

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

Comment [C1]: No. Poor term. Humans are no link and do not exchange most parasites with dogs: no *Cryptosporidium*, no *Toxocara*, no *Ancylostoma*, no *Dipylidium*, no *Echinococcus*, no *Trypanosomes* ...Look for another expression.

Comment [C2]: I thought we had talked about this before. It seems that you still do not understand the biology of these zoonoses or the terminology. I definitively cannot accept this.

Comment [C3]: Cats also share similar genera of some parasites as dogs, you know...

Comment [C4]: How is this going to happen? Who should be the main conductor of information and action? Communities have more pressing worries. Should it be veterinarians? Should it be a program at the Ministry of Health or at the Agricultural and Animal Husbandry Ministry? communities have very little power and knowhow and resources. Your paper is not going to be read by any community, but by others...such as...

Comment [C5]: Which is it? Helminthes? Helminths?

Comment [C6]: Sorry!!! No.

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 making it possible for disease
29 transmission to occur through direct contact or indirectly via contamination of water or food by
30 infective stages.

Comment [C7]: Parasite transmission? Disease may or may not develop.

31 Dogs are hosts to many parasites that may be transmitted to humans. Helminths and protozoa
32 represent some of the important parasites that may/may not have detrimental effects on dogs
33 and but have severe clinical consequences in humans.

Comment [C8]: Through dog feces...
Are you a dog hater? Why do you insist in blaming the dog? It is the responsibility of dog owners to avoid all these parasites by keeping the animals well fed, dewormed, sterilized (no puppies), bathed and loved. Somebody or some law should take proper care of stray animals, which are really the ones contaminating the environment.

34 Zoonotic parasites from dogs can be transmitted to humans through direct contact with infected
35 animals or exposure to environments contaminated with infected dog faeces or indirectly via
36 vectors. A close contact between dogs and people increases the risk of faecal-oral transmission

Comment [C9]: I gather that instead of raising awareness you seem to want to scare or alarm people.

37 due to the high possibility of direct contact with the infective stages of the parasite. Children are
38 often at greatest risk of orally transmitted infections especially intestinal ones because of their
39 play habits and affection for pets. Due to increased urbanization, the presence of pets especially
40 dogs within houses has also increased in popularity [7]. In these urban settings, dog faeces
41 represent an important environmental contaminant as they are not regularly removed.

Comment [C10]: If this were true we all would be infected and ill. You should use correct terms, not to unduly frighten or alarm, but properly inform.

Comment [C11]: Except for *Toxocara canis*, infection in children are so rare, that when they happen they usually deserve a publication.

42 Moreover, vehicular traffic, as well as the wind, can facilitate spread of viable pathogens present
43 in the dog faeces, resulting in contamination of food and/or water which may later be a source of
44 infection for humans. Additionally, parasite eggs can also be carried into human houses if
45 adhered to shoes or dog's paws or fur [8-9]. Other environmental factors, such as water runoff
46 from rain, may also play an important role in the transmission of these pathogens through
47 contamination of water sources [10].

Comment [C12]: How about this: "These animals, often living in the same households with toddler-age children, pass enormous numbers of eggs in the feces daily for many months. Although the feces of a small dog or cat will be dissipated in a short time, the eggs of their parasites accumulate in the environment". Now this, besides being scientifically correct, is beautifully said. It goes on and on, but I am not going to write it all. Beaver PC, Jung R, Cupp E. Lea & Febiger, 9th. Edition, 1984.

Comment [C13]: Feces of dogs within houses are simply not there, owners take care of proper disposal.

Comment [C14]: Better state: stray, unkept dogs that defecate indiscriminately...

Comment [C15]: From an epidemiologic point of view, almost no importance.

48 In Zambia, not many studies have been conducted to determine occurrence of most zoonotic
49 infections that are known to be transmissible to humans [5,11-12], with limited data on parasitic
50 infections. The country has seen an increase in urbanization and keeping of dogs for security as
51 well as pets. Information and knowledge on the occurrence and prevalence of zoonotic
52 infections is important for communities to be well informed and for policy makers to have

Comment [C16]: Of dogs?

53 appropriate intervention measures. This review is aimed at giving an update and creating
54 awareness on the occurrence of some common parasitic zoonotic infections (helminths and
55 protozoa) in dogs and their prevalence in dog populations in Zambia.

56 2. *CRYPTOSPORIDIUM* spp.

57 *Cryptosporidium* species are apicomplexan, protozoan parasites that infect the gastrointestinal
58 tract of a wide range of vertebrates, including humans [13-14]. They are transmitted via the
59 faecal-oral route by environmentally resistant oocysts that are in shed faeces, contaminating soil
60 and water, and thus, providing multiple routes into the food chain [15]. *Cryptosporidium* spp. are
61 common parasites of humans, domestic animals and wild vertebrates. Cryptosporidiosis, the
62 disease caused by *Cryptosporidium* spp. has been considered to be a zoonotic disease for
63 some time due to the wide host range [14].

64

65 Human populations at risk of infection include young children, health-care workers, day-care
66 centre personnel, users of communal swimming pools and travellers to regions of endemicity
67 [16]. Immuno-compromised individuals such as those with HIV infection and AIDS are at
68 increased risk of infection and may suffer severe clinical consequences such as very severe
69 chronic diarrhoea with considerable fluid and weight loss, which may result in death [17]. The

70 illness may have a variable presentation namely; transient infection, intermittent relapsing
71 infection, cholera-like infection or chronic infection [18]. Most infections in humans are due to

72 the human specific *C. hominis* and the zoonotic *C. parvum* [14]. Apart from *C. parvum*, other
73 zoonotic species including *C. canis*, *C. suis*, *C. felis*, *meleagridis* and *C. muris* have been

74 identified in humans, occurring occasionally especially in immunocompromised individuals.

75 *Cryptosporidium canis*, in particular, is known to be dog specific (based on molecular analysis
76 and host specificity) but several studies have reported the possibility of zoonotic transmission
77 from dogs to humans [19-24]. Even if the role of dogs in the transmission of human

78 cryptosporidiosis appears to be insignificant as evidenced in some studies in the United States

Comment [C17]: I have read Meinhardt paper several times and she says nothing of what you wrote in the sentence above. On the contrary, she is very careful in the use of words, and is constantly reminding the reader with words like: "still unclear", "may be", "conflicting evidence", "caution is warranted in the use of these surveys" ... etc. At the beginning of her paper she states: "The severity, persistence and ultimate outcome of the infection is typically dependent..."; "in immunocompetent" ... "in immunocompromised..." , etc. Please, take example, be careful.

Comment [C18]: Should this sentence precede the anterior one?

Comment [C19]: None of these, with the exception of *C. canis* has anything to do with dogs.

79 [25], Guinea-Bissau [26]; and Indonesia [27], the canines appear to be linked to some zoonotic
80 transmission of the parasite in both the developed and developing countries. Reports of human
81 infections have been made in England, Wales, USA, Thailand, Kenya, Venezuela and Peru
82 among others [19-24]. In the Peruvian study [19], *C. canis* was isolated from both dogs and
83 children included in the study and these were from the same household. It is therefore important
84 to consider dogs as possible sources of *Cryptosporidium* infection even if information regarding
85 the exact role of companion animals in the transmission of *Cryptosporidium* species is generally
86 insufficient especially in immunocompetent individuals. In Zambia, a number of studies have
87 reported *Cryptosporidium* infections in humans [28-30] but genotypes isolated from these are
88 not known.

89 Management of cryptosporidiosis is mainly supportive. There is no specific drug that is known to
90 eliminate the infection. However, nitazoxanide has been shown to have some clinical efficacy
91 against *Cryptosporidium* infection. It has been observed to reduce duration of diarrhoea and
92 oocyst shedding [29,31]. In HIV/AIDS patients, chemotherapy and antiretroviral therapy are
93 recommended in addition to supportive therapy. Personal hygiene and often hand washing in
94 this particular group (HIV/AIDS) and in general is paramount in preventing infection; and
95 immunocompromised patients should avoid coming into close contact with dog faeces [31-32].

96
97 In dogs, there are many reports of *C. canis* in many countries worldwide [33-35]. Despite the
98 many reports, there is no information on its presence in dogs in Zambia. Only one study is
99 known to have been conducted in domestic dogs to determine the occurrence of
100 *Cryptosporidium* spp and other parasites but no *Cryptosporidium* oocysts were detected in the
101 20 dogs that were tested [36]. The possibility of zoonotic transmission highlighted by some
102 studies (19-24), warrants epidemiological studies in Zambia to determine occurrence and
103 species of *Cryptosporidium* in dogs.

Comment [C20]: Only Ref. 19 relates to a "possible" dog-child transmission; in another the transmission was to an HIV infected person, not the rest 20-24.

Comment [C21]: Why all this paragraph when nothing is for sure? You definitely have a bias in writing this paper, therefore the outcome cannot be considered scientific and truly informative.

Comment [C22]: Contamination from infected humans or their feces are definitively more important than dog's. In that case the sentence should better read: "...contact with faeces, be it human or dog..."

105 There is no specific drug available for treatment of cryptosporidiosis in dogs, therefore
106 management is mainly supportive. Most infections are however, asymptomatic [37]; in cases
107 where it results in disease, infection is normally self-limiting in immune-competent hosts and
108 therefore resolves spontaneously [32]. In the absence of specific treatment, strict hygienic
109 measures are necessary to prevent spread of infection, especially that *Cryptosporidium* oocysts
110 are already infective when excreted in faeces and are highly resistant to chemical disinfection.
111 The hygienic measures may include daily removal and proper disposal of dog faeces from
112 kennels, home surroundings and play parks; steam cleaning and chemical disinfection (reduces
113 oocyst concentration) of kennels or dog shelters [38].

Comment [C23]: Are you talking about humans?
Immunocompetent dogs??

115 3. GIARDIA

116 *Giardia duodenalis* (synonyms *Giardia lamblia*, *Giardia intestinalis*) is a protozoan parasite that
117 infects the intestinal tract of many animal species including humans. Environmentally resistant
118 cysts are passed in the faeces of infected animals, and are immediately infective if ingested by
119 other susceptible hosts [39-40]. As such, *Giardia* species have been considered zoonotic
120 probably because morphologically similar organisms infect humans and a variety of mammals
121 and birds [41]. However, evidence of the exact role of animals in the transmission of giardiasis
122 is still limited.

Comment [C24]: Giardia from birds are
morphologically very different. There is no evidence
for human infection with Giardia of birds.

123 There are currently seven genotypic assemblages (assemblages A to F), which are distinct
124 evolutionary lineages, as defined by phylogenetic analysis and enzyme electrophoresis [42-43].
125 Assemblage A and B are considered to be predominantly for humans while C and D make up
126 the majority of isolates from dogs. Assemblage E is isolated from hooved animals. Cats are
127 hosts of Assemblage F while rats are hosts for Assemblage G [44-45]. Given the distribution of
128 the assemblages between different animal species and humans, the zoonotic transmission of
129 *Giardia* has been a topic of debate for a long time.

130

131 Dogs acquire *Giardia* infection via the faecal-oral route. They suffer minimal consequences of
132 the disease, except in young puppies that may develop complications of persistent infection,
133 impairment of growth and development. [39,46]. Even if dogs appear to harbour only the canine
134 oriented assemblage C and D as indicated by Hopkins et al. and Bowman [44-45], recent
135 studies have reported zoonotic forms in pet dogs. A study in the United States reported that
136 28% and 41% of client-owned dogs presenting with infection with *Giardia* to veterinary clinics in
137 the western United States had potentially zoonotic assemblages A and B, respectively, while
138 15% and 16% had host specific assemblages C and D, respectively [47]. Another study in
139 Thailand reported finding assemblages A (79%) and B (21%) in addition to the dog specific
140 assemblages C (12%) and D (31%) from the 104 dogs tested [48]. This data suggest the
141 possibility of the potential for transmission of non-canine-specific assemblages from owners to
142 their dogs as well as zoonotic transmission from dogs to humans.

143 There is very little information on *Giardia* in animals in Zambia. Only a single study by Asha et
144 al. [49] reported the presence of *G. duodenalis* and this was not in dogs but in the African
145 painted dog (*Lycaon pictus*) with both canine specific assemblages C and D as well as the
146 zoonotic assemblages A and B being reported. The zoonotic assemblages were more common
147 compared to the canine host specific C and D, suggesting that these two assemblages have the
148 potential for zoonotic transmission from the captive animals to humans due to close interaction.

149 One study in domestic animals reported *Giardia* prevalence of 5% in domestic dogs [36].
150 *Giardia* infection in dogs can be treated with fenbendazole. A combination of
151 febantel/pyrantel/praziquantel can also be used [38]. Shampooing of dogs with products
152 containing chlorhexidine digluconate at the beginning and the end of treatment, removal of dog
153 faeces and strict personal hygiene may assist in reducing transmission, hence infection and re-
154 infections in animals (and humans) [50].

Comment [C25]: ...and therefore, this particular region or area or whatever you may want to call it, was considered of epidemiologic importance in the transmission human-dog-human... or something like that.

Comment [C26]: Only in that specific area of temples in Thailand. Don't spread it all over.

Comment [C27]: Another study in domestic dogs? Animals? Which animals? In Zambia...

Comment [C28]: Not for *Giardia* specifically. This combination may be used in multiparasitized dogs.

Comment [C29]: (and humans) The purpose is to keep animals free of parasites.

156 In humans infection is acquired through faecal-oral route directly by person to person or animal
157 to person (though still unclear) or via contaminated water or food through ingestion. Humans
158 that acquire *Giardia* infections may develop intermittent diarrhoea which is normally associated
159 with chronic infections [51]. The many reports of possible zoonotic transmission of *Giardia* from
160 dogs to humans [47,52-54] stresses the need for further insight into the exact role of domestic
161 animals in the transmission of this parasite. Furthermore, the study by Traub et al. [48]
162 highlighted the possibility of zoonotic transmission of *Giardia* from dogs to humans and humans
163 to dogs which should seriously be considered.

Comment [C30]: By the ingestion of *Giardia* cysts....

164 As opposed to cryptosporidiosis, effective drugs are available for treatment of giardiasis. In
165 human infections, the drug of choice is metronidazole [55]. However, high re-infection rates
166 have been reported with *Giardia* infection especially in highly contaminated areas, which may
167 lead to failure to eliminate infection [55]. Because of the high re-infections rates, treatment
168 without clinical disease is thought to be of little benefit. It is suggested that treatment should be
169 accompanied by appropriate education programs designed to prevent faecal-oral transmission
170 and re-infections [50,56].

Comment [C31]: In this one place in Thailand only....

Comment [C32]: Spelling. ...for treatment of human giardiasis. In this paragraph, which I consider out of place since it deals with human giardiasis and has nothing to do with dogs, the author either shortens it using appropriate language and definitions, or eliminates it altogether.

171 4. *TRYPANOSOMA* SPECIES

172 In tsetse-infested sub-Saharan African countries, pathogenic protozoan trypanosome species
173 are commonly transmitted to a wide range of susceptible mammalian hosts, including dogs.
174 Transmission is through the intermediate host tsetse fly (*Glossina* spp.) bites when taking a
175 blood meal [57]. Dogs are specifically affected by *Trypanosoma evansi*, *Trypanosoma*
176 *congolense*, and *Trypanosoma brucei brucei* [58] causing Canine African Trypanosomosis
177 (CAT) with varying clinical presentation depending on species. In exotic breeds of dogs, *T.*
178 *brucei* subspecies tend to cause acute disease [12] while infections due to *T. congolense*
179 appear to be more chronic [12,59]. On the other hand, indigenous dog breeds appear to be
180 more trypanotolerant and do not exhibit any clinical signs [57]. These trypanotolerant dogs
181 therefore may act as a reservoir of infection for other animals as well as humans. Dogs that

182 harbour the human infective *T. brucei rhodesiense* and *T. brucei gambiense* and are usually
183 asymptomatic but may serve as a reservoir of infection for other dogs as well as humans [61-
184 61].

185 Although trypanosomosis is commonly reported in farm animals [62-63], Canine African
186 trypanosomosis (CAT) is less frequently reported [59,64]. However, recent studies have actually
187 indicated the significance of the trypanosome parasite in dogs. Affected animals that become
188 clinically ill exhibit clinical signs that may be severe, including lymphadenopathy, oedematous
189 forelimbs, distended abdomen, bilateral corneal opacity, conjunctivitis with mucopurulent
190 discharge, pyrexia, dyspnoea and evidence of anaemia [12,65] with death occurring in some
191 cases.

192 In Zambia, the first case of *rhodesiense* Human African Trypanosomiasis (rHAT) was reported
193 in 1910 by Stephens and Fantham [66] in the then northern Rhodesia. Since then, a number of
194 cases have been reported; some documented [67-69] while others are not. Mwanakasale et al.
195 [68] reported two cases of rHAT in two teenagers that had presented with different clinical
196 symptoms (atypical chronic, mild form and typical acute and severe form) and highlighted the
197 possibility of the existence of two strains of *T. b. rhodesiense* in Zambia. Most of the cases of
198 rHAT in Zambia have been related to some national parks in the eastern and northern parts of
199 the country [69]. At risk are people that cohabit with wildlife in game management areas and
200 tourists that visit national parks. With the available data indicating the presence of the infection
201 in humans and the occurrence of the human infective parasites in “man’s best friend” [12,70],
202 mechanisms to prevent transmission of trypanosomes in both animals and humans are
203 necessary and cannot be over emphasized. Vector control is the most important aspect in
204 preventing *T. rhodesiense* infections. In addition, awareness campaigns and health education
205 activities must be carried out to have well informed communities and prevent infection in
206 humans [58].

207

Comment [C33]: Was there any indication that the dog was the reservoir?

208 5. HELMINTHS

209 Some helminths impede the successful rearing of dogs if puppies are not treated promptly. The
210 outcome of infection is lowered resistance to infectious diseases, retarded growth, reduced
211 work/activity and feed efficiency and general ill-health [71]. Parasitized animals show a variety
212 of symptoms, depending on the parasite species and density. These signs are attributable to
213 intestinal obstruction, irritation, mal-digestion, malabsorption blood loss and protein losing
214 enteropathies [72]. Some of these helminths are of public health importance as zoonotic
215 transmission can occur.

216 5.1 *Toxocara canis*

217 *Toxocara canis*, a cause of toxocariasis, is a common roundworm of dogs and infection occurs
218 transplacentally, transmammary and through ingestion of an infected paratenic host such as
219 mice, rabbits and slugs containing *T. canis* encysted larvae. Infection may also occur through
220 ingestion of embryonated eggs containing the infective second stage larvae (L2) from the
221 environment [71,73-74]. *Toxocara canis* infection is most severe in young puppies and less
222 commonly seen in dogs more than one year of age. Puppies may present with ill thrift, failure to
223 gain weight, a poor hair coat and a pot-bellied appearance. Severe infections in neonatal
224 puppies can result in acute death as a result of large numbers of larvae migrating en route to
225 the small intestine [45]. It is important that puppies are treated early to prevent infections.
226 Pyrantel pamoate is recommended for puppies aged two weeks while a combination of febantel,
227 praziquantel and pyrantel pamoate is advised for puppies older than three weeks [45]. Pregnant
228 bitches should be treated to prevent transplacental and transmammary transmission of *T. canis*
229 larvae to puppies; and nursing dams should be treated at the same time as the puppies (45).
230
231 In humans, toxocariasis is considered one of the most common zoonotic infections especially in
232 disadvantaged communities; and has been reported worldwide [75-77]. Humans get infected by
233 accidentally ingesting embryonated *Toxocara* eggs through soil contaminated with *Toxocara*

Comment [C34]: Human toxocariasis?

Comment [C35]: very rarely, slugs....

Comment [C36]: And their establishment in

Comment [C37]: Not to prevent only, but to get rid of the infection and avoid eggs of *T. canis* be spread in the environment.

Comment [C38]: Is? In?

234 eggs. In rare cases, infection has also been reported to occur by eating undercooked or raw
 235 meat from paratenic hosts containing encapsulated *T. canis* larvae [78].

236 Infection in humans causes larva migrans syndromes (visceral and ocular larva migrans) and
 237 covert toxocariasis [79-80]. Initially only visceral and ocular larval migrans were reported but it is
 238 now known that a syndrome known as covert toxocariasis, characterised by abdominal pain,
 239 coughing, wheezing, eosinophilia does occur in humans [79,81]. Central nervous system
 240 involvement has also been reported which results in neurotoxocariasis. This may present with
 241 seizures, mental retardation and developmental delays [82]. Although most human infections
 242 are usually asymptomatic, some individuals may develop systemic disease (characterized by
 243 fever, lymphadenopathy, coughing, wheezing and eosinophilia) or localised symptoms confined
 244 to the eye resulting in blindness [83]. The severity and type of disease in humans depend on
 245 how many larvae are ingested or number of migrating larvae, the frequency of re-infection, and
 246 the age of the host [75,83].

247 In Zambia, *T. canis* has been reported in domestic dogs several times [5, 84-85] with varying
 248 prevalence; 7.6%, 14% and 4.8%, respectively. However, it is not known whether human
 249 infections are there because there are no reports or documentation available. Nevertheless,
 250 there are reports of *Toxocara* infections in humans in some southern African countries.

251 Recently, Liao et al. [77] reported a 44.6% seroprevalence of *T. canis* in children in Swaziland,
 252 highlighting the occurrence of zoonotic infection. Presence of a dog in a household has been
 253 reported as the most important risk factor associated with human toxocariasis. The increased
 254 urbanization in Zambia has come with an increase in the keeping of dogs for both security and
 255 as pets, which may come with a risk of possible zoonotic transmission of *Toxocara* and other
 256 helminths if preventive measures are not put in place [6]. Apart from having a dog in the
 257 household, geophagy is also an important factor that can significantly contribute to infection in
 258 humans especially in heavily contaminated areas [86]. Periodic deworming of dogs and proper

Comment [C39]: Localized? I looked this up and this is the right spelling in English anywhere.

Comment [C40]: What Despommiers writes:...visual unilateral impairment, that is sometimes accompanied by strabismus. The most serious consequence of the infection is the invasion of the retina, leading to granuloma formation. ...distopia, heteropia, detachment of the macula, endophthalmitis, papillitis... It continues and mentions the macula and is careful to state that visual acuity impairment depends on the specific area involved, etc. But you go straight to blindness....If I am a doctor or a veterinarian I would be more interested in the nature of the localized symptoms

259 disposal of dog faeces, hand washing to prevent faecal-oral transmission, improved sanitation
260 and access to clean water may help in preventing human infections with this parasite [45,87].

261 5.2 *Ancylostoma caninum*

262 Infections with *A. caninum* remain common in dogs, with the high prevalences being reported
263 world-wide [85,88-90]. Dogs acquire the infection through skin penetration at hair follicles or
264 sweat glands, especially between the footpads where contact with soil is frequent; and through
265 direct ingestion of the larvae. Clinical consequences include unthriftiness and chronic anaemia
266 (which can be fatal in young puppies) in debilitated and malnourished animals; [67]. Anorexia,
267 weakness and emaciation usually accompany chronic disease. Diarrhoea with dark, tarry faeces
268 is seen in severe infections. Mature, well-nourished dogs are usually asymptomatic but act as a
269 direct or indirect source of infection for puppies [45]. Development of clinical disease depends
270 on the magnitude of the challenge and host factors.

271

272 Humans acquire *A. caninum* infection through contact with moist/wet sand soil containing
273 filariform larvae from the faeces of dogs. This usually occurs in areas where there is heavy soil
274 contamination such as densely populated areas with unsecured or free roaming dogs. Larval
275 invasion of skin in humans produces pruritic papules [91]. Zoonotic infection with *A. caninum*
276 may also occur through ingestion of the larvae in soil or in tissues of paratenic hosts. This may
277 result in enteric disease known as eosinophilic enteritis [88,92]. Skin penetration by larvae may
278 also lead to cutaneous larval migrans (CLM) which may cause pruritus and creeping eruptions
279 which may persist for several months [93-94].

280 *Ancylostoma caninum* infections are common in dogs in Zambia [84-85]. Islam and Chizyuka
281 [84] reported a prevalence of 8% in Lusaka district, and years later Bwalya et al. [85] reported a
282 prevalence of 72.9% and 70.6% in dogs from Lusaka and katete districts, respectively. The
283 amount of disease in people is unknown and this could be due to the fact that infections are
284 either not documented or are not there. However, human infections with *A. caninum* have been

Comment [C41]: Katete with capital letter?

Comment [C42]: Imagine: so high prevalence and not one local publication of human larva migrans cutanea...

285 reported elsewhere [92]. *Ancylostoma braziliense* is reported to be more frequently involved in
286 CLM than *A. caninum* but *A. caninum* is also an important cause [94]. Periodic deworming of
287 dogs with drugs such as pyrantel pamoate, febantel, fenbendazole helps to prevent infections
288 and reduces environmental contamination by the hookworm eggs [45,87].

289 5.3 *Dipylidium caninum*

290 *Dipylidium caninum* is a zoonotic tapeworm infection which is acquired from dogs when a
291 person accidentally ingests a flea carrying the larval stage of the tapeworm. Infection is
292 especially common in young children (< six months) who exhibit symptoms of diarrhoea and
293 pruritus [95-97]. Infection has a characteristic feature of passage of proglottids in faeces in both
294 dogs and infected children [95]. Additionally, dogs tend to scoot to relieve the anal pruritus
295 associated with the infection [98].
296 In infected dogs, praziquatel is the recommended drug for eliminating of infection
297 [45]. Controlling the fleas (which are carriers of the infective stage of the tapeworm) on the
298 animals would help prevent infections in both dogs and humans.

299 A number of studies have reported the presence of *D. caninum* in dogs in various districts in
300 Zambia [5,84-85] with varying prevalence, 2.2%, 25% and 3.8%, respectively. Even if human
301 infections are rare, the reported infections especially those occurring in infants [96] are of
302 concern and should stimulate inquiry especially in areas where infections are endemic in dogs.
303 Epidemiological studies are needed to determine the risk *D. caninum* dog infections pose to
304 humans in Zambia.

305 5.4 *Echinococcus* species

306 *Echinococcus* species are parasitic cestodes that affect a number of animal species.
307 *Echinococcus ganulosus* and *E. multilocularis* are of veterinary and public health importance
308 [99]. Although the geographical distribution of *E. granulosus* is considered worldwide, it is higher
309 especially in areas (for example central Asia, China, South America, Northern Africa, Australia,
310 Kenya) where livestock (Ssheep and cattle) are the major intermediate hosts [100,101].

Comment [C43]: Especially common? From time to time?
"The symptoms evoked in children, who are seldom infected with more than a single worm, are mild and consist of slight intestinal disturbances, including indigestion and loss of appetite. Proglottids migrating from the anus of a child frequently cause anxiety in the parents". Beaver PC, Jung R, Cupp E. Clinical Parasitology, Lea & Febiger, 1984.
Reid CJD et al said:... rarely in children, when the infection may be unrecognized or misdiagnosed"...
Molina CP et al said:... few reported cases of human infection...
I find the term "especially common" not quite correct and trustful. Because it is rare or uncommon that a case is published.

311 Different strains of *E. granulosus* exist, but *E. granulosus* "sheep" strain (G I) is generally
312 considered as the most widespread strain worldwide and is endemic in Africa [45,102]. It is the
313 common cause of cystic echinococcosis (~~H~~hydatidosis or hydatid disease) in humans [103-104].
314
315 In dogs, *E. granulosus* infection is transmitted through ingestion of food contaminated with
316 hydatid cysts while scavenging or when fed infected offals (liver and lung) from domestic
317 animals such as ruminants [105] (<http://www.oie.int/doc/ged/D13941.PDF>). The disease in dogs
318 causes very minimal effects and is usually asymptomatic. In Zambia, *E. granulosus* has been
319 reported in domestic cattle [106-107], an indication that the parasite maybe present in most
320 villages/areas in Zambia where livestock rearing is common. Pandey and Sharma [108] and
321 Banda et al. [107] reported presence of hydatidosis in cattle from abattoirs in Lusaka and
322 Western provinces, respectively. There is however, very little information available on
323 echinococcosis in dogs. Only two studies have reported the presence of *E. granulosus* in dogs
324 [5,84], with one study reporting a prevalence of 1% [84].
325
326 *Echinococcus* infection in humans occurs as a result of infection by the larval stages of *E.*
327 *granulosus*, resulting in hydatid disease. Infection occurs through accidental ingestion of eggs
328 [109]. The symptoms and severity of the disease depend on the organ(s) involved, the size,
329 mass and numbers of cysts or metacestode and the location where the cyst develops; immune
330 status of the host, complications related to cyst rupture, spread of protoscoleces, and secondary
331 bacterial infection. The cysts are usually slow growing such that even if infection is acquired
332 early in life, symptoms only manifest in adult patients (except in infection of the brain where
333 symptoms may be seen in children). Additionally, the cyst usually has a layer of fibrous tissue
334 around it and so may only produce symptoms when it has reached a size that exerts pressure
335 on adjacent organs [110]. The liver is the most common site for *Echinococcus* cyst development
336 followed by the lungs and less frequently the spleen, kidneys, heart, bone and brain [110]. Cysts

337 in the liver cause hepatic enlargement, right epigastric pain, nausea, and vomiting with
338 complications of jaundice, fever, portal hypertension and cholangitis [110-112]. Lung
339 involvement presents with respiratory symptoms such as chronic cough, dyspnoea,
340 haemoptysis, pneumothorax, pleuritis, lung abscess, eosinophilic pneumonitis [113].

341

342 In Zambia, only one study was conducted on *Echinococcus* infection in humans [114]. The
343 authors reported a prevalence of 0.009%. These reports of *Echinococcus* infections in dogs in
344 Zambia [5, 84], though few, are important because of the role dogs play in human infection
345 especially in rural communities where there is close contact with dogs as well as in other risk
346 groups which include animal handlers, veterinarians, and dog owners [113]. Dogs shed eggs in
347 the environment which can easily contaminate fruits, vegetables or water, or can stick to the fur
348 of dog. The eggs can be transferred from the dog to hands and to the mouth. Well planned
349 regular deworming, avoiding feeding dogs uncooked offals (and sanitary disposal of
350 slaughterhouse waste to prevent access by dogs) and destruction of stray dogs in areas of
351 heavy transmission will help prevent environmental contamination and hence further infections
352 in both dogs and humans. Additionally, community public health education to create awareness
353 on the transmission mode and dangers of the infection is a key prevention measure [102].

354 6. CONCLUSION

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

Comment [C44]: A wrong expression. Please correct.

Comment [C45]: What do you mean? Are dogs not domestic?

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

367 **ETHICAL APPROVAL**

368 Not applicable

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