Review Article

A Review on Rodent-Borne Parasitic Zoonosis: Public Health Risk to Humans

ABSTRACT

Rodent species such as *Rattus rattus diardii* and *Rattus norvegicus* are invasive species and potential reservoirs of significant pathogens of humans. The zoonotic infections are among the most common on earth and are responsible for over 60% of all human infectious diseases. This is due to several factors such as urbanization, poor sanitation, and climate change across the globe, that has led to change or increase the occurrence of rodent-borne diseases. This review summarizes the public health importance of some rodent-borne parasitic zoonoses. Many parasitic pathogens (*Cryptosporidium* spp, *Entamoeba* spp, *Hymenolepis* spp., *Giardia* spp.) that are directly or indirectly transmitted by rodents to humans have a serious consequence in human health. Furthermore, human-rodent interaction has substantially contributed to the transmission of zoonotic parasitic infections to humans. The conclusion in this review is that rodents play an important role in transmission of several parasitic diseases to humans. therefore, it is crucial to pay adequate attention on control of rodents and surveillance.

Keywords: *rodents; zoonoses; parasitic infection; pathogens; human health*

1. INTRODUCTION

According to the World Health Organization, most of the emergent and re-emergent infectious diseases affecting humans are of zoonotic (transmitted from animals to humans) in nature (1). This has led to the understanding that zoonotic diseases, especially those associated with rodents and other wild animals constitute a significant threat to human health and wellbeing (2,3).

Rodents are one of the most important groups of mammalian animals that have successfully adapted to different environment in the world. They constitute more than 42% of the mammalian species, there are more than 1,700 species of rodent which belongs to three different families; Muridae, Microtidae, and Sigmodontidae. Muridae are omnivorous species, there are mostly found in Africa, Eurasia, and Australia (e.g *Mus sp.*, *Rattus rattus diardii*, and *Rattus norvegicus*). The family Microtidae are mostly found in Eurasia (e.g. *Microtus*), and Sigmodontidae are found in America, e.g. *Peromyscus* (4).

In recent decades, there are increased recorded cases of zoonotic infections being reported (5,6). However, several factors that include habitat modification, overpopulation, and mass migration of populations caused by natural or man-made disasters, had triggered the emergence of zoonotic diseases. Furthermore, the clearing of new areas for cultivation purposes and other land uses has resulted in human settlements in areas were animal populations and parasites were previously isolated from humans (7). The urban environment, particularly residential areas, is of great concern regarding zoonotic disease emergence, because urban cities provide favorable habitats to certain wild species leading to regular increased contact with humans (8). Of all the animals found in urban areas wild rats (*Rattus rattus* spp.) are one the most dangerous because of their high number (high reproductive capacity), zoonotic potential, and their propensity towards close association with humans (9,10). The zoonotic diseases associated with rodents are caused by protozoan (e.g. toxoplasmosis, leishmaniasis), helminths (e.g. hymenolepiasis, trichinellosis, echinococcosis, capillariasis) viruses (e.g. Lassa fever, Hantavirus diseases, tick-borne encephalitis, Argentine and Bolivian hemorrhagic fever), and bacteria (e.g. plague, leptospirosis, lyme disease, relapsing fevers) (4). Table 1. provides the summary contribution of rodents in transmission of different parasitic pathogens to humans.

The parasitic zoonotic pathogens such as *Toxoplasma gondii*, *Cryptosporidium* spp. and *Leishmania* spp. have gained importance as human pathogens due to their ability to cause disease in immuno-compromised individuals. Most of the zoonotic parasitic diseases are due to either cestodes, trematodes, nematodes pentastomids, and protozoa (11). However, protozoa are likely to account for emerging parasitic infections, and there are also clear examples of metazoan infections as emerging or re-emerging diseases (12). For many people, it will come as a surprise to learn that wild rats still remains to be the source of zoonotic pathogens responsible for significant human illness and mortality in cities around the world, for example, *Hymenolepis nana* and *Hymenolepis diminuta* are parasites of rats which infect more than 175 million people worldwide (13). A serious case of *Hymeneolepis nana* and *Hymenolepis diminuta* infection can cause severe diseases, even life-threatening conditions in immunosuppressed individuals (14,15). These diseases can be transmitted to humans either directly through bite wounds, consuming food or water contaminated with rodent feces or urine, indirectly via vectors (ectoparasites) such as mites, ticks, and fleas (16).

Several studies have been conducted on the distribution of parasitic fauna of rodent across the globe. Despite this, no attempt has been made to compare the occurrence of these parasites together and assess the public health risk to humans. Therefore, the aim of the present review, is to determine parasitic zoonotic pathogens associated with rodents in order to understand the possible health risks to humans.

Table 1. A summary of different parasitic pathogens that can be transmitted from rodents to humans and their consequences.

Disease	Agent group	Carrier/reservoir	Pop. at risk	Chance	Health impact
Toxoplasmosis	Sporozoea	Reservoir	3	2	2
Babesiosis	Sporozoea	Reservoir	3	2	1
Cryptosporidiosis	Sporozoea	Reservoir	3	2	1
Chagas disease	Zoomastigophorea	Reservoir	3	1	3
Leishmaniasis	Zoomastigophorea	Reservoir	3	2	3
Giardiasis	Zoomastigophorea	Reservoir	3	2	1
Taeniasis	Cestoda	Reservoir	1	1	1
Rodentolepiasis	Cestoda	Reservoir	1	1	1
Echinococcosis	Cestoda	Reservoir	2	1	3
Schistosomiasis	Trematoda	Reservoir	3	2	1
Human fasciolosis	Trematoda	Reservoir	3	1	1
Brachylaimiasis	Trematoda	Reservoir	1	1	2
Alariasis	Trematoda	Reservoir	1	1	0
Echinostomiasis	Trematoda	Reservoir	1	1	0
Trichinosis	Nematoda	Reservoir	3	2	1
Capillariasis	Nematoda	Carrier	3	1	1
Angiostrongylosis	Nematoda	Reservoir	2	1	3
Toxascariasis	Nematoda	Carrier	1	2	0
Baylisascariasis	Nematoda	Carrier	1	2	1
Aelurostrongylosis	Nematoda	Reservoir	0	0	0
Amoebiasis	Lobosea	Reservoir	3	1	3

Note: Population at risk: focal: 1, regional: 2, more than 2 continents : 3, Chance: chance of contracting the disease (all pathways, not only via rodents): small chance :1, moderate chance: 2, high chance: 3 Health impact: Mortality without treatment <5%=1, 5 to 10% = 2, >10% = 3. No mortality = 0.

2. RODENTS-BORNE PARASITIC ZOONOSIS

Rodents are known to transmits diseases and act as a reservoir host for many zoonotic pathogens, including diverse groups of protozoan and helminths parasites that pose a health risk to humans. The major zoonotic parasites in rodents belong to five groups; nematode, cestode, trematodes, acanthocephalans, and protozoa groups (17).

2.1. Protozoan

2.1.1 Cryptosporidiosis

The cryptosporidiosis infection is a parasitic zoonotic protozoan infection caused by the genus *Cryptosporidum* (18). The *Cryptosporidium* spp. was first recognized in mice in 1907 by Tyzzer (19), in humans, the first case of cryptosporidiosis was reported in immunosuppressed individual in 1976 (20). Thereafter, more attention was given to cryptosporidiosis infections since it was observed to cause death in immune deficiency syndrome patients (HIV). Currently, about 26 species of *Cryptosporidium* and more 50 different genotypes are known. Studies have shown that out of 26 species of *Cryptosporidium* recognized 8 species are responsible for most human cryptosporidiosis infection. The species include *Cryptosporidium hominis, Cryptosporidium parvum, Cryptosporidium canis, Cryptosporidium meleagridis, Cryptosporidium ubiquitum, Cryptosporidium cuniculus, Cryptosporidium viatorum* (21–23), with *Cryptosporidium hominis* and *Cryptosporidium parvum* being the most commons species worldwide (24).

Rodents have been generally considered as reservoirs of *Cryptosporidium* parasites related to cryptosporidiosis in humans and farm animals (25). Humans and animals can acquire *Cryptosporidium* infection through direct contact with infected individuals or contaminated fomites or by consuming food or water contaminated with oocysts (26). A report on epidemiology of *Cryptosporidium* have reported more than 400,000 residents in Milwaukee, WI, USA were infected by *Cryptosporium hominis* as a result of consumption of contaminated drinking water. This was reported as the largest world waterborne outbreak (27). Furthermore, it was estimated that 1 to 10% of the developing countries' populations were infected with *Cryptosporidium* particularly among 1-9 year-old children and toddlers (28). Cryptospodiases infection in humans is usually manifested as self -limiting watery diarrhea that usually goes away within a week or two weeks, but it could be a life-threatening infection and have a very severe consequence in immuno-suppressed individuals. Several studies have highlighted the role of rodents in the transmission of *Cryptosporidium* to humans, particularly when rat and mouse population explosions occur in the rural or ubran communities (29). Therefore, special attention to care in the treatment of drinking water can prevent most cases of cryptosporidiosis. This is especially important for immunocompromised individuals in whom it can be devastating and life threatening.

2.1.2 Toxoplasmosis

Toxoplasma gondii is one of the most important zoonotic protozoan parasites, affecting one-third of the world's population (30). The infection with *Toxoplasma gondii* is widespread in humans and animals, including poultry (31). Cats and rats are the definitive and intermediate host of *Toxoplasma gondii.* Though rats may not serve as a direct source of *Toxoplasma* infection to humans, they can be as intermediate host for *Toxoplasma gondii* which later serves as a source of infection for cats and other animals that in turn serves as sources of infection to humans (32,33). Humans get infected with this parasite after ingesting the oocysts from contaminated water and food, or through taking improperly cooked meat harboring the tissue cysts, via a congenital transmission or through blood transfusion (34,35). The seroprevalence of *Toxoplasma gondii* was reported to be up to 98%, indicating high environmental contamination with oocysts (36–38). In poultries (chickens, turkeys, and ducks) the seroprevalence of *Toxoplasma gondii* was reported to between 9%-85% (39–41). Therefore, the consumption of undercooked poultry meat may be considered a risk factor for toxoplamosis in humans or animals (31). Previously reported findings have shown that pregnant women and immune-compromised persons like HIV positive persons are most susceptible, as could suffer complications arising from *Toxoplasma gondii* infection (42). In the pregnant women, a severe complications and even death have been also reported (43).

2.1.3. Giardiasis

Giardiasis is a parasitic protozoan infection caused by *Giardia lamblia* and is considered one of the most common intestinal parasites affecting humans worldwide (44). The common symptom of giardiases in both humans and animals is diarrhea, other clinical manifestation includes fever, loss of appetite, vomiting, and lethargy. If untreated these symptoms may last only last for six weeks or longer. However, most cases of giardiasis are asymptomatic, with only one-third of the infected people exhibit the symptoms (45). Humans get infected with giardiasis by ingesting or consuming water or food contaminated with giardia cyst. It can also be transmmited from an infected person to other individuals. Childrens are the high risk group, espcially those in nursery and pre-nursery schools (46). Over 2.5 million cases of giardises have been reported yearly in developing countries. Most cases are attributed to several factors such as poor sanitation, poor water supply and the presence of animals that served as the main source of environmental contamination (47).Several studies have demostrated that rodents can act as a reservoir host for *Giardia* and *Cryptosporidium* infection especially those rodent species with commensal relationships with humans e.g. wild house mice, *Mus* spp. and rats *Rattus* spp. (48,49). Previous studies have reported direct animal to human outbreaks of giadiases infection. Two food-borne outbreaks of giardiasis were related to animals: a Christmas pudding tainted with rodent feces and a tripe soup produced from an infected sheep's offal (50).

2.1.4. Amoebiasis

The *Entamoeba histolytica* was responsible for causing parasitic diseases known as amoebic dysentery or amoebiasis in humans and animals. Amoebic dysentery is transmitted through contaminated food and water. It can be present with no, mild, or severe symptoms, the symptoms might include abdominal pain, diarrhea and dysentery (51). According to the World Health Organization (1), there are 50 million cases of amoebiases with 40,000-100,000 deaths annually. In a severe case of amoebiasis, the trophozoites mostly invade the intestinal mucosa, and enter the circulation and spread causing the development of extra-intestinal abscesses. In most cases, it will end up in the liver tissue causing amoebic liver abscesses. Other tissues such as the brain and lungs may be also infected, but cases are rare. Several studies have reported that rodents may serve as a reservoir host for *Entamoeba histolytica* which poses a health risk to humans (52).

2.1.5. Babesiosis

Babesiosis infection is caused by intracellular parasites of the genus Babesia, it is one of the common parasitic infections of free-living animals worldwide, and it is gaining increasing interest as an emergent zoonosis in humans (53). Human babesiosis is caused by one of the several species of babesia that have different geographical distribution based on the occurrence of the host. In North America, it has been reported that babesiosis is predominantly cause *Babesia microti* a rodent *Babesia* species. (54–56), whereas in Europe though the occurrence of Babesia infection is rare but it is lethal and caused by species of babesia called *Babesia divergen* (55). It is generally believe that ticks are responsible for the transmission of *Babesia* to both humans and animals. However, the efficiency of ticks in transmitting babesia infection is attributed to the tick saliva, which undoubtedly facilitates the infection with its anti-inflammatory and immunosuppressive pharmacological activity (57). Human gets infected with *Babesia* parasites in several ways: (i) the bite of an infected tick, (ii) through blood transfusion from an infected patient, (iii) through congenital transmission. The clinical manifestation associated with babesia infection in humans is caused by the asexual reproductive stage of the parasites in red blood cells of the host and subsequently lysis of host cells. This leads to a broad clinical spectrum that directly reflects of the level of parasitemia in the blood.

2.2 Nematodes

2.2.1 Angiostrongylosis

Angiostronylosis is a severe parasitic zoonotic disease cause by nematode species *Angiostrongylus* spp. About 20 different species of Angiostrongylus have been described previously, but however, only two species are known to cause human infections (58). The *Angiostrongylus* spp. can cause a severe gastrointestinal or central system disease in humans, depending on the species. For instance, *Angiostrongylus cantonensis* that is commonly known as rat lungworm is the major cause of eosinophilic meningitis in Malaysia and Southeast Asia (59). The Adult parasite of

Angiostrongylus cantonensis inhabit the pulmonary arteries of several genera of rodents as definitive hosts, mostly species of *Rattus* and *Bundicota*. The symptoms of *Angiostrongylus cantonensis* infection in humans range from mild (flu-like) to severe (including paralysis, coma, and eosinophilic meningitis). It is typically described as a tropical parasite but appears to be adapting to gastropod (snail) host from more temperate climate (60). The intermediate snail host of this parasite plays a role in maintaining the life cycle of this parasite among the rodents population. Hence, uninfected rodents acquiring the infection through ingesting the intermediate host contaminated with the larval stage of the parasites.

Humans acquire *Angiostrongylus* infection by ingesting intermediate or paratenic host that contained the larvae or by consuming vegetables contaminated with slime from the intermediate host (snail) containing the larvae which have escaped in this secretion. The larvae then penetrate the intestinal mucosa and travel through bloodstreams to the liver, lungs and later to the central nervous system (61,62). In humans, the symptoms of *Angiostrongylus* infections differ in both adult and children. In adults, the clinical manifestation includes vomiting and nausea, headache, stiff neck, and fever. Where as in children the symptoms include vomiting, nausea, fever are common than headache (62–64). Other species of *Angiostrongylus* that can cause infections in humans which lead to a disease called abdominal angiostrongylosis is *Angiostrongylus costaricensis* (65). The presence of *Angiostrongylus cantonenesis* can be an indication of the nature of disorder within the human community and the consequent general failure of direct and indirect disease control measures, either in rats or in human cases of neurological angiostrongyliasis in particular.

2.2.2 Capillariasis

The parasites *Capillaria hepatica* is responsible for a disease known as hepatic capillariasis, a zoonosis mostly associated with rats. In humans, *Capillaria hepatica* is responsible for a condition called hepatic capillariasis and spurious. Currently, 163 human cases of Capillaria hepatica (72 reports of hepatic capillariasis, 13 serologically confirmed infections, and 78 observations of spurious infections) have been reported in humans from different parts of the world (66,67). In Malaysia *Capillaria hepatica* was first reported by Audy (68). Apart from rodents and humans, this parasite has also been reported to parasitize the liver tissue of more than 30 mammal species, including dogs, cats, and monkeys (69). The life cycle of *Capillaria hepatica* is simple and direct, after the ingestion of eggs, larvae hatch in the caecum and invade the liver through the portal vein. Adult worms parasitize in the liver of its mammalian hosts where the females lay eggs into the liver parenchyma after mating (70).

2.2.3 Trichinosis

Trichinosis is a meat-borne parasitic infection caused by nematode species belonging to the genus trichinella (71–73). About 7 different species of *Trichinella* were recognized. However, the common species associated with human disease is *Trichinella spiralis* (74). Other species such as *Trichinella pseudospiralis,* and *Trichenella papuae* also infect humans. Humans get infected with Trichinosis by consuming raw or undercooked meat from certain wildlife species. Rodents species particularly wild rats are reservoir of Trichinosis (75). Studies have reported that the spread of Trichinosis has been influenced by the passive introduction of the pathogen by wild rats and domestic pigs in a different regions of the world (76). When humans get infected with Trichinella, symptoms such as nausea, dysepsia, diarrhea and heartburn appear within 1-2 days of infection. However, the severity of the symptoms depends on the number of worms ingested by the patients (71). Rats are important reservoirs in the domestic lifecycle of Trichinella (77). Although a large number of rodent species is able to carry Trichinella (e.g., *Microtus pennsylvanicus, Sigmodon hispidus, Peromyscus leucopus,* and *Mus musculus* (78), it remains largely unknown what species of the parasite they carry (76), and thus, whether a sylvatic cycle of the disease exists independently and poses a potential threat to human health.

2.3 Cestodes

2.3.1 Hymenolepiasis

Hymenolepiasis is one of the neglected parasitic zoonotic disease in humans, caused by two cestodes species *Hymenolepis nana* and *Hymenolepis diminuta*. These parasites are distributed worldwide, more especially in Asia, Central and South America, Southern and Eastern Europe and

Africa (79). Hymenolepiasis infections in humans mostly appears asymptomatic, but some times mild symptoms such as diarrhea, abdominal pain, vague gastrointestinal and anorexia occurs (80). Humans gets infected with hymenolepiasis by accidentally ingesting food or feces contaminated with egg of Hymenolepis or accidentally ingesting insects containing the infective stage (cysticercoid). The ova of this species hatch in the intestine of the host without being passed outside and grow into adult worms (81). This causes the number of adult worms in the host of the intestine to increase thus increasing the opportunity for the host to contaminate the environment. The occurrence of zoonotic cestodes particularly the genus Hymenolepis in the urban habitat should also be viewed seriously as a health threat. It has been previously reported that more than 21 million people in the world suffer from hymenolepiasis infection and most of them are from the tropical and subtropical regions (82). The prevalence of *Hymenolepis* spp. in the urban rodents is of particular interest due to its unique development pathway called auto-reinfection. Therefore,there is is need for the development of effective prevention and control measures.

2.3.2 Taeniasis

Taeniasis is one of the important parasitic zoonotic infection that is caused by tapeworms that belongs to the genus taenia (83). The adult parasites live in the intestine of carnivores and omnivorous animals which include humans. However, the life cycle of *Taenia* is complex which involves two hosts: definite host (humans, canids, and felids) and the intermediate host (rodents, lagomorphs, and artiodactyls) (84,85). Humans acquire the infection following the ingestion of viable larvae (for *Taenia solium*) in contaminated pork. Eggs are shed into environment by the adult or via feces. Pigs or other animals become infected following the ingestion of contaminated food or water or through coprophagia, thus completing the life cycle. The clinical manifestation of taeniasis relating to the presence of cysticerci in the brain causes neurocysticercosis, which leads to seizures, epilepsy, neurological sequelae or death. Humans are the definitive host for *Taenia solium*, and *Taenia saginata* and *Taenia asiatica*. Whereas animals are the definitive host of *Taenia crassiceps, Taenia ovis, Taenia taeniadormis, Taenia hydatigena, Taenia multiceps, Tenia seialis* and *Teania brauni* (86). To prevent infection with *Taenia* spp. especially the one responsible for humans taeniasis (*Taenia solium* and *Taenia saginata*) there is need to avoid or reduced the intake of undercooked pork or beef.

2.4 Trematodes

2.4.1 Schistosomiasis

Schistosomiasis is the second most worldwide common parasitic infection, apart from malaria, that caused by any of three species that include *Schistosoma heamatobium*, *Schistosoma japonicum*, *Schistosoma mekongi* (87,88). According to the world health organization over 200 millions people from 74 different countries across the world are infected with schistosomiases and nearly 800 million are at the risk of infection worldwide. Children and people working in the agricultural sector are at the risk of getting schistosoma infection (89). However, human gets infected with schistosomiases by contact or drinking water contaminated with the infective stage of the parasites (88). Although, schistosomiasis is being successfully controlled in many countries but it still remains a major public health problem (87). The health implication of *Schistosoma japonicum* and *Schistosoma mansoni* in humans include hepatic perisinusoidal egg granulomas, portal hypertension, Katayama fever and Symmers' pipe stem periportal fibrosis. Whereas for *Schistosoma heamatobium* include calcification, squamous cell carcinoma, hematuria, scarring and occasional embolic egg granulomas in the brain or spinal cord (90). Though the definitive host of this parasite is usually man, other mammalian animal species such as rodents have also been found to be infected. The transmission of this parasite to the definitve host take place in freshwater. The free-swimming cercariae, released from the freshwater snails that act as intermediate hosts, penetrate the skin of the definitive host and migrate in the blood via a number of tissues before they finally come to reside in the mesenteric blood vessels of the intestine. Studies have shown that rodents are the most common species affected (91). The factors that could explain the occurrence of schistosoma species in rodents are; a habitat in humid areas, and activity rhythms corresponding to the emergence of cercariae, and immunological compatibility.

2.4. Acanthocephalans

2.4.1. Acanthocephaliasis

Acanthocephaliasis is one of the parasitic zoonosis caused by common parasites of wildlife, humans and some domestic animal species, but they rarely infect humans. However, the human acanthocephaliasis is as a result of infection with any of the following acanthocephalan species include *Macracanthorynchus hirudinaceus, Macracanthorbychus ingens, Moniliformis moniliformis, Moniliformis hirudinaceus Acanthocephalus rauchi, Pseudoacanthocephalus bufonis, Corynosoma strumosum and Bolbosma* spp. The *Moniliformis hirudinaceus* and *Moniliformis moniliformis* are the most common species implicated in human infections (92).The life cycle of acanthocephalan spp. requires at least two hosts in order to complete its life cycle, and their intermediate host is either beetles or cockroaches, which must be eaten by a definitive host. Humans acquire the infection by accidental consumption of the intermediate host (beetles or cockroaches) containing the infective stage of the parasites or by eating food that is infested with arthropods, eating raw or undercooked insects, especially children. In humans the infection with any of the two acanthocephalan *Moniliformis hirudinaceus* and *Moniliformis moniliformis* is often severe, due to the mechanical damage caused by the parasites through insertion of the armed proboscis into the into the mucosa of the host´s intestine. Low infection or early infection may be asymptomatic, but include abdominal pain and digestive complaints (93). Several studies have reported human infections of *Moniliformis moniliformis* have been reported from Italy, British Honduras and Sudan (94).

3.THE TRANSMISSION OF PARASITIC RODENTS-BORNE PATHOGENS TO HUMANS

Rodents are important reservoirs of zoonotic agents hosting a wide range of bacteria, protozoa, helminths, and viruses that cause different types of diseases to humans as shown in Table 1 (4). However, the transmission of the pathogens from rodents to humans occurs because of their propensity to live in different habitats combined with other factors that are favorable for parasitic growth in rodents (95). Rodent-borne pathogens can be spread through two different pathways, the first way is through a direct route. In this case, rodents can spread pathogens to humans, through biting them or when humans consume food products or water that is contaminated with rodent feces or urine. Rodent-borne pathogens can also be spread to humans indirectly. In this case, the rodents can serve as amplifying hosts of the pathogens and can bring them into direct contact with humans by mean of ectoparasitic arthropod vectors such as ticks, mites, fleas, and lice. The transmission of the pathogen to humans can take place by bites from an infected tick or mite (Figure 1) (96). Rodents that are accidentally or on purpose ingested by livestock (e.g. pigs, ducks) can also transfer pathogens which can result in human disease if these food products are not properly cooked. Moreover, rodents can help to maintain pathogen transmission cycles in several different environments, varying from densely populated urban areas to rural areas and in the wilderness.

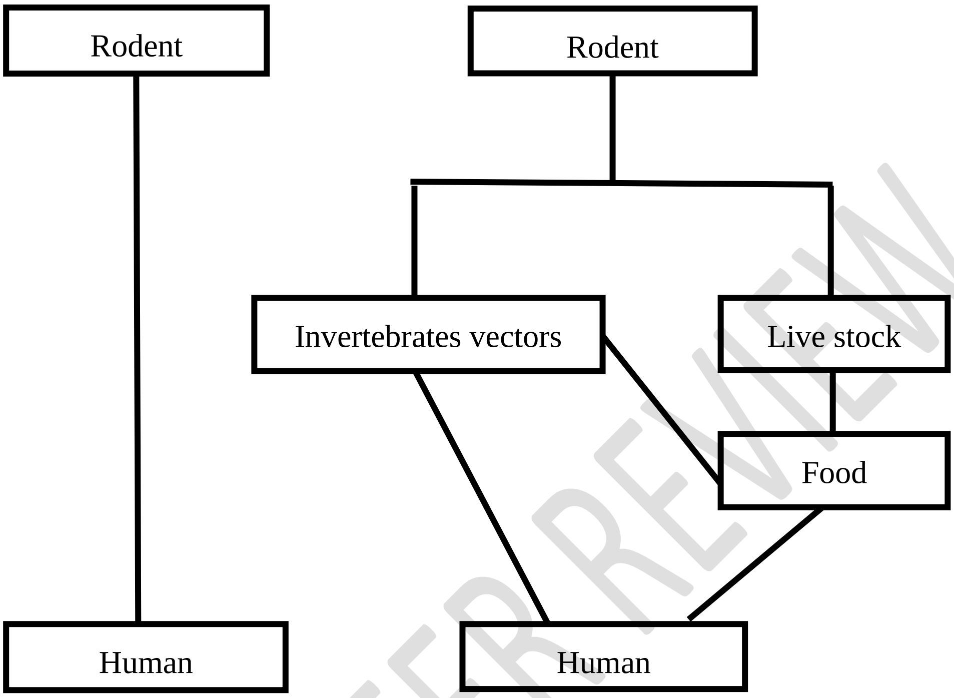

Figure 1. Routes of rodent-borne pathogen transmission to human: On the left is direct route, on the right is indirect route.

4. HUMAN-RODENT INTERACTION- ZOONOTIC TENDENCY

The current interaction of rodents with humans makes them a common source of zoonotic infection. However, this is due to the recent changes in the global climate and ecosystem composition, which has caused the rodent to proliferate worldwide (97). Other factors such as lack of a sanitary environment and availability of food were also responsible for rodents co-habiting with humans in the same environment. This situation indicates a significant proportion of emerging and re-emerging of rodent-borne diseases in the world more especially in urban cities. Therefore, considering the complex relations between humans, rodents, and the environment, any intervention that seeks to tackle the problem of rodent-borne parasitic diseases from a non-holistic, single focus point of view is bound to fail. The pyramid in Figure 2. shows a zoonotic tendency of human-rodent interaction (i) the environment represents the ecosystem in which the host (rodents), humans and the parasite live (ii) The interaction between humans and animals in the same environment has contributed significantly in the spread of zoonotic diseases to human (iii) Some these zoonotic diseases transmitted from animal to humans are parasitic disease

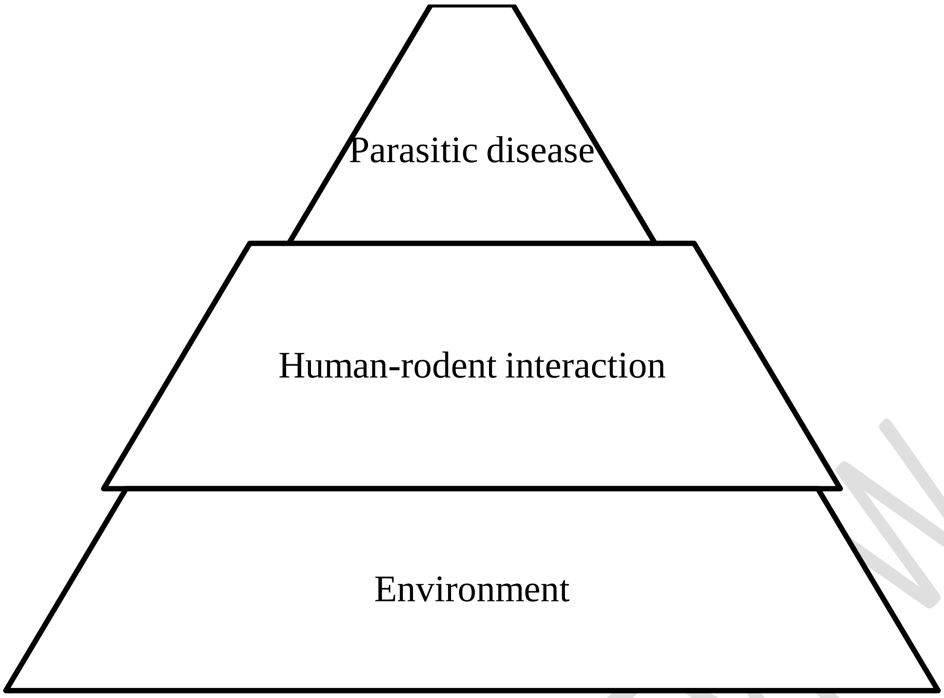

Fig. 2. Zoonotic tendency of human-rodent interaction

5. CONTROL OF RODENTS

Effective control of rodents always depends upon obtaining the cooperation of the people who live in the areas where control is being undertaken. Good communication with these populations and an understanding of their perceptions of the issues is essential if control strategies are to be applied effectively within the environments in which they live. There are ranges of control techniques available to reduce rodent populations, these include the use of toxicants, trapping, and environmental management (4). According to Paul (98), rodent control programs should be instituted in residential areas to minimize the breeding of rodents, such measures could include proper sanitation, proper waste disposal, use of rodenticides and blocking the access of rodents to residential quarters.The biology, ecology, and behavior of each species occurring in the different environments must be examined carefully to developed a successful rodent control program. The benefits of rodent control are well documented such that urban areas are not reservoirs of zoonotic diseases carried by rodents. This is especially important in the era when livestock, pests, humans, and wildlife are encroaching into each other's territories thereby promoting the spread of diseases (99). The rodenticide uses in controlling rodents have an important role in some circumstances, for instance, in an outbreak of disease or for the initial reduction of a large rodent population. But it should not be used as the main strategy for rodent control. Labuschagn (100), reported that worldwide rodent pests are of both public health and economically significant. Controlling rodent pests will, therefore not only benefit human and animal health but also to food security***.***

6. CONCLUSION

In this review, some aspects of parasitic zoonotic diseases were summarized. This study have showed the importance of rodents in the transmission of several numbers of parasitic zoonotic diseases, some of which have potential risk to cause epidemic in human population, such as cryptosporidiasis and amoebiasis. Therefore, there is a need for an integrated prevention strategies and these strategies should depend on the better understanding of the ecology and biology of the host and vectors. Further studies are required to understand the possible ways to interrupt the transmission cycle of parasitic rodent-borne diseases to humans.

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