

Minireview paper

Parasitic zoonoses from dogs: how common are they in Zambia

ABSTRACT

Zoonotic parasitic diseases including helminths and protozoa are common especially in areas with poor living conditions in developing countries. The poor living conditions combined with poor veterinary services and lack of awareness of the zoonotic diseases exacerbates the risks of disease transmission from animals to humans. Dogs serve different purposes, offering several benefits to humans, including companionship, life-saving actions, security as well as hunting and farming. However, dogs have also served as a link for parasite exchange among domestic livestock, wildlife and humans, and remain an important source of infectious diseases. The close relationship between dogs and humans and the fact that dogs live in close proximity to humans makes it possible to maintain the transmission cycle of parasites. This review is aimed at giving an update and creating awareness on the occurrence of some zoonotic infections (*Cryptosporidium*, *Giardia*, *Trypanosoma* spp and helminthes) from dogs in Zambia, and highlights the need for epidemiological studies to understand the exact role dogs play in these infections. Information generated from these studies; and awareness and knowledge of these zoonotic diseases by communities will assist in preventing such infections.

Key words: Zoonoses, dogs, *Cryptosporidium*, *Giardia*, Trypanosomes, helminths, Zambia

1. INTRODUCTION

In almost all human societies, dogs are widely used for different purposes, offering several benefits to humans, including companionship, life-saving actions, security as well as hunting and farming ([1-2]. The loyalty of the dogs to man has earned them the name "man's best friend". In terms of companionship, dogs, in some homes, replace children who have grown and moved away from home [3]. From a public health perspective, however, dogs have been sources of zoonotic parasites [4-5]. Dogs have also served as a link for parasite exchange among domestic livestock, wildlife and humans, and remain an important source of emerging

27 and re-emerging infectious diseases [6]. The importance of dogs in zoonotic diseases is related
28 to the fact that dogs live in close proximity to humans and are therefore able to maintain the
29 transmission cycle of these parasites.

30 Dogs are hosts to many parasites that may be transmitted to humans through direct contact with
31 infected animals or exposure to environments contaminated with infected dog faeces or
32 indirectly via vectors. A close contact between dogs and people increases the risk of

33 transmission. Children are often at greatest risk of infections especially intestinal ones because
34 of their play habits and affection for pets. Due to increased urbanization, the presence of pets
35 especially dogs within houses has also increased in popularity [7]. In these urban settings, dog
36 faeces represent an important environmental contaminant as they are not regularly removed.

37 Moreover, vehicular traffic, as well as the wind, can facilitate spread of viable pathogens present
38 in the dog faeces, resulting in contamination of food and/or water which may later be a source of
39 infection for humans. Additionally, parasite eggs can also be carried into human houses if
40 adhered to shoes or animals' paws [8-9]. Other environmental factors, such as the rain, may
41 also play an important role in the transmission of these pathogens [10].

42 In Zambia, not many studies have been conducted to determine occurrence of most zoonotic
43 infections that are known to be transmissible to humans [5,11-12], with limited data on parasitic
44 infections. The country has seen an increase in urbanization and keeping of dogs for security as
45 well as pets. Information and knowledge on the occurrence and prevalence of zoonotic
46 infections is important for communities to be well informed and for policy makers to have
47 appropriate intervention measures. This review is aimed at giving an update and creating
48 awareness on the occurrence of some zoonotic on common parasitic zoonotic infections
49 (helminths and protozoa) in dogs and their prevalence in dog populations in Zambia.

50 2. *CRYPTOSPORIDIUM* spp.

51 *Cryptosporidium* species are apicomplexan, protozoan parasites that infect the gastrointestinal
52 tract of a wide range of vertebrates, including humans [13-14]. They are transmitted via the

Comment [C1]: Are you sure? How does close proximity of humans maintain the transmission cycle of these parasites?? I don't know that humans are necessary links to maintain life cycles of parasites of dogs. None of the parasites in this Minireview require humans to complete their life cycles.

Comment [C2]: Are you sure? What kind of transmission you mean? Humans become infected when ingesting infective stages of the parasites, be it from the environment, the soil, an intermediate host, etc. could it be: "a close contact between infective stages of parasites from dogs..." I find your English language poor, confusing and misleading. Also, you should have treated parasites of dogs in a subdivision and disease in humans caused by parasites of dogs in another subdivision. Otherwise, all your terminologies become very confusing, inexact and unsuited for publication.

Comment [C3]: Again, be careful.

Comment [C4]: and dog fur.

Comment [C5]: How can rain transmit diseases? Could it be "spreading"? "Concentrating infective stages in certain soiled areas"? other words?

53 faecal-oral route by environmentally resistant oocysts that are in shed faeces, contaminating soil
54 and water, and thus, providing multiple routes into the food chain [15]. *Cryptosporidium* spp. are
55 common parasites of humans, domestic animals and wild vertebrates. Cryptosporidiosis, the
56 disease caused by *Cryptosporidium* spp. has been considered to be a zoonotic disease for
57 some time due to the wide host range [14].

58 Important *Cryptosporidium* species include *Cryptosporidium parvum* mainly in young calves
59 (<30 days) *C. bovis* (older calves) and *C. andersoni* in adult cattle, *C. suis* in pigs, *C. felis* in
60 cats, *C. wrairi* in guinea pigs, *C. meleagridis* and *C. baileyi* in birds, and *C. muris* in reptiles.
61 Amongst these *Cryptosporidium* species, *C. parvum* stands out as the most "important" zoonotic
62 species as it has been reported in humans in many countries, in addition to being common in
63 other domestic animals. *Cryptosporidium canis* has been isolated primarily in dogs, with
64 occasional reports in humans [16-17]. Other zoonotic species include, *C. suis*, *C. felis* *C. canis*,
65 *meleagridis* and *C. muris*, occurring occasionally especially in immunocompromised individuals.
66 Despite the many reports of *C. canis* in dogs in many countries worldwide [18-20], there is no
67 information on its presence in dogs in Zambia. Only one study is known to have been conducted
68 in domestic dogs to determine the occurrence of *Cryptosporidium* spp and other parasites but
69 no *Cryptosporidium* oocysts were detected in the 20 dogs that were tested [21]. Even if the role
70 of dogs in the transmission of human cryptosporidiosis appears to be insignificant as evidenced
71 in the studies in the United States [22], Guinea-Bissau [23]; and Indonesia [24], the canines
72 appear to be linked to some zoonotic transmission of the parasite in both the developed and
73 developing countries. Reports of human infections have been made in England, Wales, USA,
74 Thailand, Kenya, Venezuela and Peru among others [16,25-29]. In the Peruvian study [16], *C.*
75 *canis* was isolated from both dogs and children included in the study and these were from the
76 same household. It is therefore important to consider dogs as possible sources of
77 *Cryptosporidium* infection even if information regarding the role of companion animals in the
78 transmission of *Cryptosporidium* species is generally insufficient especially in immunocompetent

Comment [C6]: Suggestion: Why not start discussing thoroughly (what kind of patients could be at risk of infection? (HIV+), how was *C. canis* differentiated from other species? What should be the preventive measures?) *C. canis* from dogs, since this is the reason for this Minireview, and then continue with other species from other animals (that have little to do here)? So as not to loose focus.

79 individuals. In Zambia, a number of studies have reported *Cryptosporidium* infections in humans
80 [30-32] but genotypes isolated from these are not known.

81 Management of cryptosporidiosis is mainly supportive. There is no specific drug available for
82 treatment of cryptosporidiosis dogs. Infection is normally self-limiting and therefore resolves
83 spontaneously [33]. In the absence of specific treatment, strict hygienic measures are
84 necessary to prevent spread of infection, especially that *Cryptosporidium* oocysts are highly
85 resistant. The hygienic measures may include daily removal and proper disposal of dog faeces
86 from kennels, home surroundings and play parks; steam cleaning and chemical disinfection of
87 kennels or dog shelters [17]. In humans, nitazoxanide has been shown to be effective against
88 *Cryptosporidium* infection [31,34]. In HIV/AIDS patients, chemotherapy and antiretroviral
89 therapy are recommended in addition to supportive therapy. Personal hygiene is paramount in
90 preventing infection and immunocompromised patients should avoid coming into close contact
91 dog faeces [33,34].

92 3. GIARDIA

93 *Giardia duodenalis* (synonyms *Giardia lamblia*, *Giardia intestinalis*) is a protozoan parasite that
94 infects the intestinal tract of many animal species including humans. Environmentally resistant
95 cysts are passed in the faeces of infected animals, and are immediately infective if ingested by
96 other susceptible hosts [35-36]. As such, *Giardia* species have been considered zoonotic
97 probably because similar organisms infect humans and a variety of mammals and birds [37].

98 However, evidence of the exact role of animals in the transmission of giardiasis is still limited.
99 There are currently seven genotypic assemblages (assemblages A to F), which are distinct
100 evolutionary lineages, as defined by phylogenetic analysis and enzyme electrophoresis [38-39].
101 Assemblage A and B are considered to be predominantly for humans while C and D make up
102 the majority of isolates from dogs. Assemblage E is isolated from hooved animals. Cats are
103 hosts or Assemblage F while rats are hosts for Assemblage G [40-41]. Given the distribution of
104 the assemblages between different animal species and humans, the zoonotic transmission of

Comment [C7]: Since this Minireview is on parasites of dogs, does this refer to management in dogs? Do dogs experience disease?

Comment [C8]: in

Comment [C9]: or humans

Comment [C10]: in immuno-competent hosts

Comment [C11]: already infective when excreted in faeces and...

Comment [C12]: to what?

Comment [C13]: None has been proven effective against Crypto.

Comment [C14]: No drug has been tested effective against *Cryptosporidium*; nitazoxanide may reduce the number of diarrheic episodes only, providing some relief to the patient.

Comment [C15]: In that particular group (HIV/AIDS) and in general

Comment [C16]: and often handwashing

Comment [C17]: With

Comment [C18]: Morphologically similar

105 *Giardia* has been a topic of debate for a long time. Even if dogs appear to harbour only the
106 canine oriented assemblage C and D, some studies have reported zoonotic forms in pet dogs. A
107 study in the United States reported that 28% and 41% of client-owned dogs presenting with
108 giardiasis to veterinary clinics in the western United States had potentially zoonotic
109 assemblages A and B, respectively, while 15% and 16% had host specific assemblages C and
110 D, respectively [42]. This data suggest the possibility of the potential for transmission of non-
111 canine-specific assemblages from owners to their dogs as well as zoonotic transmission from
112 dogs to humans.

Comment [C19]: Do you mean clinical disease?
Or simply infection with *Giardia*?

113 There is very little information on *Giardia* in animals in Zambia. Only a single study by Asha et
114 al. [43] reported the presence of *G. duodenalis* and this was not in dogs but in the African
115 painted dog (*Lycaon pictus*) with both canine specific assemblages C and D as well as the
116 zoonotic assemblages A and B being reported. The zoonotic assemblages were more common
117 compared to the canine host specific C and D, suggesting that these two assemblages have the
118 potential for zoonotic transmission from the captive animals to humans due to close interaction.
119 One study in domestic animals reported *Giardia* prevalence of 5% in domestic dogs [21]. Even
120 though dogs may suffer minimal consequences of the disease, young puppies may develop
121 complications of persistent infection, impairment of growth and development. [35,44], Humans
122 that acquire *Giardia* infections, on the other hand, may develop intermittent diarrhoea which is
123 normally associated with chronic infections [45]. The many reports of possible zoonotic
124 transmission of *Giardia* from dogs to humans [42,46-48] stresses the need for further insight into
125 the exact role of domestic animals in the transmission of this parasite.

Comment [C20]: Only one publication from
Thailand positively identified *Giardia* from dogs in
space around a temple where dogs roamed freely,
infective to humans, but I misplaced the reference.

126 As opposed to *Cryptosporidium*, drugs are available for treatment of *Giardia* infections in
127 animals and humans. Fenbendazole is recommended in dogs. A combination of
128 febantel/pyrantel/praziquantel can also be used [17]. In humans, the drug of choice is
129 metronidazole [49] However, high re-infection rates have been reported with *Giardia* infection
130 especially in highly contaminated areas, which may lead to treatment failure [49]. Shampooing

Comment [C21]: Are we talking of human to
human transmissions? since you go from one host to
another, maybe it is convenient to make it clear.
Otherwise, it could read: humans that acquire
Giardia infections (from dogs)...

Comment [C22]: As suggested before, why not
separate parasitic diseases of dogs in a subdivision
and the disease caused in humans in another
subdivision? *Toxocara canis* should really be the star
in this minireview; *Cryptosporidium canis* is
important for immunocompromised individuals, and
of lesser importance *Dipylidium*, *Echinococcus*, etc.
Jumping from dog to human disease without proper
clarification confuses and misleads the uninformed
reader and steals seriousness to the paper.

Comment [C23]: (Re-)infection (in humans) is
not the same as disease, therefore in humans it may
not be treatment failure but due to the ubiquitous
presence of *Giardia* cysts that facilitates frequent
re-infections. Is this a matter of interpretation?

Comment [C24]: Again, are we talking of human
giardiasis acquired from humans? Please explain.
In so many studies with human subjects, control
individuals have equal or higher percentages of
infection than the study patients, that treatment of
infection without disease is not even considered.

131 of dogs with products containing chlorhexidine digluconate at the beginning and the end of
132 treatment, removal of dog faeces and strict personal hygiene may assist in reducing infection
133 and re-infections in both animals and humans [50].

Comment [C25]: "Reducing and preventing reinfections in dogs and preventing, if any, infection in humans." Could this be a cleared sentence?

Comment [C26]: This has not been proven.

134 4. *TRYPANOSOMA* SPECIES

135 In tsetse-infested sub-Saharan African countries, pathogenic protozoan trypanosome species
136 are commonly transmitted to a wide range of susceptible mammalian hosts, including dogs.

137 Transmission is through the infective tsetse fly (*Glossina* spp.) bites when taking a blood meal
138 [51]. Dogs are specifically affected by *Trypanosoma evansi*, *Trypanosoma congolense*, and

Comment [C27]: Intermediate host...

139 *Trypanosoma brucei brucei* [52] causing Canine African Trypanosomosis (CAT) with varying
140 clinical presentation depending on species. In exotic breeds of dogs, *T. brucei* subspecies tend

141 to cause acute disease [12] while infections due to *T. congolense* appear to be more chronic
142 [12,53]. On the other hand, indigenous dog breeds appear to be more trypanotolerant and do

143 not exhibit any clinical signs [51]. These trypanotolerant dogs therefore may act as sources of
144 infection for other animals as well as humans. Dogs that harbour the human infective *T. brucei*

Comment [C28]: How? Where is the vector? Do you mean "act as a reservoir of infection"

145 *rhodesiense* and *T. brucei gambiense* and are usually asymptomatic but may serve as "an

146 unknown" sources of infection for humans, providing a source for vectors, leading to
147 transmission [54-55].

Comment [C29]: Source is singular. Do you mean reservoir?..

Comment [C30]: For other dogs as well as humans...

Comment [C31]: the vector is present as in endemic areas...

Comment [C32]: Do dogs provide a source for vectors? Grammatical construction of sentences. Do you mean: ...providing the right vector is not only at hand, but in the right conditions to complete its life cycle and transmit the disease?

Comment [C33]: May be (two different words)

148 Although trypanosomosis is commonly reported in farm animals [56-57], Canine African
149 trypanosomosis (CAT) is less frequently reported [53,58]. However, recent studies have actually
150 indicated the significance of the trypanosome parasite in dogs. Affected animals that become
151 clinically ill exhibit clinical signs that maybe severe, including lymphadenopathy, oedematous
152 forelimbs, distended abdomen, bilateral corneal opacity, conjunctivitis with mucopurulent
153 discharge, pyrexia, dyspnoea and evidence of anaemia [12,59] with death occurring in some
154 cases.

155 In Zambia, the first case of *rhodesianse* Human African Trypanosomiasis (rHAT) was first
156 reported in 1910 by Stephens and Fantham [60] in the then northern Rhodesia. Since then, a

Comment [C34]: Spelling

Comment [C35]: Twice first: once should be enough

number of cases have been reported; some documented [61-63] while others are not. Mwanakasale et al. [62] reported two cases of rHAT in two teenagers that had presented with different clinical symptoms (atypical chronic, mild form and typical acute and severe form) and highlighted the possibility of the existence of two strains of *T. b. rhodesiense* in Zambia. Most of the cases of rHAT in Zambia have been related to some national parks in the eastern and northern parts of the country [63]. At risk are people that cohabit with wildlife in game management areas and tourists that visit national parks. With the available data indicating the presence of the infection in humans and the occurrence of the human infective parasites in “man’s best friend” [12,64], mechanisms to prevent transmission of trypanosomes in both animals and humans are necessary and cannot be over emphasized. Vector control is the most important aspect in preventing infections. In addition, awareness campaigns and health education activities must be carried out to have well informed communities and prevent infection [52].

5. HELMINTHS

Helminths impede the successful rearing of dogs. The outcome of infection is lowered resistance to infectious diseases, retarded growth, reduced work/activity and feed efficiency and general ill-health [65]. Parasitized animals show a variety of symptoms, depending on the parasite species and density. These signs are attributable to intestinal obstruction, irritation, mal-digestion, malabsorption, and protein losing enteropathies [66]. Some of these helminths are of public health importance as zoonotic transmission can occur.

5.1 *Toxocara canis*

Toxocara canis, a cause of toxocariasis, is a common roundworm of dogs and infection occurs transplacentally, transmammary and through ingestion of an infected paratenic host such as slugs. Infection may also occur through ingestion of eggs containing the infective second stage larvae (L2) from the environment [65,67-68]. Humans get infected by accidentally ingesting

Comment [C36]: *Trypanosoma rhodesiense* infections. ...?

Comment [C37]: In humans? In dogs? In dogs and humans...?

Comment [C38]: Some helminths? Could you say: “When puppies are not treated promptly, some helminths.....”?

Comment [C39]: Blood loss..

Comment [C40]: Allow me to cite the last paragraph in a recent publication: “Recognition of toxocariasis as a common parasitic disease in the US and possibly an even greater health problem in developing countries is a first important step to national and international efforts to combat this neglected infection of poverty.” Hotez P. PLoS Negl Dis 2009; 3(3<9:e400. The reason will be clear if you take the time to read this publication. As the aim of this Minireview states: giving an update and creating awareness, *T. canis* infection in humans stands as probably number one in the list of human Neglected Tropical Diseases.

Comment [C41]: Epidemiologically, and probably not in domestic dogs, there are other paratenic hosts more important than slugs, like small mammals (mice and other small rodents) and birds infected with *T. canis* larvae.

Comment [C42]: Your usage of words do not denote clear concepts, since you lack specific descriptions. Undercooked or raw meat, providing it is meat from paratenic hosts, that is, it contains encapsulated larvae of *T. canis*.

Comment [C43]: By discussing the infection of humans together with dog infection, you convey the mistaken idea that humans develop the adult worms, just like the dog. One has to read further and then the reader, a student maybe or an uninformed person, may not understand what do you mean.

183 *Toxocara* eggs through soil contaminated with *Toxocara* eggs. In rare cases, infection has also
184 been reported to occur by eating undercooked or raw meat.

185 Toxocariasis is one of the most common zoonotic infections and has been reported worldwide
186 [69-71]. Infection in humans causes larva migrans syndromes (visceral and ocular larva migrans
187 and covert toxocariasis) [72-73]. Initially only visceral and larval migrans were reported but it is
188 now known that a syndrome known as covert toxocariasis, characterised by abdominal pain,
189 does occur in humans [72]. However, most human infections are usually asymptomatic, though
190 some individuals may develop systemic disease or localised symptoms confined to the eye
191 resulting in partial or complete blindness [74]. The severity and type of disease in humans
192 depend on how many larvae are ingested or number of migrating larvae, the frequency of re-
193 infection, and the age of the host [69,74].

194 In Zambia, *T. canis* has been reported in domestic dogs several times [5, 75-76] with varying
195 prevalence; 7.6%, 14% and 4.8%, respectively. However, it is not known whether human
196 infections are there because there are no reports or documentation available. Nevertheless,
197 there are reports of *Toxocara* infections in humans in some southern African countries.
198 Recently, Liao et al. [71] reported 44.6% seroprevalence of *T. canis* in children in Swaziland,
199 highlighting the occurrence of zoonotic infection. Presence of a dog in a household has been
200 reported as the most important risk factor associated with human toxocariasis. The increased
201 urbanization in Zambia has come with an increase in the keeping of dogs for both security and
202 as pets, which may come with a risk of possible zoonotic transmission of *Toxocara* and other
203 helminths if preventive measures are not put in place [6]. Apart from having a dog in the
204 household, geophagy is also an important factor that can significantly contribute to infection
205 especially in heavily contaminated areas [77]. It is important that dogs are treated to prevent
206 infections. Pyrantel pamoate is recommended for young puppies while a combination of
207 febantel, praziquantel and pyrantel pamoate is advised for puppies older than 3 weeks [41].

208 5.2 *Ancylostoma caninum*

Comment [C44]: What about neurotoxocariasis?

Comment [C45]: Visceral larva migrans? Why the "and"? what does larva migrans mean to you?

Comment [C46]: Not only. What about hypereosinophilia, which is a highly suspected sign in the absence of any other cause for hypereosinophilia? Also, cough, sleep disturbance, irritability...

Comment [C47]: Could this sentence read: "Although most human infections are usually asymptomatic, some individuals..."

Comment [C48]: Very important to describe the symptoms in this systemic disease, since you are already mentioning all other presentations of VLM.

Comment [C49]: spelling

Comment [C50]: very rarely *T. canis* larvae affect both eyes.

Comment [C51]: Contribute to infection in the dog? In humans?

Comment [C52]: What is the minimum age to treat a puppy? Never less than 2 weeks...How about treating the bitch after whelping?

209 Infections with *A. caninum* remain common in dogs, with the high prevalences being reported
210 world-wide [76,78-80]. Dogs acquire the infection through skin penetration at hair follicles or
211 sweat glands, especially between the footpads where contact with soil is frequent; and through
212 direct ingestion of the larvae. Clinical consequences include unthriftiness and chronic anaemia in
213 debilitated and malnourished animals; the anaemia of which can be fatal in young puppies [61].
214 Anorexia, weakness and emaciation usually accompany chronic disease. Diarrhoea with dark,
215 tarry faeces is seen in severe infections. Mature, well-nourished dogs are usually asymptomatic
216 but act as a direct or indirect source of infection for puppies [41]. Development of clinical
217 disease depends on the magnitude of the challenge and host factors.
218 Humans acquire *A. caninum* infection through contact with moist/wet sand soil containing
219 filariform larvae from the faeces of dogs. This usually occurs in areas where there is heavy soil
220 contamination such as densely populated areas with unsecured or free roaming dogs. Larval
221 invasion of skin in humans produces pruritic papules [81]. Zoonotic infection with *A. caninum*
222 may also occur through ingestion of the larvae in soil or in tissues of paratenic hosts. This may
223 result in enteric disease known as eosinophilic enteritis [78,82]. Infections may also lead to
224 cutaneous larval migrans (CLM) which may be self-limiting or cause creeping eruptions which
225 may persist for several months [83-84].
226 *Ancylostoma caninum* infections are very common in dogs in Zambia [75-76]. Islam and
227 Chizyuka [76] reported a prevalence of 8% in Lusaka district, and years later Bwalya et al. [76]
228 reported a prevalence of 72.9% and 70.6% in dogs from Lusaka and katete districts,
229 respectively. The amount of disease in people is unknown and this could be due to the fact that
230 infections are either not documented or are not there. However, human infections with *A.*
231 *caninum* have been reported elsewhere [82]. *Ancylostoma braziliense* is reported to be more
232 frequently involved in CLM than *A. caninum* [36] but *A. caninum* is also an important cause [84].
233 Periodic deworming of dogs with drugs such as pyrantel pamoate, febantel, fenbendazole helps
234 to prevent infections and reduces environmental contamination by the hookworm eggs [41,85].

Comment [C53]: Grammatic? Of which?

Comment [C54]: Skin penetration of larvae

Comment [C55]: Rarely. The difference between human infection with larvae from dog parasites and larvae of human origin is precisely the long duration of symptoms in the zoonotic one....

235 5.3 *Dipylidium caninum*

236 *Dipylidium caninum* is a zoonotic tapeworm infection which is acquired from dogs when a
237 person accidentally ingests a flea carrying the larval stage of the tapeworm. Infection is
238 especially common in young children (< six months) who exhibit symptoms of diarrhoea and
239 pruritus [86-88]. Infection has a characteristic feature of passage of proglottids in faeces in both
240 dogs and infected children, though it is usually asymptomatic [86]. Additionally dogs tend to
241 scoot to relieve the anal pruritus associated with the infection [89]. Controlling the fleas (which
242 are carriers of the tapeworm) on the animals would help prevent infections in dogs. In infected
243 dogs, praziquatel is the recommended drug for eliminating of infection [41].

244 A number of studies have reported the presence of *D. caninum* in dogs in various districts in
245 Zambia [5,75-76] with varying prevalence, 2.2%, 25% and 3.8% respectively. Even if human
246 infections are rare, the reported infections especially those occurring in infants [87] are of
247 concern and should stimulate inquiry especially in areas where infections are endemic in dogs.
248 Epidemiological studies are needed to determine the risk *D. caninum* dog infections pause to
249 humans in Zambia.

250 5.4 *Echinococcus* species

251 *Echinococcus* species are parasitic trematodes that affect a number of animal species.
252 *Echinococcus granulosus* and *E. multilocularis* are of veterinary and public health importance
253 [90]. Although the geographical distribution of *E. granulosus* is considered worldwide, it is higher
254 especially in rural communities in developing countries [91]. Clinically, there are three broad
255 morphological forms of echinococcosis that are recognized: cystic echinococcosis (Hydatidosis
256 or hydatid disease) caused by *E. granulosus*, alveolar echinococcosis (Alveolar hydatid
257 disease) (*E. multilocularis*) and polycystic echinococcosis (*E. vogeli* and *E. oligathrus* - mostly
258 in South America) [92-93]. The *E. granulosus* "sheep" strain (G I) is generally considered as the
259 most widespread strain worldwide and the common cause of cystic echinococcosis in humans

Comment [C56]: You just said ...exhibit symptoms of diarrhea and pruritus....

Comment [C57]: Cysticercoid or infective stage of the ...

Comment [C58]: And humans..

Comment [C59]: Pause? Pose? spelling

Comment [C60]: NO! this is a Cestode!

Comment [C61]: Not necessarily in developing countries. The most extensive endemic regions are those of sheep and cattle raising countries, South Australia, New Zealand, Kenya, Argentina, Uruguay, Chile, southern Brazil, in addition to eastern Europe, southern Japan, Syria, Lebanon, Israel to name a few.

Comment [C62]: They all have specific geographic limitations and different definitive and intermediate hosts. If mentioning the three types of echinococcosis, then mention as well their geographic places and definitive hosts. Dogs would be incidental definitive hosts in two cases.

Comment [C63]: The disease caused is known as Neotropical Echinococcosis.

260 who get infected through accidental ingestion of eggs [94]. This strain of *Echinococcus* is
261 endemic in Africa [41,95].
262 In dogs, *E. granulosus* infection is transmitted through ingestion through scavenging food
263 contaminated with hydatid cysts or when fed infected offals (liver and lung) from domestic
264 animals such as ruminants [96] (<http://www.oie.int/doc/ged/D13941.PDF>). The disease in dogs
265 causes very minimal effects and is usually asymptomatic. In Zambia, *E. granulosus* has been
266 reported in domestic animals [97-98], an indication that the parasite maybe present in most
267 villages/areas in Zambia where livestock rearing is common. Pandey and Sharma [99] and
268 Banda et al. [98] reported presence of hydatidosis in cattle from abattoirs in Lusaka and
269 Western provinces, respectively. There is however, very little information available on
270 echinococcosis in dogs. Only two studies have reported the presence of *E. granulosus* in dogs
271 [5,75] and only one in humans [98], reporting a prevalence of 0.009%. In dogs, the prevalence
272 reported was 1% [75].

273 These reports of *Echinococcus* infections in dogs in Zambia [5, 75], though few, are important
274 because of the role dogs play in human infection especially in rural communities where there is
275 close contact with dogs as well as in other risk groups which include animal handlers,
276 veterinarians, and dog owners [100]. Dogs shed eggs in the environment which can easily
277 contaminate fruits, vegetables or water, or can stick to the fur of dog. The eggs can be
278 transferred from the dog to hands and to the mouth. Well planned regular deworming, avoiding
279 feeding dogs uncooked offals (and sanitary disposal of slaughterhouse waste to prevent access
280 by dogs) and destruction of stray dogs help prevent environmental contamination and hence
281 further infections. Additionally, community public health education to create awareness on the
282 transmission mode and dangers of the infection is a key prevention measure [95]. The clinical
283 consequences of *E. granulosus* infection in humans may be severe in infected tissue (especially
284 lungs and liver). The symptoms, however, depend on the organ(s) involved, the size, mass and
285 numbers of cysts or metacestode and the location where the cyst develops; immune status of

Comment [C64]: Sentence construction

Comment [C65]: In areas of heavy transmission....?

Comment [C66]: I find the whole clinical description erratic and somewhat chaotic. Does not follow a step wise pattern. Hydatid disease due to *E. granulosus* is always serious, although the gravity depends on the type of tumor, as well as the organ or tissue (brain, osseous, liver, lung, heart valve) in which it becomes implanted. The cyst usually has a layer of fibrous tissue around it and may produce symptoms 5 or 20 years later, when it has reached a size that presses upon adjacent organs. And then there are the different clinical presentations. So, not really what is described here.

Comment [C67]: Take many years to develop and manifest itself unless etc.

286 the host, the complications related to cyst rupture, spread of protoscoleces, and bacterial
287 infection. Affected organs may become fibrotic. Other complications such as jaundice, fever,
288 abdominal pain, hepatomegally, portal hypertension and cholangitis may occur [100-102].

Comment [C68]: Associated? Contaminant?

289 6. CONCLUSION

290 Although the potential role of dogs as source of zoonotic infections to humans has been
291 recognized as a significant public health problem, investigations on the prevalence of most
292 parasite infections have not been extensively conducted in Zambia. There is little documentation
293 and these are mostly in domestic animals. The documented data may also not be complete and
294 does not give a clear picture of the situation in the country. There is need to have well-
295 documented country and regional data to have a comprehensive sub-Saharan picture of these
296 zoonotic parasitic diseases.

297 In all these zoonotic infections, veterinarians need to take a lead as they understand the
298 potential risks to humans. Client education especially on preventive measures and/or treatment
299 should be part of the services offered, including how to minimize the risk of zoonotic
300 transmission. In addition, awareness campaigns, in conjunction with medical and public health
301 personnel should be carried out on the benefits and risks of keeping dogs.

302 ETHICAL APPROVAL

303 Not applicable

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