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Review Article

Public Health Section

# Tackling Worm Infestations with a Multifactorial Approach in the 21st century: An Indian Perspective

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## ABSTRACT

Soil-Transmitted Helminths (STH) or geohelminths are an important cause of morbidity worldwide. A large proportion of the infection burden occurs in India, including STH infections due to roundworms (*Ascaris lumbricoides*), whipworms (*Trichuris trichura*) and hookworms (Necator americanus or *Ancyclostoma duodenale*). Apart from direct health impacts, they are also implicated in anaemia, nutritional deficiencies and delayed cognitive development in children. They also have been shown to have detrimental impact on economic development and future income earning potential. The current global strategy on STH control is through increased utilisation of Preventive Chemotherapy (PC) for at-risk population, comprising mainly pre-school and school age children. This is crucial for India, as there can be significant proportion of untreated subjects in the community, who may act as a reservoir of infection for treated subjects to get re-infected. Additionally, inculcating healthy behaviour modifications and adopting WASH interventions meant a major shift in social and cultural norms in many societies. Overall, the multifaceted nature of STH control in India requires concerted efforts and significant mobilisation of human and financial resources. In this regard, several recent initiatives including Swachh Bharat Abhiyan, Nirmal Gram Puraskar, Water Sanitation and Hygiene (WASH) interventions, Clean India: Clean schools etc., have brought a positive change, apart from the provision of deworming for morbidity control through National Deworming Day. In this paper, authors have narrated major initiatives in recent years that are expected to bring a lasting solution to the problem of STH infection in India.


**Keywords:** Ascaris, Hookworm, India, Mass drug administration, Soil-transmitted helminths, Trichuris

## INTRODUCTION

STH constitute the most common parasitic (worm) infections worldwide. The transmission route is feco-oral, primarily due to soil-contamination by eggs present in human faeces [1]. The most important STH are roundworms (*Ascaris lumbricoides*), whipworms (Trichuris trichura) and hookworms (*Necator americanus* or *Ancyclostoma duodenale*) [1].

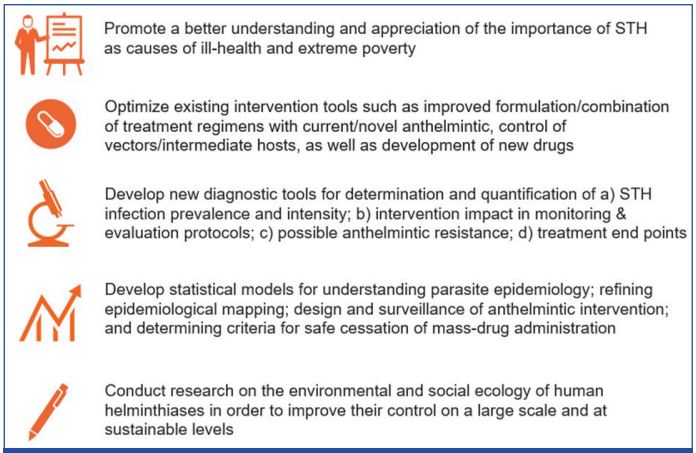
Globally, around 1.5 billion people (or 24% of world's population) are infected with STH, with highest cases in the tropical and sub-tropical regions [1]. For India, high STH prevalence among School-Age Children (SAC) has been documented across 6 States [2,3]. However, the data is considerably heterogenous, probably due to varying climatic conditions, demographics and sociocultural practices of the population. For instance, STH prevalence has been found to be relatively higher in rural India compared to urban areas [4,5].

Undoubtedly, STH control has now become a public health priority globally. Studies show that for robust STH control, adopting measures like PC, improvement in sanitation, clean drinking water, use of pit-latrines and good hygiene practices will be crucial [5-7]. Currently, the WHO strategic plan (2011-2020) recommends similar measures for 'at-risk' populations residing in STH endemic areas [8]. Over the years, India has also ramped-up STH control measures through several innovative programmes [9], including National Deworming Day, Swachh Bharat Abhiyan, Nirmal Gram Puraskar, Water Sanitation and Hygiene (WASH) interventions, Clean India: Clean schools, etc. In this paper, authors relooked at such initiatives that have positively impacted STH burden trends and public health in India. Using keywords and Boolean operators, authors have searched electronic databases (Pubmed, IndMed, PsychInfo, Science-Direct and Google Scholar) and grey literature to identify recent articles on STH control in India. A formal review/meta-analysis was not conducted; authors present the findings in the form of succint description of literature according to the identified theme- challenges and opportunities in STH control in India.

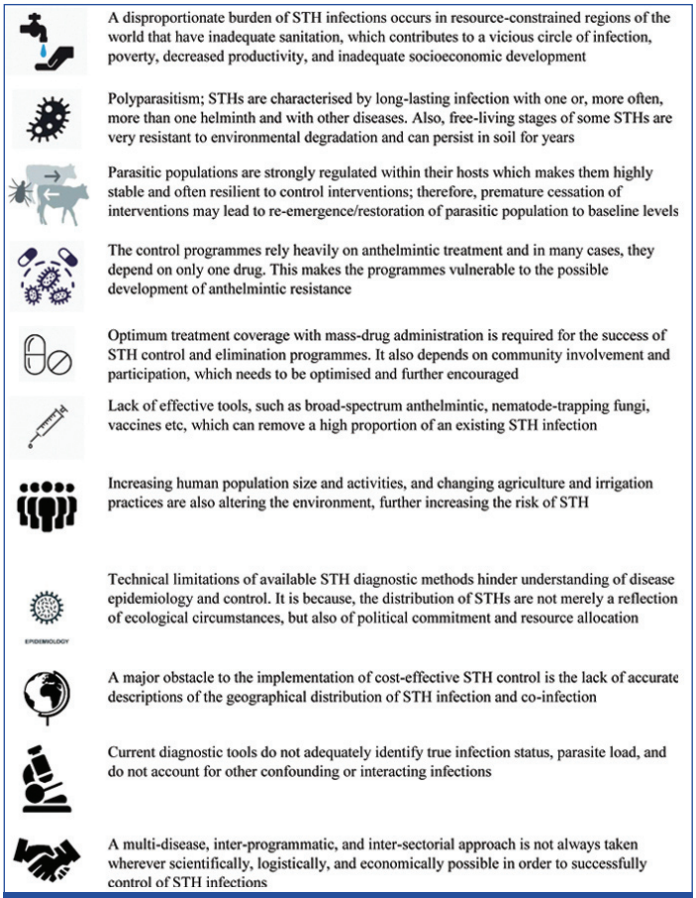
## STH CONTROL STRATEGIES IN INDIA

According to WHO, India has nearly 241 million children between ages 1 and 14 (68% of SAC) constituting 'at-risk' category for STH infections. This represents approximately 28% of the global burden [2]. Multiple surveys conducted over the years indicate infection with more than one STH species [10-16]. For instance, Greenland K et al., in a cross-sectional survey (using stool-sample) among children in 20 schools across Bihar reported STH prevalence of 68% (10-86% across schools). The prevalence of ascariasis, hookworm and trichuriasis was 52%, 42% and 5%, respectively [10]. Ganguly S et al., reported overall weighted STH prevalence of 75.6% across 130 primary schools in 9-agro climatic zones in Uttar Pradesh [11]. Kaliappan SP et al., in their cross-sectional study with one-stage cluster sampling of 22 clusters (n=1237) in Tamil Nadu, reported overall STH prevalence of 39%, with hookworm 38% and *Ascaris lumbricoides* 1.5% [15]. There has also been an increase in morbidity statistics not only for India, but globally as measured by Disability-Adjusted Life Years (DALY) [17]. Moreover, while the impact of hookworm infection appears to disproportionately affect SAC, studies show that women in child-bearing age group, pregnant women and even adults seem to be at high risk of STH-related morbidity [5,6,8,17-20].

Overall, effective STH control will require identifying major gaps that impede sustained control and elimination measures [Table/Fig-1] [21]. This is because, apart from sanitation, several other factors are known to drive the persistence and re-emergence of STH infections in humans [Table/Fig-2] [21]. In this regard, having expanded health programmes which promote healthy behaviour modifications apart from benefits of deworming and good WASH practices was essential. Such efforts would have required mobilisation of consequential human and financial resources. Of late, India has




**[Table/Fig-1]:** Gaps that hinder sustainability of STH control and elimination measures [21].
This figure has been independently created by GSK for illustration purposes only; Figure adapted from Lustigman S, Prichard RK, Gazzinelli A, Grant WN, Boatin BA, McCarthy JS, et al. A research agenda for helminth diseases of humans: the problem of helminthiases. PLoS Negl Trop Dis. 2012;6(4):e1582. [Reference 21]




**[Table/Fig-2]:** Factors driving the persistence and re-emergence of STH infections [21].
The list is not exhaustive; created independently by GSK for illustration purposes only; Figure adapted from Lustigman S, Prichard RK, Gazzinelli A, Grant WN, Boatin BA, McCarthy JS, et al. A research agenda for helminth diseases of humans: the problem of helminthiases. PLoS Negl Trop Dis. 2012;6:e1582. [Reference 21]

prioritised its health resource to introduce several novel solutions for STH control [Table/Fig-3] [9,22-28].

## National Deworming Day

The WHO '2020 Roadmap on Neglected Tropical Diseases (NTD)' (released 2012) emphasised targeted deworming programmes aimed at 'at-risk' populations including children (age ≥1 year), non-pregnant adolescent females (age 10-19 years), non-pregnant women of the reproductive age-group (age 15-49 years) and pregnant women (second and third trimester) to control morbidity associated with STH. In areas where the baseline prevalence of any STHs >20%, the recommendation is an annual dose of albendazole (400 mg; 200 mg for children age 1-2 years) or mebendazole (500 mg).

| Timeline | Description | Reference |
|---|---|---|
| 1954 | First formal sanitation programme launched as a part of the First Five Year Plan of the Government of India | [9,22] |
| 1963 | National Centre for Disease Control (NCDC) starts conducting STH surveys in different parts India | [9,22] |
| 1986 | Launch of Central Rural Sanitation Programme primarily with the objective of improving the quality of life of the rural people and to provide privacy and dignity to women | [9,23] |
| 1996 | Launch of Total Sanitation Programme; a "demand driven" approach emphasised more on information, education and communication, human resource development, capacity development activities to increase awareness among the rural people and generation of demand for sanitary facilities | [9,23,24] |
| 1999 | NCDC adopts WHO sampling methodologies and Kato-Katz technique for stool sample examination and STH surveys conducted in different ecological zones in India | [9,22] |
| 2002 | Launch of Swajaldhara, a national level program to change the way in which water and sanitation services are supported in rural areas, by decentralizing service delivery responsibility to rural local governments and user groups | [22,25] |
| 2003 | Launch of Nirmal Gram Puraskar to give a fillip to Total Sanitation Campaign (first awards given in 2005) | [26] |
| 2008 | Launch of National Urban Sanitation Policy (NUSP) by the Ministry of Urban Development (MoUD), emphasising the need of defining integrated city/state-wide sanitation plans | [9,24] |
| 2010 | Launch of national level reward scheme (under MoUD) for ranked cities achieving measurable milestones in becoming sanitised, livable Nirmal Shahars. The rankings are based on 19 sanitation parameters, on the basis of which cities were assigned either of four colour code rating; 'red category' (in need of immediate remedial action, score < 33), 'black category' (needing considerable improvement, score 34-66), 'blue category' (recovering, score 67-90) and 'green category' (healthy clean city, score 91-100). | [24,25,26] |
| 2012 | Launch of Nirmal Bharat Abhiyan (later restructured as Swachh Bharat Abhiyan). Its main objective was to accelerate the sanitation coverage in the rural areas to comprehensively cover the rural community through renewed strategies and saturation approach. | [25] |
| 2014 | Launch of Swachh Bharat Mission (SBM) or Swachh Bharat Abhiyan (SBA) or Clean India Mission to eliminate open defecation (by 2019) and improve Solid Waste Management (SWM) in urban and rural areas in India. The mission was split into two: rural (SBM Gramin) and urban (SBM Urban). | [25] |
| | Launch of Swachh Vidyalaya or "Clean India: Clean Schools" with primary goal is to make a visible impact on children's health and hygiene through improving both their health and hygiene practices and those of their families and communities | [27] |
| 2015 | The first round of National Deworming Day conducted in February 2015 | [28] |
| | NCDC undertakes countrywide mapping of the STH prevalence and intensity | [9, 22] |
| 2018 | Launch of Swajal project (under the National Rural Drinking Water Programme), designed as a demand driven and community centered program to provide sustainable access to drinking water to people in rural areas. It was initiate as a pilot scheme in six states of Bihar, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and Uttarakhand. | [22-25] |

**[Table/Fig-3]:** Major initiatives contributing to STH control and elimination in India [9,22-28].
*The above list is not exhaustive

In areas with baseline STH prevalence >50%, the recommendations is biannual deworming. In addition, if the STH prevalence of anaemia >40% among pregnant women, deworming is conditionally recommended [8]. The overall objective is to ensure 75% of Pre-SAC (PSAC) and SAC in need of treatment are regularly treated, by targeting 75% PC coverage in 100% countries by 2020 [8].

India launched its first 'National Deworming Day' (NDD) on February 10, 2015. The exercise, one of the largest in the world, included massive school-based deworming effort across twelve States to treat all children 'at-risk' for STH [28]. The NDD was followed by a Mop-Up Day (MUD) on February 13, 2015 with the intent of deworming children who missed the dose on February 10, 2015 [28]. The main objective of NDD is to deworm all PSAC/SAC (enrolled and non-enrolled) between the ages of 1-19 years biannually through the

platform of local schools and Anganwadi centres. This would ensure improvement in overall health, nutritional status, access to education and quality of life for these children [28,29].

After the first round of NDD (2015), nearly 8.9 crore SAC were administered deworming tablet across 12 States/Union territories (Assam, Bihar, Chhattisgarh, Delhi, Dadra and Nagar Haveli, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Rajasthan, Tamil Nadu and Tripura) achieving approximately 85% national coverage [28]. Over the next two years (2016-17), the outreach expanded the coverage 88% against the initial set targets of NDD. Approximately 26.68 crore children have been administered Albendazole (400 mg and 200 mg for children age between 1-2 years and 2-19 years, respectively) till February 2018, and more than 114 crore doses of Albendazole were administered to children between ages 1 and 19 years, since 2015 [28]. Both Albendazole and Mebendazole (500 mg) are WHO recommended drugs; are safe, effective, inexpensive and easy to administer by even non-medical personnel (e.g., teachers) [8]. Both drugs are donated to national ministries of health through WHO in all endemic countries for STH treatment of all PSAC and SAC. Ivermectin use against S. stercoralis is expected to be available at affordable price from 2021 [8].

## Swachh Bharat Mission (SBM)

To adhere to United Nations Sustainable Development Goal 6 (SDG 6) [30], and to expand the public health needs, in 2014, India launched a fully funded national hygiene, sanitation and waste management campaign called Swachh Bharat Mission to eliminate open defecation and improve SWM in the country [25]. The transition of a Swachh Bharat to a healthier India has also been advocated by numerous public figures.

The strategy is to move towards a 'Swachh Bharat' i.e., Clean India by making it a massive mass movement ('Jan Andolan') that seeks to engage everyone in the task of cleaning his/her living area and surroundings in a collective quest. The mission was split into two; in rural areas (SBM- Gramin, under Ministry of Drinking Water and Sanitation) and urban areas (SBM- urban, under Ministry of Housing and Urban Affairs) [25]. Also, volunteers known as Swachhchagrahis or 'Ambassadors of cleanliness', was trained to promote indoor plumbing and community approaches to sanitation at village level.

The relationship between cleanliness and better health has been propagated since the inception of the Swachh Bharat Abhiyan. As on date, the progress reported for rural sanitation coverage is 98.8%; 92 million toilets have been constructed, and 604 districts have been declared with 'Open Defecation Free' (ODF) status [25]. With respect to urban sanitation, 5.4 million individual household toilets, community, and public toilets have been constructed. Approximately, 3461 cities/town were declared with ODF status in 2019 [25].

The states of Chhattisgarh, Jharkhand, Madhya Pradesh and Rajasthan have already reported stark change in their sanitation coverage ≥80%. In the latest Swachh Survekshan Survey 2019, Indore was adjudged as the cleanest city, while Chhattisgarh was the cleanest state in India [25]. Additionally, in the two years since Swachh Bharat Abhiyan was launched, the deaths due to unsafe water and sanitation as percentage of total deaths across the country were reportedly reduced to 5% in 2016 (compared to 13% in 1996) [25]. Child diarrhoea deaths in India were also reported to decrease by 12.7% in 2016 i.e., from 1,21,889 cases in 2014 to 1,02,813 cases in 2016 [25]. The percentage of under-five children dying from diarrhoea came down from 13% to 9% [25].

## National Urban Sanitisation Policy

The 2001 Census reflected the need for healthier urban living, which would mean healthier sanitation and waste disposal practises [2,23]. To this effect, in November 2008, India launched the 'National Urban Sanitation Policy' (NUSP) with the objective of creating 'totally sanitised cities' that are ODF, safely collect and treat all their waste water, eliminate manual scavenging and dispose solid waste safely [24]. By 2010, nearly 12 States had completed drafting state sanitation strategies based on the policy. Currently, additional 120 cities/town have completed or are in the process of preparing city sanitisation plans [24].

The Ministry of Urban Development (MoUD) has also introduced a national level reward scheme (Nirmal Shahar Puraskar) based on its survey of cities/states that achieve measurable milestones in becoming sanitised, livable Nirmal Shahars (exemplary city) [9,23,24]. Each year if the city improves its ratings, specifically on achieving 'green category' status, cities are typically invited for the national award. The rankings are based on 19 sanitation parameters such as access to community toilets, safe management of human excreta, SWM etc. Four colour codes have been assigned to the cities based on the points they obtained in the rating; 'red category' (in need of immediate remedial action, score < 33), 'black category' (needing considerable improvement, score 34-66), 'blue category' (recovering, score 67-90) and 'green category' (healthy clean city, score 91-100). Currently, three cities are found to be in the category of "recovering" in terms of sanitation facilities, including Chandigarh (73.480), Mysore (70.650), Surat (69.080), and the New Delhi Municipal Corporation administered area (68.265) [23,24].

The MoUD survey rating serves as a baseline to measure improvements in the future and to prioritise actions. Such ratings also support implementation of the NUSP, to create healthy competition among cities as each strives to earn the glory of being a Nirmal Shahar, that will determine its sanitation and healthy living status [23,24].

## Total Sanitation Campaign

In 1999, India had initiated a demand-driven, public sanitation programme under 'Total Sanitation Campaign' (TSC), resembling 'Community-led Total Sanitation' (CLTS) with subtle differences viz., while CLTS focused more on preventing open defecation through self-awareness and shame, TSC focused more on building sanitation infrastructure. The main goal of TSC was to eradicate the practise of open defecation by 2017 [23,24]. It was modelled on the 1986 'Central Rural Sanitation Programme' (CRSP), one of the first programmes to provide financial assistance to below poverty level families for constructing individual household toilets [23,24]. Under the CRSP scheme, the Union government contribution was 60% cost, the State government was 20% and the rest was to be borne by the household for cost up to INR 1500. The programme also noted the importance of sanitary complexes for community spaces and provisioned an amount of up to Rs. 2 lacs for construction of such facilities [23,24].

The uniqueness of TSC was its adherence to 'demand-driven' approach, that paid emphasis on information, awareness/capacity building activities, education and communication, human resource development and demand generation for sanitary facilities [9,23,24]. As a result, by December 2017, total sanitation coverage throughout India had improved to 73% (compared to 42% on October 2, 2014, the day Swachh Bharat Abhiyan was launched) [25].

Moreover, as an encouragement to this endeavour, Nirmal Gram Puraskar (NGP) aka Clean Village Award was launched in 2003, to recognise the efforts in terms of monetary awards for those who have contributed significantly in ensuring full sanitation in their area of operation. The project is being implemented in rural areas taking district as a unit of implementation [26]. As on December 2013, 28002 Gram Panchayats have been awarded the NGP. An independent National level study was conducted by the Ministry of Drinking Water and Sanitation, Govt. of India in 2010 for impact assessment of NGP. The study covered 664 Gram Panchayats awarded NGP in 12 States. Main findings of the study included: 19.1% surveyed households reported limited of access to any type of sanitation facility, 67% surveyed households reported all members

using the latrine regularly, and 91% of the schools and 71% of the Anganwadis had sanitation facilities [26].

### WASH Interventions

The term 'WASH' expands into 'wash, sanitation and hygiene', denoting SDG 6 public health provisions that must be available universally, in an affordable and sustainable way [30,31]. Several studies from India have shown that attention to WASH can improve health, life expectancy, student learning, gender equality and other important issues of international development [31-33]. The data also informed several policy decisions, including provision of 'flush-pit latrines' and community mobilisation in village populations where parasitological measures of STH were recorded [32,33].

Apart from Swachh Bharat Abhiyan, another key campaign in driving WASH strategy is Swachh Bharat, Swachh Vidyalaya aka 'Clean India: Clean Schools', initiated on September 24, 2014 [27]. The main feature of the campaign is to ensure that every school in India has a set of functioning and well-maintained WASH facilities and must incorporate human development components that help to prevent WASH related disease [27]. In other words, every school in India must have six essential requirements in their school WASH programme:

1. Gender segregated toilets having soap/washing facilities and private cleaning/disposal facilities for menstrual waste.
2. Adequate group handwashing facilities which allows groups of students (10-12) to wash their hands at the same time.
3. Apart from daily access to safe drinking water, water for handwashing, school-cleaning, food preparation/cooking, appropriate handling and storage of drinking water should be practiced throughout the school.
4. WASH facilities need to be clean/sanitised and well maintained with periodic checks to ensure intended results are achieved.
5. WASH behaviour change communication activities should be part of the daily routine of all children.
6. Capacity building at various levels within the sector, to develop the right mix of skills, knowledge and experience to facilitate, finance, manage and monitor WASH programmes in schools effectively [27].

Apart from STH control, several benefits of a school-based WASH intervention have been identified. First, WASH facilities in school ensures a healthy school environment and protect children from illness and exclusion [27]. Hygiene education promotes practices that would prevent infectious diseases as well as encourage healthy behaviour in future generations of adults. Hygiene in school also supports school nutrition, as the simple act of washing hands with soap pre-'mid-day meal' assists to break disease transmission routes. Having gender segregated toilets and WASH facilities hugely benefits girls, who may be vulnerable to school drop-out if such facilities are unavailable or non-private. Differently-abled children are also vulnerable to school drop-out, hence effective WASH programme seeks to remove barriers by promoting inclusive design, user-friendly, child-friendly facilities that benefit all users. WASH facilities in schools also promotes equity, as children nurture their right to access to safe drinking and WASH facilities and gain benefits through the improved hygiene practices promoted in schools. Overall, having a clean school fosters a child's pride in his or her school and community. It enables every child to become an agent of change for improving WASH practices in their families and community [27].

## BEST PRACTICES, OPPORTUNITIES, AND CHALLENGES FOR STH CONTROL IN INDIA

### Enhanced Monitoring of Programme Impact

To achieve good STH control, the WHO Roadmap set out strict targets that have been difficult for most nations to comply [34]. By far the biggest issue for India has been in identifying the patient base i.e., who needs treatment, since conducting parasitological survey is costly and time consuming. This is mainly attributed to India's expansive geography, diverse climatic conditions and socio-political landscape [2,5]. Such diversities often have a strong influence on disease distribution; as a result, STH infections in India take varied forms, including forest versus tribal or urban versus rural disease trends, requiring adaptive surveillance and containment measures [5].

However, India has been efficient in handling mega public health issues historically, aided by some of the largest surveillance programmes in the world. In fact, its track record in handling small pox, polio and malaria has been exemplary. Sometimes, frugal yet effective initiatives, like 'finger marking' in polio, have proved to be a cost-effective surveillance tool; a useful measure that could be applied in the NDD programme [35].

Furthermore, India also resourced information on STH prevalence through Global Atlas Helminth Infections (GAHI), to ensure quality data and decipher regional trends [36]. The GAHI is an online open-access information source on the distribution STH, schistosomiasis and lymphatic filariasis. Based on the GAHI project data from 127 surveys implemented in India between 1999 to 2007, the national STH prevalence was estimated at 21% [36].

However, for a vast country like India, it is difficult to reliably obtain data from rural areas. To cater this, India has been investing into advanced solutions for comprehensive Monitoring and Evaluation (M&E) of STH burden. Much of its understanding was derived from Africa's recent progress in data sharing and transparency for NTD through the work of ESPEN (Expanded Special Project for Elimination of NTDs) and their data portal [37]. The ESPEN portal is an electronic platform designed to enable health ministries and stakeholders to share and exchange sub-national programme data, in support of NTD control and elimination goals. Additionally, countries are starting to adopt high-tech methodologies like remote sensing proxy environmental data for rapid epidemiological assessment of STH prevalence among SAC [38,39]. Advanced measures like spatial analysis and risk mapping of STH infections using Bayesian geostatistical models are also underway in many countries, including India [40,41].

### Identifying at-risk Groups Other than Children

Deworming of PSAC/SAC has been shown to reduce high-burden of the disease in a cost-effective manner [7]. However, for most nations, empirical evidence from both multi-year deworming programmes and modelling studies suggested that targeting SAC alone for PC is insufficient for sustained control and elimination of STH infection [42,43]. This is especially true for T. trichura (due to poor drug efficacy) and for hookworm (due to typically convex age-intensity profiles or reach a plateau in adulthood) [44,45]. Data also showed that adults could be at high risk of hookworm infection and thus contribute substantially to STH transmission [46].

Although, India's NDD has been a testament of how large-scale PC could be benefitting, the requirement to scale-up sentinel surveillance in order to predict, detect and treat widely dispersed pockets of STH transmission is essential. However, a meticulous approach targeting 'at-risk' will be needed, also regarding current drug availability and added cost of this approach. Kenya's 'Breaking Transmission Strategy' (2019-2023) is a similar example of large-scale national strategy for elimination of endemic Preventive Chemotherapy-NTD (PC-NTD) including STH, schistosomiasis, lymphatic filariasis and trachoma [47].

### Holistic Approach Against Anti-helminthic Drug Resistance

Several reports indicate that there is variable degree of anthelmintic resistance among different species of gastrointestinal nematodes [48-50]. Overall, human populations with long history of single

drug deworming in places with low STH burden, due to reach transmission peak, are likely to be at greatest risk of developing drug-resistant parasites [48-50].

Although, advancement in field-applicable diagnostics including quantitative Polymerase Chain Reaction (qPCR) that can identify and monitor signs of emerging resistance, have been crucial in STH control measures, further research is still needed [51]. In many instances, newer modalities like maintaining parasites in 'refugia' without exposure to anthelmintic have been tried to delay emergence of anthelmintic resistance, as susceptible genes are preserved [52]. Additionally, not relying solely on drug-based STH control schemes but employing sustainable options like parasite-resistant breeds, pasture management, nematode-trapping fungi, anti-parasitic vaccine and botanical dewormers can prove beneficial [52]. This is because; such measures reduce reliance on the use of non-environmental friendly, harmful chemicals.

### Employing Validated Programme Stage-specific Diagnostics

The need for newer diagnostics that are appropriate for informing key decision points for national STH programs has been long identified [53]. The widely employed Kato-Katz technique, although inexpensive, has lower positive-predictive values in low-prevalence settings [54-56]. In addition, preliminary analysis using microscopy and/or PCR can even mis-identify hookworm infection [53,56].

In this regard, newer diagnostics have been validated including direct smear technique, formol-ether concentration technique, agar-plate culture technique, Baermann technique, Water Emergence technique for detecting strongyloides larvae in feces, Harada-Mori technique, Merthiolate-Iodine-Formaldehyde-Concentration Technique (MIFC), Flotation techniques, Stoll's Dilution Egg-Counting technique, McMaster Method for Quantitative fecal examination and Antigen technique [56]. However, on-field tests that are highly sensitive, with quick turn-over time is the need of the hour, especially those that can be employed in settings that from STH control to elimination. Field-diagnostic and laboratory protocols need to be standardised, along with establishment of reference laboratories and training development for different contexts and languages. Identifying additional gap areas like sustaining animal models, conducting field studies to calculate test performance in various settings will be crucial follow-up activities [57].

### Identifying WASH Indicator(s) to be included in STH Control Measures

The 2020 WHO roadmap identified the critical role of WASH in STH control, but did not set actionable targets [8,58] In several geographies, establishing a structure for engagement with the WASH sector has been difficult. However, the recent development of the WASH-NTD joint strategy provides an entry point and guidance for improved collaboration [58].

Recent meta-analysis demonstrates effective WASH intervention can immensely reduce STH infection and prevalence rates [59,60]. Ziegelbauer K et al., demonstrated that availability of sanitation facilities was associated with significant protection against STHs (OR 0.46 to 0.58) [59]. Strunz EC et al., concluded WASH practices are generally associated with reduced odds of STH infection by atleast 33% [60]. In most studies, apart from WASH interventions, access to water and hygiene also appears to significantly reduce odd of STH [59,60].

Apart from monitoring of WASH indicators, as part of STH control programming, mapping of certain behavioural or practise adoption (like shoe-wearing) is important especially in STH-endemic areas [61]. Additionally, identifying consistent indicators across WASH programmes (like water sources, food hygiene) can essentially reflect unmet areas and guide policy making [62].

## CONCLUSION(S)

The current piece, although, having the limitations of a narrative review, provides a succinct understanding of various STH control strategies in India and identifies areas of opportunities. The key take-away is India's substantial progress in increasing coverage of PC and introduction of novel STH-control strategies. However, there remain knowledge gaps and the need to address region-specific needs regarding STH control. This can be achieved through active collaboration by pertinent agencies including governments, NGOs, civil society, WHO, bio/pharmaceutical industry and multi-sectoral co-ordination.

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