in contact humans. The major zoonotic parasites recorded in cats in Bangladesh include *Paragonimus westermani* (9.09%), *Ancyclostoma tubaeforme* (36.36%), *Dirofilaria immitis* (9.09%), *Toxocara cati* (45.45%) and *Toxoplasma gondii* (9.09%), in dogs include *Diphyllobothrium latum* (13.3%), *Diphylidium caninum* (16.69%), *Echinococcus granulosus* (9.17%), *Ancylostomum caninum* (9-100%), *Gnathostoma spingerum* (40.0%), *Toxocara canis* (23.3%), *Trichuris vulpis* (13.8%) and in pigs include *Entaemebea histolytica* (17.24%) and *Balantidium coli* (60.34%). The prevalence of zoonotic protozoan diseases recorded in humans in Bangladesh include amebiasis (*E. histolytica* 4.71% & *E. dispar* 12.6%), giardiasis (21% in children & 51% in malnourished children), cryptosporidiasis (1.4 to 3.5% in diarrheic patients) and visceral leishmaniasis (kala-azar) which was first reported in Jassore in 1824 but still sporadic outbreaks are occurring in the different districts in Bangladesh. Sero-surveillance studies showed 16 to 17% cattle, 17.65 to 53.6% sheep, 12.09 to 35.4% goats and 15.89% women had *T. gondii* antibodies in Bangladesh. It appears from these results that all types of emerging, reemerging and neglected zoonotic diseases are widely prevalent and pose a great threat to human health in Bangladesh. Neglected Veterinary medical profession and its extension services, poor people without any knowledge of zoonotic diseases who are in close contact with livestock and their products, and unhygienic processing, maintaining and marketing the livestock and livestock products have made the situation graver in Bangladesh.

Key words: Zoonotic diseases, bacterial, viral, parasitic, fungal, humans, animals, birds, Bangladesh

INTRODUCTION

WHO defines zoonoses as 'those diseases and infections which are naturally transmitted between vertebrate animals and man.' There are approximately 1415 pathogens known to affect humans, of which about 61% of all human pathogens are zoonotic (Anon, 2011d). Nearly half of all humans' infectious diseases known today can be classified as emerging and about 75% of emerging infectious diseases are caused by zoonotic pathogens.

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Emerging diseases that (a) have been recently recognized or evolved, (b) have recently increased in incidence or prevalence, (c) have recently expanded in geographic or climatologic range or (d) have transpired from animal populations into humans. This differs somewhat from reemerging infectious diseases, which are diseases that have been discovered previously in a species often at enzootic levels but for some reason, have significantly increased in incidence at a given point of time or in a specific geographic region (Anon., 2011e). Zoonotic diseases have both direct and indirect effects on livestock health and production. The direct impact of zoonoses can be considerable with illness, monetary loss, adverse effect on morale of personnel, unfavorable publicity and legal implications. Indirect effects occur as a result of the risk of human infection, barriers to livestock trade, the added costs associated with control programs, marketing produce to ensure it is safe for human consumption and the loss of market awing to reduce consumer confidence (Anon., 2011e,f). A recent retrospective study of 335 emerging infections episodes over a 64-year period (1940-2004) emphasized the role of wildlife as a source of emerging infections, although research efforts have so far been focused toward either humans or economically related species (Daszak *et al*., 2007). Zoonotic diseases are common throughout the world and the public health threat of emerging, reemerging and neglected zoonoses in the industrial world has been reported (Cutler *et al*., 2010; Weese *et al*., 2002) but it constitutes an important threat to human health in developing countries like Bangladesh. An overview of livestock research reports published during the twentieth century in Bangladesh has been reviewed (Samad, 2000b). This paper describes the summarized results of the available published inland research reports on the prevalence and effects of zoonotic diseases in humans and animals, which could be helpful for planning to prevent these communicable diseases in endemic population in Bangladesh.

Major bacterial zoonotic diseases

Anthrax

The word anthrax is derived from the Greek word, 'anthrakis' (or 'coal') in reference to the black skin lesions victims develop. The disease occurs worldwide and is enzootic in certain African and Asian countries including Bangladesh. It is caused by *Bacillus anthracis* which are mainly released from infected carcasses and form resistant spores affecting on exposure to air. This organism causes acute infectious disease in mainly wild and domestic herbivores. Humans are infected when they are exposed to infected animals carcasses or by handling infected animal products (hides and skin, wool, bone, flesh) or by inhaling anthrax spores from contaminated animal by-products and contaminated soil (Dixon *et al*., 1999; Thappa and Karthiklyan, 2001; Samad, 2008). Anthrax infection in human can occur in three forms: cutaneous which affects the skin; inhalation, which affects lungs and ingestion which affects the digestive tract.

Anthrax is endemic in Bangladesh and periodic outbreak of this malady in cattle have been a concern in this country from long time and Anthrax spore vaccine is used under field condition to control the disease. Published reports of anthrax in animals in Bangladesh date back to 1948 (Mohan and Ali, 1948). However, sporadic anthrax outbreaks in cattle and humans (Samad and Haque, 1986) and elephant (Mustafa, 1984) have been reported in Bangladesh. During 2009 to 2012, more than 25 outbreaks of anthrax have occurred simultaneously in both cattle and humans and more than 650 humans cases recorded in 15 districts during summer and monsoon seasons (April to October) from Bangladesh (Table 1). An investigation of 25 anthrax outbreaks in 414 human cases showed 378 (91.30%) had cutaneous, 27 (6.52%) had gastro-intestinal and 11 (2.66%) had concurrent cutaneous and gastro-intestinal anthrax (Anon., 2011c). Simultaneous investigation of 190 anthrax suspected animals, cattle (n = 126), goats (n = 59), sheep (n = 4) and buffalo (n = 1) were identified, of which 126 (66.32%) died for illness, 54 (28.42%) slaughtered after illness onset and 10 (5.26%) sold to the market (Anon. 2011c). Majority of the patients developed cutaneous anthrax had history of butchering sick animals, handling raw meat, contact with animal skin or were present at slaughtering sites (Herrimen,1012). Inadequate livestock vaccination coverage, lack of awareness of the risk of anthrax transmission from animal to humans, social norms and poverty contributed to these outbreaks (Chakraborty *et.al.,* 2012).

This is the first time in Bangladesh that two human fatalities occurred among patients with anthrax about two weeks after onset of symptoms. These two death cases were in two different outbreaks, one in Bogra (70-year-old male) in July 2011 and the other in Tangail (40-year-old male) in August 2011 and both the patients had symptoms of concurrent cutaneous and gastro-intestinal anthrax. History showed that both of them participated in butchering sick animals (Anon. 2011c) and even all the human cases have been linked to slaughtered infected cattle. These were the largest anthrax outbreaks in the nation's history which resulted in the government declaring a red alert on 5th September 2010 throughout the country. Eventually this 'red alert' was withdrawn

after about a month (7th October 2010) mainly considering the ensuing Eid-ul-Azha. Even after the 'red alert' withdrawal several simultaneous anthrax outbreaks in cattle and humans have been reported in the districts of Pabna and Sirajgong which might be due to inadequate and inappropriate control measures (Table 1). However, anthrax affected human patients had claimed that the disease could have broken out from the beef which they had purchased at a lower price than usual and a few days after consuming having the meat, most of them began to feel sick while others spotted small spots on different parts of the body. Some villagers are tainted or contaminated beef and had processed and/or come into contact with hides of anthrax-infected cattle.

Table 1. Reported anthrax outbreaks in animals and humans in Bangladesh

Year	Months	Districts	No. of outbreaks	No. of animal cases	No. of human cases	References
1982-'83	-	Sirajgonj	2	62 / 43 (69%)*	27	154
1984	-	Dhaka Zoo	1	1 elephant	0	119
2009	August	Pabna	1	-	35	23,31
	Sept. & Oct.	Sirajgonj	2	-	20	23,31
2010	April-June	Tangail	4	-	44	31
	July & August	Sirajgonj	5	-	141	31
	July-August	Pabna	2	-	52	31
2010	July-Sept	Sirajgonj	-	104	607	66
2009-10	August-Oct.	Bangladesh	14	140	273	25,26,51
2010	September	Lalmonirhat	1	19 Cattle, 43 goats	76	27
2011	April	Pabna	3	-	22	31
	May	Sirajgonj	5	-	45	31
	June	Bogra	1	-	28*	31
	June	Meherpur	1	-	13	31
	August	Tangail	1	-	14*	31
2011	April-August	RMCH	-	-	15#	176
2012	May & June	Sirajgonj	5	-	74	66
	May	Kushtia	1	-	05	36
	June	Bogra	1	-	13	36
	June	Tangail	1	-	14	36

#All cases cured with 2 months oral ciprofloxacin combined with flucoxacillin for 2 weeks
*One man in Borga and one in Taingail died due to anthrax

Anthrax is an important disease of herbivorous animals and an endemic disease of cattle in Bangladesh. The districts of Pabna and Sirajgonj of Bangladesh are the main cattle rearing areas which are also recognized as 'anthrax belt.' The anthrax carcasses are usually thrown on the field. Eventually the carcass eating birds and animals consume them and break them open which result in the formation and release of highly resistant spores in presence of air (oxygen). Therefore, the anthrax spores normally exist in the soil of Bangladesh especially with higher prevalence in 'anthrax belt' areas. Livestock become ill after consuming contaminated grass, especially during or after the monsoon when water carries it to the surface. Slaughtering of sick animals, processing and handling their meat and hide and cooking and eating their meat may cause rapid disease transmission, even cooking does not deactivate the anthrax spores.

Anthrax infection occurs when spores enter the body and it is generally estimated that as low as 10 anthrax spores may initiate an infection and infection with a large number of spores (> 10,000) could be fatal (Ahmed *et al*., 2010; Kuddus, 2010). However, anthrax spores entering through skin wounds and eyes cause cutaneous anthrax indicated by dark (black) colored wounds which is not fatal if treated in time. For this reason no human with cutaneous anthrax has died but the outbreak has caused panic among people of Bangladesh. As a result, demand for beef and mutton has significantly plumped (nearly 90% in comparison to normal time). The sharp fall in the number of cattle slaughtered has drastically limited the supply of hides to the tanneries. The total population of animals slaughtered in whole Bangladesh per day is not estimated but about 5000 cattle are slaughter a day in the capital city, Dhaka but due to anthrax panic, this rate was reduced to less than 100 cattle per day. There are more than 200 tanneries in Bangladesh employing 70,000 people but millions of others such

as farmers, dairy owners and traders are directly and indirectly dependent on the cattle industry. Bangladesh tannery companies earned US dollar 460 million in leather and leather goods through export annually. Due to anthrax crisis, the tannery industry owners lost more than 100 million US dollars during the month of anthrax outbreak.

Public education and awareness about anthrax, a complete and routine vaccination of cattle, quarantine and testing of all imported and slaughtered cattle, proper disposal of carcasses and contaminated materials, meat inspection by the Vets and meat sale by the licensed meat vendors would certainly help to control anthrax in Bangladesh.

Tuberculosis

Tuberculosis (TB) is caused by acid-fast bacillus of the Mycobacterium and the most common species are *M. tuberculosis* (man, non-human primates, cattle, dogs, swine, psittacines), *M. bovis* (cattle, dogs, swine, man) and *M. avium* (birds, swine, sheep). All the three species are capable of causing disease in man although *M. tuberculosis* is by far the most common. Human tuberculosis is the world's second commonest cause of death from infectious disease after HIV/AIDS. It is estimated that 1.7 million died and 9.4 million new cases of human TB emerged in the world in 2009, of which the majority were in Asia and Africa. Of the people who died of TB in 2008, it is estimated that 400,000 were infected with HIV. Bangladesh ranks 6th among 22 most TB affected countries (225/100,000 cases in 2009) in the world, with 300,000 new cases and 70,000 deaths reported every year (WHO, 2005). Nationwide tuberculosis prevalence survey in Bangladesh 2007 to 2009 detected an overall adjusted prevalence 79.4% per 100,000 persons ≥ 15 years and higher in males and rural residents (Anon. 2010e)

Bovine tuberculosis (BTB), which is caused by *M. bovis,* is one of the most important zoonotic diseases worldwide. Of the 176 countries reported tuberculosis, 4 indicated BTB to be an exceptional occurrence, 62 reported as low sporadic occurrence, 21 reported it as enzootic, 3 reported a high occurrence and 7 stated that the disease exists but the occurrence is unknown (Samad, 2008). Between 1994 and 2000, 1931 human cases of culture-positive TB have been identified in France, of which 129 (6.7%) infected with *M. bovis* and 1802 with *M. tuberculosis* (Bob, 2011; Huq and Moyenuddin, 1984; Samad, 2008).

BTB mainly affects cattle but also affect man and other domestic and wild species. BTB in humans caused by *M. bovis* is clinically indistinguishable from TB caused by *M. tuberculosis*. Globally, human TB due to *M. bovis* has recently been estimated to be the cause of 5 to 10% of all human cases. About 25% of patients reported with children and the main site of disease has been reported to have occurred in extra-pulmonary (cervical and mesenteric nodes, the peritoneum and gastro-intestinal tract) in 53% patients (Samad, 2008). In developed countries, animal TB control and elimination programs, together with milk pasteurization have drastically reduced the incidence of disease caused by *M. bovis* in both cattle and humans, whereas in developing countries, animal TB is widely distributed, control measures are not applied or are applied sporadically and pasteurization is rarely practiced (Cosivi *et al*., 1998).

The reports on the prevalence of BTB in Bangladesh revealed 2.10% zebu and 7.80% cross-bred cattle had positive reactors to tuberculin test (Samad and Rahman, 1986). Recently 27.5% breeding bulls of Central Artificial Insemination Center, Savar, Dhaka (Islam *et al*., 2007) and more recently Rahman and Samad (2008) reported that 30% prevalence of tuberculosis in Red Chittagong cattle (Table 2). It appears from the review of literature that about 4.5% of the tuberculosis positive cattle could excrete tuberculosis organism in their milk (Samad, 2008).

Although there is a testing and treatment program of HTB at national level in fact there is no such testing and culling program of BTB at national level in Bangladesh. People have close contact with animals and they often consume raw milk or unpasteurized milk and those who consumed poorly heat-treated meat are at high risk. Animal farm workers, veterinarian, abattoir workers and farmers have a high occupational risk due to close contact with infected animals. Even poor villagers often share their houses with animals for sleeping which is also a risk.

Table 2. Prevalence of major bacterial zoonotic diseases in Bangladesh

S/N	Disease	Hosts	No. of population tested	Types	Test used	Positives No. (%)	Reference numbers
①	Anthrax	Cattle	62	Clinical	Culture	43 (69.0)	154
		Humans	27	Clinical	Culture	27 (100)	154
		Elephant	01	Clinical	Culture	01 (100)	119
		Cattle	190	Clinical	Culture	>100	Table 1
		Humans	> 650	Clinical	Culture	> 650	Table 1
②	Tuberculosis	Cattle	3036	A. healthy	Tuberculin	172 (5.67)	98,143,155
		Cattle	30	A. healthy	Ab test kit	09 30.0)	143
③	Brucellosis	Humans	526	A. healthy	Sero-tests	165 (12.36)	118, 120, 140, 141
		Cattle	2485	A. healthy	Sero-tests	233 (9.38)	3, 123, 129,136, 138, 139
		Goats	350	A. healthy	Sero-tests	77 (21.85)	141
		Sheep	362	A. healthy	Sero-tests	13 (03.59)	151
		Buffaloes	288	A. healthy	Sero-tests	20 (6.96)	130
		Stray dogs	30	A. healthy	Sero-tests	03 (10.00)	182
④	Salmonellosis	Water	100	RPTT water	Culture	0-60 (0-60)	Table 3
⑤	Campylobacteriosis	Humans	300	A. healthy	Fecal test	58 (19.33)	58,59,71,181
⑥	Leptospirosis	Humans	359*	Clinical	RT-PCR	63 (17.55)	35

A = Apparently RPTT = River, Pond, Tape, Tube-well *Dengue negative sera

Brucellosis

Brucellosis remains one of the most common zoonotic diseases worldwide with more than 500,000 human cases reported annually. The disease occurs worldwide in both animals and humans, except in those countries where bovine brucellosis has been eradicated by using vaccination and/or method of screening and culling (Samad, 2008). Five out of the nine known *Brucella* species can infect humans and the most pathogenic and invasive species for human is *Br. melitensis* (sheep, goats), followed in descending order by *Br. suis* (swine), *Br. abortus* (cattle, sheep) and *Br. canis* (dogs), and accordingly, *Br. melitensis*, *Br. suis* and *Br. abortus* are listed as potential bio-weapons (Seleem *et al*., 2010). It is generally transmitted to consumers through raw milk and milk products (cheese), but the human-to-human transmission of the infection does not occur. The importance of brucellosis is not known precisely, but it can have a considerable impact on human and animal health, along with wide socio-economic impacts, especially in countries where rural income relies largely on livestock breeding and dairy products. Some specific occupational groups including farm workers, Veterinarians, animal caretakers and butchers are considered at higher risk to brucellosis. Brucellosis in humans is characterized by extreme weakness, joint and muscle pain, headache, undulant fever, hepatomegaly, splenomegaly and night sweats. Brucellosis in animals, mainly affects reproduction and fertility, causes late abortion, reduces survival chances of newborns and reduces milk yield (Islam *et al*., 1983; Rahman *et al*., 2006; Samad, 2008). When the incidence of brucellosis is controlled in the animal reservoirs, there is a corresponding and significant decline in the incidence in humans.

Salmonellosis and Colibacillosis

Salmonellosis (Salmonella food poisoning and enteric paratyphosis) is a public health concern because most of the strains of Salmonellae are potentially pathogenic to humans and animals worldwide. There are over 1800 food-poisoning serotypes of Salmonella exist in the world and about 5 million human cases of salmonellosis are diagnosed annually in the United States (Bob, 2011) and problem may be more severe in Bangladesh.

Salmonellae are common commensalisms of mammals, birds, reptiles and are excreted in feces. Host-adapted strains may cause disease like *S. dublin* in cattle, *S. pullorum* in chickens, but most human food-poisoning Salmonellae do not cause clinical disease in animals. Infection in animals is maintained by recycling slaughterhouse waste as animal feed, fecal oral spread and fecal contamination of hatching egg (Borhanuddin *et al*., 1986). Transmission occurs when organisms introduced into the kitchen in poultry carcasses, meat or

unpasteurized milk, multiply in food owning to inadequate cooking, cross-contamination of cooked foods and inadequate storage. Transmission by direct contact and indirect transmission via contaminated food and water (Table 3) with feces and contaminant of sewage. The incubation period varies from 12 to 72 hours in humans and 1 to 5 days in animals. Typically, gastro-enteritis (watery diarrhea) for about 10 days, leading to dehydration, colic and low-grade fever and occasionally septicemia and abscess in humans are reported. Sub-clinical infection is common in animals and many animals may be intermittent or persistent carriers. Cows may suffer with fever, diarrhea and abortion but calves undergo epizootic outbreaks of diarrhea with high mortality. Infected small ruminant and birds usually show no signs of infection. The causative agent of colibacillosis, *Escherichia coli* isolated form humans and animals have been characterized in Bangladesh (Ali *et al*., 1998).

Salmonella enteritidis is one of the most important bacterium which is usually transmitted through infected eggs which can pose a health risk to human if exposed. It appears that birds mainly acquire the infection from the environment and that infected birds play a relatively small role in the transmission of infection to animals and humans. Symptoms appear similar to food poisoning such as gastro-enteritis (diarrhea).

Public health concerns and the potential for food borne zoonotic transmission have made Salmonella the subject of numerous international, national and local surveillance programs.

Table 3. Bacterial status of water in Bangladesh (137)

S/N	Sources of samples	No. of samples tested	Species of bacteria identified, No. (%)		
			Salmonella spp.*	*Escherichia coli*	
①	River water	100	25 (25.00)	60 (60.00)	* Salmonella species include:
②	Pond water	100	10 (10.00)	40 (40.00)	
③	Tape water	100	04 (04.00)	15 (15.00)	*S. typhimurium*
④	Tube-well water	100	00 (00.00)	02 (02.00)	*S. enteritidis*

Campylobacteriosis

Campylobacteriosis is an important zoonotic disease, associated with bacterial gastro-enteritis and may be responsible for as many as 400 to 500 million human cases emerging worldwide annually. Although the genus *Campylobacter* is composed of 17 described species, clinical disease is primarily with *Campylobacter jejuni* and *C. coli*. Microbio-chemical investigation of 300 diarrheic stool samples of children in Bangladesh showed 58 (19.33%) had Campylobacter infection (Table 2), of which 40 (68.97%) isolates had *C. jejuni*, 5 (8.62%) had *C. coli* infection and the 13 (22.41%) remain unidentified (Talukder *et al*., 2008). The *C. jejuni* has been identified to be associated with predominantly watery diarrhea and isolated in frequencies varying from 17 to 26% in Bangladesh (Datta *et al*., 2003; Debnath *et al*., 1986; Haq and Rahman, 1991; Talukder *et al*., 2008). Though distributed worldwide the incidence is high in developing countries due to inadequate personal and domestic hygiene. It is a commensal organism which is isolated from 3 to 100% apparently healthy animals and birds. The organism is viable for three weeks in feces and milk, four weeks in water and five weeks in urine at 40 °C. This organism is shed in the feces for at least six weeks after infection.

Transmission is by the feco-oral route, through contamination of food and water, and direct contact with infected fecal material. Poultry and cattle are the reservoirs for human infection, which is acquired by ingesting contaminated raw milk, under-cooked chicken or other food contaminated in the kitchen. Disease in humans is characterized by acute gastro-enteritis (diarrhea) with or without blood, abdominal pain and fever, and also may cause pseudo-appendicitis and rarely septicemia and arthritis.

Leptospirosis

Leptospirosis is a zoonotic disease, caused by pathogenic leptospires belong to the species *Leptospira interrogans*, which is sub-divided into more than 200 sero-vars. The main natural reservoirs for human infection vary with serovar: *L. canicola* in dogs, *L. hardjo* in cattle, *L. pomona* in swine, and *L. icterohaemorrhahiae* in rats. Infection usually results when water or soil contaminated with the urine of an infected animal comes in contact with human skin or mucous membrane. Clinical manifestations of leptospirosis can range from a self-limited febrile syndrome to a fatal illness, characterized by hemorrhage, renal failure and jaundice. So far, there is evidence on the occurrence of leptospirosis in Bangladesh (Anon., 2011g) which was conducted in connection

to dengue fever and 17.55% of dengue-negative patient's sera showed positive reaction for leptospirosis (Table 2). It has also been found that the case fatality rate among leptospirosis patients (5%) was higher than among dengue fever patients (1.2%).

Although leptospirosis has been reported in most of the neighboring countries of Southeast Asia, the work on this disease is not done in Bangladesh where diagnostic tests for leptospirosis are not available. However, environmental factors such as floods, humidity and water contamination are amenable to the spreading of the disease in both man and animals in Bangladesh.

Major zoonotic viral diseases

There are more than 5,000 viruses known to man and they are evolving every day. Some important zoonotic virus diseases are associated with human deaths globally every year. Most of the statistics on the morbidity and mortality rates are taken from WHO reports.

Avian and swine flu

Much has been made in the press of the recent 'avian flu' and 'swine flu' pandemic, caused by the spread of the H5N1 and H1N1 virus respectively. But the truth is, influenza has been a prolific killer for centuries. The symptoms of influenza were first described more than 2,400 years ago by Hippocrates. Pandemic generally occur three times a century, and can cause millions of deaths. The most fatal pandemic on record was the Spanish flu outbreak in 1918, which caused between 20 million and 100 million deaths.

Avian influenza (AI) is an important emerging infectious disease, caused by highly pathogenic avian influenza (HPAI) virus A affecting birds and mammals including humans. A new strain of HPAI A (H5N1) virus has been circulating among birds in Asia since 1996. The first officially announced AI outbreak caused by H5N1 in Bangladesh occurred in 27 March 2007. Since then the virus has spread to 51 out of 64 districts and more than 480 outbreaks have been officially reported and more than two million birds have been culled. The status of AI outbreaks in chickens (Biswas *et al*., 2008) and its risks in backyard chickens (Biswas *et al*., 2009) has been reported from Bangladesh (Table 6). The country's poultry sector is currently worth Tk. 250 billion (US $ 3.5 billion) and AI has cost Tk. 55 billion (US $ 757.9 million) due to outbreaks of AI in 2007. Bangladesh is a high risk country for an influenza pandemic because of its dense human population, widespread backyard poultry raising and endemic H5N1 infection in poultry.

Since 2003, the WHO has recorded (up to August 2012) 598 cases of human infection with Avian influenza virus of which 352 have died in the world, leading to great concern that the H5N1 avian influenza virus could cause a devastating pandemic if it adapts to spread easily among humans (WHO, 2012a). So far, about six human cases of H5N1 have been reported since its first appearance in 2007 from Bangladesh (Table 4).

Bangladesh has about 220 million chickens and 37 million ducks, of which 185 million are backyard poultry with minimum bio-security (Biswas *et al*., 2009). About 21 species of migratory birds capable of carrying the virus visit the country annually every winter. In addition to chicken, this disease has been recorded in ducks, pigeons and non-migratory wild birds (mostly crows) in Bangladesh (Baqi and Khyam, 2011).

These zoonotic diseases from 2003 to August 2012, a total of 598 human cases have been reported from the world, of which 352 persons died (WHO, 2012a). Between 2005 and 2010, H5N1 HPAI virus spread rapidly to over 60 countries on three continents. So far, the AI control program has been implemented through 170 projects, actively involving 130 countries. In Bangladesh a number of projects have been implemented and financed by FAO, World Bank, ADB with millions of US dollars, mostly for strengthening disease surveillance, virus elimination and communication campaigns. But the recent FAO report reveals that AI virus remains firmly entrenched and the virus elimination effort faces three major obstacles in Bangladesh which include the structure of the poultry industry, the quality of Veterinary and poultry production service and the level of commitment by all sectors. Therefore, AI in Bangladesh remains a significant threat to avian health and welfare, public health, agricultural productivity, economics and livelihoods of the poorest farmers.

Table 4. Confirmed human cases of Avian influenza virus (H5N1) infection in humans in Bangladesh

S/N	Year	Cases	Description	References
①	2008	01	The first human case of HPAI A (H5N1) virus was recognized in Bangladesh in a 16 month-old boy from the capital city Dhaka on 22 January 2008. He developed fever and difficulty breathing but recovered. The most likely source of H5N1 virus exposure was from a chicken that was slaughtered in his household.	19,21
②	2011	02	The 2nd and 3rd cases of AI in humans in Bangladesh were reported in 2011. The 2nd case was diagnosed in a 31-month-old child who has presented with a history of cough and fever in Dhaka on 15th March 2011, confirmed by real-time RT-PCR.	22,30
③	2012	03	The 3rd case of Avian influenza was detected in the Kamalapur area of the capital Dhaka. The 4th case was a 40 year-old male from Dhaka city who was identified as part of the live bird market surveillance system on 26 February 2012. The case was presented with cough and recovered. Following that report, two more cases were reported: a 26 year-old and an 18 year-old male who presented with history of cough from the same live market but they were recovered.	189-192

Rabies

Rabies is a highly fatal viral infection of the central nervous system which occurs virtually in all warm blooded animals and humans and is transmitted by the bite of affected animals. Dogs, cats, jackals and other wild animals are the carriers of this infection but in Bangladesh most of the rabies cases in both humans and animals are due to dog bites. Rabies virus laden saliva via bite, scratch or abrasion. Rabid dogs shed virus in saliva 5 to 7 days before showing clinical signs, whereas cat does so for only three days before signs (Bob, 2011). Among the domestic animals, cattle and goats are most commonly affected with rabies in Bangladesh.

Rabies is being considered as a priority zoonosis in Bangladesh. Sporadic incidence occurs in all parts of the country throughout the year. Bangladesh has human population of about 160 million, 22.90 million cattle and 36.90 million goats. No estimate has been made of the dog population but there is a large number of stray dogs compared to lower number of pet dogs in Bangladesh have made rabies infection a more common than elsewhere.

Almost all human deaths caused by rabies originated from Asia and Africa (Samad, 2008). There are an estimated 55,000 human death annually from rabies worldwide with about 31,000 in Asia and 24,000 in Africa. According to the Bangladesh Government reports, dogs bit nearly 100,000 people and at least 2,000 died of rabies in 2009, the highest per capita rate in the world. The number of deaths in animals is unknown but probably the higher than the figure for human cases. Approximately, 50,000 human beings and 8,000 domestic animals received post-exposure vaccine treatment due to dog bite in Bangladesh annually. However, many bites are not reported due to ignorance and lack of facilities (Table 6). The Dhaka City Corporation alone kills up to 20,000 stray dogs a year and this stray dog culling program is only limited to the City corporation in the country. In addition, approximately 5000 pet dogs are vaccinated with locally produced vaccine. Epidemiological studies of rabies in Bangladesh are very limited (Ali *et al*., 1982; Biswas *et al*., 1996) to formulate an effective control program.

Nipah virus infection

Nipah virus (NiV) infection is an important zoonotic emerging infectious disease (EID) that causes fatal disease in humans, characterized primarily by fever and encephalitis. Nipah virus is a member of the genus *Henipavirus*, a new class of virus in the family *Paramyxoviridae*. Nipah virus was first recorded in 1998 when it caused an outbreak of neurological and respiratory disease on pig farms in Peninsular Malaysia, resulting in 257 human cases, including 105 human deaths and the culling of one million pigs and then linked to fruit bats (Luby *et al*., 2009a). In Singapore, 11 cases including one death, occurred in abattoir workers exposed to pigs imported from the affected Malaysian farms. The name 'Nipah' is taken after the place, Kampong Nipah in Negeri Sembilan where the virus was first isolated from humans in that area.

The recurrent outbreaks of NiV infection have been recognized since 2001 in Bangladesh (Gurley *et al*., 2007; Hsu *et al*., 2004; Luby *et al*., 2009a) and human beings infected with NiV as a result of consuming date palm sap that had been contaminated by infected fruit bats (*Pteropus giganteus*) that lives in Bangladesh and the blood

samples of this bats and the neighboring Indian bats have antibodies to NiV infection (Hsu *et al*., 2004; Harcourt *et al*., 2005; Luby *et al*., 2009b). Accordingly, the Nipah outbreak sites lie within the range of *Pteropus giganteus* species of bats. Apart from pigs and humans, Nipah virus is also prevalent in other domestic animals like horses, goats, sheep, cats and dogs. Since 2001, human outbreaks and clusters of cases have been reported periodically in Bangladesh (Table 5).

Table 5. Morbidity and mortality caused by Nipah virus in humans in Bangladesh

S/L	Period	District	Morbidity	Mortality	Reference No.
1	April to May 2001	Meherpur	13	09 (69)	16,17,
2	January 2003	Naogaon	12	08 (67)	18,
3	January to February 2004	Manikganj and Rajbari	42	14 (33)	20,
4	February to April 2004	Faridpur	36	27 (75)	24,
5	January 2005	Tangail	12	11 (92)	48,
6	January to February 2007	Thakurgaon	07	03 (43)	70,
7	March to April 2007	Kushtia	08	05 (63)	81,
8	February to March 2008	Manikgonj and Rajbari	09	08 (89)	111,112,
9	April 2008	Shatkira and Jessore	02	01(50)	113,
10	January 2010	Faridpur	08	07 (88)*	117,
11	February 2011	Lalmonirhat	24	17 (71) + 21**	186
	Total:		**173**	**110 (63.58%)**	

*During March, one physician of Faridpur Medical College Hospital carrying for confirmed Nipah case died (76)
**Death of 21 school children caused by Nipah virus due to consumption of uncooked fruits and fruit products contaminated with urine and saliva from infected fruit bats.

Review of literature of all the human NiV infection recognized in Bangladesh revealed that the fruit bats are the reservoir host in all the identified 23 introductions of NiV into human populations in Central and Northwestern Bangladesh from 2001 through 2011. So far, 173 human cases of NiV infection have been identified in Bangladesh, of which 110 (63.58%) died (Table 5). The primary pathways of transmission from bats to people in Bangladesh are through contamination of raw date palm sap by bats with subsequent consumption by humans and through infection of domestic animals, presumably from consumption of food contaminated with bat saliva or urine with subsequent transmission to people.

It was observed that the illness onset occurred from December through May but not every year. Although fruit bat is the main natural reservoir host of NiV in Bangladesh but about 51% (n = 62) Nipah cases were recognized as person-to-person transmission (Blum *et al*., 2009; Luby *et al*., 2009a), where clinical signs developed 5 to 15 days after close contact with another Nipah case-patient. In addition, risk factors of Nipah virus encephalitis in Bangladesh have been described (Montgomery *et al*., 2008). Therefore, efforts to prevent transmission should focus on decreasing bat access to date palm sap and reducing family members' and friends' exposure to infected patients' saliva.

Japanese encephalitis

Japanese encephalitis (JE) is a vector-borne zoonotic disease, caused by JE virus of the genus *Flavivirus* and family *Flaviviridae*. This disease was first emerged in Japan in the 1870s, followed by isolation of the causative virus in 1935. Most extensive epidemics of JE have occurred in Japan and Korea, in 1949 when almost 2500 deaths have been reported in South Korea due to JE. Then it has spread across Asia and now recognized as worldwide distributed but it is most important cause of epidemic encephalitis in over 25 countries including Bangladesh (Hussain *et al*., 2004). An estimated three billion people live in countries where the JEV is endemic and the annual incidence of the disease is 35,000 to 50,000 cases and 10,000 to 15,000 deaths annually (Erlanger *et al*., 2009).

Vaccination programs, increased living standard and mechanization of agriculture are key factors in the decline in the incidence of this disease in Japan and South Korea. However, transmission of JE is likely to increase in Bangladesh (Table 6) and other countries because of population growth, intensified rice farming, pig rearing and lack of vaccination program and surveillance (Erlanger *et al*., 2009).

Japanese encephalitis has been recognized in Bangladesh since an outbreak in 1977 in a rural area in Mymensingh. A prospective hospital based surveillance study carried out by ICDDR'B, CDC, USA beginning June 2003 in Dhaka, Mymensingh and Rajshahi to find out the causes of encephalitis proved that are 6% patient who were admitted to the hospital with the signs and symptoms of encephalitis patients had JEV infection (Hussain *et al*., 2004).

Analysis of the Rajshahi Medical College Hospital (RMCH) data showed 12.38% encephalitis patients had JEV infection (Hussain *et al*., 2004). It also appears from another report that 20 (4%) of 492 cases had laboratory evidence of recent JEV infection of which two patients died, 5 (33%) patients had physical disability and 7 (47%) patients reported cognitive difficulties (Table 6). These results indicate that the JE is an emerging cause of encephalitis in Bangladesh (Khan *et al*., 1981).

The JEV is transmitted in a zoonotic cycle among mosquitoes and vertebrate amplifying hosts, chiefly pigs and wading water birds like herons and egrets. JEV has been isolated from 10 different species of *Culex,* 4 species of *Anopheles*, and 8 species of *Mansonia mosquitoes*, but the most important human infection is spread by *Culex triaeniorrhynchus* and *Culex vishnui* groups which breeds in pools of stagnant water such as rice paddy field.

Our study on the sero-prevalence of JE in pigs showed 38.19% pigs had JEV infection in Bangladesh (Biswas *et al*., 1986). Pigs are the most important natural host for transmission to humans in rural areas. They have also prolonged and high viremia and produce many offspring. JEV does not typically cause encephalitis in these natural hosts, although abortions occur in pregnant sows (38.19%). The origin, evaluation and control methods of Japanese encephalitis have been described in Southeast Asia (Solomon, 2006; Solomon *et al*., 2003).

Table 6. Prevalence of major viral zoonotic diseases in Bangladesh

S/N	Disease	Hosts	No. of population tested	Types of population	Test used	Positives	Reference numbers
						No. (%)	
①	Avian influenza	Chickens	>2 million	Culled	Lab test	> 2 culled	21,22,89
		Humans	06	Clinical	Lab test	06	Table 4
②	Rabies	Humans	100,000	Dog bite	Field test	2000 (2.0)*	11,151
		Dogs	100	Stray dogs	Serum (NT)	7 (7.00)	11,45
					Saliva (FAT)	0 (0.00)	11,45
					Brain (FAT)	1 (0.00)	11,45
		Cattle	2608	Carcass	Field test	43 (1.65)	99
		Buffalo	2266	Carcass	Field test	25 (1.10)	99
		Sheep	239	Carcass	Field test	03 (1.25)	99
		Goat	917	Carcass	Field test	18 (1,96)	99
③	Nipah virus infection	Human	173	Clinical	Lab tests	110 (63.58)*	Table 5
④	Japanese encephalitis	Pigs	288	A. healthy	HIT	110 (38.19)	44
		Cattle	060	A. healthy	HIT	- ve	44
		Dogs	052	A. healthy	HIT	- ve	44
		Humans	597	Patients	IgM ELISA	26 (4.36)	82,88
⑤	Rotavirus	Buffalo	242	Diarrheic	ELISA	29 (12.00)	156
		calves	108	Non-diarrheic	ELISA	03 (03.00)	156
		Kids	484	Diarrheic	PAGE-SS	42 (08.68)	60
		Calves	402	Diarrheic	PAGE-SS	176 (43.78)	9,133
		Broiler	251	Diarrheic	PAGE-SS	033 (13.15)	103
		Humans	220	Adult diarrheic	„ + ELISA	012 (5.45)	5,167
		Children	26668	Diarrheic	ELISA+ PAGE-SS	5851 (21.94)	9,67,132, 167
⑥	Contagious echthyma	Goats	05	Patient	Clinical	005 (100)	150
⑦	Dengue fever	Humans	1356	Febrile patients	ELISA , RT-PCR	566 (41.74)	13,14,52,80, 122,146

*Died

Rotavirus

Rotavirus infection is caused by RNA virus of the family *Reoviridae*, mainly associated with gastro-enteritis (diarrhea) in humans and animals worldwide. This virus was first identified in 1973 and currently WHO estimates that this virus causes deaths of more than half a million (about 611,000/year) children annually. In fact, by the age of five, virtually every child on the planet has been infected with the virus at least once. Immunity builds up with each infection, so subsequent infections are milder where inadequate healthcare is limited the disease if often fatal. Of the seven groups (A to G) known, group A rotavirus causes more than 90% of human infection and group B cause diseases in humans and pigs in China, whereas C is distributed worldwide. There are at least 15 different serotypes of rotavirus, 14G serotypes are based on G protein and there are 20p serotypes based on p proteins (Dey *et al*., 2009; Rahman *et al*., 2007).

The prevalence of rotaviruses has been reported in buffalo calves (Samad and Ahmed, 1990), cow calves (Selim *et al*., 1991; Ershaduzzam *et al*., 1992; Rahman *et al*., 1992; Alam *et al*., 1994), kids (Dey *et al*., 2007), broiler birds (Islam *et al*., 2009) and human adult (Sanekata *et al*., 2003) and children (Ahmed *et al*., 1989; Alam *et al*., 1994; Kilgore *et al*., 1996; Ahmed *et al*., 1991; 1999; Alam *et al*., 1999; Amim *et al*., 1999; Sanekata *et al*., 2003; Islam *et al*., 2009) from Bangladesh (Table 6).

Rotaviruses cause gastro-enteritis in man and animals, and they are generally species-specific but cross-species transmission with man or animal rotaviruses have been confirmed. Several case studies have indicated infection of humans by animal rotaviruses. Comparison of genetic sequences between human and animal rotaviruses often reveals close identity. Surveillance of circulating rotaviruses in the human population has revealed the presence of several uncommon genotypes. Many of these have been found in domestic animals and it is possible that they arose in the human population through zoonotic transmission (Cook *et al*., 2004). The low incidence of uncommon strains would suggest that such transmission or at least the establishment of an animal rotavirus or a human / animal reassortment virus in the human population does not happen with any great frequency. However, millions of people will be exposed year on year to animal rotaviruses due to close contact with animals in farming communities and rural peoples. There may be a continual input of rotavirus strains or sequences in the human population from the animal population albeit at a very low level.

Contagious ecthyma and Foot-and-mouth disease

Contagious ecthyma (Orf) is a zoonotic disease that primarily affects in sheep and goat worldwide. Although the clinical occurrence of this disease in goats has been reported from Bangladesh (Samad, 2000a), its transmission from animals to humans has not yet been documented locally. This virus disease is caused by Contagious ecthyma virus (CEV) which belongs to the genus *Parapoxvirus* of the Family *Poxviridae*. This virus is highly resistant and persists for many years and can be transmitted easily from animals to man via contact. Disease in goats is characterized by lesions at the oral commissars and then spread to the muzzle and nostrils, then buccal mucosa, whereas in humans it appears as large painful nodules usually distributed in the hands, arms or face and weeping surfaces (Samad, 2008).

Foot-and-mouth disease is an endemic disease mainly affecting ruminants in Bangladesh and severe outbreaks are mostly recorded in cattle (Islam and Samad, 1998). Although it has been reported as one of the important zoonotic disease elsewhere (Samad, 2008), its zoonotic importance has not been evaluated under local conditions.

Dengue fever and Dengue hemorrhagic fever

Dengue fever (DF) and Dengue hemorrhagic fever (DHF) are the mosquito-borne viral diseases of humans, caused by four antigenically distinct but closely related Dengue virus transmitted primarily by *Aedes aegypti.* DHF, the severe form of the disease is endemic in Southeast Asia resulting in frequent hospitalizations and deaths of humans. Monkeys may become infected with Dengue virus but are mostly sub-clinical and they act as a source of infection for mosquitoes during the viremic phase (Samad, 2008). Dengue is now endemic in more than 100 countries including Bangladesh (Yunus *et al*., 2001; Wagatsuma *et al*., 2004), especially tropical and sub-tropical regions, predominantly in urban and peri-urban areas. WHO estimates that a whopping 2.5 billion people (two fifths of the world's population) are now at risk from Dengue. It puts the total number of infections at around 50 million cases of dengue infection worldwide every year.

Dengue was first reported in Bangladesh in 1964 and the outbreak cause is known as Dhaka fever (Aziz *et al*., 1967; 2002). Subsequently reports (Russell *et al*., 1966; Gaidamovich *et al*., 1980; Amim *et al*., 1999; Hossain *et al*., 2003) suggested that DF may have been occurring sporadically in Bangladesh between 1964 and the

outbreak that began in 2000 (Yunus, 2000; Aziz *et al*., 2002; Rahman *et al*., 2002) during which predominantly DENV-3 was recovered from patients (Yunus, 2000) during which 5,551 cases and 93 Dengue-related deaths were reported (Amim *et al*., 2000; Ahmed *et al*., 2001).

Dengue causes more illness and death than any other arboviral infection in the world. DHF is caused by Dengue type-3 virus (Podder *et al*., 2006) and is characterized by fever, hemorrhagic tendency, thrombocytopenia and evidence of plasma leakage. The first outbreak highlights the geographic expansion of DHF in Bangladesh, where classic DF outbreak started in 2000. In addition to fever, it may be characterized by myalgia (84.5%), headache (82.5%), arthralgia (68.0%), lethargy (80.4%) and retro-orbital pain (49.5%) and rash (Pervin *et al*., 2004). Results of the different inland reports on DF (Table 6) indicate that many dengue cases go undiagnosed and physicians obviously are not very much acquainted with this disease of public health importance. Disease surveillance, vector surveys and epidemiologic studies to identify risk factors will provide key information for controlling dengue.

Major zoonotic fungal diseases

Dermatomycosis

Dermatomycosis (ringworm) is a zoonotic disease distributed worldwide and caused by fungi of three genera (*Microsporum*, *Trichophyton* and *Epidermophyton*), belonging to the group referred to as dermatophytes. These three genera have the ability to be transmissible to animals as well as humans which signifies their intensity as animal and human health problem worldwide. Some species of dermatophytes will only infect humans or certain animals, whereas other can be spread from animals to animals. It appears from literature that *Microsporium canis* and *M. gypseum* affect mainly animals and *M. canis* is the normal cause of ringworm in dogs and cats, and can cause infection in humans. *Trichophyton mentagrophytes* and *T. verrucosum* can cause rignworm in both humans and animals.

It is estimated that approximately 10% of human infections in urban and 80% in rural areas are of animal origin (Anon., 1956; Samad, 2008). Over 70% of cases are caused by *M. canis*, 20% by *M. gypseum* and 10% by *T. mentagrophytes.* The prevalence of clinical dermatomycosis has been reported 9.3% in cattle, 18.6% in goats and 25.2% in their contact humans, and higher prevalence of the disease was reported in young calves up to 6 months of age, laborer, animal attendant and house-wife, 30 to 50 years old people in monsoon season in Bangladesh (Nooruddin and Khaleque, 1986; Rashid *et al*., 1996a;b). It has been concluded that the higher prevalence of the disease in human population might be due to greater contact with animals. The isolation frequency of *T. verrucosum* (72.0%) has been reported to be higher than *T. mentagrophytes* (28.0%) in cattle and goats. However, the prevalence of anthopophilic molds (*T. violaceum*, *P. hortae*) has been reported to be higher (53.4%) than 46.6% zoophilic molds (*T. verrucosum*, *T. mentagrophytes*) in humans (Rashid *et al*., 1996a,b).

Any infected pet is likely to contaminate furniture, bedding and carpets with resistant ringworm spores which may persist for up to 10 months. Humans can be infected and develop lesions following direct contact with clinically or asymptomatically affected animals, particularly cats. Indirect transmission via contaminated hair or scale in the environment or on fomites may also occur.

Major zoonotic parasites

Parasitic infections, caused by intestinal protozoa, helminths and arthropod parasites are among the most prevalent infections in humans and animals in developing countries (Crompton, 1999; Youn, 2009). Zoonotic parasites may be separated into four categories such as (a) Direct zoonotic parasites infecting humans directly from animals e.g. *Entamoeba histolytica*, *Cryptosporidium parvum*, *Toxoplasma gondii*, *Sarcoptes scabiei*, (b) Meta-zoonotic parasites infecting humans from invertebrate intermediate hosts e.g. *Fasciola gigantica*, *Diphyllobothrium latum*, *Dipylidium caninum*, *Dirofilaria immitis*, (c) Cyclo-zoonotic parasites having vertebrate intermediate hosts e.g. *Taenia multiceps*, *Taenia saginata*, *Tania solium*, *Echinococcus granulosus*, and (d) Sapro-zoonotic parasites meaning that parasites can infect humans from soil or water e.g. *Ancylostoma caninum*, *Ascaris suum*, *Strongyloides stercoralis*.

Major zoonotic trematodes

Among the trematode parasites of zoonotic importance, only *Fasciola gigantica* in ruminants (Samad, 2008; Kabir *et al*., 2010; Rahman and Samad, 2010) and *Paragonimus westermani* in cats (Samad and Rahman, 1998) have been reported from Bangladesh (Table 7). However, schistosome dermatitis in humans has been reported from Bangladesh (Islam and Awal, 1991).

Major zoonotic cestodes

The prevalence of zoonotic parasites in pigs (Basak *et al*., 1988), dogs (Rahman, 1973; Karim *et al*., 1982; Rahman *et al*., 1988; Tarafder and Samad, 2010), cats (Samad and Rahman, 1998) and cattle (Rahman *et al*., 1988; Rahman and Samad, 2010) have been reported from Bangladesh and their zoonotic importance have been described (Table 7). The important zoonotic cestodes recorded from Bangladesh include *Diphyllobothrium latum* (13.3%), *Diphylidium caninum* (16.67%) and *Echinococcus granulosus* (9.17%) in dogs (Table 7). The larval taenids parasites have also been reported in goats (Karim *et al*., 1982). *Diphyllobothrium latum*, a parasite with freshwater fish its intermediate host, occasionally infects people who frequently eat under-cooked or raw freshwater fish.

Echinococcosis

Echinococcosis (Hydatidosis or Hydatid disease) is an important zoonotic parasitic dangerous disease of humans and animals throughout the world. *Echinococcus granulosus* causes cystic disease, *E. multilocularis* causes alveolar disease and *E. vogeli* causes polycystic disease (Bob, 2011). Cystic echinococcosis (CE) is a condition of food animals and humans that arises from eating infective eggs of the cestode *E. granulosus*. Dogs are the primary definitive hosts for this parasite with livestock being as intermediate hosts and humans as aberrant intermediate hosts. Man acquires infection directly by contact with infected dogs or indirectly through contaminated food and water. The outcome of infection in livestock and humans is cyst development in the liver, lungs or other organ system (Islam, 1979; 1980a; 1981; 1982; Islam *et al*., 2003). The liver cyst may remain silent for 10 to 20 years or more until it becomes large enough to be palpable as an abdominal swelling to produce pressure effects or to produce systems due to leakage or rupture. If cyst ruptures, anaphylaxis and death may result.

Table 7. Prevalence of zoonotic parasites in man and animals in Bangladesh

S/NSpecies of parasites	Recognized in hosts, No. + ve / No. tested (%)			
	Pigs (41) (144,175)	Dogs (92,105,134, 145,183)	Cats (164,174)	Cattle
A. Trematodes				
① *Paragonimus westermani*	-	-	02/22 (9.09)	-
B. Cestodes				
① *Diphyllobothrium latum*	-	08/60 (13.3)	-	-
② *Diphylidium caninum*	-	10/60 (16.67)	-	-
③ *Echinococcus granulosus*	-	11/120 (9.17)	-	-
C. Nematodes				
① *Ancylostoma caninum*	-	60/60 (100)	-	-
② *A. tubaeforme*	-	-	8/22 (36.36)	-
③ *Dirofilaria immitis*	-	-	2/22 (9.09)	-
④ *Gnathostoma spinigerum*	-	24/60 (40.0)	-	-
⑤ *Toxocara cati*	-	-	10/22 (45.45)	-
⑥ *Toxocara canis*	-	14/60 (23.33)	-	-
⑦ *Trichuris vulpis*	-	8/60 (13.8)	-	-
D. Protozoa				
① *Cryptosporidium parvum*	-	-	-	-
② *Entaemobea histolytica*	20/120 (17.24)	-	-	-
③ *Balantidium coli*	70/120 (60.34)	-	-	11/87 (12.64)
④ *Giardia lamblia*	-	-	-	-
⑤ *Toxoplasma gondii*	-	-	2/22 (9.09)	66/399 916.54)

The results on the prevalence of cystic echinococcosis in humans and animals are analyzed from inland published reports (Table 8). These findings demonstrate the necessity for increased monitoring and control of cystic echinococcosis. Prevention of cystic echinococcosis could be done by prophylactic treatment of pet dogs with praziquantel or albendazole and prevention of feeding offal to dogs.

Major zoonotic nematodes

The prevalence of nematode parasites in humans and animals have been reported from Bangladesh (Samad, 2000b), but dogs and cats are the main reservoirs of the zoonotic nematodes for humans (Table 7).

Table 8. Prevalence of cystic echinococcosis in man and animals in Bangladesh

S/N	Diseases	Host	No. of population tested	Types	Test used	Positives No. (%)	Reference No.
	Hydatid disease	Buffaloes	2704	Carcass	Field test	604 (22.34)	85,87,94
		Cattle	2608	Carcass	Field test	610 (23.39)	100,114
		Sheep	763	Carcass	Field test	331 (43.43)	90,100
		Goats	13798	Carcass	Field test	1188 (08.61)	91,93,100

Major zoonotic protozoa

There are about 65,000 species of protozoan parasites in the world. The most common zoonotic protozoan diseases are amoebiasis, Giardiasis, Balantidiasis, Cryptosporidiosis and Toxoplasmosis (Hoque *et al*., 1994; Haque *et al*., 2009).

Amoebiasis

Amoebiasis is a parasitic disease caused by the protozoan *Entamoeba histolytica*. This disease is prevalent worldwide but is most prevalent and severe in tropical countries where prevalence rate may exceed 40% under conditions of crowding, poor sanitation and poor nutrition. Amoebiasis is the third leading cause of death from parasitic diseases worldwide, with its greatest impact on the people of developing countries. WHO estimates that approximately 50 million people worldwide suffer from invasive amoebic infection annually, resulting in 40,000 to 100,000 deaths annually (Haque, 2007). The occurrence of this protozoan has been reported from 0 to 3% in the feces of apparently healthy Rhesus monkeys and up to 30% in other non-human primate (Samad, 2008). The prevalence of *E. histolytica* infection has been reported in 5% and *E. dispar* in 13% of asymptomatic 2 to 5 year-old children from an urban slum of Dhaka, Bangladesh (Haque *et al*., 1999).

Transmission is usually by ingestion of infective cysts which contaminated with food and water. The cysts remain viable for 12 days in moist environment and 30 days in water. It is characterized in humans by mild to moderate colitis, recurrent diarrhea, stools streaked with blood and mucus. Hepatic amoebiasis is characterized by fever, hepatomegaly, pain and localized tenderness. This disease can be prevented by strict sanitation and personal hygiene, protective clothing and gloves. In addition, fecal contamination of feed and water should be prevented, and fecal screening of NHP and adequate cooking to destroy the cysts need to be done.

Giardiasis

Giardiasis is a recognized zoonotic parasitic disease caused by *Giardia intestinalis* (*G. lamblia, G. duodenalis*). It infects the intestinal tract of many animal species including humans which is the most prevalent parasitic cause of diarrhea in both the developed and developing world. Giardia species have long been considered zoonotic because morphologically similar organisms infect humans and a variety of mammals and birds. This protozoan has both a cyst (infective) and trophozoite form. Motile trophozoite stages occur in the intestines and environmentally resistant cysts are passed in the feces of infected animals, which are immediately infective if ingested by other susceptible hosts. Only the cyst form is infectious by the oral route whereas trophozoites are destroyed by gastric acidity. Humans are the reservoir for this protozoa but dogs, cats and bears have been implicated as a zoonotic source of infection. This disease has also been reported in calves and psittacines birds especially cockatiels and budgerigars. Most infections are sporadic resulting from cysts transmitted as a result of fecal contamination of water and food, by person-to-person contact or by anal-oral sexual contact.

The ingested cysts are converted to trophozoites in the duodenum and jejunum, which cause epithelial damage, atrophy of villi and hypertrophic crypts. Most infections are asymptomatic in humans but some cases may develop acute or chronic diarrhea, mild to severe, with bulky, greasy, frothy, malodorous stools, free of pus and blood (Bob, 2011). The most common signs of giardiasis in dogs are diarrhea which can be acute, chronic or intermittent.

Table 9. Prevalence of major zoonotic protozoan diseases in Bangladesh

S/N	Diseases	Host	No. of population tested	Types	Test used	Positives No. (%)	Reference No.
①	Amoebiasis	Children	289	Diarrheic	Fecal test	231 (80.00)	72
			680	A. healthy	Fecal test	032 (4.71)[+]	73
②	Balantidiasis	Cattle	1108	Diarrheic	Fecal test	19 (1.71)	8,144
		Buffaloes	000	Diarrheic	Fecal test	83 (0.00)	101
③	Cryptosporidiasis	Calves	208	Diarrheic	Fecal test	29 (14.00)	128
		Calves	202	Non-diarrheic	Fecal test	02 (01.00)	128
		Humans*	165	Diarrheic	Fecal test	14 (08.48)	128
		Humans	155	Non-diarrheic	Fecal test	000 (0.00)	128
		Humans	1585	Diarrheic	Fecal test	060 (3.79)	76,108,128
④	Giardiasis	Humans	2534	A. healthy	Fecal test	322 (12.71)	69,74,75
⑤	Leishmaniasis	Humans	131480	A. healthy	Rapid test	2986 (2.27)	1,42,116
⑥	Toxoplasmosis	Cattle	399	A. healthy	IHT, LAT	066 (16.54)	153, 159
		Sheep	117	A. healthy	LAT	033 (28.21)	159, 163
		Goat	415	A. healthy	LAT	049 (11.81)	158,159, 163
		Goat	015	R disorders	LAT	004 (26.67)	159
		Pregnant	447	A. healthy	ELISA	261 (58.39)	161,166
		women	447	R. disorders	ELISA	186 (41.61)	
			186	A. healthy	ELISA	075 (40.32)	163,166
		Cats	24	A. healthy	LAT	008 (33.33)	163

*Humans- animal handlers and family members [+]*E. histolytica* 32 (4.71%) and *E. dispar* 86 (12.6%)

The age specific prevalence of *G. lamblia* has been reported in two Bangladeshi villages and malnourished children in Dhaka city hospitals. Infection has shown to be acquired early (<1 year) and in 16% of infected children persisted for longer than three months. Prevalence has recorded higher in 5 to 10-year old village children (21%) and one to five-year-old malnourished children (51%) in Bangladesh (Gilman *et al*., 1985).

Zoonotic giardiasis may be controlled by routine screening of feces of dogs and non-human primates. Hygiene and protective clothing when handling animals are needed. Prevention requires safe water supplies, sanitary disposal of human feces, adequate cooking of foods to destroy cysts, protection of foods from fly contamination, washing hands after defecation and before preparing or eating foods.

Balantidiosis

Blandidiasis is an infectious feco-oral transmitted zoonotic disease caused by a single-celled protozoan called *Blantidium coli* that infect the digestive system. This disease is found worldwide with more prevalence in the tropics. This protozoa infect a wide variety of mammals and especially common in monkeys and pigs which generally regarded as the main reservoir for human infection. Prevalence in pigs ranges from 20 to 100% and human balantidiosis usually exhibits an increased prevalence in communities that like in close association with pigs. For example, in Papua New Guinea, where pigs are the principal domestic animals, the prevalence among swine herders and slaughter house workers has been reported to be as high as 28% (Schuster and Ramirez-Avila, 2008). Human-to-human transmission has also been documented and this method of transmission is likely to occur in environment with crowding and poor personal hygiene. It is transmitted primary by eating food or drinking water that has been contaminated by human or animal feces containing *B. coli* cysts. Balantidiosis associated with diarrhea in cattle (Alam *et al*., 1979) and water buffaloes (Islam *et al*., 2000) and pigs (Basak *et al*., 1988) has been reported from Bangladesh (Table 7 & 9) but its zoonotic significance has not been evaluated under local conditions.

Cryptosporidiosis

Cryptosporidiosis is a zoonotic disease affecting mainly the gastro-intestinal system of man, animals and birds, caused by *Cryptosporidium parvum.* This causal agent is a coccidian, oocyst-forming apicomplexan protozoa which complete their life cycle both in humans and animals, through zoonotic and anthroponotic transmission.

The distribution of this parasite may be associated to environmental (e.g. geographic and temporal clusters) and host determinants of the infection (e.g. age, immunological status, travels, community behaviors). Cryptosporidium species are transmitted via the fecal-oral route by environmentally resistant cysts that are shed in the feces, contaminating soil and water, and, thus, providing multiple routes into the food chain.

Infection with this parasite is usually asymptomatic or mild and self limiting diarrhea in immune-competent hosts but can be severe, can be life-threatening and chronic in immuno-compromised individual such as patients with AIDS or in severely malnourished children. The infection may be transmitted by direct person-to-person spread, contact with infected animals or by ingestion of contaminated food or water.

In humans, the most commonly detected species are the anthroponotic *C. hominis* and the zoonotic *C. parvum* (cattle). The dog is the natural host of *C. canis* and cats for *C. felis* have also been demonstrated in infected humans suffering diarrhea. Young children and immuno-compromised individuals are at greatest risk.

Cryptosporidiosis has been recognized as a significant cause of diarrheal disease in young children of Bangladesh (Shahid *et al*., 1985; Khan *et al*., 2004). In addition, the occurrence of this infection in calves and their handlers (Table 9) has also been reported in Bangladesh (Rahman *et al*., 1984). Retrospective case-control studies on this disease revealed 1.4 to 3.5% diarrheic patients had cryptosporidium infection as one of the major enteropathogens significantly associated with diarrhea in young children in Bangladesh (Khan *et al*., 2004). Cryptosporidiosis has been found in people, neonatal farm animals, pets living in the same environment, suggesting the potential for zoonotic transfer between species exists. Symptoms in humans include watery diarrhea, fever, abdominal cramps, nausea and vomiting but infection in immuno-suppressed individuals like very young, the elderly or those with HIV/AIDS may be life threatening. Personal hygiene including careful hand-washing by those in contact with any animals with scours is needed for prevention.

Leishmaniasis

Leishmaniasis is caused by more than 20 different leishmanial species of flagellated protozoan parasites reported from at least 80 countries of the world including Bangladesh. WHO estimates the worldwide prevalence to be approximately 12 million cases, with annual mortality of about 60,000 and the population at risk is about 350 million. Several forms of leishmaniasis exist which include cutaneous (CL, oriental sore, Delhi boil), mucocutaneous and visceral (VL, also called 'kala-azar') which after treatment, is often followed by a dermal manifestation known as 'post-kala-azar' dermal leishmaniasis (PKDL). The 'kala-azar', the most lethal form of the disease is caused by *Leishmania donovani*, which is of major public health importance in Bangladesh, India and Nepal, affecting the poorest population groups, primarily in rural areas. More than 60% of the world's VL cases are reported from these three countries and an estimated 150 million people are at risk of VL in 109 districts. The region reports 40,000 or more cases per year and results in an estimated loss of 400,000 disability-adjusted life years (DALYS) annually (Mondal *et al*., 2009).

The VL ('kala-azar') was first described in 1824, in Jessore district in Bangladesh (Sengupta, 1944) and endemic peaks were recorded in Bengal in the 1820s, 1860s and 1940s. Then this malady was control during the intensive vector control for malaria in the 1950 to 1960s. It again shows an increasing trend in incidence since 1995 (Bern and Chowdhury, 2006). Recently, sporadic outbreaks of leishmaniasis have been recorded and even sporadic outbreaks are continuing in humans in the different districts of Bangladesh including Mymensingh, Panchagarh and others (Rahman and Islam, 1983; Talukder *et al*., 2003; Rahman *et al*., 2009).

Transmission of leishmaniasis is most often zoonotic; the *Leishmania* are transmitted from a animal reservoir like wild animals, small rodents and dogs, by the bite of the female phlebotomine sand fly. Person-to-person, congenital and blood-borne transmission is also possible. *L. donovani* produces visceral lesions in dogs, with enlarged lymph nodes, liver and spleen, and in humans it is characterized by intermittent irregular fever occurs with sweats, enlarged spleen, weight loss and anemia leading to ascites, edema, diarrhea and secondary infections (Bob, 2011). The expansion of leishmaniasis and the alarming rise in the number of cases is related to environmental changes such as deforestation, building of dams, new irrigation schemes and poverty status of these people. Vector control by use of insecticides in house and buildings, eliminate rubbish heaps which are breeding areas for vector sand flies, avoid sand fly bites by using insect repellents and insecticides-treated nets and reservoir control could be effective in preventing kala-azar'(Elias *et al*., 1989).

Toxoplasmosis

Toxoplasmosis is an important protozoan disease of man and animals, caused by the protozoan parasite *Toxoplasma gondii*. An estimated 500 million humans have been infected with the protozoa (Bob, 2011). Analysis of global sero-survey reports revealed that about 32.9% cats, 38.5% man, 29.0% sheep, 24.2% goats, 18.6% cattle, 20.7% swine, 16.9% horse, 39.3% dogs, 17.7% buffaloes and 18.7% camels had *T. gondii* antibodies (Samad and Begum, 1990). The fecal examination of 4232 cats from 22 reports of 10 countries showed that about 2.7% of the cat population would have been shedding *T. gondii* oocysts at any one time

(Samad and Begum, 1994). Sero-surveillance studies on toxoplasmosis on man and animals showed 16 to 37% cattle, 17.65 to 53.6% sheep, 12.09 to 36.4% goats and 15.89% women had *T. gondii* antibodies in Bangladesh (Samad *et al*., 1982; Samad *et al*., 1993a,b,c).

In addition, reproductive disorders in goats (Samad, 1992; Bari *et al*., 1993) and women (Samad *et al*., 1993c; Samad *et al*., 1998) associated with toxoplasmosis have been reported from Bangladesh. Economic losses due to toxoplasmosis are mainly associated with abortion and congenital infection in man and animals.

Cats are the definitive hosts for *T. gondii,* which they acquire when they eat infected intermediate hosts (rodents and many other mammals) or ingest oocysts excreted in the stools of other infected cats. Infected cats are important in the epidemiology and public health importance of toxoplasmosis because they excrete and widely disperse the environmentally resistant oocysts. Presumably all serologically positive cats have shed toxoplasma oocysts and could re-shed oocysts during re-infection or reactivation by induction of hypercorticism or superinfection with other feline microorganisms.

Epidemiologic evidence suggests that the human become infected by ingesting food and water contaminated with oocysts shed in the feces of infected cats (ingesting sporulated oocysts from cat), or consumption of undercooked meat from infected animals containing cysts, or drinking of raw goat's milk containing tachyzoites and transplacentally. Vast majority of the human infections are either asymptomatic or result in only mild clinical disease but the major concern is congenitally acquired toxoplasmosis. Reproductive wastages due to toxoplasmosis can only occur when a previously unexposed (non-immune) women acquires toxoplasmosis during pregnancy. In this situation, there is approximately a 40% chance that the fetus will acquire the infection, and is around 10% of these cases, severe neurological or ocular disease is present at birth. However, clinically evident toxoplasmosis has been reported in about 11.7% with AIDS, 45.7% with blood cancer and 8.5% with transplant patients. The methods of diagnosis and control of toxoplasmosis in domestic animals and humans have been described (Samad and Begum, 1994).

Major zoonotic arthropods

Sarcoptes scabiei, causing scabies, is the most important zoonotic arthropod in Bangladesh (Huq *et al*., 1985) and around the world (Samad, 2008).

Zoonotic diseases and poverty in developing country Bangladesh

Zoonotic diseases are common throughout the world and constitute an important threat to human health in developing countries like Bangladesh. It appears from the literatures that meat (Rahman *et al*., 1997), milk (Samad, 2008), eggs (Borhanuddin *et al*., 1986), water (Rahman *et al*., 1978b) and other foods contained high numbers of coliforms, staphylococci, salmonella pathogens. The poor people in particular may tend to be at risk from zoonotic diseases for a number of reasons: (a) The poor often live in close contact with their livestock and are thus at increased risk of contracting zoonotic diseases, (b) Access to education on the prevention of zoonotic diseases in often unavailable to the poor livestock keepers, (c) Poor consumers may be at greater risk from food-borne diseases, (d) Informal sales of animal products make the maintenance of hygienic conditions and the control of food quality very difficult, (e) In poor and remote areas, hygienic abattoirs and facilities for meat inspection are often limited. Contracting a zoonotic disease may have serious consequences for a poor person who will probably have poor access to healthcare and can ill afford to have his/her ability to work impaired by sickness.

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