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REVIEW ARTICLE
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The status of schistosomiasis japonica control in the Philippines: The need for an integrated approach to address a multidimensional problem

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Abstract

Schistosomiasis japonica remains a public health concern in many areas of the Philippines. Adequate and updated information is essential to enhance policy and service delivery toward control and elimination. Despite the efforts on schistosomiasis control in the Philippines, some challenges remain in these dimensions. An integrated surveillance system is recommended to determine the prevalence of infection in humans, animal reservoirs, and snail intermediate hosts, allowing the identification of high-priority areas for targeted interventions. This will entail the enhancement of laboratory diagnosis capacity through the use of more sensitive techniques, complemented by capacity building of concerned human and animal health professionals. Given the zoonotic nature of schistosomiasis japonica, adopting the One Health approach is essential to influence policies and interventions that may accelerate control and elimination. This can be achieved through the attainment of mass drug administration coverage targets and intensified case finding and management, robust implementation and integration of veterinary public health activities, the conduct of snail control measures, provision of safe water, sanitation, and hygiene services, and health promotion and education into the national schistosomiasis control and elimination program. This review aimed to describe the status of schistosomiasis japonica control in the Philippines in the context of human health, animal health, vector ecology and management, environmental health, and sociocultural dimensions.

Keywords: neglected tropical diseases, One Health, schistosomiasis japonica, The Philippines.

Introduction

Neglected tropical diseases (NTDs) such as schistosomiasis (SCH) are diseases of poverty commonly found in tropical and subtropical regions [1]. NTDs are included as targets for global action in the United Nations Sustainable Development Goal 3.3, which aims “to end epidemics caused by NTDs” by 2030 [2] to “ensure healthy lives and promote well-being for all at all ages” [1].

SCH is a parasitic infection caused by blood flukes of the genus *Schistosoma*. Transmission occurs through skin penetration of infective cercariae on exposure to snail-infested waters [3]. In 2017, approximately 143 million people were infected with SCH [4]. In the Philippines, SCH japonica affects approximately 12 million people, with 2.5 million directly exposed to the infection [5].

The World Health Organization (WHO) aims to eliminate SCH as a public health problem by lowering the prevalence of heavy intensity infection to <1% by 2025 [6]. The WHO recommends an integrated approach to overcome the global impact of SCH which includes: (1) preventive chemotherapy (PC); (2) innovative and intensified disease management; (3) veterinary public health services; (4) vector ecology and management; and (5) provision of safe water, sanitation, and hygiene (WASH) [7].

In the Philippines, the implementation of these strategies is spearheaded by the Department of Health (DOH) through the SCH Control and Elimination Program (SCEP) [8]. The SCEP aims to interrupt the transmission of SCH by reducing the incidence of infection in humans, animals, and snails to zero by 2025 [5]. However, achieving the target remains a challenge despite decades of implementation of the SCEP.

A review of the available evidence is essential to provide the basis for enhanced policy and improved service delivery to accelerate SCH control and elimination in the Philippines. With the recent issuance of the SCEP Strategic Plan for 2019-2025, this study aimed to review the status of schistosomiasis japonica control in the Philippines in the context of human health, animal public health, vector ecology and management, environmental health, and sociocultural dimensions.

Human Health

Schistosomiasis japonica has an estimated age-specific aggregate disability impact of 9.8% and 18.6% for children and adults, respectively [9]. The infection is associated with hepatomegaly, splenomegaly, portal hypertension, and variceal bleeding [10]. These lead to undernutrition, poor physical and cognitive development among children, and decreased adult productivity, contributing to persisting poverty [11]. Central nervous system involvement may also occur when schistosome eggs reach the brain, presenting with seizures, focal neurologic deficits, and/or acute encephalopathy. This form of SCH accounts for up to 3-5% of all cases [12]. Mortality from schistosomiasis japonica is usually a result of infectious complications of untreated patients [13].

Microscopy of stool processed using the Kato-Katz (KK) technique remains the standard diagnostic procedure for routine surveillance of SCH in countries in the Western Pacific Region [14]. However, the KK technique is known to have limited sensitivity, particularly in detecting low-intensity infections [15]. More sensitive techniques such as the FLOTAC [16] and McMaster flotation [17] are becoming more popular. Immunological methods such as assays for the detection of circulating anodic antigen and circulating cathodic antigen [14] as well as enzyme-linked immunosorbent assay (ELISA) antigen tests [18,19] can also be used for more sensitive and accurate diagnosis of SCH. However, only a few countries have adopted sero-diagnostics for SCH surveillance due to its invasiveness and high cost [20]. Quantitative polymerase chain reaction (qPCR) has a high level of sensitivity in the detection of SCH in low transmission settings, making it ideal for use in confirming transmission interruption of the infection [21]. Loop-mediated isothermal amplification (LAMP) assay is simple, rapid, and sensitive detection technique. It may also be considered as it can amplify a large amount of *S. japonicum* DNA more rapidly than PCR without the need of sophisticated equipment [22].

Multiple surveys to determine prevalence have been conducted since the endemicity of SCH was established in the Philippines in 1906 [23]. The first SCH prevalence survey conducted in 1940 revealed a high national prevalence of 20.0%. World War II impeded further surveys until 1951, and the prevalence was found to have remained high at 12.2% [24]. Despite the establishment of the national SCH control program [14], a high national prevalence of 16.5% was recorded in 1975. The SCH Control Council was subsequently created in 1976. A decade after the institutionalization of the council, there was a marked decrease in the national prevalence to 10.4% [24].

In 1991, the government launched the Philippine Health Development Program (PHDP) which helped sustain the gains and intensified control efforts of the SCH program. Mass drug administration (MDA) with praziquantel (PZQ) alongside other supplementary measures began through the PHDP. A loss in national and subnational capacity followed the conclusion of the PHDP in 1995. MDA targeting high prevalence areas was only resumed in 2007 [14]. This resulted in a rebound in the national prevalence to 6.6% in 2008, from 3.8% in 1999. As of 2019, the national prevalence was 4.0% (Figure-1) [24]. However, it must be noted that recent national prevalence figures were derived from focal surveys which may provide a less accurate picture of the current status of SCH in the Philippines as compared to national prevalence surveys. The infection remains endemic in 28 provinces across 12 regions, with endemicity centered mostly in Central and Southern Philippines (Figure-2) [24].

PC delivered through MDA is the main public health strategy recommended by the WHO for morbidity control of SCH. It involves periodic use of the anthelmintic PZQ distributed to a targeted population regardless of infection status [25]. The WHO targets ≥75% MDA coverage of all school-age children in endemic regions by 2020 [14]. The DOH, through the SCEP, conducts MDA for SCH every January and targets ≥85% MDA coverage in individuals aged 5-65 years old in endemic areas [26]. Deworming for SCH utilizes both school-based and community-based approaches [26,27]. MDA is facilitated in some local government units (LGUs) through the deployment of a barangay (village) task force for house-to-house distribution of PZQ [28]. However, from 2009 to 2019, annual MDA coverage for SCH had consistently been below both national and global targets ranging from 20 to 65% (Figure-3) [24].

Apart from PC, the SCEP also promotes intensified case finding and management, veterinary public health activities, snail mapping and control,

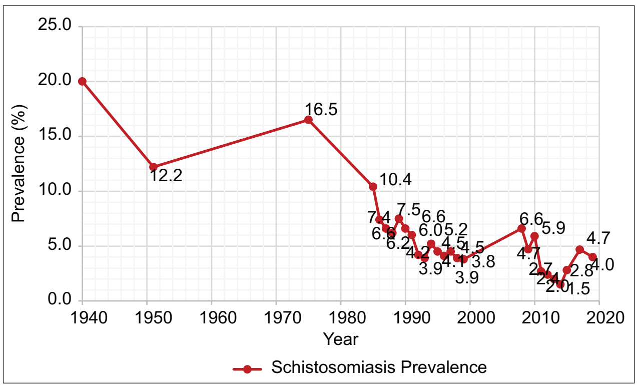
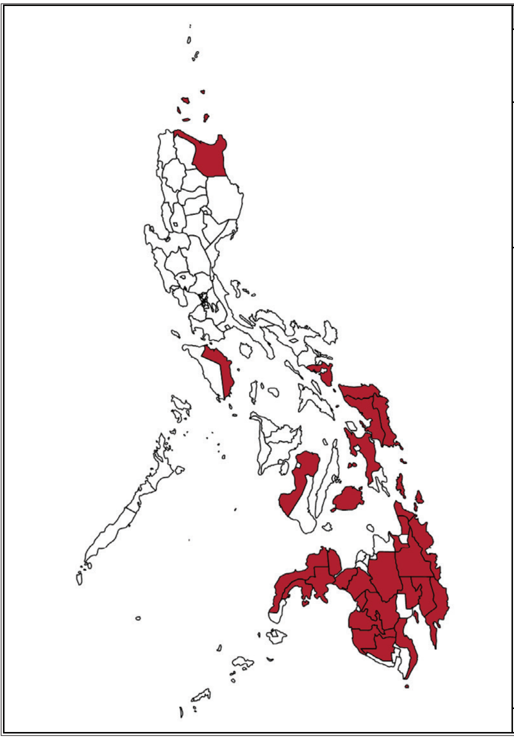


Figure-1: National schistosomiasis japonica prevalence, 1940-2019 [24].



Island Group	Region	Province
Luzon	II	Cagayan
	IV-B	Oriental Mindoro
	V	Sorsogon
Visayas	VI	Negros Occidental
	VII	Bohol
	VIII	Northern Samar
	VIII	Western Samar
	VIII	Eastern Samar
	VIII	Leyte (North)
Mindanao	IX	Zamboanga del Norte
	IX	Zamboanga del Sur
	IX	Zamboanga Sibugay
	X	Misamis Occidental
	X	Bukidnon
	X	Lanao del Norte
	XI	Davao del Norte
	XI	Davao del Sur
	XI	Davao Oriental
	XI	Davao de Oro
	XII	South Cotabato
	XII	North Cotabato
	XII	Sultan Kudarat
	XIII	Agusan del Norte
	XIII	Agusan del Sur
	XIII	Surigao del Norte
	XIII	Surigao del Sur
	ARMM	Lanao del Sur
	ARMM	Maguindanao
TOTAL	12	28

Figure-2: Map of the Philippines highlighting provinces with barangays known endemic for schistosomiasis [24].

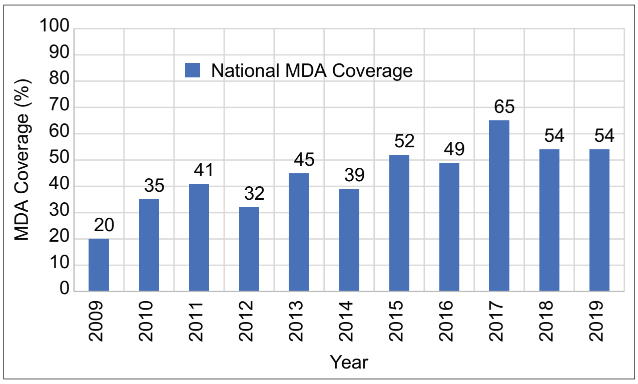


Figure-3: Annual mass drug administration coverage for schistosomiasis, 2009-2019 [24].

provision of safe WASH, and health education, among others [8]. The program has also adopted the One Health approach in its current strategic plan for SCH elimination [24].

Veterinary Public Health

Schistosomiasis japonica is a zoonotic disease known to infect over 40 mammalian hosts, including cattle, water buffaloes, pigs, goats, dogs, cats, rats, and monkeys [29-32], contributing to its persistence in humans [33]. Bovines, particularly cattle and carabaos (water buffaloes) used in agricultural activities, are important reservoirs of SCH that excretes as much as 195,000 viable eggs per day into the environment [34,35]. Manure-based fertilizers may also increase human exposure to bovine feces in agricultural settings [36].

Laboratory techniques for the detection of SCH in animal reservoir hosts include miracidium hatching technique (MHT), Danish Bilharziasis Laboratory (DBL) technique, KK technique, ELISA, formalin-ethyl acetate sedimentation (FEA-SD) technique, PCR, and qPCR. The MHT, DBL, and KK have low sensitivities in detecting schistosomiasis japonica in carabaos, while ELISA, FEA-SD, and qPCR have higher sensitivity at 82.6%, 90.9%, and 100.0%, respectively. Most of these techniques have satisfactory specificity, reaching as high as 100.0% [35,37].

The past coprological surveys in the Philippines reported a low prevalence of schistosomiasis japonica in carabaos, suggesting their minimal contribution as reservoirs to human infection [38]. Recent evidence generated through more sensitive techniques, however, identified carabaos as major reservoirs of SCH, with prevalence close to 90% [39]. In the provinces of Western Samar and Northern Samar, the prevalence in carabaos by qPCR was 90.9% and 80.0%, respectively [35,40]. The prevalence of SCH in carabaos using qPCR was 51.5% and 46.0% in the provinces of Leyte [37] and Cagayan [41], respectively. A recent study in South Cotabato showed that 48.6% of cattle and 60.5% of water buffaloes were positive for the infection using FEA-SD technique [42]. Another recent study revealed that 8.6% of sampled water buffaloes in Maragusan, Davao de Oro, were positive for *schistosomiasis japonica* [43]. As mentioned above, schistosomiasis japonica was also noted in other mammalian reservoir hosts [29-32]. Using DBL technique, a survey on other mammalian reservoir hosts in the provinces of Sorsogon and West Samar revealed a prevalence of 11.9%, 19.9%, 2.9%, and 31.3% in dogs, cats, pigs, and rats, respectively [29].

The national policy on animal SCH has been included in the SCEP Strategic Plan. Implementation of policy and training at the local level is scheduled to begin in 2023 [24]. The DOH provides financial assistance for most animal public health activities that cover the capacity building of veterinary health teams in priority areas and joint planning and implementation of priority operational research [14]. A demonstration project was conducted by the DOH in Northern Samar for the control of animal SCH and the promotion of animal health [5]. The current DOH SCEP strategic plan also included the following activities for the control of SCH in animal reservoirs: (1) conduct of annual animal surveillance, (2) biannual deworming of animals, and (3) mandatory testing of outgoing animals from endemic areas [24].

Vector Ecology and Management

An important factor in the persistence of *S. japonicum* in the Philippines is the presence of the snail intermediate host, *Oncomelania hupensis quadrasi*, in freshwater habitats. *O. h. quadrasi* snails, although amphibious in nature, are mostly aquatic and are commonly found in wet soil surfaces, wet swamps, wet rice fields, ponds, and banks of streams [14]. Fishermen and farmers who are always in direct contact with snail-infested water bodies and children who frequently play in the surrounding areas are at increased risk for SCH [44].

The crushing method, where snails are crushed and mounted between two glass slides and examined under a microscope for cercariae or sporocysts, is recommended in determining SCH in *O. h. quadrasi* [45]. However, this technique has limited sensitivity in areas where there is low parasite burden, aborted development of sporocysts, and prepatent infection [46]. More sensitive techniques include LAMP [47] and PCR [48], which are useful for monitoring and confirming SCH in snails in these low infection settings. LAMP assay using 28S rDNA primers may be a preferable tool, as it is rapid, easy, and inexpensive [48]. Despite the diagnostic accuracy of these novel techniques, microscopy remains the most widely used technique because of its technical simplicity, applicability in the field, and ease of application in resource-poor settings [46]. The molecular analysis by qPCR of environmental DNA involves assessing soil samples [49] for the presence of *O. h. quadrasi* snails or freshwater samples for the presence of *S. japonicum* and *O. h. quadrasi* snails, may also be utilized [50].

Malacological surveys provide data on snail density, distribution, and infection rate [51]. A survey conducted in 147 sites in Samar Province revealed that 55 sites harbored infected snails [45]. In Lanao del Norte Province, 25 of the 29 villages surveyed had snails infected with *S. japonicum* [52], while five of the 11 sites surveyed in Leyte Province harbored infected *O. h. quadrasi* snails [50].

Vector ecology and management is one of the five key strategies recommended by the WHO to control NTDs [7] and utilizes ecological methods such as reducing or removing snail habitats for control through reclamation and conversion of wet fields and submerging of habitats by creating fishponds [53].

Grass cutting followed by the use of molluscicides and land reformation from wetlands to rice fields, integrated with MDA, and proved to be effective in reducing the SCH prevalence in Bohol to <1% [14]. Other ecological snail control methods for Asian schistosomiasis include the construction of cement water pipes and ditches. Although environmental modification may have positive long-term effects, these require considerable investments [14], especially if snail sites are widely distributed [54].

Chemical methods, such as the use of molluscicides, may be employed when ecological methods are not sufficient. Molluscicides, however, are less effective against *Oncomelania* spp. snails that transmit *S. japonicum* as their amphibious nature allows them to bury themselves in the soil or temporarily leave the water to escape the chemicals, requiring repeated application [53]. *O. h. quadrasi* snails are the most amphibious among the nine [50]. Furthermore, the use of molluscicides is prohibited in the Philippines under the Clean Water Act of 2004 [14]. Expensive snail control measures and environmental modification remain supplementary measures as control programs mainly focus on MDA.

Snail control and surveillance are included in the SCEP comprised activities such as annual snail mapping, environmental modifications (e.g., monthly or quarterly clearing of snail colonies), cementing of pathways or water walling, earth filling, and construction of canals and footbridges [24].

Environmental Health

Repeated contact with freshwater during fishing, farming, swimming, washing, bathing, and recreational activities promotes the transmission of SCH [53]. Transmission is also facilitated by environmental pathways through dams and irrigation systems [55,56]. In a climatically homogenous region, the presence of an irrigation system for agricultural use is one of the most important determinants of intensity of SCH in humans [57], with people residing near these areas having an estimated risk ratio of 4.7 for contracting intestinal SCH [58]. In the province of Samar, the infection rate in snails was higher in irrigated areas than in rain-fed villages [45].

The persistence of SCH in snail intermediate hosts is also influenced by climatic and environmental conditions that promote the development of parasite [59]. Climatic conditions affect the distribution and density of snails and the rate of schistosomal development in the snail host [60]. The parasite develops optimally within *O. hupensis* at 30°C [61]. Development may persist at a temperature threshold of 15.4°C, below it, parasite development is arrested [62]. Continuous rainfall and subsequent flooding may also facilitate the introduction and distribution of snail colonies on vegetation [63].

Access to safe water and adequate sanitation and hygiene facilities are also associated with SCH transmission. Accessibility to safe water was associated with significantly lower odds (odds ratio: 0.53, 95% confidence interval: 0.47-0.61) of SCH [64]. The prevalence of the infection was significantly lower (p=0.025) in communities where more than 50% of the people were using hygienic lavatories [65]. The defecation behavior and unsanitary disposal of waste were also found to be strongly associated with infection status [66]. Hygiene practices, particularly soap use, also play a role in SCH prevention as soap is toxic to cercariae, miracidia, and specific freshwater snails [67].

Approaches to the provision of safe WASH include: (1) access to sanitation facilities and management of fecal waste to reduce human excreta in the environment; (2) safe water supply to prevent consumption of contaminated water and enable personal hygiene practices; (3) water resource, wastewater, and solid waste management for vector control and contact prevention; and (4) hygiene measures such as handwashing with soap, laundry, food hygiene, and face washing for overall personal hygiene [68]. In 2016, the Department of Education launched the WASH in Schools Program to promote good hygiene and sanitation practices among schoolchildren in all elementary and secondary schools nationwide. Key strategies include the provision and maintenance of water and sanitary facilities and daily supervision on handwashing [69].

"Ensuring availability and sustainable management of water and sanitation for all" by 2030 is included as the sixth Sustainable Development Goal [2]. In the Philippines, the DOH has developed programs that specify national WASH targets. Provision of safely managed water to 62.5% of all households (HHs) by 2022 is a target of the DOH. The National Sustainable Sanitation Promotion Plan aims to achieve 100% sanitary toilet coverage by 2022 [5,70] and includes programs such as the Local Sustainable Sanitation Promotion Program (LSSP) and Zero Open Defecation Program (ZODP).

The LSSP localizes the national plan and ensures that goals are achieved through effective planning and implementation at the local level [70]. The ZODP aims to end open defecation by 2022 through the Community-Led Total Sanitation (CLTS) approach which seeks to engender behavioral change and empower communities to collectively act to become Zero Open Defecation (ZOD) areas [71,72].

In the Philippines, the proportion of the population with access to safely managed drinking water, safely managed sanitary facilities, and basic handwashing facilities was 47%, 52%, and 78%, respectively [73]. A reduction from 10.86% to 5.74% on practicing open defecation was also observed from 2000 to 2015 [68].

Initiatives such as the *Kapit-Bisig Laban sa Kahirapan*-Comprehensive and Integrated Development of Social Services, which constructed water systems and provided toilets to selected communities nationwide, aided in improving access to safe water and sanitation [74]. Some LGUs also implement WASH interventions in combination with health promotion and education activities, such as orientation on proper handwashing for children and on CLTS for health workers and parents, which increase stakeholder participation [75].

Sociocultural Factors

Adequate knowledge on the transmission, clinical manifestation, and risk factors of SCH is vital in controlling and preventing infection. Misconceptions and gaps in knowledge may cast doubt on health programs, which may serve as barriers or limit participation in intervention activities. Examples of these are the notions that participation is not needed if one is asymptomatic or cannot take anthelmintics in the absence of a prior stool examination [76]. Selective treatment was also sometimes preferred over mass treatment by some individuals [77]. Another deterrent to MDA compliance was the fear of possible side effects of PZQ, such as nausea and vomiting. In a knowledge, attitude, and practice (KAP) study done in Guimaras on the soil-transmitted helminthiasis control program, some parents doubted that the teachers administering the drugs had the capacity to manage its side effects [78]. There was also a belief that anthelmintics are too potent for children and may lead to maternal or fetal harm [79]. Furthermore, social acceptance is affected by the stigma of being labeled by other community members as *bitokon* or being worm-infested if one is seen taking deworming drugs [80].

The conflicting schedule of MDA with work hours caused infected men to defer treatment [77], because participation resulted in eventual income loss from disrupted work and diminished productivity due to side effects of PZQ. Farmers also tend to resist using protective measures such as wearing boots because they find them too cumbersome [81].

Poverty and its associated characteristics are among the main factors which put individuals and families at risk of SCH [82]. Poor and marginalized populations of indigenous people (IP) communities who settle in geographically isolated and disadvantaged areas (GIDAs) and those who reside in areas with peace and order conflicts are hardly reached by primary health services, WASH facilities, and quality health education [83]. They are thus more likely to be exposed to contaminated water [55,84] and are more likely to have a higher prevalence of parasitic infections [85]. High risk for SCH was also observed among individuals with lower educational status and lower income levels [86].

In the Philippines, the higher prevalence of SCH was observed among adults, particularly those

25-29 years of age in the Visayas and 55-59 years of age in Mindanao, likely due to increased occupational roles in agriculture and aquaculture [87]. This may also explain the higher prevalence observed among men than women in farming communities as men more than the women were engaged in farming-related tasks [58].

The One Health Approach to Address SCH in the Philippines

SCH continues to be a public health concern across the country despite efforts geared toward its control. Addressing individual determinants has resulted in only a limited decrease in prevalence and morbidity. There is increasing recognition of SCH as a multidimensional problem that requires a multidisciplinary solution, as embodied by One Health, a holistic and multidisciplinary approach to addressing a wide range of health issues [88].

The One Health approach is particularly suitable for the control of SCH, as it involves designing and implementing programs, policies, legislation, and research in which multiple sectors communicate and mobilize together to achieve better health outcomes [88]. Examples of areas in which a One Health approach can be applied are in the development of more sensitive and less expensive diagnostics for SCH, integration of surveillance systems, strengthening of animal public health activities, improving access to safe WASH, and empowerment of the local government.

Enhancing Laboratory Diagnosis Capacity

The low sensitivity of commonly used field diagnostic techniques for humans, animals, and snails suggests the need for more enhanced methods. The KK technique has low sensitivity, particularly in identifying light infections [15], which may lead to the underestimation of actual prevalence. The more sensitive sero-diagnostic and molecular methods for surveillance may complement KK, but come with high costs [14,89]. Thus, there is a need to identify more sensitive but affordable surveillance tools that maintain sensitivity even in low-transmission settings. The development of point-of-care (POC) diagnostics has been given priority in the NTD Roadmap for 2030 [1]. POC circulating cathodic antigen assays, for example, allow immediate diagnosis in the field and faster dissemination of prevalence results and offer patient convenience by utilizing urine instead of fecal samples, with the added advantage of rapid diagnostic tests such as ease and longer duration of storage and portability [90]. The SCEP Strategic Plan, cognizant of the need for POC diagnostics, has also prioritized the development of a rapid diagnostic test [24].

Stool examination in animals is also burdened with sensitivity issues. There is a difficulty in detecting schistosome eggs in the stool of large animals due to the size of their excreta [41]. Although the FEA-SD has a higher sensitivity than most coprological techniques, implementing it in field settings may be challenging as it may be labor-intensive, have a lengthy processing time, and specific equipment requirements. Molecular methods may also be considered for SCH surveillance in animals as they provide the highest sensitivity but may also be challenging to implement in field settings. New evidence also suggests that snail surveillance would benefit from a transition to precision mapping by satellite imagery [91] and the use of serologic and molecular methods such as the assessment of soil samples [49] to detect *O. h. quadrasi* snails and freshwater samples [50] to detect *O. h. quadrasi* snails and *S. japonicum* through environmental DNA, instead of labor-intensive malacological surveys as snail populations are temporally and spatially variable, providing a mere snapshot of the risk.

Since the use of more sensitive techniques must be performed by trained individuals, it must be complemented with capacity building of human and animal health professionals, which include medical doctors, medical technologists, veterinarians, and local health and laboratory personnel involved in malacological surveys. One such initiative was the Medical Teleparasitology Project, which was launched by the Department of Science and Technology as an information and communications technology-based referral platform which aims to connect local medical technologists with expert parasitologists [92].

Integrated Surveillance System and Mapping

The burden of SCH may be underestimated with the lack of an integrated surveillance system and mapping [6]. The integration of human and animal prevalence surveys, including malacological surveys, will provide a better cross-sectional picture of prevalence across humans, animal reservoirs, and snail intermediate hosts. Moreover, limitations of current sampling and site selection methodologies may lead to endemic areas being misclassified or missed, resulting in overtreatment in some areas, and more importantly, undertreatment or non-treatment of areas that need it most [93]. Poor mapping of endemicity and snail sites has been noted [24], as surveillance is mainly limited to known endemic areas, attention must also be directed to the identification of new endemic foci where the burden may remain high. This may be done beginning with areas adjacent to endemic barangays and traversed by waterways [94]. Other areas that could be included are flood-prone, have vegetation surrounding water bodies, and have intermediate and reservoir hosts for SCH [95]. However, the precision mapping may provide more detailed information on high-risk zones and eliminate errors by possibly examining all schools within a given locality [93]. Geographic information systems may also play a critical role in mapping the information generated from integrated surveillance [94].

Moreover, collection and mapping of data on these variables are helpful in the investigation of spatial epidemiology to identify high priority areas for targeted interventions; however, this will require the conduct of geo-referenced prevalence surveys in humans. In addition, the use of more sensitive diagnostic techniques for more accurate prevalence data is contingent on generating quality spatial epidemiologic data [96]. Although these methods may be intensive, limited data on disease transmission foci may lead to inadequate efforts to eliminate SCH, delaying transmission interruption. Hence, data generated by these mapping activities and a coordinated collection of data may result in cost savings from well-informed, evidence-based interventions [93] and from sharing resources among different sectors [7].

Integration and Strengthening of Animal Public Health Activities

Addressing SCH reservoir hosts remain vital in working toward the elimination of SCH. In the Philippines, carabaos are significant reservoirs of infection [35]. Improvements in the detection of SCH in animal reservoirs will aid in identifying priority areas for veterinary interventions. Replacement of water buffaloes with machines in farming proved to be effective in reducing transmission [14]. Despite the high initial cost, the mechanization of agriculture may help reduce the risk of SCH transmission in farming communities in the Philippines. Annual MDA of water buffaloes and the development of a veterinary vaccine, may also aid in reducing transmission of SCH in animals [39,97].

Integration of veterinary public health activities into national strategies for SCH is of utmost priority, complemented by strengthened collaboration between the DOH and Department of Agriculture (DA). A national policy on control, diagnosis, management, and treatment of animal SCH is currently being developed by the DA. However, time will be needed to mobilize resources and set up mechanisms for veterinary public health activities in the Philippines. In addition, the appointment of animal SCH coordinators at the national and regional levels of the DA to manage veterinary public health activities [24] is a significant step toward addressing the role of animals in SCH transmission in the Philippines.

Snail control has been recognized by the WHO to be an important component of SCH control and elimination [98]. Information on the prevalence and distribution of *O. h. quadrasi* snails in the country is limited and must be periodically updated to identify priority sites for snail control measures [51]; however, as previously mentioned, snail distribution varies across space and time with the introduction of new snail colonies by flooding [94] or population movement [99].

Ecological methods of snail control, particularly environmental modification, showed positive long-term effects in many countries [14]. Most LGUs, however, are incapable of meeting the steep budgetary requirements for these interventions [24]. Engagement of the private sector may be done to gain additional support for these interventions. As the use of molluscicides is prohibited under The Clean Water Act of 2004, further review of its benefits may be undertaken, followed by careful consideration for its exempted use in highly endemic areas for SCH [14].

Improving Access to WASH

Integrating WASH indicators in monitoring is crucial to provide sound guidance for program managers [100]. Improvements in sanitation are critical because they minimize the need for pharmacological interventions and contribute to more sustainable results in SCH control. Elimination of SCH is contingent on providing universal access to improved WASH [7].

Although improvements in WASH conditions in the Philippines were seen over the years, this progress remains variable across the regions. There is a wide gap between the percentage of HHs with access to both safe water and sanitation in the National Capital Region (99%) and Autonomous Region in Muslim Mindanao (71%). Variability across regions may be partly explained by the devolved health system of the country and the localized implementation of WASH-related initiatives. The lack of safe WASH facilities in many endemic barangays, especially in rural areas, continues to be a major problem in the prevention of SCH. Connecting with non-government organizations and partners from the private sector may be a means of gaining additional investment in WASH. ZOD monitoring, certification, and validation teams have not been established in some LGUs [24], contributing to the lack of WASH data to guide program managers. In the Philippines, CLTS has mostly been spearheaded by international non-government organizations. The lack of a formal and sustainable system for monitoring CLTS progress data remains a challenge [101].

Aside from improvements in WASH “hardware” (e.g., toilets, latrines, sewage treatments, and provision of safe water), attention must also be given to “software” elements (e.g., behavior change the promotion and community resource management) [100]. Improving coordination and strengthening the advocacy for ZOD programs within LGUs are essential to eliminating unsanitary practices such as open defecation and bathing or wading in irrigation canals and streams [24].

Addressing Sociocultural Barriers to Service Delivery

Consistently delivering health promotion and education is a challenge for NTD control programs including SCH. Inconsistencies in the KAP of locals in endemic communities point to gaps in the implementation of local health education initiatives. Misconceptions regarding the implementation of

MDA as well as the effects of anthelmintics are critical issues requiring clarification during health education campaigns. Understanding prevailing local concepts of etiology may improve the delivery of treatment at the individual and community levels [102]. Risk communication may also address unsanitary practices, which may contribute to greater participation in WASH programs.

Understanding sociocultural aspects contributing to SCH endemicity is vital in improving health outcomes through enhanced service delivery. For instance, people living in GIDAs are hardly reached by primary health services, safe WASH facilities, and quality health education [83]. As agriculture and aquaculture are primary sources of income in IP communities, this exposes them to intersecting axes of risk and disadvantage, making them more likely to have a high prevalence of parasitic infections. They are also more likely to have misconceptions about the disease or the MDA strategy, fear of possible adverse effects of anthelmintics, and preference toward case-by-case treatment over mass treatment. Targeted education initiatives for vulnerable groups are recommended to address the compounding disadvantage and burden brought about by overlapping risk factors such as age, gender, socioeconomic status, and ethnicity, among others.

Considering alternative schedules of MDA implementation for the working class may help increase anthelminthic coverage in this population. The identification of these barriers will help guide national and local stakeholders in the implementation of targeted interventions for specific populations.

Health promotion and education activities for SCH are set to be integrated with the initiatives being implemented under the SCEP, maximizing the available resources and infrastructure in schools [24].

Conclusion

Given the zoonotic nature of SCH, the One Health approach is a key to its effective control and elimination. The adoption of a One Health approach requires that disciplines within human, animal, and environmental health, each with its respective programs already in place, develop an integrated approach to address the multidimensional nature of SCH [14].

The SCEP has taken a major step forward with the adoption of the One Health approach, as seen in the inclusion of strategies on veterinary public health, snail mapping and control, provision of safe WASH, and health education. Monitoring and evaluation remain vital to ensure the effectiveness of implementation by concerned sectors. Ensuring adequate capacity of front lining LGUs is essential for improved service delivery. In addition, ensuring adequate expertise for the generation of evidence to enhance policy and planning will contribute in major ways for the control and elimination of SCH in the Philippines [14].

Authors' Contributions

VYB, AEC, RCN, MJCF, VBM, SNMD, JRCM: Conceptualization, data curation, formal analysis, methodology, project administration, supervision, visualization, writing - original draft preparation, writing - review and editing. CRL: Data curation, formal analysis, methodology, project administration, visualization, writing - original draft preparation, writing - review and editing.

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Competing Interests

The authors declare that they have no competing interests.

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