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ORIGINAL RESEARCH ARTICLE

Spatial Distribution of Geohelminths in Awe and Nassarawa Eggon Local Government Areas of Nasarawa State, Nigeria

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ABSTRACT

Helminth infections impose a great burden on poor populations in the developing world. This study investigated the spatial distribution and prevalence of geoheliminths from two hundred and eighty-eight (288) soil samples collected from Awe and Nassarawa Eggon Local Governments Areas (LGAs) of Nasarawa state, Nigeria. The result of this finding showed a predominance of Helminth species over other parasites group *Strongyloides stercoralis* was found to be the most prevalent species (41.61%) accompanied by hookworm species (33.21%) and *Ascaris lumbricoides* (10.22%). The least prevalent species, with 0.36%, were *Giardia* species, *Platyosomum fastosum,* and *Trichuris trichiura* ($p< 0.0001$). The study also recorded more geohelminths parasites occurring at shallow soil dept (56.93%) than in the deeper soil (43.07%), although their abundance with respect to soil depth was statistically the same (χ^2=1.921, df = 1, P= 0.1657). The occurrence of soil-transmitted helminths and other parasites was highest in the market's environment 99(36.13%), followed by the school's environment 90(32.85%), and the least was dumpsites 85(31.02%). However, there no significant variation statistically in the distribution of parasites with respect to collection sites (χ^2 = 0.40219, df = 2, P = 0.8178). The study found a significant difference (χ^2=52.83, df = 2, $p< 0.0001$). In the prevalence of parasites in relation to their developmental stages, with larval forms 161 (58.76%) being the most dominant, followed by the ova with 111(40.51%) occurrence rate and the least in the adult parasite forms with 0.73% prevalence rate. The comparison of the prevalence of geohelminths between the two LGAs revealed a higher (54.38%) occurrence of parasites in Nassarawa Eggon LGA than in Awe LGA (45.62%) with no statistical variation (χ^2= 0.76738, df = 1, p= 0.381). The helminths and protozoan groups observed in this study are an indication that the residents of these areas are at risk of infection with geohelminths. The results can inform public health strategies and interventions to mitigate the risk of parasitic infections in the study areas. The study's findings also suggest a further study to understand the factors contributing to the high prevalence of geohelminths in the study areas so as to develop effective control measures.

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INTRODUCTION

Helminth infections impose a great burden on poor populations in the developing world (WHO, 2023). It comprises *Ascaris lumbricoides, Trichuris trichiura*, the hookworms (*Ancylostoma duodenale* and *Necator americanus*), and *Strongyloides stercoralis*, which are the cause of helminthiases known as the leading Neglected Tropical Diseases (NTDs) prevalent in the tropics and sub-tropics. Recent worldwide estimates suggest that *A. lumbricoides* infects 1.221 billion people, *T. trichiura* 795 million, and hookworms 740 million. The greatest numbers of STH infections occur in the Americas, China and East Asia, and Sub-Saharan Africa. *Strongyloides stercoralis* is also a commonly Soil-Transmitted Helminth in some of these regions, although detailed information on the prevalence of strongyloidiasis is lacking because of the difficulties in diagnosing human infection. The life cycles of *Ascaris, Trichuris*, and hookworm follow a general pattern. The adult parasite stages inhabit the gastrointestinal tract (*Ascaris* and hookworm in the small intestine; *Trichuris* in the colon), reproduce sexually, and produce eggs, which are passed in human feces and deposited in the external environment (CDC, 2019; CDC, 2024).

Several factors, such as environment, food habits, cultural tradition, social status, economic situations, and others, determine the distribution of parasitic infections. Each parasite has its own natural and social habitat, and a favourable environment is a prerequisite for its

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transmission (Tigabu *et al.* 2019). Most activities with respect to STH-mapping have been attempted in African countries (Pullan *et al.*, 2014). At the global level, it is estimated that intestinal parasite infections affect more than one-third of the world's population, with the highest rates in school-age children. Stunting usually occurs between 6 months and 2 years of age, which overlaps with the period in which the soil-transmitted helminths begin to emerge. STH has been documented as causing impairment of growth and nutrition. The hookworms damage the intestinal mucosa, leading to bleeding, loss of iron, and anemia. Infections by *Trichuris trichiura* produce a chronic reduction of food intake. During pregnancy, mild or severe infections with hookworms can cause anemia to the mother and damage to the fetus, leading to low birth weight. In areas where helminths are common, deworming activities can be done once or twice per year to the population at risk (without access to improved sanitation facilities), including deworming for pregnant women after the first trimester. Deworming during pregnancy has also been found useful in reducing severe maternal anemia, increasing birth weight, and reducing infant mortality (WHO, 2011).

The most striking epidemiological features of human helminth infections are aggregated distributions in human communities, predisposition of individuals to heavy (or light) infection, rapid re-infection following chemotherapy, and age-intensity profiles that are typically convex (with the exception of hookworms). As a rule, 20 percent of the host population harbors approximately 80 percent of the worm population. This over-dispersion has many consequences, both with regard to the population biology of the helminths and the public health consequence for the host, because heavily infected individuals are simultaneously at the highest risk of disease and constitute the major source of environmental contamination. One feature that may help explain over-dispersion is that individuals tend to be predisposed to heavy (or light) infections (Oladejo *et al.*, 2014).

Spatial patterns can be perceived, and correlations visualized through the use of maps, symbols, and colours can communicate detail or the relative importance of certain features (Oladejo *et al.*, 2014). For the geographical distribution of neglected tropical diseases to be understood necessary to understand the distribution of each of the diseases, to identify areas with overlapping, and to focalize areas for integrated interventions (preventive chemotherapy, health education, water and sanitation, etc.) (WHO, 2011).

MATERIALS AND METHODS

Study Area

The study was conducted within selected areas of Awe local government Area of Nasarawa State, Nigeria. Awe is a Local Government Area in Nasarawa State, Nigeria. Its headquarters is the town of Awe, and the LGA is made up of several towns, which include Azara, Kanje, Mahanga, Ribi, Wuse, Kekura, Baure, Tsohon gari, Bajinba, Tunga. It has an area of 2,800km^2 and 1,100 square meters. The town is 286.8km from Abuja, the nation's Federal Capital Territory, and 95.5km from Lafia, the Nasarawa State Capital. Awe is located latitude 8°6'36.53"N and a longitude of 9°8'34.25"E, respectively. Awe has a population of 116,080 (2005 estimates) and a density of 110/sqm/41/km^2. From North to South of Awe, runs the river called Baking Abu that provides water for drinking, washing and the outlet of some marshy places for rice farming. Awe and Lafia also experience a rainy season that lasts from April to October and a dry season from November to March yearly.

Nassarawa Eggon Local Government Area (LGA) is situated in Nasarawa state, North-central geopolitical zone of Nigeria. The town is 163.2km from Abuja, the nation's Federal Capital Territory, and 29.2km from Lafia, the Nasarawa State Capital. The headquarters of the LGA is the town of Nassarawa Eggon, and the LGA is made up of several towns, districts, and villages, which include Kagbu, Alongam, Mada station, Umme, Agunji, Ogba, Wogan, and Arikpa. Members of the Eggon tribe mostly populate the area. Nassarawa Eggon LGA has an area of 1,208 km^2 and a population of 149,129 at the 2006 census and has an average temperature of 30^0 degrees centigrade. The LGA hosts a number of hills and elevations, such as the popular Eggon Hills, which is a major tourist attraction in the area. The total precipitation in Nassarawa Eggon LGA is at 1340 mm of rainfall per annum. The postal code of the area is 960.

Sample Collection

Soil samples were purposively collected from markets, schools, and dumpsites due to the high likelihood of human and animal activity contributing to soil contamination, making these sites critical for understanding geohelminth prevalence. Soil samples were collected after ensuring the absence of recent rainfall to maintain consistency in soil moisture content. Strict protocols were followed to avoid cross-contamination, with tools disinfected between each collection. The samples taken were put into a plastic bag, closed, and labeled by names and numbers, then it was transferred to the Zoology laboratory of the Federal University of Lafia and the Microbiology laboratory of Isa Mustapha Agwei Polytechnic Lafia in Nasarawa State for analysis. The analysis was conducted using the Sedimentation method, Baermann Funnel Techniques (principles), and Centrifugal method.

Sample Analysis

Baermann Funnel Examination of Soil Sample

The Baermann Funnel technique was chosen for its high sensitivity in detecting larvae, particularly of *Strongyloides stercoralis*. However, it may under-represent ova due to the need for them to hatch into larvae before detection, a limitation mitigated by also employing the centrifugal method. Drops of water were collected slowly from the bottom of the tube by slowly releasing the clamp of the tubing using a test tube (Amadi *et al*., 2020). The mixtures were allowed to sediment for 10 to 15 minutes and the supernatant was discarded. A drop of deposit was placed on a binocular microscope glass slide covered with a cover slip and viewed to detect worms, cysts, eggs, and larvae of soil parasites using X10, X40, and X100 objectives lenses of the microscope (Amadi *et al*., 2020).

Concentration Technique of Soil Samples

About 3g of soil sample was emulsified in about 7 ml of distilled water contained in a screw bottle using an applicator stick. The emulsified sample was sieved, and its suspension was collected in a beaker. The suspension was then transferred into a plastic centrifuge tube and about 3ml of diethyl ether was added into the tube. The tube was vigorously shaken for 1 minute and then centrifuged immediately at 3000rpm for another 1 minute. An applicator stick was used to loosen the layer of the soil debris for the slide of the tube, and the supernatant (containing ether and dissolved soil debris with water) was poured away, leaving only the sediments. The deposit was re-suspended by tapping the bottom of the tube with the finger, after which it was transferred to a slide using a pasture pipette. The slide was covered with a clean grass-free cover slip and examined under X10, X40, and X100 objectives lenses of a microscope for the detection of worms, cysts, eggs, and larvae (see Appendix) of soil geohlminths (Amadi *et al*., 2020).

Identification of the Parasite

The parasite was identified using an identification key by practical guidance for clinical microbiology, epidemiology, diagnosis, and control of Helminth parasites of swine and the Helminth handbook for identification and counting of parasitic helminth eggs in urban wastewater (Garcia, 2016).

Data Analysis

Data obtained were analyzed using R-console software (Version 4.0.2). Chi-square test was used to determine the association of frequency of infection occurrence of geohelminths. P values <0.05 were considered statistically significant.

RESULTS

Composition of Geohelminths and other parasite species in two selected areas

Table 1 presents the checklist of geohelminths found in the different collection sites within Awe and Nassarawa Eggon LGAs of Nasarawa State. The study predominantly noted parasites of the helminths group and a few protozoan groups, including *Ascaris lumbricoides*, *Bayliscaris* species, *Enterobius vermicularis*, Hookworm, *Platyosomum fastosum*, *Spirometra* species, *Strongyloides stercolaris*, *Trichuris trichiura*, *Toxocara canis*; while the protozoan group recorded only *Entamoeba* species and *Giardia* species. However, *Platyosomum fastosum* and *Trichuris trichiura* were only recorded in Nassarawa Eggon Local Government Area. On the other hand, *Giardia lamblia* was recorded in Awe Local Government Area, Nasarawa State.

Prevalence of Geohelminths and Other Parasites in Relation to Soil Depths

The prevalence of geohelminths and other parasites in relation to the soil depths revealed a relatively higher (56.93%) parasite in the shallow soil depth than in the deeper soil (43.07%), as shown in Table 2. However, there was no statistically significant difference (χ^2=1.921, df = 1, P= 0.1657) in the prevalence of parasites in relation to soil depths in the two study areas. In Awe Local Government Area, the deeper soil recorded a relatively lower parasite occurrence 56(44.80%) than in the shallow soil depth 69(52.20%). Yet, there was no statistically significant variation (χ^2=0.56454, df = 1, P= 0.4524) in the prevalence of geohelminths in relation to soil depths in the Awe Local Government Area.

A higher 87(58.39%) occurrence of parasites was recorded for shallow soil depths than the deeper soil depths 62(41.61%) in Nassarawa Eggon Local Government Area. However, the difference in the occurrence of parasites in relation to the soil depths was not statistically significant (χ^2=2.8157, df = 1, P= 0.09335).

Occurrence of Geohelminths and other parasites in relation to Sources/Points of Collection

The occurrence of soil-transmitted helminths and other parasites was highest in the markets 99(36.13%), followed by the occurrence in Schools 90(32.85%), and the least was dumpsite 85(31.02%), as shown in Table 3. However, the variation in the occurrence of geohelminths and other parasites in relation to the sources/points of soil collection was not significant (χ^2 = 0.40219, df = 2, P = 0.8178).

Determination of the Prevalence of Geohelminth Parasites in Relation to their Developmental Stage

From both Local Government Areas, the prevalence of geohelminths and other parasites in relation to their developmental stages suggested that the larval form was the most dominant 161 (58.76%), followed by the ova with 111(40.51%) occurrence rate. While the least was recorded in the adult parasite forms with (0.73%) prevalence rate (Table 4). Thus, there was a statistically significant difference (χ^2=52.83, df = 2, p< 0.0001) in the prevalence of parasites in relation to their developmental stages in the two study areas.

In Awe Local Government Area, larval forms also recorded the highest proportion, 71(58.40%) of the parasite prevalence, followed by ova 52(41.60%)while the least dominant was the adult stage 2(1.6%) as shown in Table 4. Therefore, the variation in the prevalence of parasites in Awe LGA in relation to developmental stages also showed a statistically significant difference (χ^2=50.28, df = 2, p< 0.0001).

Table 1: species composition of Geohelminths and other parasite Species in the Study Area

Group/Category	Parasites	Awe	Nassarawa Eggon
Geohelminths			
	Ascaris lumbricoides	+	+
	Bayliscaris species	+	+
	Enterobius vermicularis	+	+
	Hookworm species	+	+
	Platyosomum fastosum	-	+
	Spirometra species	+	+
	Strongyloides stercolaris	+	+
	Trichuris trichiura	-	+
	Toxocara canis	+	+
Protozoan			
	Entamoeba Species	+	+
	Giardia lamblia	+	-

Table 4 shows that the prevalence of geohelminth and associated parasites in relation to their developmental stages in Nassarawa Eggon Local Government Area revealed that the larval stage had the highest prevalence 90(60.40%), and this was accompanied by the ova stage 59(39.60%) and no adult stage was recorded. Hence, the proportion between developmental stages of the parasites in Nassarawa Eggon Local Government Area showed a statistically significant difference (χ^2=56.49, df = 2, p< 0.0001).

Comparison of the Prevalence of Geohelminths between Awe Local Government Area and Nassarawa Eggon Local Government Area

The prevalence of geohelminths in relation to the parasite species indicated the highest prevalence (41.61%) in *Strongyloides stercolaris*; this is accompanied by Hookworm (33.21%) and *Ascaris lumbricoides* (10.22%). The least prevalence was recorded in *Giardia* species, *Platyosomum fastosum*, and *Trichuris trichiura*, with a prevalence rate of 0.36% each. However, the variation in the prevalence of geohelminths in relation to parasite species showed a very high significance difference (χ^2 = 244.82, df = 11, p < 0.0001, Table 5).

The comparison of the prevalence of geohelminths between Awe Local Government Area and Nassarawa Eggon Local Government Area revealed a higher (54.38%) occurrence of parasites in Nassarawa Eggon than in Awe Local Government Area (45.62%). Therefore, the prevalence of parasites in relation to the study areas was the same (χ^2 = 0.76738, df = 1, p = 0.381, Table 5).

Table 2: Prevalence of Geohelminths and other Parasites in Relation to Soil Depths in the two sites

Parasites	Awe		Nassarawa Eggon		OSS	ODS	Total (%)
	SS	DS	SS	DS			
Ascaris lumbricoides	7	3	11	7	18	10	28(10.22)
Bayliscaris species	2	3	2	3	4	6	10(3.62)
Entamoeba species	4	6	4	0	8	6	14(5.10)
Enterobius vermicularis	2	0	2	0	4	0	4(1.45)
Giardia species	1	0	0	0	1	0	1(0.36)
Hookworm species	20	22	25	24	45	46	91(33.2)
Platyosomum fastosum	0	0	1	0	1	0	1(0.36)
Spirometra species	0	1	2	3	2	4	6(2.18)
Strongyloides stercolaris	31	21	40	22	71	43	114(41.60)
Trichuris trichiura	0	0	0	1	0	1	1(0.36)
Toxocara canis	2	0	0	2	2	2	4(1.45)
Total (%)	**69** (52.20)	**56** (44.80)	**87** (58.39)	**62** (41.61)	**156** (56.93)	**118** (43.07)	**274** (100.00)

Key: SS: Shallow Soil; DS: Deeper Soil; OSS: Overall Shallow Soil; ODS: Overall Deeper Soil
Overall prevalence of parasites in relation to soil depths: χ^2=1.921, df = 1, p>0.05
Prevalence of parasites in relation to soil depths in Awe LGA: χ^2=0.56454, df = 1, p>0.05
Prevalence of parasites in relation to soil depths in Nassarawa Eggon LGA: χ^2=2.8157, df = 1, p>0.05

Table 3: Occurrence of Geohelminths and other parasites in relation to the study sites

Study Site	Parasite occurrence (%)		Total (%)
	Awe	Nassarawa Eggon	
Dump Site	42 (33.60)	43 (28.86)	85 (31.02)
Schools	42 (33.60)	48 (32.21)	90 (32.85)
Markets	41 (32.80)	58 (38.93)	99 (36.13)
Total	125 (100.00)	149 (100.00)	274 (100.00)

χ^2=0.40219, df = 2, p>0.05

Table 4: Determination of the Prevalence of Geohelminth Parasites in Relation to their Developmental Stage in the two sites

Parasites	Awe			Nassarawa Eggon			Total (%)		
	Ova	Larva	Adult	Ova	Larva	Adult	Ova	Larva	Adult
Ascaris lumbricoides	1	9	0	5	13	0	6	22	0
Bayliscaris species	5	0	0	5	0	0	10	0	0
Entamoeba species	10	0	0	4	0	0	14	0	0
Enterobius vermicularis	2	0	0	0	2	0	2	2	0
Giardia lamblia	1	0	0	0	0	0	1	0	0
Hookworm species	30	12	0	33	16	0	63	28	0
Platyosomum fastosum	0	0	0	1	0	0	1	0	0
Spirometra species	1	0	0	5	0	0	6	0	0
Strongyloide stercolaris	0	50	2	3	59	0	3	109	2
Trichuris trichiura	0	0	0	1	0	0	1	0	0
Toxocara canis	2	0	0	2	0	0	4	0	0
Total	**52**	**71**	**2**	**59**	**90**	**0**	**111**	**161**	**2**
(%)	**(41.60)**	**(56.80)**	**(1.60)**	**(39.60)**	**(60.40)**	**(0.00)**	**(40.1)**	**(58.76)**	**(0.73)**

Comparison of the overall prevalence of parasites in relation to developmental stages:χ^2=52.83, df = 2, p< 0.0001
Prevalence of parasite developmental stages in Awe LGA: χ^2=50.28, df = 2, p< 0.0001
Prevalence of parasite developmental stages in Nassarawa Eggon LGA: χ^2=56.49, df = 2, p< 0.0001

Table 5: Comparison of the Prevalence of Geohelminths between Awe LGA and Nassarawa Eggon LGA

Parasites	Occurrence (%)		Total parasite occurrence	Percentage (%)
	Awe	Nassarawa Eggon		
Ascaris lumbricoides	10 (35.71)	18 (64.29)	28	10.22
Bayliscaris species	5 (50.00)	5 (50.00)	10	3.65
Entamoeba species	10 (71.43)	4 (28.57)	14	5.12
Enterobius vermicularis	2 (50.00)	2 (50.00)	4	1.46
Giardia species	1 (100.00)	0 (0.00)	1	0.36
Hookworm species	42 (46.15)	49 (53.8)	91	33.21
Platyosomum fastosum	0 (0.00)	1 (100.0)	1	0.36
Spirometra species	1 (16.67)	5 (83.33)	6	2.19
Strongyloides stercolaris	52 (45.61)	62 (54.39	114	41.61
Trichuris trichiura	0 (0.00)	1 (100.00)	1	0.36
Toxocara canis	2 (50.00)	2 (50.00)	4	1.46
Total	**125** (45.62)	**149**(54.38)	**274**	**100**

Comparison of prevalence between Geohelminth species: χ^2= 244.82, df = 11, P< 0.0001
Comparison of prevalence between locations: χ^2= 0.76738, df = 1, P= 0.381

DISCUSSION

Soil-transmitted parasites are the large group of parasites that live in the soil during their development (WHO, 2023). Contamination of soil with parasite eggs, infective larvae, cysts, and oocysts constitutes the most important risk factor for zoonotic parasite infection. Geohelminths pose great threats to the well-being of the human population. The presence of parasites like *Ascaris limbricoides, Bayliscaris species, Enterobius vermicularis*, Hookworm, *Platyosomum fastosum*, *Spirometra* species, *Strongyloides stercoralis*, *Trichuris trichuria*, *Toxocaracanis*; *Entamoeba histolytica* and *Giardia* species poses a significant public and veterinary health risk to the residents and animals in Awe and Nassarawa Eggon Local Government Areas of Nasarawa State. The current study identifies the soil as the main environmental reservoir for geohelminth parasites. Parasite contamination in soils with geohelminth eggs is not only distinct to this study, but it has been reported globally (Kafle *et al.*, 2014; Obaid, 2019; and Fessehaye *et al.*, 2022), especially in Africa and specifically Nigeria (Umar and Bassey, 2010; Arosoye *et al.*, 2021; and Imalele *et al*., 2023). The observation of *Ascaris lumbricoides*, hookworm, *Trichuris trichuria,* and *Strongyloides stercolaris* tallies with the findings of Nkouayep *et al.* (2017) who surveyed the profile of geohelminth eggs, cysts, and oocysts of protozoans contaminating the soils of ten primary schools in Dschang, West Cameroon. This observation is also in tandem with a recent report by Imalele *et al.* (2023) on environmental contamination by soil-transmitted helminths ova and subsequent infection in school-age children in Calabar, Cross River State, Nigeria. A Preliminary Survey of Soil-Transmitted Helminths in Some Selected Primary Schools in Okitipupa Local Government Area, Ondo State, South West Nigeriaby Arosoye *et al.* (2021) also aligns with the current studies. The parasites above have been described to be almost ubiquitous as they inhabit many environments while resisting environmental challenges with the aid of their biochemically equipped cysts. This finding is, however, in contrast with reports by Tavalla *et al.* (2012), who evaluated the prevalence of parasites in soil samples in Tehran public Places and reported quite dissimilar parasite species. The record of *Toxocaracanis* may implicate the populace of the areas to zoonotic disease incidence or outbreak, as opined by Mahartina *et al.* (2020), who understudied the identification and distribution of soil-transmitted helminths around the Shed and Grazing Fields of Madura Cattle in Sub-District of Geger, Bangkalan Regency. The presence of *Giardia* species and *Entamoeba* species may predispose the residents to foodborne diseases like giardiasis and amoebiasis/amoebic dysentery. Studies by Kafle *et al.* (2014) reported giardia species as the most common protozoan parasite in soil examination studies, hence aligning with the current finding.

The lack of variation in the prevalence of geohelminth and other parasites in relation to the soil depths revealed that parasites inhabited the soil as deep as 10 cm beneath. The higher occurrence of parasites reported for shallow soil depth may be related to the opinion suggesting that shallow depths (0-5cm) present an optimum environment for parasites' residence (Stojcevic *et al*., 2010). The presence of parasites' eggs in the superficial layer of soil avails the soil as potent reservoirs, especially in eggs that can essentially resist adverse weather and chemical variations (Paller and Babia-Abion, 2019). Egg/larva survivability in the soil may increase with a decrease in depth, for example, *T. trichiura*. Conversely, the parasites' survivability may also increase with increase in the soil depth, as in *Ascaris* species (Beaver, 1980). The higher occurrence of parasites in the shallow soil depth is in concordance with the findings by Paller and Babia-Abion (2019), who understudied STH eggs contaminating soils in selected farms in Philippines.

In the Awe Local Government Area, geohelminth and other parasites prevailed more in the shallow soil depth. Even so, the variation in the prevalence of the geohelminth and other parasites in relation to shallow and deeper depths revealed a high variation. Similarly, the depth-based prevalence of parasites in Nassarawa Eggon Local Government Area proved to be higher in shallow soil depths than the deeper soil depths. The lack of variation in the prevalence confirms the concurrent spread of parasite forms across the different depths. This may expose farmers, builders, and those whose occupation requires contact with soil to a number of parasitic infections.

The occurrence of parasites in relation to source or points of collection showed the highest occurrence in the soil samples collected from the market. The high occurrence of parasites in the soil samples sourced from markets may be related to the usually high influx of people into the market from different locations of the study areas, hence serving as avenues to transport parasite forms via soil particles stocked on the shoe soles of potential vehicle individuals. Also, farm produce brought to the market may also carry infested soil particles contaminated from farms that utilizes animal waste/dung as organic manure. These factors may contribute to the high occurrence of geohelminths observed. The high occurrence of parasites sourced from the market is in alignment with studies by Badaki *et al.* (2018), who investigated the soil parasite contamination of public places within the Lokoja metropolis, Kogi state, and found high parasitic contamination in soil samples collected from the market. The low occurrence of parasites in the soil samples collected from dumpsite is not consistent with a recent study by Imalele *et al.* (2021) in Calabar, who reported high parasitic contamination in soil samples collected from dumpsite.

The endemicity of geohelminth parasites relies greatly on the availability of infected persons, continuous or habitual faecal contamination of the soil, and a physical and chemically favourable soil environment for the development of the infective stages (Etewa *et al*., 2016). The high prevalence of the larval forms of geohelminths indicates the viability of the parasites, as the larval forms are usually the infective stages, especially in the cycle of *Strongyloides stercoralis* (L_3 larva), as observed in the current study. Consequently, making the populace vulnerable to strongyloidiasis and other Soil Transmitted Helminths diseases. This observation does not conform to the findings by (Nwoke *et al*., 2013), who examined soil samples in South Eastern Nigeria. Nwoke and others reported a cumulatively higher proportion of the oval developmental stage than the larval stage, with no record of the adult stages. The larval developmental stages of geohelminths and other parasites were also found to have contaminated the soil samples collected in both Awe and Nassarawa Eggon Local Government Areas. It is worthy of recall that *Strongyloides stercoralis* recorded a remarkably high number of larval developmental stages bearing over 60% of the total proportion of the developmental stages of parasites reported; hence, the prevalence observed in the larval developmental stages of parasites.

The high prevalence observed in *Strongyloides stercoralis*, hookworm, *Ascaris lumbricoides,* and *Toxocara canis* may be associated with intensive human and animal activities that involve unhygienic/unsanitary practices such as open defecation. According to field observations and scholarly opinions, open defecation and indiscriminate refuse disposal in rural and sub-urban areas are common practices (Chege *et al.*, 2020). Geohelminths display high fecundity and require soil for development. For example, *Ascaris* species layover 200,000 eggs daily, while *Trichuris trichiura* and *Toxocara canis* lay about 10,000 eggs by daily estimation. The high fecundity is one of parasites' strategies to increase their chance for transmission to the next hosts.

Moreover, most STH eggs are thick-shelled and resistant to different unfavorable conditions such as dehydration and exposure to chemicals. These characteristics of parasite eggs allow them to withstand adverse environmental conditions so they can survive longer in soil environments (Paller and Babia-Abion, 2019). The survival advantage of soil-dwelling stages of *S. stercoralis* is supported usually by the sandy, damp, or friable soil with decaying plant materials hence the prevalence observed. The current finding is consistent with earlier studies by Nwoke *et al.* (2013), who evaluated soil samples for the incidence of geohelminth parasites in Ebonyi North Central Area of Ebonyi State, Nigeria. Nwoke and colleagues also reported a high prevalence of *Strongyloides stercoralis*, *Ascaris lumbricoides*, hookworm, *T. trichiura,* and *Enterobius vermicularis*. A similar finding was also noted by Paller and Babia-Abion (2019), who investigated soil-transmitted helminth eggs contaminating soils in selected organic and conventional farms. They also reported high occurrences in Strongylid, *Ascaris* species, hookworm, and *Toxocara* species. Yawson *et al.* (2017) surveyed soil-transmitted helminths in top soils used for horticultural purposes in Ghana and recorded roundworms and hookworms as the most prevalent parasites.

The study proved that soil samples collected from the Nassarawa Eggon Local Government Area were more contaminated than those collected from the Awe Local Government Area. Awe and Nassarawa Eggon Local Government Areas are both agrarian areas where local farmers utilize organic fertilizers to grow their crops; the fertilizers may consequently be contaminated with parasites, which could have accounted for the high prevalence recorded in both areas. The relatively higher occurrence of parasites could be tied to the difference in locations and the difference in altitude and topography. According to Marshall *et al.* (2013), during or after rainfall, the runoff water moves from uplands to lowlands or plains and, as a result, may carry along debris or contaminated soil matter from the uplands to settle in the lowlands. Perhaps this geographical peculiarity in Nassarawa Eggon may have influenced the concentration of parasitic contaminants in the soil. Opinions from Adewumi and Salako (2017) have relayed evidence that the Awe Local Government Area hosts a significant deposit of salt. This implies that the area is characteristically defined by a high salinity, hence altering the soil chemistry. Studies by April *et al.* (2021) on the role of parasite introduction in host distribution and response to salinity in invaded estuaries have demonstrated how high salinity can affect the survivability of parasite forms.

CONCLUSION

Contamination of soil with parasite eggs, infective larvae, cysts, and oocysts constitutes the most important risk factor for zoonotic parasite infection. This study predominantly noted parasites of the helminth group and a few parasites of the protozoan group which implicates the residents of the area to parasitic infections. This also reported that the prevalence of geohelminths and other parasites in relation to the soil depths indicated a relatively higher parasite occurrence in the shallow soil depth than in the deeper soil. The occurrence of soil-transmitted helminths and other parasites was highest in the markets. The prevalence of geohelminths and other parasites in relation to their developmental stages suggested that the larval form was most dominant parasitic stage. The study established that the prevalence of Geohelminths in relation to the parasite species indicated the highest prevalence in *Strongyloides stercolaris,* Hookworm, and *Ascaris lumbricoides*. The comparison of the prevalence of geohelminths between the Awe Local Government Area and Nassarawa Eggon Local Government Area revealed a higher occurrence of parasites in Nassarawa Eggon than Awe Local Government Area. Sequel to the soil contamination rate, it is therefore crucial to sensitize the people on the current status of STH and the control and prevention methods.

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APPENDIX


Plate 1: ***Strongyloides stercolars***

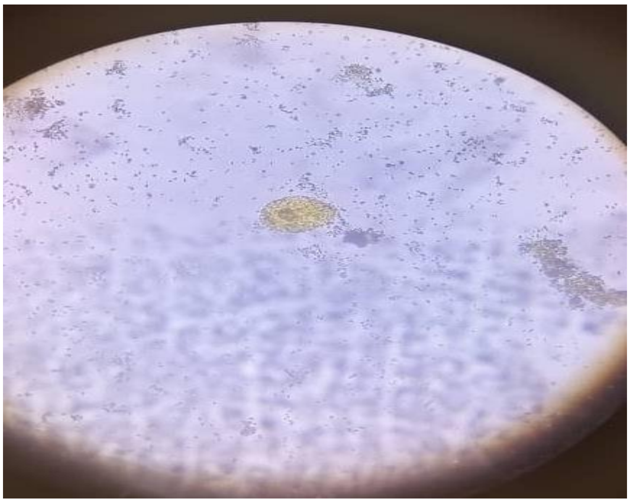
Plate 2: Egg of hookworm

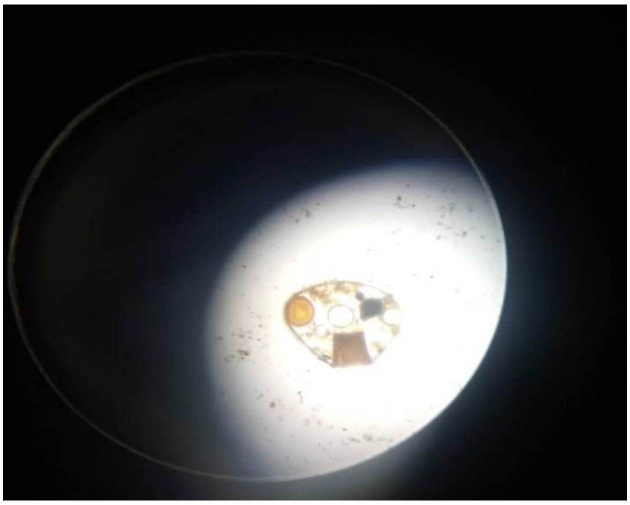
Plate 3: Egg of ***Ascaris lumbricoides***


Plate 4: ***Giardia*** **cyst**


Plate 5: ***Enterobius vermicular***