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.

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Schistosomiasis is one 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 golougensis, Talinium tranugulare, 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 trematodiasis, 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.
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 Schistosoma 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. spinadalis and S. rohrai 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 focuses 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* species (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 *Neisseria gonorrhoeae*, *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
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 reproduce 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 (Adenowoja 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

Figure 2. Flow route of schistosomiasis infection.
Table 1. Plant Molluscicides with ability of killing human schistosomiasis intermediate host (snail).

<table>
<thead>
<tr>
<th>Plant</th>
<th>Plant Parts</th>
<th>Snail Species</th>
<th>Extraction Medium</th>
<th>Activities/ (LC&lt;sub&gt;50&lt;/sub&gt;, ppm)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jatropha Curcas</td>
<td>Seed</td>
<td>Bulinus natalensis and Bulinus truncatus</td>
<td>Methanol</td>
<td>0.25</td>
<td>Rug and Ruppel (2000)</td>
</tr>
<tr>
<td></td>
<td>Root</td>
<td>Bulinus truncatus and Bulinus natalensis</td>
<td>Ethanol</td>
<td>60.00</td>
<td>El Kheir and El Tohami (1979)</td>
</tr>
<tr>
<td></td>
<td>Leaves</td>
<td>Bulinus globosus and Bulinus rholfsi</td>
<td>Methanol</td>
<td>0.30</td>
<td>Angaye (2013)</td>
</tr>
<tr>
<td></td>
<td>Leaves</td>
<td>Bulimphalaria pfefferi</td>
<td>Methanol</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seed</td>
<td>Bulimphalaria pfefferi</td>
<td>Methanol</td>
<td>25.00</td>
<td>Rug and Ruppel (2000)</td>
</tr>
<tr>
<td>Jatropha glauca</td>
<td>Leaves</td>
<td>Bulimphalaria pfefferi</td>
<td>Acetone</td>
<td>6.76</td>
<td>Al-Zanbagi et al. (2000)</td>
</tr>
<tr>
<td>Zanha goluogensis</td>
<td>Stem</td>
<td>Bulimphalaria glabrate</td>
<td>Ethanol</td>
<td>60.00</td>
<td>Agboola et al. (2012)</td>
</tr>
<tr>
<td>Blighia Unijugata</td>
<td>leaf</td>
<td>Bulimphalaria glabrate</td>
<td>Ethyl-acetate</td>
<td>7.6</td>
<td>Agboola et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>Bark</td>
<td>Bulimphalaria glabrate</td>
<td>Butanol</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Croton floribundus</td>
<td>leaf</td>
<td>Bulimphalaria glabrate</td>
<td>Hexane</td>
<td>37.4</td>
<td>Medina et al. (2009)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ethanol</td>
<td>14.8</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>methanol</td>
<td>4.2</td>
<td>Hassan et al. (2011)</td>
</tr>
<tr>
<td>Euphorbia aphylla</td>
<td>Arial</td>
<td>Bulimphalaria alexandrina</td>
<td>Ethanol</td>
<td>87.60</td>
<td></td>
</tr>
<tr>
<td>Tetrapleura tetraptera</td>
<td>Fruit</td>
<td>Bulimphalaria globusos</td>
<td>Ethanol</td>
<td>1.33</td>
<td>Adedasanmi (2007)</td>
</tr>
<tr>
<td>Terminalia catappa</td>
<td>Leaves</td>
<td>Bulimphalaria pfefferi</td>
<td>Ethanol</td>
<td>1095.70</td>
<td>Adetunji and Salawu (2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>864.10</td>
<td></td>
</tr>
<tr>
<td>Carica papaya</td>
<td></td>
<td>Bulimphalaria globusos</td>
<td>Chloroform</td>
<td>15.50</td>
<td>Angaye et al. (2014)</td>
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<tr>
<td>Azadirachta indica</td>
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<td>Bulimphalaria pfefferi</td>
<td>Hexane</td>
<td>10.31</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Acetone</td>
<td>13.00</td>
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<td></td>
<td></td>
<td></td>
<td>Ethanol</td>
<td>9.35</td>
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<td></td>
<td></td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Rhizophora mangle</td>
<td>Leaf</td>
<td>Bulimphalaria pfefferi</td>
<td>Methanol</td>
<td>87.50</td>
<td>Angaye et al. (2015)</td>
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<tr>
<td></td>
<td></td>
<td>Bulimphalaria globusos</td>
<td>Methanol</td>
<td>87.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulimphalaria rholfsi</td>
<td>Methanol</td>
<td>108.22</td>
<td></td>
</tr>
<tr>
<td>R. racemosa</td>
<td></td>
<td>Bulimphalaria pfefferi</td>
<td>Methanol</td>
<td>150.00</td>
<td></td>
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<tr>
<td>Avicennia germinans</td>
<td>leaves</td>
<td>Bulimphalaria pfefferi</td>
<td>Methanol</td>
<td>175.00</td>
<td></td>
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<tr>
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<td>Methanol</td>
<td>89.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulimphalaria rholfsi</td>
<td>Methanol</td>
<td>123.74</td>
<td></td>
</tr>
<tr>
<td>Languncularia racemose</td>
<td>leaves</td>
<td>Bulimphalaria pfefferi</td>
<td>Methanol</td>
<td>102.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulimphalaria globusos</td>
<td>Methanol</td>
<td>125.00</td>
<td></td>
</tr>
<tr>
<td>Euphorbia helioscopia</td>
<td>leaves</td>
<td>Bulimpharius wright</td>
<td>Methanol</td>
<td>152.03</td>
<td>AL-Zanbagi (2005)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulimphalaria wright</td>
<td>hot water</td>
<td>96.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>methanol</td>
<td>11.3</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>chloroform</td>
<td>80.5</td>
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<td></td>
<td></td>
<td></td>
<td>acetone</td>
<td>8.9</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>hexane</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>
and rainfall), while the distribution and abundance are influenced by the biotic and non-biologic 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 *Schistosoma haematobium* exposed to *Tetrapleura tetraptera* extracts exposed to *Tilapia nilotica* and *Tilapia galilaeae* 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 organisms varies among species. As such research should be focused on:

- Toxicity level on other aquatic organisms especially fishries, planktons and benthic organisms.
- Possible alteration in water quality parameters with the application of plant molluscicides
- The population density of the snail on the aquaic ecosystem
- Potential usage 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
- Adaptation mechanisms of the snail that them surviuve in slow flowing water.

Table 1 Cont.

<table>
<thead>
<tr>
<th>Plant/Species</th>
<th>Solvent</th>
<th>LC$_{50}$ ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Euphorbia schimperiana</em> leaves</td>
<td>Builnus wright</td>
<td>cold water 81.8, hot water 72.8, methanol 2.3, chloroform 3, acetone 10.1, hexane 18</td>
</tr>
</tbody>
</table>

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*, *Talnium trigularae*. 

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 galilaeae* 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 organisms varies among species. As such research should be focused on:

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- 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
- Adaptation mechanisms of the snail that them surviuve in slow flowing water.
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.

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