Sky Journal of Biochemistry Research Vol. 5(6), pp. 075 – 082, December, 2016
Available online http://www.skyjournals.org/SJBR
ISSN 2315-8786 ©2016 Sky Journals

Full Length Research Paper

Ecology of human schistosomiasis intermediate host and plant molluscicides used for control: A review

Sylvester Chibueze Izah* **and Tariwari C.N. Angaye**

Department of Biological Sciences, Faculty of Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

Accepted 7 October, 2016

Schistosomiasis is a vector-borne disease, caused by parasites of the genus *Schistosoma*. The disease is endemic in several countries in the world including Nigeria. The parasite that causes schistosomiasis requires the intermediate host (snails), humans, slow flowing or stagnant water to cause infection. The snails that transmit human schistosomiasis are of the genus *Bulinus* (which causes urinary schistosomiasis and are transmitted by *Schistosoma haematobium*) and *Biomphalaria* (which transmit intestinal schistosomiasis and can be transmitted by *Schistosoma mansoni*). These snails could be controlled by studying their ecology. Elimination of these snails is one suitable approach through which the parasite can be controlled. Besides environmental manipulation and application of synthetic molluscicides, the use of plant based molluscicides can be effective method for the control of the snails. Some plant with base molluscicides includes *Azadirachta indica, Jatropha Curcas, Jatropha glauca, Zanha goluogensis, Talinium trangulare, Tetrapleura tetraptera, Terminalia catappa, Carica papaya, Rhizophora mangle*, *R. racemosa, Avicennia germinans* and *Languncularia racemosa.* The ecotoxicological potential of plant-derived molluscicides needs to be unraveled, prior to their field application. Hence research should be focused on potential toxicity on other aquatic organisms to determine at what concentration the extract could be toxic to non-targeted species that co-habit with intermediate host (snails).

Key words: Environment, parasites, plant molluscicides, schistosomiasis snails.

INTRODUCTION

Schistosomiasis which is also referred to as bilharziasis or snail fever is major tropical parasitic disease caused by blood fluke known as *Schistosoma* (Alhassan, 2013; Alhassan et al., 2013, Nafiu et al., 2016; Dawaki et al., 2015; Mbata et al., 2008; WHO, 2014; Ugochukwu et al., 2013; Ahmad et al., 2014), especially in West Africa were its endemic in many countries (Mbata et al., 2008). Schistosomiasis is often regarded as one of the most prevalent neglected tropical diseases considered to be public health problem in several developing nations in both tropics and subtropics (Dawaki et al., 2015). Akande and Odetola (2013) listed with tropical neglected diseases to include schistosomiasis, ascariasis, buruli ulcer, chagas disease, and cysticercosis, food borne trematodiases, hookworm disease, leprosy, lymphatic filariasis, trachoma, trichuriasis, leishmaniasis, guinea worm, trypanosomiasis and oncocerciasis. Of these, Schistosomiasis is ranked second among wide spread parasitic diseases in different countries in sub-Saharan Africa (Adenowoa et al., 2015).

Tropical diseases cause approximately 534,000 deaths per annum in sub-Saharan Africa and an estimated 57 million disability-adjusted life-years are lost per annum due to the neglected tropical diseases (Adenowoa et al., 2015). Typically, Schistosomiasis is a global menace to human health. Useh (2013) reported that approximately 240 million and 779 million people are infected and at risk of schistosomiasis globally respectively. Hamed (2010) also reported that about 200 million individuals are affected in 74 countries. While about 120 million

*Corresponding author: E-mail: chivestizah@gmail.com. Tel: +234 703 0192 466.

Figure 1. Pier toilet system along coastal community in Niger Delta region of Nigeria.

individuals people infected are estimated to be symptomatic and about 20 million develop severe disease conditions (Hamed, 2010; Ayanda, 2009; Useh 2013). In similar perspective, World Health Organization reported that 249 individuals needed preventive treatment at as 2012 and repetition of the drugs over a period could reduce the morbidity attributed to the deadly virus (WHO, 2014). Schistosomiasis infections have been reported in 78 countries of the world and endemic in 52 of them (WHO, 2014). Approximately 90% of those requiring treatment for schistosomiasis live in Africa (WHO, 2014).

Schistosomiasis is caused by S*chistosoma mansoni, S. haematobium* and *S. japonicum* (which are endemic in Africa) and (*S. intercalatum* and *S. mekongi)* which are found mainly on selected regions. Others such as *S. bovis, S. mathei*, *S. hippopotami, S. sprinadalis* and *S. rohhaini* cause diseases in animals (Okpala et al., 2004; Angaye, 2013).

Studies on the prevalence of human schistosomiasis in Nigeria have shown that two predominant species viz: *S. mansoni* and *S. haematobium* are the prevalent parasite that causes schistosomiasis in Nigeria (Alhassan, 2013). Specifically, authors have variously reported that schistosomiasis infection occurs in school children around 5 - 20 years of age (Uweh et al., 2014; Barnabas et al., 2012; Angaye, 2016). Schistosomiasis in children can causes anaemia, stunting and a reduced ability to learn (WHO, 2014). Schistosomiasis infection produces several devastating effects which majorly depend on age, immunological characteristics and quantity of worms as well as its egg (Adedasanmi, 2007).

Nigeria has been variously reported to have the highest incidence of schistosomiasis globally, with about 29 million infected cases and about 101 million others are at risk of infection (Steinmann et al., 2006; WHO, 2011; Hotez et al., 2012; Hotez et al., 2009; Dawaki et al., 2015). Similarly Agi and Awi-waadu (2008), Anosike et al. (2006), Ibor (2015) have reported that about 22 million Nigerians, including 16 million children are infected with schistosomiasis. Thus schistosomiasis is endemic in Nigeria (Adedasanmi, 2007). Making the country the most endemic in the world. Nigeria is often regarded as the most populous country in Africa with population of over 170 million. The incidence case suggests that over 59.4% are risk, 17.1% are infected with schistosomiasis. As such, schistosomiasis effects need to be taken very seriously.

Schistosomiasis is mainly transmitted by different species of aquatic snails often referred to as the intermediate host of the disease. Typically schistosoma eggs in urine or stool reaching fresh water hatch to give miracidia that infect the appropriate snail, cerceriae come out of the snails in water to infect human. The miracidia are usually many and they are the free-swimming larvae stage (Nafiu et al., 2016). Humans contact the disease when the cercariae penetrate the human skin via water contact (Simoonga et al., 2009; Mtethiwa et al., 2015; Nafiu et al., 2016).

In Africa, schistosomiasis is endemic in most rural settlement aligning coastal bodies. This is attributed to suitable environmental condition that favours the proliferation of the intermediate; including river, creek, creeklets, ponds, lakes, slow flowing water. This water is typically used for domestic activities and indiscriminate sewage disposal (Nwosu et al., 2015) (Figure 1).

The prevalence of schistosomiasis is widely attributed to the ecology of the intermediate host. For instance, Mohammed et al. (2014) stated that the prevalence and distribution of Schistosomiasis in some parts of endemic countries is due to variation in human migration, ecological and climatic conditions. Hence this paper focus on the predominant human schistosomiasis in Nigeria and the snails' biology are discussed in brief. The ecology of schistosomiasis and plant molluscicides used for their control is also discussed. Areas research should focus on based on the control via plant molluscicides are highlighted.

Predominant type of schistosomiasis in Nigeria

The snails that transmit schistosomiasis in human are typically belong to two different genera viz; *Bulinus* and *Biomphalaria* (Brown, 1994; Simoonga et al., 2009). The *S. haematobium* that causes urinary schistosomiasis is transmitted by *Bulinus* species, while *disease condition caused by S. mansoni are transmitted.* by *Biomphalaria* speices (Brown, 1994; Simoonga et al., 2009; Alhassan, 2013).

Schistosomiasis infection occurs nearly in the entire region of Nigeria. A recent prevalent review by Angaye (2016) showed that schistosomiasis occurs in all the state of the federation. Several drugs including praziquantel, oxamniquine and metrifonate have been used against schistosomiasis. Specifically, praziquantel is used for all type of schistosomiasis. However, Nigeria has adopted the use of Praziquantel for the control of schistosomiasis. But for the control of intermediate host in rural area, the cost of synthetic molluscicides hinders their applications. Houmsou (2012) reported that high risk level of becoming infected by schistosomes snails is mainly due to low literacy level, poverty, sub-standard hygiene, and inadequate public infrastructure. This section of the paper discusses the type of human schistosomiasis.

Urinary schistosomiasis

The genus *Bulinus* which has *globosus* and *truncatus* as species have been implicated with urinary schistosomiasis (Ekwunife et al., 2008; Bassey et al., 2013; Angaye, 2013; Angaye et al., 2015; Hamed, 2010). Urinary tract schistosomiasis is usually associated with the presence of blood in urine and pains during and or after urination. Urinary schistosomiasis causes renal failure due to obstructive uropathy, pyelonephritis or bladder carcinoma (occurring usually 10 - 20 years after the initial infection) (Alhassan, 2013), fibrosis of the bladder and ureter, and kidney damage (WHO, 2014). The parasite itself (*S. haematobium*) could cause lesions in the female lower genital tract (i.e. cervix, vulva, vagina) (Alhassan, 2013; WHO, 2014), while in men it can prompt pathology of the seminal vesicles, prostate and other organs (WHO, 2014). Nafiu et al. (2016) noted that in urinary Schistosomiasis, the worms reside in the blood vessels of the bladder and nearly 50% of the eggs are excreted during urination while the remaining once continues to damage the essential organs of the body (Nafiu et al., 2016). Basically, urinary Schistosomiasis is endemic in Nigeria and as such ranked as one of the public health problem affecting inhabitants especially in rural areas (Nafiu et al., 2016). *S. haematobium* infection is one of the predominant problem facing the public health especially in in children (Sulyman et al., 2009; Fana et al., 2009; Nafiu et al., 2016; Akinboye et al., 2011). *S. hematobium* can co-exist with other sexually transmitted infections such as *Neiserria gonorrheae, Chlamydia trachomatis, Mycoplasma genitalium* and *Trichomonas vaginalis* in female (35%) compared to men (17%) and commonly found in younger population (15 - 24 years) compared to older or elderly populations (Alhassan, 2013).

Intestinal schistosomiasis

The human intestinal schistosomiasis is mainly caused by *S. mansoni* in Nigeria with the intermediate host being *Biomphalaria glabrata, B. alexandrina, B. pfeifferi* (Angaye et al., 2015). Other species of *Schistosoma* including *S. intercalatum*, *S*. *japonicum* and *S. mekongi* and their respective intermediate host have been previously reported by Hamed (2010). Several diseases are caused by intestinal Schistosomiasis. Alhassan (2013) reported that pulmonary arterial hypertension complication may develop in nearly 7.7% of individuals with hepatosplenic disease resulting from *S. mansoni, S. japonicum,* and sometimes *S. mekongi* infections. Others symptoms include abdominal pain, diarrhoea and blood in the stool, liver enlargement, accumulation of fluid in the peritoneal cavity and hypertension of the abdominal blood vessels (WHO, 2014)

Ecological studies of schistosomiasis intermediate host

Snail of the genus *Bulinus* and *Biomphalaria* are medically important snails, due to the inevitable role they play in the transmission of Schistosomiasis. They are small freshwater aquatic mollusks. The *Bulinus* genus are tropical endemic freshwater snails, belonging to the Planorbidae family. There are four groups of the *Bulinus* genus, with over 30 species. This genus is medically important because several species of *Bulinus* function as intermediate hosts for the schistosomiasis blood fluke (Kane et al., 2008). The shell of species in the genus *Bulinus* is sinistral. It has a very large body whorl and a small spire. The *Biomphalaria* genus is an air-breathing freshwater snail, belonging to the Planorbidae family. The shell of this species is appears sinisterly dextral and in

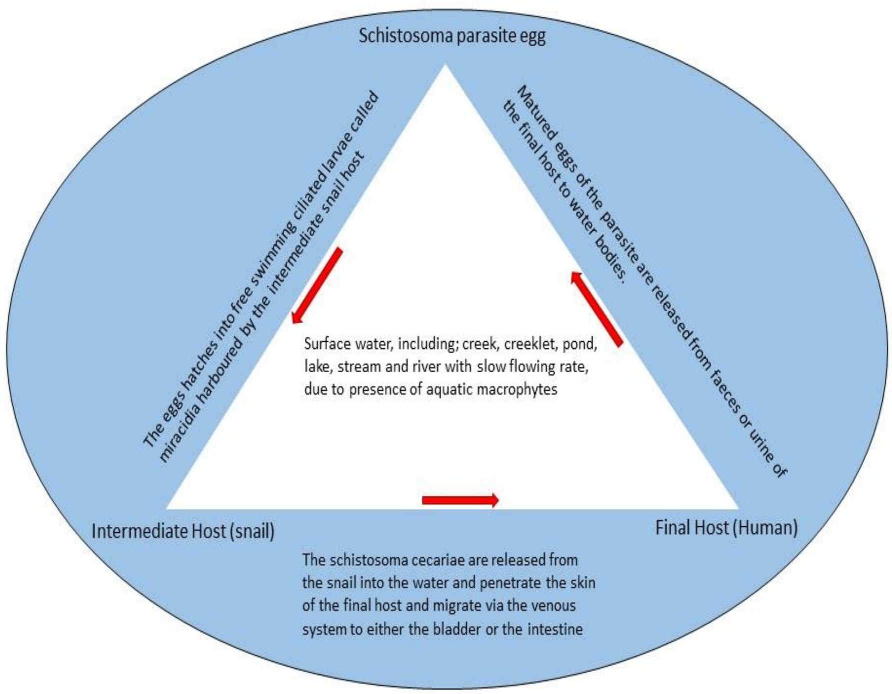

Figure 2. Flow route of schistosomiasis infection.

coiling, like a ram's horn. There are over thirty species belonging to this genus, with most species endemic in America (Majoros et al., 2008).

The ecology of schistosomiasis basically requires four factors including the intermediate host (snail), water (aquatic ecosystem), parasite and humans (Figure 2). These factors function together to cause schistosomiasis infection. The parasite, intermediate hosts (snails) and the human hosts form an association for the parasite to reproduces and is disseminate (Ivoke et al., 2014). Various factors (including climatic changes and global warming, proximity to water bodies, irrigation and dam construction as well as socio-economic) are responsible for the continuous and persistent transmission of schistosomiasis in sub-Saharan Africa (Adenowoa et al., 2015).

These intermediate hosts of the parasite inhabits in slow flowing water and they infect human during swimming, playing, fetching of water, washing, crossing of water, bathing, fishing and or other recreational activities. Owing to the reasons that they are transmitted via contact with surface water hence they have environmental components. Authors have variously reported that Schistosomiasis is an environmental disease (Malone, 2005; Liang et al., 2007; Simoonga et al., 2009; Hamed, 2010). The prevailing environmental conditions that promote the transmission of schistosomiasis include socio-economic and demographic status. Similarly, the infection is usually high in inhabitant of coastal region especially communities and villages aligning water bodies. In addition, the life cycle of Schistosomiasis which include the intermediate snails also play essential role in controlling the snails. However, detailed description of the life cycle of Schistosomiasis has been reported by Angaye (2016).

The snails are typically found in freshwater. Generally water has several characteristic that influences the survival of aquatic life. When the hydrology of the water is altered or changed, some aquatic life dies while several others may change to enable them adapt the environmental condition. Intermediate host snails that cause schistosomiasis varies in their adaptations capability to biotic and abiotic factors that govern their population and distribution in space and time (Salawu and Odaibo, 2012). Also, In a case study, Salawu and Odaibo (2012) reported that occurrence of schistosomiasis snails shows spatial variation, which the authors attributed to variation water in-situ parameters such as conductivity, total dissolved solid, dissolved oxygen, and seasonal influence (wet and dry season).

Environmental parameters appear to influence the density and population dynamics of the snails. The density and dynamics of the snails is majorly influenced by the current flow rate of the water, presence of aquatic plants such as water hyacinths, lower invertebrates such as shrimps that may feed on the snails. Others factors including physical geography of area, land contours, soil composition, hydrography, and climate (i.e. temperature

Table 1. Plant Molluscicides with ability of killing human schistosomiasis intermediate host (snail).

Plant	Plant Parts	Snail Species	Extraction Medium	Activities/ (LC_{50}, ppm)	References
Jatropha Curcas	Seed	*Bulinus natalensis* and *Bulinus truncatus*	Methanol	0.25	Rug and Ruppel (2000)
	Root	*Bulinus truncatus* and *Bulinus natalensis*	Ethanol	60.00	El Kheir and El Tohami (1979)
	Leaves	*Bulinus globosus* and *Bulinus rholfsi*	Methanol	0.30	Angaye (2013)
			Crude Extract	>500	
	Leaves	*Biomphalaria pfeifferi*	Methanol	30.00	
	Leaves	*Biomphalaria pfeifferi*	Crude Extract	>500	
	Seed	*Biomphalaria pfeifferi*	Methanol	25.00	Rug and Ruppel (2000)
Jatropha glauca	Leaves	*Biomphalaria pfeifferi*	Acetone	6.76	Al-Zanbagi et al. (2000)
	Leaves	*Biomphalaria pfeifferi*	Chloroform	16.50	
Zanha goluogensis	Stem Bark	*Biomphalaria glabrata*	Ethanol	60.00	Agboola et al. (2012)
Blighia Unijugata	fruit pericarp	*Biomphalaria glabrata*	Ethyl-acetate	7.6	Agboola et al. (2011)
			Butanol	15	
			Water	25	
Croton floribundus	leaf	*Biomphalaria glabrata*	Hexane	37.4	Medina et al. (2009)
			Ethanol	14.8	
			methanol	4.2	
Euphorbia aphylla	Arial portion	*Biomphalaria alexandrina*	Ethanol	87.60	Hassan et al. (2011)
Talinium trangulare	Root	*Bulinus truncatus*	Ethanol	400 - 600	Okeke and Ubachukwu (2011)
Tetrapleura tetraptera	Fruit	*Bulinus globosus*	Methanol	1.33	Adedasanmi (2007)
Terminalia catappa	Leaves	*Bulinus globosus*	Ethanol	1095.70	Adetunji and Salawu (2010)
		Biomphalaria pfeifferi		864.10	
Carica papaya		*Bulinus globosus*		619.10	
		Biomphalaria pfeifferi		2716.30	
Azadirachta indica	Leaves	*Bulinus globosus*	Chloroform	15.50	Angaye et al. (2014)
			Hexane	10.31	
			Acetone	13.00	
			Ethanol	9.35	
Rhizophora mangle	Leaf	*Biomphalaria pfeifferi*	Methanol	87.50	Angaye et al. (2015)
		Bulinus globosus	Methanol	87.50	
		Bulinus rholfsi	Methanol	108.22	
R. racemosa		*Biomphalaria pfeifferi*	Methanol	150.00	
		Bulinus globosus	Methanol	125.00	
		Bulinus rholfsi	Methanol	85.51	
Avicennia germinans		*Biomphalaria pfeifferi*	Methanol	175.00	
		Bulinus globosus	Methanol	89.21	
		Bulinus rholfsi	Methanol	123.74	
Languncularia racemose		*Biomphalaria pfeifferi*	Methanol	-	
		Bulinus globosus	Methanol	102.09	
		Bulinus rholfsi	Methanol	152.03	
Euphorbia helioscopia	leaves	*Bulinus wright*	cold water	80	AL-Zanbagi (2005)
			hot water	96.6	
			methanol	11.3	
			chloroform	80.5	
			acetone	8.9	
			hexane	99	

Table 1 Cont.

Euphorbia schimperiana	leaves	*Bulinus wright*	cold water	81.8
			hot water	72.8
			methanol	2.3
			chloroform	3
			acetone	10.1
			hexane	18

and rainfall), while the distribution and abundance are influenced by the biotic and non-biotic environment, behavior, reproduction, genetics, interactions within and between species, and human influences (Barbosa and Barbosa, 1994). Similarly, Ayanda (2009) also reported that temperature, food supply, predators, parasites, rainfall and water composition influences the density of the snails in their habitat.

Control of schistosomiasis intermediate host

The intermediate host of schistosomiasis can be controlled through environmental mechanisms including water chemistry (i.e. calcium concentration, total dissolved chemical content and oxygen), temperature, current speed, light and shade, circadian rhythms, snail-plant association; molluscicides including chemical molluscicides (i.e. niclosamide, an ethanolamine salt of 2', 5-dichloro-4'-nitrosalicylanilide), plant molluscicides (several species of plants); biological control (i.e. snails and different organisms relationship, host parasite relationship, genetic control) (Hamed, 2010). Molluscicides have shown to be effective for the control of the intermediate host (snail) of schistosomiasis appears to environmentally acceptable alternative.

Adedasanmi (2007) reported that the use of plant molluscicides could be suitable and cost effective approach for controlling schistosomiasis intermediate host (snail). Like the chemical agents of Schistosomiasis control, Molluscicides approach has merits and limitations which have been comprehensibly documented by de Souza (1995). Several plants have been demonstrated to be effective for the control of the snails (Table 1). Different solvent of extraction also play vital role in the bioactive components of the plants. Adedasanmi (2007) reported that micracidia and cercariae of *Shistosoma haematobium* exposed to *Tetrapleura tetraptera* for 2 h showed that a concentration of 400 ppm has lethal effects on both Micracidia and cercariae after 30 min and concentration below 10ppm showed no effect on their mortality.

Other biological specimens have also demonstrated potential for the control of Schistosomiasis intermediate stage. These species can be used as predatory competitor. For instance, Sokolow et al. (2015) reported that river prawn (*Macrobrachium vollenhovenii*) which is indigenous to the west coast of Africa is a low-cost and sustainable means of control the snail, when used in synergy with existing drug distribution campaigns.

Future direction

Some plant molluscicides have the potential to affect non-target aquatic organisms such as fisheries, planktons (zooplanktons and phytoplanktons) and benthic organisms and even alter the water quality parameters. For instance Adedasanmi (2007) reported that *Tetrapleura tetraptera* extracts exposed to *Tilapia nilotica* and *Tilapia galilaea* died after 24 h of exposure with LC_{50} of 0.35 and 0.44 ppm respectively. The findings of this study suggested that toxicity of plant molluscicides on aquatic organsims varies among species. As such reasearch should be focused on:

-Toxicity level on other aquatic organsisms especially fishries, planktons and bethic organisms.
-Possible alteration in water quality paramters with the application of plant molluscicides
-The population density of the snail on the aqutaic ecosystem
-Potential usuage of the water
-Rainfall pattern in the area which will facilitate the dilution effects
-Flow rate of the water body
-Temperature of the water body prior to the use of plant molluscicides
-Adapation mechnisms of the snail that them surviuve in slow flowing water.

Conclusion

Human schistosomiasis is endemic in several tropical countries especially in Africa. Schistosomiasis infection is caused by parasites which inhabit in snails (intermediate host) in slow-moving water body. The schistosomiasis infection requires the snails, humans, parasites and suitable habitats i.e water. As such understanding the ecology of the snails (intermediate host), is essential for the control of schistosomiasis; since snails is an essential link to the proliferation of the parasite. Notwithstanding, several plant molluscicides have demonstrated huge potentials for the control of schistosomiasis snails including *Azadirachta indica, Jatropha Curcas, Jatropha glauca, Zanha goluogensis, Talinium trangulare,* *Tetrapleura tetraptera, Terminalia catappa, Carica papaya, Rhizophora mangle*, *R. racemosa, Avicennia germinans* and *Languncularia racemosa.* Based on molluscicides, alcoholic solvents including methanol, ethanol showed be more efficient for the control of the snails. The ecotoxicity of these plant based molluscicides to non-targeted aquatic biota need to be unraveled in further studies. As such field investigation should be carried out, as well as suitable environmental condition at which molluscicides should be used against the snails.

Acknowledgement

The authors wish to thank the three anonymous reviewers of this publication and the Editor of Sky Journal of Biochemistry Research for their valuable suggestions and comments.

REFERENCES

Adedasanmi AJ (2007). *Tetrapleura tetraptera* molluscicidal activity and chemical agents. Afr. J. Trad. CAM. 4(1): 23 – 36.

Adetunji VO, Salawu OT (2010). Efficacy of ethanolic leaf extracts of *Carica papaya* and *Terminalia catappa* as molluscicides against the snail intermediate hosts of schistosomiasis. J. Med. Plants Res., 4(22): 2348-2352.

Agboola OI, Ajayi GO, Adesegun S, Adesanya SA (2012). Investigating the molluscicidal potential of some members of Nigeria sapindaceae family. Arch. Appl. Sci. Res., 4 (3):1240-1243

Agboola OI, Ajayi GO, Adesegun SA, Adesanya SA (2011). Comparative Molluscicidal Activities of Fruit Pericarp, Leaves, Seed and Stem Bark of *Blighia Unijugata* Baker. Pharmacognosy J. 3(25): 63 – 66.

Agi P1, Awi-waadu GD (2008). The status of *S. haematobium* infection in Anyu community in the Niger Delta, Nigeria. J. Appl. Sci. Environ. Manage., 12(2): 21 —24.

Ahmad MM, Getso BU, Ahmad UA (2014). Water Contact Patterns and Urinary Schistosomiasis Transmission among School Children in Endemic Area of Wudil, Kano, Nigeria. IOSR J. Pharmacy Biol. Sci. 9(3):01-04.

Akande IS, Odetola AA (2013). Epidemiological Survey of Human and Veterinary Schistosomiasis. http://dx.doi.org/10.5772/53523.

Akinboye DO, Ajisebutu JU, Fawole O, Agbolade OM, Akinboye OM, Amosu AM, Atulomah NOS, Awodele O, Oduola O, Owodunni BM, Rebecca SN, Falade M, Emem O (2011). Urinary Schistosomiasis: Water contact frequency and infectivity among secondary school students in Ibadan, Nigeria. Nigerian J. Parasitol., 32(1): 129-134.

Alhassan A (2013). Prevalence of schistosomiasis among primary school pupils in Birnin-Gwari Local Government Area, Kaduna State. A thesis submitted to the School of Postgraduate studies, Ahmadu Bello University, Zaria, Nigeria.

Alhassan A, Luka SA, Balarabe ML, Kogi E (2013). Prevalence and Selected Risk Factors ofIntestinal Schistosomiasis among Primary School Children in Birnin-Gwari Local Government Area, Kaduna State, Nigeria. Inter. J. Appl. Biol. Res., 5(1): 72 – 81.

Al-Zanbagi NA, Banaja AEA, Barrett J (2000). Molluscicidal activity of some Saudi Arabian Euphorbiales against the snail *Biomphalaria pfeifferi*. J. Ethno-pharmacol., 70: 119 - 125.

AL-Zanbagi NN (2005). Two Molluscicides from Saudi Arabian Euphorbiales against *Bulinus wright.* JKAU: Sci. 17: 11-19

Angaye TC (2013). In-vitro Comparative Molluscicidal Activities of Aqueous and Methanolic Extracts of *Jatropha curcas* Leaves against *Bulinus globosus* and *Bulinus rholfsi*; vectors of urinary schistosomiasis. M.Sc. thesis, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

Angaye TC (2016). A review on the epidemiology and control of schistosomiasis in Nigeria. J. Med. Health Res. 1(2): 1 -23.

Angaye TCN, Bassey SE, Ohimain E1, Izah SC, Asaigbe PI (2015) Molluscicidal and Synergicidal Activities of the Leaves of Four Niger Delta Mangrove Plants Against Schistosomiasis Vectors. J. Environ. Treat. Techniq. 3(1): 35-40

Angaye TCN, Zige DV, Didi B, Biobelemoye N, Gbodo EA (2014). Comparative Molluscicidal Activities of Methanolic and Crude Extracts of *Jatropha curcas* Leaves against *Biomphalaria pfeifferi*. Greener J. Epidemiol. Public Health, 2 (1): 016-022.

Anosike JC, Nwoke BE, Uwaezuoke JC (2006). Epidemiological assessment of vesical schistosomiasis in Bende Local Government Area of Abia State, Nigeria. J. Appl. Sci. Environ. Manage., 10(2): 55 - 60.

Ayanda OI (2009). Prevalence of snail vectors of schistosomiasis and their infection rates in two localities within Ahmadu Bello University (A.B.U.) Campus, Zaria, Kaduna State, Nigeria. J. Cell Animal Biol., 3 (4): 058-061.

Barbosa FS, Barbosa CS (1994). The bioecology of snail vector for Schistosomiasis in Brazil. Cad. Saùde Pùbl. Rio de Janeiro 10 (2): 200-209.

Barnabas BB, Aliyu MB, Gbate M, Obi UP, Attairu AA (2012). Survey Of Schistosomiasis And Other Intestinal Helminthiases Among School-Aged Children In Agaie, Niger State, Nigeria. J. Pharm. Biomed. Sci., 15(15): 1-5.

Bassey SE, Ohimain EI, Angaye TC (2013). The Molluscicidal Activities of Methanolic and Aqueous Extracts of *Jatropha curcas* leaves against *Bulinus globosus* and *Bulinus rholfsi*, Vectors of Urinary Schistosomiasis. J. Parasitol. 103: 115-122.

Brown DS (1994). Freshwater Snails of Africa and their Medical Importance. Taylor & Francies (2nd ed.), London, UK, 1–608.

Dawaki S, Al-Mekhlafi HM, Ithoi I, Ibrahim J, Abdulsalam AM, Ahmed A, et al. (2015) The Menace of Schistosomiasis in Nigeria: Knowledge, Attitude, and Practices Regarding Schistosomiasis among Rural Communities in Kano State. PLoS ONE 10(11): e0143667. doi:10.1371/journal.pone.0143667.

de Souza CP (1995). Molluscicde control of snail vectors of Schistosomiasis. Mem. Inst. Oswaldo Cruz. Rio de Janeiro 90(2): 165 – 168.

El Kheir YM, El Tohami MS (1979). Investigation of molluscicidal activity of certain Sudanese plants used in folk-medicine. Amer. J. Trop. Medicine Hyg. 82: 237-241.

Fana SA, Ekejindu IM and Nnamah AK (2009). Urinary schistosomiasis among school children in Argungu, Kebbi State. Nig. J. Parasitol. 30(2): 152-155.

Hamed MA (2010). Strategic Control of Schistosome Intermediate Host. Asian J. Epidemiol. 3: 123-140.

Hassan AA, Mahmoud AE, Attia RAH, Huseein AEM (2011). Evaluation of The Ethanolic Extracts Of Three Plants For Their Molluscicidal Activities Against Snails Intermediate Hosts of Schistosoma Mansoni And Fasciola. Inter. J. Basic Appl. Sci. 1(3): 235-249.

Hotez PJ, Asojo OA, Adesina AM (2012). Nigeria: ‘‘Ground Zero” for the high prevalence neglected tropical diseases. PLoS Negl. Trop. Dis. 6(7): e1600. doi: 10.1371/journal.pntd.0001600.

Hotez PJ, Kamath A (2009). Neglected tropical diseases in sub-Saharan Africa: Review of their prevalence, distribution, and disease burden. PLoS Negl. Trop. Dis. 3(8): e412. doi: 10.1371/journal.pntd. 0000412.

Houmsou RS (2012). Profile of a one year epidemiological study of urinary schistosomiasis in two Local Government Areas (LGAs) of Benue State, Nigeria. J. Biomed. Sci., 1(2:2): 1-11.

Ibor UW (2015). Human Behavioural Risk Factors of Urinary Schistosomiasis in Cross River State, Nigeria, J. Health Medicine Nursing 21: 50-58

Ivoke N, Ivoke ON, Nwani CD, Ekeh FN, Asogwa CN, Atama CI, Eyo JE (2014). Prevalence and transmission dynamics of *S. haematobium* infection in a rural community of southwestern Ebonyi State, Nigeria. Trop. Biomedicine 31(1): 1–12.

Kane RA, Stothard JR, Emery AM, Rollinson D (2008). Molecular characterization of freshwater snails in the genus Bulinus: A role for barcodes". Parasites Vectors. 1: 15. DOI: **10**.1186/1756-3305-1-15

Liang S, Seto EYW, Remais JV, Zhong B, Yang C, Hubbard A, Davis GM, Gu XG, Qiu DC, Spear RC (2007). Environmental effects on parasitic disease transmission exemplified by schistosomiasis in western China. Proceed. Nat. Acad. Sci. United States Amer.104: 7110–7115.

Majoros GB, Fehér Z, Deli T, Földvár i G (2008). Establishment of Biomphalaria tenagophila Snails in Europe. Emerg. Infect. Dis. 14 (11): 1812–1814

Malone JB (2005). Biology-based mapping of vectorborne parasites by geographic information systems and remote sensing. Parassitologia. 47: 27–50.

Mbata T, Orji M, Oguoma V (2008). The Prevalence of Urinary Schistosomiasis In Ogbadibo Local Government Area Of Benue State, Nigeria. The Internet J. Infect. Dis., 7(1): 1-4.

Medina JM, Peixoto JLB, Silva AA, Haraguchi SK, Falavigna DLM, Zamuner MLM, Sarragiotto MH, Vidotti GJ (2009). Evaluation of the molluscicidal and *Schistosoma mansoni* cercariae activity of *Croton floribundus* extracts and kaurenoic acid. Brazilian J. Pharmacognosy 19(1B): 207-211.

Mohammed K, Abdullah MR, Ikeh E. I., Ismail A, Omar J, Popoola FJ (2014). A Multivariate Analysis on the Assessment of Risk Factors Associated with Infections and Transmission of Schistosomiasis Haematobium in Some Selected Areas of North-Western, Nigeria. J. Med. Bioeng., 4(1): 7-11.

Mtethiwa AHN, Bakuza J, Nkwengulila G (2015). Prevalence and Intensity of Schistosomiasis in Communities around Water Reservoirs in Malawi. J. Trop. Dis. 4: 183. doi:10.4172/2329-891X.1000183.

Nafiu S, Inuwa B, Abdullahi A, Alkali Z, Ibrahim BA (2016). Prevalence of Urinary Schistosomiasis Among Primary School Pupils In Kofa Primary School, Tafa Local Government, Niger State, Nigeria. Ewemen J. Epidemiol. Clin. Med., 2(1): 7 – 13.

Nwosu DC, Nwachukwu PC, Avoaja DA, Ajero CMU, Nwanjo HU, Obeagu EI, Nnorom RM, Okpara KE, Kanu SN (2015). Index of potential contamination for urinary Schistosomiasis in Afikpo North L.G.A. Ebonyi State, Nigeria. Euro. J. Biomed. Pharma. Sci. 2(1): 439-450.

Okeke OC, Ubachukwu PO (2011). Molluscicidal Effects of Talinum triangulare on Bulinus truncates. Nig. J. Biotechnol., 22: 13-16.

Okpala HO, Agwu E, Agba MI, Chimezie OR, Nwobu GO, Ohihoin AA (2004). A survey of the prevalence of Schistosomiasis among pupils in Apata and Laranto areas in Jos, Plateau State. Online J. Health Allied Sci. 1:1. http://www.ojhas.org/issue9/2004-1-1.htm.

Rug M, Ruppel A (2000). Toxic activities of the plant Jatropha curcas against intermediate snail hosts and larvae of schistosoomes. Trop. Medical Inter. Health, 5: 423-430.

Salawu OT, Odaibo AB (2012). Preliminary study on ecology of Bulinus jousseaumei in *S. haematobium* endemic rural community of Nigeria. Afr. J. Ecol. 51: 441–446.

Simoonga C, Utzinger J, Brooker S, Vounatsou P, Appleton C, Stensgaard AS, Olsen A, Kristensen TK (2009). Remote sensing, geographical information system and spatial analysis for schistosomiasis epidemiology and ecology in Africa. Parasitol. 136: 1683–1693.

Sokolow SH, Huttinger E, Jouanard N, Hsieh MH, Lafferty KD, Kuris AM, Riveau G, Senghor S, Thiam C, N'Diaye A, Faye DS and De Leo GA (2015). Reduced transmission of human schistosomiasis after restoration of a native river prawn that preys on the snail intermediate host. Ecolog. 1-6. http://hopkinsmarinestation.stanford.edu/sokolow.pdf.

Steinmann P, Keiser J, Bos R, Tanner M, Utzinger J (2006). Schistosomiasis and water resources development: systematic review, meta-analysis, and estimates of people at risk. Lancet Infect. Dis., 6(7): 411–425.

Sulyman MA, Fagbenro-Beyioku AF, Mafe MA, Oyibo WA, Ajayi MB, Akande DO (2009). Prevalence of urinary schistosomiasis in school children in four states of Nigeria. Nig. J. Parasitol., 30:110-114.

Ugochukwu DO, Onwuliri COE, Osuala FOU, Dozie INS, Opara FN, Nwenyi UC (2013). Endemicity of schistosomiasis in some parts of Anambra State, Nigeria. J. Med. Lab. Diagn., 4(5): 54-61.

Useh MF (2013). Control of Schistosomiasis. 73 – 102. http://www.intechopen.com/books/schistosomiasis/control-of-schistosomiasis.

Uweh PO, Omudu EA, Onah IE (2014). Current Status of Schistosomiasis amongst School Children in Igedeland, Benue State, Nigeria. Nig. J. Pure Appl. Sci. 6: 16-21.

WHO (2014). Schistosomiasis. Fact sheet N°115 12 March 2014. http://www.searo.who.int/thailand/factsheets/fs0016/en/. Accessed August 1st 2016.

World Health Organization (2011). Schistosomiasis: number of people treated in 2011. Wkly. Epidemiol. Rec. 88: 81–88.