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Epidemiological Survey of Human and Veterinary Schistosomiasis

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<http://dx.doi.org/10.5772/53523>

1. Introduction

1.1. Incidence of schistosomiasis

Schistosomiasis is one of the fifteen neglected tropical diseases (NTDS) namely: schistosomiasis, ascariasis, buruli ulcer, chagas disease, cysticercosis, food borne trematodiasis, hookworm disease, leprosy, lymphatic filariasis, trachoma, trichuriasis, leishmaniasis, guinea worm, trypanosomiasis and oncocerciasis. It is a resurgent disease and *Schistosoma* sp. Infects well over 250 million people worldwide beside livestock [1]. Schistosomiasis (also called Bilharzias after the German tropical disease specialist, Theodore M. Bilharz, 1829–1862) is second only to malaria in parasitic disease morbidity. Despite control programmes in place, the distribution and the number of people estimated to be infected or at risks have not reduced. Approximately, over 600 million people in tropical and subtropical countries are at risk and of those infected 120 million are symptomatic with 20 million having severe manifestations. Schistosomiasis is endemic in many countries, not only in sub-Saharan Africa, but the Middle East, Far East, South and Central America and the Caribbean. It is endemic in about 76 countries of the world including Nigeria. Presently, an estimated 3 million Nigerian children aged between 5 and 14 years are infected.

Endemic distribution: Ten species of schistosomes can infect humans out of seventeen recognized species, but a vast majority of infections are caused by *Schistosoma mansoni*, *S. japonicum* and *S. haematobium*. Today, 85% of the numbers of infected people live in sub-Saharan Africa due to ignorance, cultural beliefs and practices and water contact patterns where *S. mansoni*, *S. haematobium* and *S. intercalatum* are endemic. Livestock such as cattle harbour *Schistosoma bovis*; sheep harbour *Schistosoma curassoni* among others. The crucial agent perpetuating this disease is the water based snail intermediate host, flourishing in slow moving waters of man-made lakes, dams, irrigations channels and other fresh water bodies important for increasing agricultural production in developing countries.

In Nigeria, *Bulinus globosus* (Morelet) and *Bulinus rohlfsi* (Clessin) are intermediate hosts of *S. haematobium* and they are widely distributed.

Symptoms: In the early stages of infection, symptoms include cough, headache, loss of appetite, aches and pains, and difficulty in breathing usually followed initial skin irritation. Nausea is common in more advanced infection, accompanied by haematuria and in some cases renal obstruction. *S. haematobium* infections usually come with haematuria, leukocyturia, urinary tract complaints, tender abdomen and supra-pubic tenderness whose outcome include chronic iron deficiency anaemia, scarring, deformity of the ureters and bladder, and chronic bacterial super infection. These could lead to severe damage of urinary tract organs, and ultimately to renal failure. Schistosomiasis generally is insidious, it begins harmlessly but the end can be fatal if no attention is given to it at the onset.

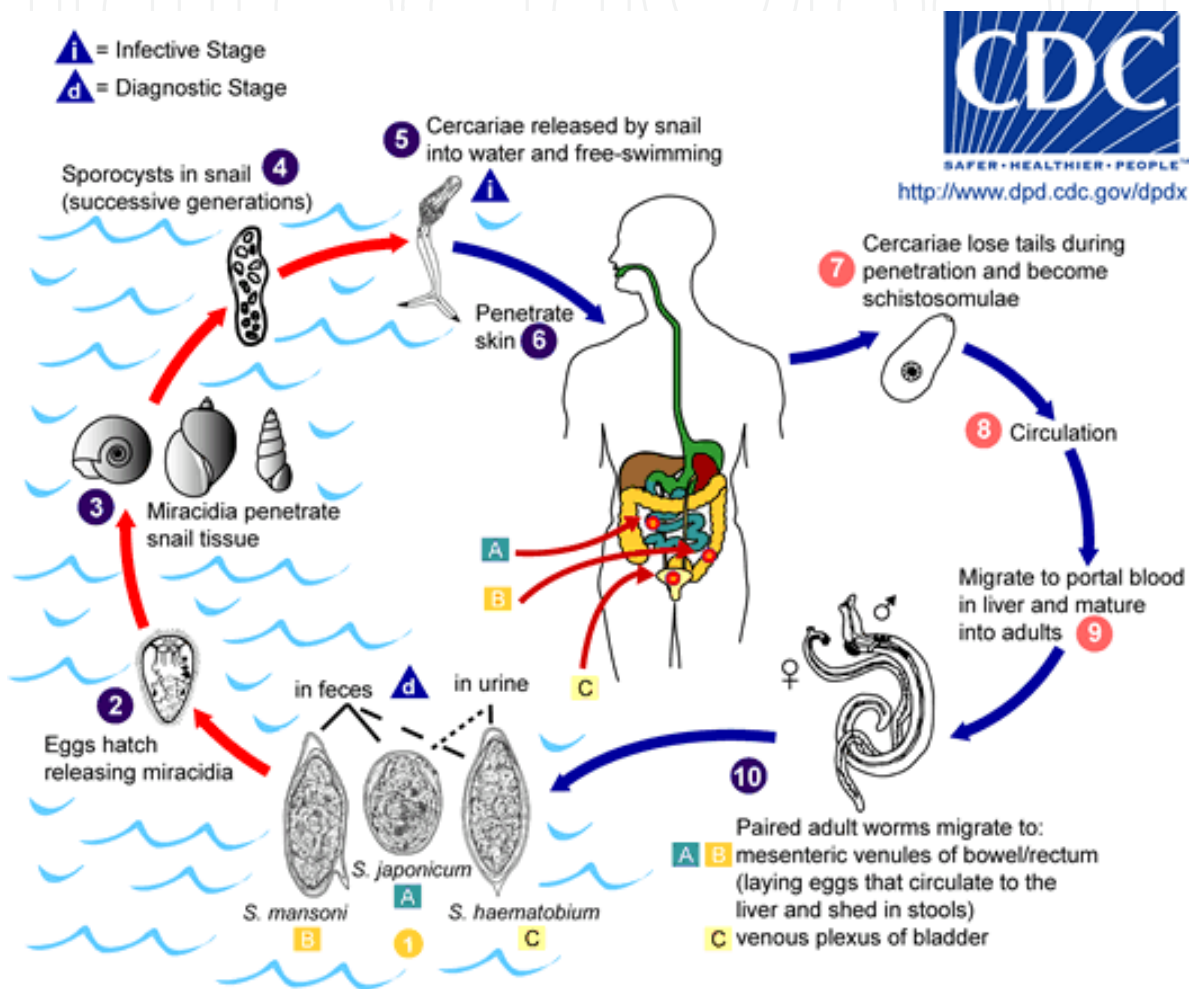
Medical treatment: Current medical management of bilharziasis relies on praziquantel, sometimes in combination with oxamniquine. Praziquantel (Biltricide®, Bayer AG, Germany) a heterocyclic prazino-isoquinoline, is highly effective against all species of schistosomes pathogenic to humans. However, since its first use, praziquantel treatment has been noted not to be 100% effective in eliminating *S. haematobium* infection. In adult schistosomes, praziquantel reduces vesication, vacuolization, and disintegration of the tegument. It also causes mature schistosome eggs to hatch. Immature eggs remain unaffected and continue to develop to maturity. In longitudinal studies, bladder wall pathology and hydronephrosis have been found to regress upon treatment, especially in active phases of the infection. However, if chronic stricture of the ureters has occurred, no significant reduction of the renal collecting system may result. In such a case, surgical intervention including mechanical dilation, resection, re-implantation, formation of an ileal ureter, and even nephro-ureterectomy may be required.

Another concern with respect to the future of praziquantel treatment is the ever-present worry over the emergence of drug resistance. Praziquantel has been in use for 4 decades, during which time it has been the drug of choice for many human and veterinary parasitic infections worldwide. The European Commission has established an International Initiative of Praziquantel Use to review reports of low efficacy in clinical trials in Senegal and Egypt, and reports of resistant *S. mansoni* strain isolated in the laboratory. While investigations suggest that no emergence of praziquantel resistance in *S. haematobium* has yet occurred, mathematical models predict that such resistance can be expected to occur as early as 2010. As a consequence new drug is being actively investigated.

Vaccines: No effective vaccine is yet available against any of the *Schistosoma* species. The Schistosoma Genome Project, created in 1992, has begun to yield comprehensive understanding of the molecular mechanism involved in schistosome nutrition and metabolism, host-dependent development and maturation, immune evasion, and invertebrate evolution. New potential vaccine candidates and drug targets are emerging.

The Life Cycle and Pathophysiology of *S. haematobium*: When eggs are excreted into fresh water, they hatch to release motile, ciliated miracidia (embryos) that penetrate aquatic bulinid snails, the intermediate host (Figures 1-3). Cercariae (larvae) emerges from the snails and penetrates the skin of humans in contact with the water (Figure 1). The cercaria (now called schistosomu-

lum) migrates to the lungs and liver, and after 6 weeks, the mature worms mate and migrate into the pelvic veins to begin oviposition. The eggs penetrate small, thin-walled vessels in the genitourinary system. During the active phase, viable adult worms deposit eggs that induce a granulomatous response with the formation of polyploidy lesions. During this phase eggs are excreted. An inactive phase follows the death of adult worms. No viable eggs are present in the urine and large numbers of calcified eggs are present in the wall of the bladder and other affected tissues. As fibrosis progresses, polypoid patches flatten into finely granular patches.



Source: Alexander J. dasilva and Melanie Moser, Public Health Image Library of the Centre for Disease Control and Prevention (CDC), USA.

Figure 1. Life cycle of schistosomes

2. Fresh water habitats harbouring snail hosts of schistosomes

Fresh water habitats can be divided into six (6) main categories having the following characteristics.

Shallow Pools: These are temporary rain filled depressions, approximately 0.5m in depth, frequently with a low electric conductivity and no aquatic vegetation. Substrate may be laterite, topsoil, sand or even granite. **Excavations:** These include borrow pits formed during road construction and deep, hand dug excavations. It is devoid of vegetation and has low conductivity. The substrates include laterite or sandy subsoil. It retains water after rains.

Small earth dam: Consist of impoundments of seasonal streams with sparse vegetation.

River and Marshes: They are characterized by having fringing hydrophytic flora and gentle flow. They are perennial, their water supply being regulated by dams.

Irrigation Channels: The substances are concrete or clay. The channels are frequently colonized by aquatic flora such as *Typhaipomoea* and *sedges*.

Reservoirs and Lakes: These are major habitats ranging in surfaces from 10 ha – 17000 ha. They undergo marked seasonal and long-term changes in water level. The aquatic vegetation is poor, the main colonizing plant being *Typha*



Figure 2. Shell of a host snail (*B.globosus*) ©



Figure 3. Shell of a host snail (*B. rohlfsi*) ©

3. Danger of schistosomiasis

Schistosomiasis cannot be eradicated worldwide at this time; neither will many of these diseases be cured by sophisticated health care services, epitomized by medical technology and large hospitals due to the insidious and complex nature of the disease. Instead the development process itself will perpetuate them [2, 3]. Irrigation projects—designed to increase the standard of living, agricultural production to improve quality of life—are often planned in or near breeding ground for vectors of water-related diseases. For instance, the prevalence of schistosomiasis in many areas around the Aswan Dam in Egypt tripled after a constant bed of slow-moving water in open irrigation channels was provided for the snail—an intermediate host for the disease. However, a safe adequate water supply is generally associated with a healthier population. When Japan installed water supplies in 30 rural areas, for example, the number of cases of intestinal diseases there was reduced by 72%—(a rather substantial decrease) showing

that schistosomiasis may be curtailed in endemic areas when major improvements in the standard of living have been introduced together with control of snails and reduction in both water contamination and contact.

Focus and attention on the new challenges in control programmes for schistosomiasis as well as priority research areas in the new century include: (1) status of schistosomiasis control programme; (2) progress in applied field research; (3) biology and control approaches of snail host; (4) novel approaches for schistosomiasis control; (5) pathogenesis and mobility of the disease; (6) immunology and vaccine development; (7) screening of population for chemotherapy in low transmission areas; (8) sustainable intervention methods in different endemic settings; (9) impact of animal schistosomiasis on agricultural development and importance of its control; (10) GIS/RS application and environmental changes that are very essential (3).

4. Continental distribution of schistosomiasis

Epidemiology of schistosomiasis refers to the prevalence, incidence and intensity of infection by a particular schistosome in man or animal. The prevalence rate gives the proportion of subjects who are infected at a given point in time, while intensity of infection" is a measure of vector burden of a subject or a group of subjects. On the other hand, the incidence rate indicates the proportion of initially uninfected subjects who become infected during a given period. Within an endemic area, focal transmission of schistosomiasis, whether human or animal, is the most common while prevalence and intensity of infection vary widely from one locality to another (4). Studies of the distribution of *S. haematobium* showed that it could be endemic with prevalence rate of up to 85%. Prevalence of infection is usually lower in those areas closer to the main roads than farther away, a pattern that usually coincides with urbanization including but not limited to the distribution of piped water.

A previous cross-sectional epidemiological survey on intestinal schistosomiasis due to *Schistosoma mansoni* in Wondo Genet, Southern Ethiopia in 1999 was made to generate pre-intervention parasitological and malacological baseline data to be used as a reference in evaluation of community-based pilot control trial. The data obtained showed that for a total of 3000 stool specimens, collected from school children enrolled in 14 schools and microscopically examined using Kato method, the overall prevalence and intensity of *Schistosomiasis mansoni* was 34.6% and 184 eggs per grain of stool (EPG) respectively. Children excreting *Schistosoma mansoni* eggs were found in all of the 14 schools surveyed with a prevalence of infection ranging from 1.9% in one school to 80.6% in another. The overall prevalence of *S. mansoni* infection among males and females was 38.4% and 27.3%, respectively ($P=0.0001$, 95% C.I = 7.5% - 14.7%) whereas the intensity of infection was 186 EPG and 181 EPG, respectively ($P = 0.8045$, 95 and C.I = 1.17% - 1.23%). Malacological surveys of 27 water contact sites revealed the occurrence of *Biomphalaria pfeifferi* in 8 sites out of which 3 harboured infected snails shedding *Schistosoma cercariae*. The result shows the necessity of initiating community-based sustainable control programme. Similarly, (6) carried out a study on the feasibility and effectiveness of introducing active

teaching methods into primary schools in Tanzania with a view to enhancing health education. The focus was on personal hygiene with reference to the control of schistosomiasis and helminth infections. In a randomly selected group of children compared with a comparison group, there was evidence of changes in both knowledge and health seeking behavior. In a survey of urinary schistosomiasis and trichomoniasis conducted among 830 inhabitants of Ikao village, in Owan Local Government area of Edo State, Nigeria between October 1999 and February 2000, 178 (21.4%) of subjects excreted *Schistosoma haematobium* ova in their urine. School children were more infected than the farmers and petty traders who unlike the school children do not arbitrarily get into water contact, thus showing the importance of health education and personal hygiene. Males were noticed to be more infected than females. Most of the inhabitants had infection, while in all, urinary schistosomiasis and trichomoniasis co-infection occurred in the genito-urinary tract of 14 (6.3%) female inhabitants.

Information on the prevalence of morbidity is needed for re-calculation of the Global Burden of disease (WHO) due to *Schistosomiasis*. The data describes expression related to logistic regression including associations between prevalence of infection and prevalence of early morbidity (diarrhea, blood in stool and abdominal pain), hepatosplenic morbidity and later morbidity (haematemesis and ascitis). Diarrhoea, blood in stool due to *S. mansoni* infection mainly occurs in communities with a high prevalence of infection. The construction of George dams and reservoirs with changes in environmental conditions will influence the chances for schistosome infection to human and animals to a high level. However, the most important factor in the epidemiology of schistosomiasis is the common daily activities of villagers living in the endemic areas which constitute the risk factors for infection. Severe disease is associated with advanced infection status with signs and symptoms of portal hypertension dominating the clinical situations, and death is usually due to bleeding from ruptured esophageal varices [6, 7, 8,9]

4.1. Advancement in methodologies for schistosomiasis survey

Recent advances in schistosomiasis epidemiological surveys have resulted in the development of models such as Geographic information system (GIS) risk models for the snail-borne diseases caused by *Schistosoma* spp. and *Fasciola* spp. based on climate and satellite – retrieved data on temperature and vegetation coverage, making it possible to describe a relationship between vegetation index (Normalized Differences Vegetation Index (NDVI), land surface temperature (T(max) and disease prevalence, but with little reference to the distribution of the corresponding intermediate host snail, despite it is a key factor determining distribution of the disease in sub-Saharan Africa. Indeed a good snail distribution mode would probably mirror the endemic area of schistosomiasis. Snail distribution data corresponds with schistosomiasis prevalence data in relation to a forecast model based on NDVI and T (max) data derived from the Advanced Very High Resolution Radiometer (AVH RR) on board the National Oceanic and Atmospheric Administration Satellite Series. The 'best fit' model included NDVI values from 125 to 145 and a T (max) data range of 10-32 degrees C. These model included 92.3, 90.4 and 94.6% of the

positive snail sample sites in GIS query overlay areas extracted from annual, dry season and wet season composite maps, respectively in Ethiopia. For other sites in Africa, other NDVI and T (max) ranges may be more appropriate, depending on the species of snails present.

Similarly, In a 4 year study a geographic information system (GIS) risk model for predicting the relative risk of schistosomiasis in Kafr Elsheikh governorate, Egypt was constructed. The model, using data collected on snail population bionomics-infection rates, water quality, underground water table and cercariometry at 13 hydrologically representative sites enabling the study of role of soil type, water table and water quality at 79 of 154 rural health unit sites, validated previous models. The model permitted retrieval of relevant data by RHU 10 (rural health unit) point location. The model for the first time in Egypt supported Ministry of Health efforts to make more accurate control programme decisions based on environmental predilection sites of endemic *Schistosoma mansoni*. The possible utilization of acute phase proteins (APPs) in predicting severity of urinary schistosomiasis among infected subjects has also been canvassed.

Presently, there is a global network for the control of snail borne diseases using satellite surveillances and GIS. It came from a team residency sponsored by the Rockefeller Foundation in Bellagio, Italy, 10-14 April 2000, where an organizational plan was conceived to create a global network of collaborating health workers and earth scientists dedicated to the development of computer-based models that can be used for improved control programs for schistosomiasis and other snail-borne diseases of medical and veterinary importance. The models consist of GIS methods; global climate model data, sensor data from earth observing satellites, disease prevalence data, distribution and abundance of snail hosts, and digital maps of key environmental factors that affect development and propagation of snail-borne disease agents. The collaboration plan calls for linking a 'central resource group' at the World Health Organization, the Food and Agricultural organization, Louisiana State University and the Danish Bilharzias Laboratory with regional GIS networks to be initiated in East Africa, South Africa, West Africa, Latin America and South Asia. An Internet site, www.gnosis.org (GIS Network on Snail borne infections with special reference to schistosomiasis) has been initiated to allow interaction of team members as a "virtual research group". The sites point users to a tool box of common resources resident on computer at member organizations, provide assistance on routine use of GIS health maps in selected national disease control programme and provide a forum for development projects and climate variation and the advancement through computerized models such as Remote Sensing (RS) by earth observing satellite, a technology particularly well suited to pinpointing constraining endemic factors. Imaging techniques such as ultrasonography echo Doppler cardiography, computerized tomography (CT scan) and Magnetic Resonance Imaging (MRI) introduced a new perspective, and expanded our knowledge on morbidity [10,11, 12,13,14].

4.2. Morbidities associated with schistosomiasis

Three well-defined syndromes caused by *Schistosomiasis infections* have been revealed. The syndromes are the stage of invasion, acute schistosomiasis (katayama fever), and chronic

schistosomiasis. The complications of the acute and chronic syndromes have also been reported, namely pulmonary hypertension, neuroschistosomiasis, association with salmonella, and association with staphylococci, viral hepatitis B and glomerulonephritis. In most individuals with hepatosplenic schistosomiasis the spleen is increased in size. Intestinal schistosomiasis in individuals with low worm burdens is very difficult to diagnose and therefore laborious to control. There is strong epidemiologic evidence linking *Schistosoma haematobium* infection with carcinoma of the bladder, the utility of cytological screening for urinary tract cancer has not been critically evaluated in *S. haematobium* – endemic populations. *S. haematobium* infection is regarded to be associated with increased risk for cytological abnormality such as metaplasia and hyperkeratosis. Correlation exists between metaplasia and *S. haematobium* infection prevalence early in life. Morbidity results from granulomatous response to *S. mansoni* eggs deposited in peripheral portal veins.

The resurgence and emergence of old and new infectious diseases in twenty first century is a major source of morbidity and mortality. Recent among these are HIV/AIDS, hanta virus pulmonary syndrome, lyme disease, haemolytic uremic syndrome, rift valley fever, dengue haemorrhagic fever, malaria, cryptosporidiosis and schistosomiasis. Related to this are the treatment modalities which include permissive use of antibiotics, the industrial use of antibiotics, demographic changes, social behavior patterns, changes in ecology, global warming and the inability to deliver minimal healthcare and the neglect of well established public health priorities that is a source of major concern globally. Since the distribution of schistosomiasis is focal, then if the resources available for control are to be used most effectively, they need to be directed towards the individuals and/or communities at highest risk of morbidity from schistosomiasis [15, 16].

5. Approaches in schistosomiasis control

The use of chemotherapy plays a leading role in the control of schistosomiasis. Snail control by the use of molluscicides is being explored in integrated control programmes. The level of effectiveness of this method however, is still subjective. It has been shown that male and female schistosomes exhibit regional and sexual differences in susceptibility to chemotherapy that represent a form of evasive strategy of the parasite. The control of schistosomiasis therefore by molluscicides is linked to the interdependence of immunotherapy and chemotherapy. Mass chemotherapy alone in regions of high prevalence, may provide good results initially, but it might be unable to give a lasting effect due to great environmental variations., hence, the need for back up approaches such as snail control.

For snail control, molluscicides such as frescon, sodium penta chlorophenate, organotin, dinitrophenol, carbamates, niclosamide and copper sulphate are effective against aquatic and amphibious snails and their eggs.

Combining low doses of praziquantel and oxamniquine ($\frac{1}{3}$ the curative dose of praziquantel plus $\frac{1}{3}$ the curative dose of oxamniquine) for instance can result in potentiating effect in animals receiving combination therapy. Also low concentration of aridanin (0.25 mg/ml)

reduced the production of cercariae by snails already shedding cercariae. Aridanin and Aridan both produced profound reduction in the worm recovery of mice infected with pretreated cercariae of *S. mansoni* and *S. bovis*, showing its efficacy at reducing the transmission of schistosomiasis at different stages of the schistosome development.

It has been reported that snails infected with *S. mansoni* and *S. bovis* and fed with a food - praziquantel mixture - stopped shedding cercariae for several days. Histological studies showed that at the exact moment of this treatment, there was a total destruction of many nearly mature cercariae. But it has also been shown that through genetic crosses between phenotypically resistant and sensitive schistosomes' resistance to hycanthone and oxamniquine by schistosomes is a common occurrence and that it behaves like a recessive trait, thus suggesting that resistance is due to the lack of some factors. Presently, advocacy is for the appropriate application of a schistosomal vaccine, which when it becomes available will expedite the eradication of this parasite infecting greater than 200 million people and livestock [17, 18].

6. Survey, identification and distribution of species of snail hosts, in Nigeria

Certain species of African fresh water snails are exceedingly important both from a medical and veterinary viewpoint. However, there is dearth of literature through which these snails can be identified in a reliable manner according to species. This is so as more species are still being discovered. Snails' species are however identifiable using criteria spelt out in the bulletin published by WHO snail identification center, Danish Bilharziasis Laboratory. The bulletin is a field guides to African fresh water snails [19, 20]. Snails of interest could be identified by the following criteria:

Bulinus rohlfsi (Clessin):

It is usually 11 x 7.7mm when fully matured but frequently smaller. The shell is usually very light, almost white and with a low spire. The distinctly arrowhead shaped mesocone of the lateral teeth only partially separated from the endocone.

Bulinus globosus (Morelet):

It is usually in the range of 16 x 12mm and 22.5 x 14mm but sometimes larger. The distinctive character is the copulatory organ with a vergic sheath, which is not wider than preputium.

With a few exceptions all mollusks of medical or veterinary importance live in fresh water. According to their great age, several of the families have an almost worldwide distribution. Some are represented on all continents while others are missing only in South America or Australia. Others are only known from the tropics but then, as a rule, are found in the New as well as the Old World. Almost all members of one and the same family of fresh water mollusks are often to great extent alike, no matter from where in the world they descend [21,22].

The determination of species is often a very difficult problem, and without sufficient experience with regard to the family and country in question, correct identification is almost

impossible except by the use of good field guide. This is due to two factors, i.e. partly the great variability found within most freshwater mollusks and partly the lack of good distinctive characters. *B. globosus* is an infrequent species in Kano State, being found in well established rain pools and restricted to the South of the 12^o parallel. It is present in Borno State. The distribution of *B. rohlfsi* is widely reported in Kano and in Ibadan and Akure in South West, Nigeria [23, 24] and in area such as Epe in Lagos State.

In these areas, temporary water bodies (being tropical zone) are the principal foci of transmission of schistosomiasis in humans. Perennial habitats were important transmission sites that represent only a small portion of the overall problem [25].

7. Ecological factors affecting intermediate snail hosts

A combination of both abiotic and biotic factors exert their influences on the fecundity and hence population density of snails in a given habitat. The effects of the two are interrelated and are discussed in the following sections.

7.1. Fresh water malacology

With a few exceptions, all mollusks of medical or veterinary importance live in fresh water. Through familiarity with the snails and bivalves within a certain area, mere looking at the shell can help determine from which lake or river an individual snail originates. This is due to the fresh water mollusks being influenced to a high degree by the environment under which they live. Most fresh water mollusks prefer stagnant or slowly running water. On the exposed shores of big lakes and in fast-flowing rivers there are few if any pulmonates whereas prosobranchs and bivalves may be present. They are usually lacking in very acid or alkaline water, but apart from these exceptions they can be found in all types of freshwater bodies from the greatest lakes to small rainwater pools. In great lakes they are most plentiful in sheltered bays with shallow water, but sometimes they live at greater depths, down to 10 meters or more for pulmonates and 150 – 200 meters for prosobranchs and bivalves. When these snails are absent at greater depths, the reason is lack of oxygen [26,27].

According to this report, smaller lakes, ponds, and sluggish streams are the preferred habitat for most of the species. Presence of water lilies, as a rule is indicative of good conditions for snail life while Nile lettuce seems to indicate poor conditions. Papyrus swamps are also regarded as bad habitats. Certain species of freshwater pulmonates (snails) are known to live preferably or entirely in temporary pools, even in pools that hold water during only a few months of the year. It is known that many populations of fresh water pulmonates are subjected to great fluctuations, which means that species abundant at one visit might seem to be very scarce a few months later. Repeated visits are therefore advised to be sure that all species have been found, even in small ponds. It has been noted that temporary water bodies in the tropical zone are the principal foci of transmission of schistosomiasis in humans. Perennial habitats are regarded as important transmission sites that represent only a small portion of the overall problem.

8. Habitat water chemistry parameters, snail's availability and spread

Although the influence and effect of ecological physico-chemical properties of fresh water (water chemistry) on snails availability, distribution and survival is in no doubt, yet no clear picture has emerged on the overall influence they exert. Usually a very few distinct relationships exist in snail ecology and there is a general lack of precise data. It is very difficult to define and evaluate the significance of an individual environmental factor- whether physical, chemical or biological when all may be mutually affecting one another and their combined effect influencing a particular species or population. Fresh water snails are capable of adapting to wide range of environmental conditions such as water bodies with moderate organic content, little turbidity and substratum rich in organic matter and moderate light [28]. It is known that major changes in patterns of transmission (i.e. availability of infected snail hosts) occur after man-made disturbances of the ecosystem, whether by physical or chemical changes to the environment. Works on the chemistry of water in different snail habitats (29, 30, 31) in Nigeria and other countries indicate that most snails are tolerant of water differing greatly in chemical content.

An outbreak of intestinal schistosomiasis reported at Richard – Toll, 130km from the dam of Diama, Senegal, was the first sign that the ecological changes caused by the dam had an impact on the prevalence of schistosomiasis. Since the main functions of the Diama dam were prevention of seawater intrusion, provision of a reservoir of fresh water for irrigation and domestic supply of water for municipal use in Dakar, it was suspected that it was likely that the dam induced both physical and chemical environmental changes. In addition to increasing the number of water bodies around the area, the Diama dam prevented salt-water intrusion into the river and the marigots of the Delta, thereby creating new habitats in areas previously unsuitable for fresh water snails [31].

In July 1983, salinities as high as 19.9‰ were recorded in the Senegal River at Richard – Toll [32,33] showed that the dam caused a gradual softening of the Lac de Guiers water: water mineralization has decreased 20% in the Northern part and nearly 50% in the Southern region. At the same time the formerly important yearly variations in salinity have distinctly diminished. However, because of the dearth or non availability of physical or chemical data from selected transmission sites at that time, it was concluded that it will be difficult predicting how the expected ecological changes influence snail habitats, especially since it is usually not possible to predict colonization of a particular habitat through chemical analysis of its water content. Interesting results have been obtained showing that the hatchability of eggs, the fecundity and survival of adult *B. africanus* had been adversely affected by salinities as low as 1.0‰, with the most significant reductions occurring between 3.5‰ and 4.5‰ [34]. From other recent studies it also appeared that trematode parasitism reduces the salt tolerance of the snail intermediate hosts. A decrease in hatching of schistosome ova with increasing salinity has also been observed. Poor survival of *B. globosus* hatchings in water with a conductivity of 125µs is known. *B. truncatus* is adapted to hard water, in contrast to *Biomphalaria* sp. Another indication that salinity may have been one of the major reasons for the low prevalence of schistosomiasis in the Senegal River Basin Delta (SRB) was the existence of an endemic focus for *S. haematobi-*

um infections in a village of Lampsar, 20km from the Atlantic Ocean. There *B. Senegalensis* and *B. globosus* were the likely intermediate hosts for *S. haematobium*. The probable reason for the presence of these bulinid species was the existence for a long time (more than 50 years) of several barrages on the Lampsar River that prevented salt intrusion from the Senegal River. There is, however, conflicting evidence on the role of salinity. The spreading of *B. globosus* in the Lampsar River is said to be linked to more stable levels of water bodies and increased irrigation channels rather than reduced levels of salinity. In contrast, in the transmission sites directly associated with water bodies in the Delta, reduction in salinity may play a role in further spread of schistosomiasis. Thus, due to all these ecological changes, areas previously unsuitable for fresh water snails are now providing ideal habitats. The results of these changes are not only increases in the size of existing snail populations, but also spread and colonization of these new habitats by other bulinid species. Influences from the parameters from various types of snail habitats in SRB (Senegal River Basin) showed no significant variations in values between the dry and rainy season except that temperatures were higher in the month of October; but pH and conductivity remained within the levels of tolerance for bulinids. Although the focal distribution of schistosomiasis is linked to water resources development, the factors contributing to local variations in prevalence and intensities of infection are not yet understood. No evidence in the Transvaal supported claiming that the chemical composition of natural unpolluted water plays any part in determining vector snail habitats but that pollutions (such as the presence of sewage or industrial wastes) and turbidity appear to have adverse effects on bilharziasis vectors. Long term population fluctuations are greatly affected by spates (flooding) associated with heavy rainfall, which of course will increase the turbidity of the water bodies so affected. In the model developed, they observed the population dynamics of the fresh water snail *B. globosus* such as abundance changes, recruitment rates, and mortality rates for adult snails in river habitats in Zimbabwe was such that the rate of recruitment into the adult population is dependent on temperature, incorporating a time lag to allow for growth to adult size using the mathematical model. It has been observed that the flood that was likely to occur as a result of constructions of three (3) George Reservoirs in Yangtze, China which could interfere with the development of snails, with the flushed beaches and migratory settlements at certain attitude becoming snail habitats, making the reservoir area, a potential transmission area of schistosomiasis due to dispersal of infectious resources. Also in a UNDP/WORLD BANK/WHO special programme for Research and training in Tropical Diseases results showed that climates and topography effectively restrict vector –borne infections to certain geographical areas, a clear illustration of how strongly the spatial distributions of these diseases rely on environmental factors. This then call for detailed study and analysis of various physico-chemical parameters in snail ecological habitats, for the purpose of better understanding of how the diseases they transmit could be checked effectively.

8.1. pH of water bodies

Low pH could be harmful to snails. This is due to the possibility of denaturation of the mucus on the exposed skin surface; extremes of pH i.e. low as well very high pH will be harmful to these snails as both could denature the glyco proteins (mucus) on their exposed skin surface.

8.2. Alkalinity

This refers to the (carbonate) CO_3^{2-} and (bicarbonate) HCO_3^- content in the water bodies. Concentration of 50mg/L is regarded as weak, 100 mg/L as medium while 200mg/L is regarded as strong (34,35).

8.3. Total Dissolved Solids (TDS)

The presence of sewage or industrial wastes in water bodies is regarded as an important factor in determining vector snail habitats, as they constitute pollutions and snails could only adapt to water bodies with moderate organic content. Water bodies may contain suspended solids, inorganic, organic chemicals, biodegradable organic matter, pathogenic microorganisms, and metals. Pathogenic microorganisms and indicator pathogens are found in high concentrations per gram of raw sewage, and if allowed to accumulate and sit, untreated water produces malodorous emissions as a result of decomposition of organic material.

Solids in water bodies are usually measured as solid, total and dissolved total solids. A typical water body contains solids, total as 350mg/L (Weak), 720 mg/L (Medium) and 1,200mg/L (Strong) while TDS in the range of 250mg/L (Weak); 500mg/L (Medium) and 850 mg/L (Strong) [35,36].

8.4. Color

Pure water is colorless but the presence of pollutions in water bodies give rise to varied colors. It has been observed that vector snails appeared to prefer clean, clear water bodies to colored water [24].

8.5. Turbidity

Snail vectors are generally intolerant of high turbidities. Intermediate host snails found in most cases in naturally turbid water tend to decrease as the turbidity of the habitat pool increase. It has also been shown that while a turbidity of 360mg/L (due to suspended mineral from granite erosion) did not affect snails themselves, it prevented development and hatching of *B. pfeifferi* eggs [37]. It was noted that both *B. globosus* and *Lymnaea natalensis* are tolerant to this concentration of suspended particles as their eggs hatch normally at a level of 190mg/L. The water composition of most snail habitats is usually eutropic, having some dissolved organic materials showing that snails are negatively affected by turbid water.

8.6. Total hardness

This is indicated by the total concentration of Ca^{2+} and Mg^{2+} ions present in water bodies, different concentrations of calcium and magnesium ions affect the mortality rates of snails while egg production by *B. pfeifferi* kept in both natural streams and artificial culture medium with high magnesium (Mg^{2+}) and Ca^{2+}) ratios (12:4 and 19:7 respectively) is usually reduced. *B. truncatus* is adapted to hard water, in contrast to *B. pfeifferi*. This fact may help to explain the reason why *B. truncatus* was fairly widespread in the Delta (Senegal River Basin) prior to

the building of the Diama dam. The existence of a relationship between the occurrence of *B. pfeifferi* and *B. globosus* and low stretches of watercourses over rocks with hardness of 5 or more in Mohs' scale of hardness in the South –eastern Transvaal, suggesting adverse effects of hard water on the thriving of snail hosts.

8.7. Chloride ion (Cl⁻)

The concentration of this ion is a measure of salinity of a particular water body. Salinity has been reported to exert great influence on the availability of vector snails in a given habitat. The hatchability of eggs and the fecundity and survival of adult *B. Africanus* had been adversely affected by salinities as low as 1.0% with the most significant reductions occurring between 3.5% and 4.5%, salinity even in low value plays a major role in the low prevalence of schistosomiasis in Senegal River Basin Delta, where the construction work brought about reduction in salinity resulting in new outbreaks of both intestinal and urinary schistosomiasis in the area. A decrease in hatching of schistosome eggs with increasing salinity has also been observed. Concentration of 30mg/L is regarded as weak, 50mg/L as medium and 100 mg/L as strong [34,35].

9. Study sites

Fresh water bodies namely: Kanye and Rimin Gado dams (Kano), Lagoon front (Unilag, Akoka, Lagos) and Oyan dam (Ogun-Osun river basin, Abeokuta) were surveyed for 3 years.

Two snail species (*Bulinus globosus* and *Bulinus rohlfsi*) were searched for and collected quarterly (May – August and November –February) in these sites because they are established sites for these snails. However, this is the first time the presence of these snails will be reported at the Lagoon front, University of Lagos.

9.1. Kanye and Rimin Gado

Kanye is a small village, located about 45km west of Kano city. The Kanye dam is about 600 x 800 m in size, with a shallow flat and steep margin and 100% exposure to sunlight. The vegetation consists of the aquatic plant *Chara sp*, which grows luxuriously during the dry season. Also present, is the aquatic flora, *sedges* and waterweeds, dense *Najas sp.* and moderate *Typha sp.* The snail species such as *B. rohlfsi*, *B. globosus* and *Biomphalaria pfeifferi* are abundant in Kanye and Rimin Gado dams, which serve as a major domestic source of water supply to the inhabitants, as only few public taps, which do not run regularly, are available. Laundry, bathing and cattle grazing are pronounced around the dam. The second dam, located at Rimin Gado and designated as Kanye II is located some 20km West of Kano city. The dam is a reservoir of a shallow impoundment of a small seasonal river. It is about 500m x 800m in size. The exposure of the surface to sunlight is 100%. The substrate is a fine sandy soil, topped by a thin layer of clay and humus. It has the same vegetational features as Kanye (I) and contains same snail species. Human interference through laundry, bathing, farming and animal grazing

is very prominent. Species of *B. globosus* and *B. rohlfsi* were collected there and water samples were taken.



Figure 4. Rimin Gado dam, Rimin Gado area, Kano, Kano state, Nigeria.

9.2. Lagoon front, University of Lagos

The Akoka Campus of the University of Lagos, an area of about 320 hectares located in the North East of Yaba Lagos, was a part of study area. Acquired in 1962, the acquisition notice gave the extent as 807 acres. The 320 hectares of the University of Lagos Land comprises of 174 hectares of good building ground and 146 hectares of swamp or swampy area. The swamps are divided into the northern swamp which covers an area of 61 hectares, eastern swamp 24 hectares, southern swamp 40 hectares and the center – finger swamps 16.5 hectares.

The Akoka Campus of the University of Lagos is located on latitude of 6°22'N – 6° 44'N and longitude of 3° 29'E. It is bounded in the west by the Ogbe River (traversed by a bridge between Abule Oja and the main gate of the University), in the North by Akoka Ilaje, in the South by Iwaya and East by the Lagos Lagoon.

The campus being located in the center of Lagos has the same climate as Lagos. The climate of Lagos is of the equatorial type. All the year round, temperature is usually above 65°F and average 85°F. There is minimal seasonal variation of about 10°F between the hottest month (March) and the coolest month (August). Relative humidity is usually between 80% and 100% dropping to about 70% in the afternoon during the dry season. April to October marks the extent of the rainy season with an average annual rainfall of 1830mm. Despite the relative flatness of the area, spatial variation is great.

9.3. Oyan Dam (Ogun-Osun river basin authority, Abeokuta)

The Oyan Reservoir is located on Latitude 7° 14" N and Longitude 3° 13" E, at an elevation of 43.3 m above sea level. It has a catchment area of approximately 9000km² within the southern climatic belt of Nigeria. The belt is characterized by a rainy season of about eight months (March – October) and a dry season of about four months (November – February); a mean annual precipitation of 1000 – 1250 mm a mean relative humidity of 75% - 100% and a mean annual temperature of about 30°C.

The soil is generally composed of crystalline acid rocks of the ferruginous tropical type that have been moderately to strongly leached with low humus content. It is characterized by weak acidic to neutral surface layers and moderately to strongly acid sub-layers. The area falls within the 'Ibadan Group' which overlies the metamorphic rocks of the basement complex [38].

The vegetation is mainly savanna of the low forest type. This is characterized by sparsely distributed short trees in a predominantly grass land, as a result of timber lumbering, bush burning and cultivation of an original rain forest.

10. Methods

10.1. Collection and selection of experimental snail samples

10.1.1. Procedures

Snail sampling for species of *Bulinus globosus* and *Bulinus rohlfsi* was carried out quarterly (May – August and November - February) during dry and rainy seasons using standard technique involving drag scoop supplemented by manual search. The contents of the scoop were searched by visual inspection and by inspection of the underside of boats, bamboo rafts, floating and submerged sticks and vegetation. All snails collected from each station (i.e. scoop and manual searches) were pooled and recorded as number of snails per site per quarter. All snails were identified (Tables 1 and 2).

Dam	<i>B. globosus</i>	<i>B. rohlfsi</i>
Rimin Gado & Kanye	293	450
Oyan	259	83
Lagoon front	158	0
TOTAL	710	533

Table 1. Total Snail catch from the study sites surveyed.

Parameter	Kanye Dam		Rimin Gado Lake		Lagoon Front		Oyan Dam	
	<i>Glob</i>	<i>Rohl</i>	<i>Glob</i>	<i>rohl</i>	<i>Glob</i>	<i>rohl</i>	<i>Glob</i>	<i>rohl</i>
Snail catch	188.0	340.0	105.0	110.0	158.0	0.0	259.0	83.0
PH at 25°C	7.2	7.3	7.2	5.6	5.9	6.9	5.6	7.5
Total alkalinity (CaCO ₃) (mg/L)	120.0	120.0	218.0	209.6	108.	180.0	47.0	49.0
Total dissolved solids (TDS) (mg/L)	158.4	160.2	596.6	618.8	296.4	301.2	205.8	208.2
Total Hardness (mg/L)	47.0	49.2	66.8	96.9	96.0	87.4	13.3	13.5
Calcium (mg/L)	40.0	42.0	29.3	30.2	32.4	28.9	7.6	7.5
Magnesium (mg/L)	7.0	7.2	37.5	66.7	63.6	58.5	5.7	6.0
Salinity (%)	14.3	13.9	14.7	14.1	27.8	28.1	2.8	2.6
Turbidity (m)	5.2	5.0	4.2	6.8	3.6	3.7	1.0	0.9
Colour (NTU)	10	10	15.0	25.0	10.0	15.0	10.0	10.0
Biochemical Oxygen demand (BOD) (mg/L)	5.0	5.8	19.5	20.2	14.2	14.8	5.0	4.8
Dissolved Oxygen (mg/L)	4.5	4.7	6.2	5.3	2.5	2.7	5.3	5.6

Glob: *B. globosus* snail caught in the surveyed water bodies

Rohl: *B. rohlfsi* snail caught in the survey water bodies

Table 2. The median values of some physico-chemical properties of surveyed water bodies.

11. Result

Survival of snails collected during the dry season subjected to aestivation for 30 days at 25°C was 20 *B. globosus* out of the 30 used representing 67.0% survival and 10 dead representing 33.0%. Similarly, 16 *B. rohlfsi* representing 88% survival while 2 or 12.0% died.

26 *B. globosus* or 87% survived while 4 or 13.0% died during starvation for 30 days, while 18 or 78.3% of the 23 *B. rohlfsi* survived while 5 or 28.0% died. No mortality was recorded in the control (fed) group.

During rainy season however, 16 *B. globosus* or 94.0% survived aestivation while 14 *B. rohlfsi* or 82.0% survived 27 *B. globosus* representing 90.0% survived starvation while 23 *B. rohlfsi* representing 76.0% survived starvation respectively.

Four *B. globosus* or 4.0% that were dead in the control group while 9 *B. rohlfsi* or 10.0% were recorded dead in the control group.

B. globosus in the control group survived best followed by *B. rohlfsi* in the same group. Aestivating *B. rohlfsi* survived the least.

Surviving snails were found buried at different depths (0.2-12.0mm) in the soil mixture while their aperture were filled with mud and were deeply retracted into the shell).

Survival was better during rainy season. The ecological conditions could be more suitable during this period survival for *B. globosus* under starvation was poor during dry season compared to rainy season while both species under feeding survived best during dry season.

There was no definite pattern in the survival but it appears that survival may be indirectly related to the infection of these snails with schistosomes.

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