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Integrated Public Health Approaches to Biomonitoring and Control of Emerging Parasitic Infections in Tropical Regions

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Abstract: *The problem of parasitic infections is one of the longest-running public health issues of tropical areas, with more than 1.5 billion individuals at risk across the world and very vulnerable groups being disproportionately affected by the problem. Despite decades of vertical disease control programs, there are still several new and re-emerging parasitic diseases that pose health security issues due to the intricate links between climate change, urbanization and population displacement, as well as compromised health systems. The conventional methods of surveillance and control, which are usually disease and department-specific and fragmented, have not been effective in responding to the complexity of these infections. This is a review of evidence on integrated public health approaches that involve the combination of both biomonitoring and multisectoral control interventions in tropical settings. We analyzed peer review material and programmatic reports published between 2010 and 2025 and concentrated on the innovations in the field of molecular diagnostics, digital surveillance systems, community-based surveillance systems, and systemic approaches to managing the vectors. We find that there is an overarching similarity in successful programs that include high intersectoral collaboration, community ownership, adaptive management systems, and exploitation of emerging technologies. The environmental DNA surveillance and molecular xenomonitoring have improved the early detection, and the mobile health platform has revolutionized real-time reporting in resource-constrained environments. Combined strategies using mass drug administration with water, sanitation and hygiene measures have synergistic effects with up to 65 percent larger disease prevalence reductions than individual interventions. Nevertheless, there are still substantial implementation obstacles, such as poor laboratory capacity, dysfunctional health information systems and lack of sustainable financing systems. This review presents a broad framework on how to enhance integrated parasitic disease control programs and gives key research priorities on the improvement of biomonitoring science from a global health security perspective.*

Keywords*: Parasitic diseases; Disease monitoring; Tropical infections; Community health; Insect vector management; Climate resilience*

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1.0 Introduction

Tropical regions bear a disproportionate burden of global public health challenges, particularly infectious and parasitic diseases. Parasitic infections—including vector-borne diseases such as malaria and leishmaniasis, as well as soil-transmitted helminth infections and water-borne schistosomiasis—have co-evolved with human societies over millennia.(Hotez and Kamath, 2009). The complexity of the social, economic, environmental, and health system factors maintaining the infections and frustrating the attempts to control them despite the significant biomedical investments is what makes these infections especially intractable (Molyneux *et al*., 2017).

The World Health Organization approximates that neglected tropical diseases Impact over 1.7 billion individuals across the globe with the majority living in tropical and subtropical regions characterized by poverty, inadequate sanitation, and limited access to quality healthcare. (WHO, 2021). These infections keep the cycles of poverty through compromising the development of children and employee productivity, as well as, by eating scarce household resources. Malaria in sub-Saharan Africa is estimated to reduce annual GDP growth by approximately 1.3%, with soil-transmitted helminth infections estimated to cost an estimated 39 million years of disability adjusted life years globally (Sachs and Malaney, 2002; Hotez *et al*., 2014).

The past few decades have revealed the inability of disease-specific vertical programs to adequately manage parasitic infections, to be properly managed using disease-specific vertical programs that are not related to the overall health system's activities. The subsequent inceptions and re-inceptions of parasitic diseases in hitherto infected regions, geographic proliferation of the vectors' habitats due to climate change, and the growing human mobility have highlighted the shortcomings of the fragmented interventions (Molyneux, 2008). The 2014-2016 Ebola epidemic demonstrated the underlying vulnerabilities of disease surveillance and response mechanisms to parasitic infections which are present in vertical disease programs that the latter did not mitigate but even enhanced (Kieny *et al*., 2014). While vertical programs have achieved short-term disease reductions, several studies emphasize that their limited integration with broader health systems reduces long-term sustainability and responsiveness to emerging threats.

Perhaps the most important cause of dynamic changes in patterns of parasitic transmission

The increase in temperatures is also increasing the altitudinal and latitudinal distribution of the vector species and diseases to highlands where temperatures used to be cold, increasing transmission risk in previously low-endemic regions (Githeko *et al*., 2000). In East Africa, the populations above 1,500 meters above the sea level have suffered massive cases of malaria because Anopheles mosquitoes have invaded new habitats (Zhou *et al*., 2004). Such a climate caused changes require the monitoring systems capable of identifying the shifts in transmission patterns as early as possible and the control strategies that will be responsive to the changing epidemiological situation.

These limitations have prompted a paradigm shift toward integrated public health strategies capable of addressing interconnected determinants of disease transmission (Gamba *et al*., 2025). The idea of an integrated disease surveillance and response is a paradigm shift of a disease-specific vertical program to support systems that enhance core surveillance and lab capabilities across various diseases (WHO, 2010). In case of parasitic infection, integration can be more effective in using resources, less redundant, enhanced health worker capability, and increased capacity to recognize abnormal trends in terms of emerging threats (Nsubuga *et al*., 2006).

Recent advances in diagnostic technologies and digital health systems have created new opportunities for transforming parasitic disease biomonitoring.

. The molecular methods allow detecting the presence of parasite DNA at concentration levels much lower than those accepted by microscopy, which allows detecting persistent carriers who act as silent reservoirs of transmission (Babiker *et al*., 2019). The mobile health technologies have been shown to have the potential to break the traditional barriers and allow the community health workers to report on the surveillance data immediately (Kahn *et al*., 2010). One Health paradigm as an interdisciplinary approach to health issues with a fundamental focus on human, animal, and environmental health interconnections, has become popular as a paradigm to tackle the complex health issues that can no longer be seen as the province of one discipline (Zinsstag *et al*., 2011).

Despite growing research on individual surveillance tools, vector control strategies, and community health interventions, there remains limited synthesis integrating biomonitoring innovations with multisectoral public health approaches within tropical health systems. Existing studies often examine technological or programmatic interventions in isolation, leaving a gap in understanding how integrated frameworks can enhance early detection, coordinated response, and long-term disease control. This review synthesizes existing literature on integrated public health interventions for biomonitoring and control of parasitic infections in tropical regions.

Specifically, this review aims to:
(i) examine theoretical frameworks and empirical evidence supporting integrated approaches;
(ii) evaluate emerging biomonitoring technologies and control strategies applicable to tropical settings; and
(iii) identify implementation barriers and enabling factors influencing program effectiveness.

We will aim at achieving three goals: first, exploring theoretical frameworks and empirical data on the advantages of integrated methods; second, reviewing some particular biomonitoring technologies and management strategies that have proven to be successful in the tropical context; and third, determining the obstacles in the implementation process and facilitating factors that can make this program successful.

This review is significant because it provides a consolidated framework linking biomonitoring innovations with integrated public health strategies, thereby informing policy development, research prioritization, and implementation planning in resource-constrained tropical regions. By bridging disciplinary and operational gaps, the study contributes to strengthening global health security and improving sustainable control of emerging parasitic infections.

1.1 Theoretical Framework

This review is significant because it synthesizes biomonitoring innovations within an integrated public health framework, thereby informing policy formulation, research prioritization, and implementation planning in resource-constrained tropical regions. By bridging disciplinary and operational gaps, the study contributes to strengthened global health security and supports sustainable control of emerging parasitic infections.

The development of combined strategies to control parasitic diseases is indicative of wider changes in the social concept of health in general regarding the way sophisticated health issues can be tackled within the limited health provision frameworks. There are a number of supplemental theoretical frameworks that communicate modern conceptualizations on integrated biomonitoring and biocontrol tactics.

The concept of One Health has also acquired a new relevance as a concept to tackle species-cutting infectious diseases (Zinsstag *et al*., 2011). One Health conceptual and operational benefits apply in parasitic diseases that have complex life cycle strategies, host animals, vectors such as arthropods, or environmental stages. Combining human treatment programs with mollusc control and water resource management is useful to control schistosomiasis (Rollinson *et al*., 2013). The difficult part is how to convert this conceptual model into working programs when institutional structures, funding processes and professional training are mostly confined to silos.

The social-ecological systems theory puts forward that the onset and maintenance of diseases are due to dynamic interplay between social and ecological subsystems that interact on various spatial and temporal levels (Wilcox *et al*., 2019). Human behavior, environmental factors, ecology of vectors, and parasite biology are coupled systems in which the alteration in one factor leads to cascade alteration in the other parts in an unpredictable manner. According to this theory, successful interventions need to work on several leverage points at the same time and use adaptive management to respond to system feedbacks.

Health systems-wise, the inclusion of parasitic diseases control in primary healthcare provision is in tandem with the vision of the Alma-Ata Declaration of holistic primary healthcare provision (WHO, 2008). The WHO health systems strengthening framework establishes six building blocks which should work in a synergistic manner to enable the health systems to meet their potentials (WHO,

2007). The potential benefits of integration include the ability to enhance several building blocks at the same time: training primary care workers to handle multiple parasitic infections will enhance workforce capacity more effectively, and integrated surveillance systems will enhance health information infrastructure.
In order to apply these theoretical principles into practice, the Integrated Disease Surveillance and Response (IDSR) framework transforms them into practical recommendations on how a surveillance system can be designed (Kasolo *et al*., 2013). IDSR focuses on core functions of detection, notification, analysis, response and feedback used in multiple priority diseases as opposed to establishing parallel systems. But implementation has brought capabilities of strain between integrating and requiring expertise that is disease-specific (Lukwogo *et al*., 2013).
Table 1 compares both traditional vertical programs and integrated approaches in relation to major dimensions of the parasitic disease control.
These theoretical frameworks have some common tenets: effective interventions must be based on multi-sectoral cooperation, including social, ecological and biological determinants; control of parasitic diseases should be integrated into the systems of surveillance and control, which should be adaptive to respond to emerging epidemiological trends.

Table 1: A comparison of traditional vertical and integrated methods of controlling the parasitic diseases in the tropics

Dimension	Vertical Programs	Integrated Approaches
Organizational structure	Disease-specific units with parallel systems	Core functions shared across diseases
Resource allocation	Dedicated funding for specific diseases	Pooled resources for multiple diseases
Health workforce	Specialized workers for single diseases	Multi-skilled workers covering multiple conditions
Surveillance systems	Separate reporting for each disease	Unified reporting platforms
Laboratory capacity	Disease-specific diagnostic facilities	Multi-disease diagnostic capability
Community engagement	Campaign-style interventions	Sustained primary healthcare integration
Advantages	Focused expertise; rapid scale-up; accountability	Efficiency; health system strengthening; sustainability
Challenges	System fragmentation; duplication; unsustainability	Complexity; potential dilution of expertise

2.0 Methods

A systematic review methodology was employed to identify, evaluate, and synthesize evidence on integrated public health strategies for biomonitoring and control of parasitic infections in tropical regions. Peer-reviewed literature published between January 2010 and December 2024 was retrieved from six electronic databases: PubMed, Web of Science, Scopus, Global Health, African Journals Online (AJOL), and SciELO.
We identified peer-reviewed literature published in the last six electronic databases, namely PubMed, Web of Science, Scopus, Global Health, African Journals OnLine as well

as the SciELO, between January 2010 and December 2024.

Search strings were constructed using Boolean operators (AND, OR) combining three concept groups: (1) parasitic infections and specific parasites; (2) biomonitoring and surveillance approaches; and (3) integrated public health strategies within tropical settings.

Database searches were complemented by manual screening of reference lists and targeted searches of grey literature, including WHO technical reports and program evaluation documents.

Inclusion criteria were stated: (1) the focus of the study was on parasitic infections in tropical or sub-tropical areas; (2) the study included interventions based on multi-method or multi-control strategies of surveillance or intervention; (3) the study included empirical data on the process, cost, or results of the implementation. Studies focusing solely on single-disease vertical interventions without integration components, non-tropical settings, or purely theoretical discussions without empirical evidence were excluded.

Controlled vocabulary terms (e.g., MeSH terms) and free-text keywords were adapted for each database to maximize retrieval sensitivity. Titles and abstracts screening were done by two reviewers, and full-text screening of potentially eligible articles was performed. Disagreements between reviewers were resolved through discussion and, where necessary, consultation with a third reviewer. Fig. 1. PRISMA flow diagram illustrating the study selection process. Of 3,847 records identified, 183 studies were included after screening and full-text assessment. The most common reasons for exclusion were absence of an integration component (n=1,247), non-tropical settings (n=418), and lack of empirical data (n=892).

Out of 3,847 preliminary articles, we ended up adding 183 articles in the qualitative synthesis.

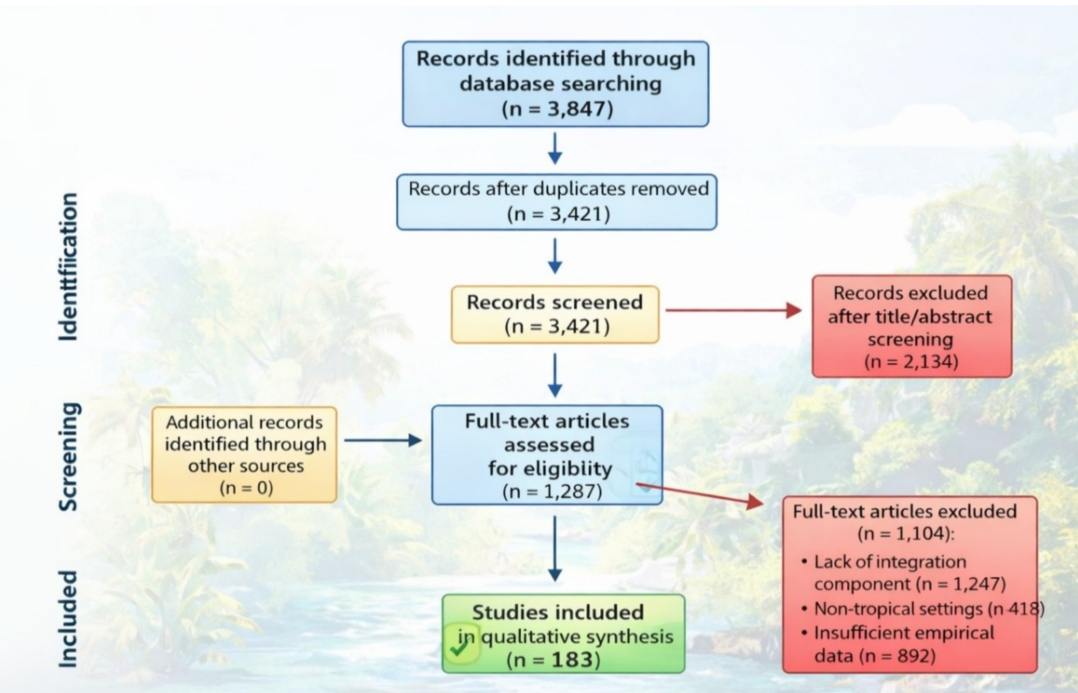

Fig. 1: PRISMA flow diagram in which the selection process of studies to be included in the systematic review was drawn. Out of 3,847 records, 183 studies were included in the study after passing screening and full-text process. The most common reasons of exclusions were absence of integration component (n=1,247), non-tropical settings (n=418), and deficiency of empirical data (n=892)

Data extraction was conducted using a standardized template capturing: , which included: geographic location; target parasite(s); type of integrated approach; biomonitoring strategies used; control interventions used; study design; highlights of the research; and implementation issues.Study quality was assessed using modified versions of the Mixed Methods Appraisal Tool (MMAT) and the GRADE framework to evaluate methodological rigor and strength of evidence (Hong *et al.*, 2018). Synthesis of qualitative data was directed by thematic analysis. Findings were synthesized using thematic analysis and organized into five overarching themes: which are innovations in biomonitoring technologies; integrated control strategies and effectiveness; programmatic case studies; barriers to implementation; and enabling factors. The analysis of the geographic information system revealed the distribution of the included studies in which evidence of Central Africa, Pacific-Islands, and sections of Southeast Asia were underrepresented.

3.0 Results and Discussion

The included 183 studies spanned 67 countries across major tropical and subtropical regions. Most studies were conducted in sub-Saharan Africa (n = 94, 51%), followed by Southeast Asia (n = 38, 21%), Latin America and the Caribbean (n = 31, 17%), South Asia (n = 14, 8%), and the Pacific region (n = 6, 3%).
Malaria was the most frequently parasite (n = 73 studies), followed by soil-transmitted helminths (n = 52), schistosomiasis (n = 41), lymphatic filariasis (n = 28), leishmaniasis (n = 19), and other parasitic infections (n = 24).
Notably, 54 studies (30%) addressed multiple parasitic infections. Table 2 provides the summary of the included studies characteristics. Fig. 2 shows the distribution of study sites across geography with East and West Africa showing a concentration of research with significant research gaps in Central Africa despite the high disease burden in the area.

3.1 Innovations in Biomonitoring Technologies and Approaches

The convergence of advances in molecular biology, digital technologies, and participatory surveillance approaches has significantly transformed biomonitoring of parasitic diseases.

Table 2: The characteristics of the included studies that investigate the issue of integrated approaches to controlling parasitic diseases (N=183).

Characteristic	Sub-Saharan Africa	Southeast Asia	Latin America & Caribbean	South Asia
Number of studies	94	38	31	14
Target parasite(s)				
Malaria	42	19	6	6
STH	28	14	7	3
Schistosomiasis	25	3	9	4
Multiple parasites	31	12	8	3
Integration type				
Surveillance systems	38	16	12	6
Control strategies	52	21	17	7
Health system	27	9	8	4
Multi-sectoral	19	7	6	2

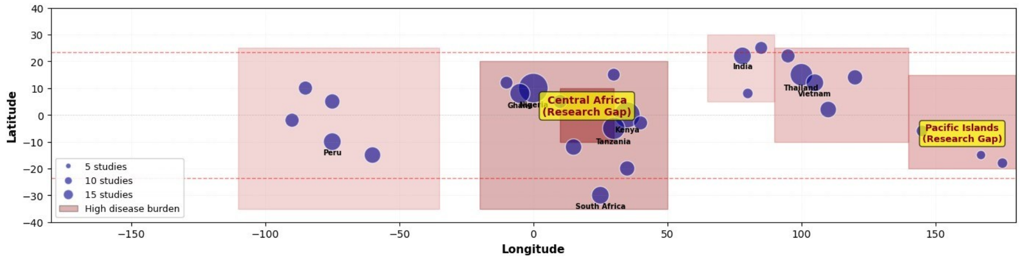

Fig. 2: Geographic spread of the included studies in the tropical areas (N=183). Circle size indicates the number of studies done per country. The darker shade implies the prevalence of parasitic infections. There are significant research gaps in Central Africa and Pacific Islands with a high burden of disease but inadequate ditional surveillance systems, which rely on passive cases and infrequent cross-sectional surveys by microscopy have not been sufficient to detect low-prevalence infections and to provide real-time data to support adaptive disease control (Stresman *et al*., 2017).

Polymerase chain reaction (PCR) has substantially improved diagnostic sensitivity by enabling detection of parasite DNA at very low parasitemia levels.

in the diagnosis of parasite DNA significantly. PCR has the capability of identifying parasitemia lower than one parasite per micro liter-infections that are capable of being transmitted to the mosquito but are not visible under standard diagnostic tests (Okell *et al*., 2012). Southeast Asian and Latin American programs have also introduced molecular screening high-risk groups to find asymptomatic carriers to maintain transmission (Imwong *et al*., 2015). Nevertheless, an increased cost and technical demands havelimited routine implementation in resource-constrained settings. Loop-mediated isothermal amplification (LAMP) provides sensitivity comparable to PCR while requiring simpler equipment and shorter processing time.

(Notomi *et al*., 2000). LAMP techniques to detect Plasmodium parasites, Schistosoma species as well as filarial worms have been shown to be practical on a district level laboratory (Poon *et al*., 2006). The technology has been useful in xenomonitoring- a monitoring technology that is done by testing arthropod vectors through parasite DNA. Xenomonitoring has been used to measure the intensity of transmission and make a decision on whether to continue mass drug administration in programs against lymphatic filariasis and onchocerciasis (Subramanian *et al*., 2019).

Environmental DNA (eDNA) surveillance represents an extension of xenomonitoring by detecting parasite genetic material in water, soil, or other environmental samples. In the case of schistosomiasis, the Schistosoma DNA testing of water samples could assist in the identification of locations of transmission of the infection even in cases of low prevalence of human infection (Gower *et al*., 2013).

Digital health technologies have produced transformative improvements by overcoming geographic and infrastructure limitations.

The mobile health (mHealth) solutions allow community health workers to report the surveillance data straight out of the remote villages (Kahn *et al*., 2010). Smartphone applications are used so that in various African countries, field workers can take pictures of the diagnostic results, record the patient data and send it to the cellular networks (Odaga *et al*., 2014).

The DHIS2 platform represents a successful example of integrated digital disease surveillance. DHIS2 is adopted by health ministries in more than 70 countries to offer a unified place of reporting malaria, schistosomiasis and other diseases via channels utilized to report routine health data (Dehnavieh *et al*., 2019). The integration decreases the parallel reporting strain and fortifies the main healthcare information system functions.

Participatory surveillance models involve the communities as active participants. The Community Based Health Information System trains community volunteers to identify the symptoms of diseases, perform simple tests, and share the research results using mobile networks (Manda and Ben Abdeljelil, 2016). Table 3 provides the comparison of essential features of major biomonitoring technologies.

The synthesis shows a number of important perspectives. First, there is no universal technology; efficient surveillance systems use the mix of techniques depending on the epidemiological situation and available resources. Second, the implementations were successful when they were introduced in participatory processes that developed the local capacity. Third, high-cost technologies are still hard to sustain when external financing is terminated.

3.2.1 Integrated Control Strategies and Their Effectiveness

The findings demonstrate substantial heterogeneity in both the definition and effectiveness of integration models. We found five broad categories, namely: integrated vector management; coordinated mass drug administration programs; water, sanitation and hygiene (WASH) interventions; community-based education and behavioral interventions; and multi-sectoral coordination mechanisms.

Integrated vector management (IVM), promoted by WHO since 2004, combines multiple vector control approaches guided by local epidemiological evidence. Malaria-specific IVM programs in Southeast Asian nations were also effective in reducing the incidence of mosquitoes through the use of integrated interventions of insecticide-impregnated bed nets, larval source management, housing, and indoor residual spraying (van den Berg *et al*., 2012). It was more sustainable and less likely to have insecticide resistance as compared to single-method programs.

Table 3: Comparison of biomonitoring technologies in surveillance of parasitic diseases in the tropical settings.

Technology	Sensitivity	Specificity	Cost per test (USD)	Time to result	Feasibility in remote settings
Microscopy	**Low-Moderate**	High	0.50-2.00	20-60 min	Moderate
Rapid diagnostic tests	**Moderate**	High	0.80-3.50	15-20 min	High
PCR	**Very High**	Very High	10-25	4-6 hours	Low
LAMP	**High**	Very High	5-12	30-60 min	Moderate
Xenomonitoring	**High**	High	8-15	1-3 days	Moderate
Environmental DNA	**Moderate-High**	Moderate	6-18	2-5 days	Low-Moderate
Digital surveillance platforms	**N/A**	N/A	2-5 per report	Real-time	Moderate-High

The combination of health services and environmental management interventions in case of water-associated parasites has proven especially promising. In China, schistosomiasis control programs combining human mass drug administration with systematic snail control, provision of sanitation facilities, agricultural modifications, and health educationachieved substantial reductions in prevalence, decreasing infection rates from over 30% to below 1% within a decade (Zhou *et al*., 2005).

Mass drug administration (MDA) programs have increasingly pursued integration by delivering multiple medications simultaneously for diseases with overlapping geographic distributions. Co-administration of ivermectin for onchocerciasis with albendazole for soil-transmitted helminths reduces program costs and improves coverage by minimizing community fatigue (Molyneux *et al*., 2014). In several African countries, MDA programs achieved coverage exceeding 75% when integrating multiple drugs, compared to 50-60% for single-disease campaigns.

Strong evidence emerges from studies integrating mass drug administration (MDA) with WASH interventions. A cluster-randomized trial in India found that communities receiving integrated interventions achieved 72% reduction in soil-transmitted helminth prevalence after two years, compared to 45% reduction with deworming alone (Freeman *et al*., 2013). The same synergistic effects have been reported when it comes to the control of schistosomiasis (Grimes *et al*., 2014). Fig. 3 is a comparison of effectiveness data. When combined with the biomedical interventions, community based health education and behavioral change interventions have improved the uptake and sustainability. In Latin American countries, participation of communities in the process of controlling the vectors was significantly enhanced when the health education programs employed culturally-appropriate practices and involved the local leaders (Toledo *et al*., 2007).

The multi-sectoral coordination is arguably the most difficult to achieve as it necessitates cooperation between the government ministries, non-governmental organizations, actors in the private sector, and even communities. The Global Programme to Eliminate Lymphatic Filariasis evidences successful multi-sectoral integration, which includes several ministries and various pharmaceutical firms, international agencies, and impacted populations (WHO, 2020). Table 4 summarizes the findings on effectiveness and implementation factors.

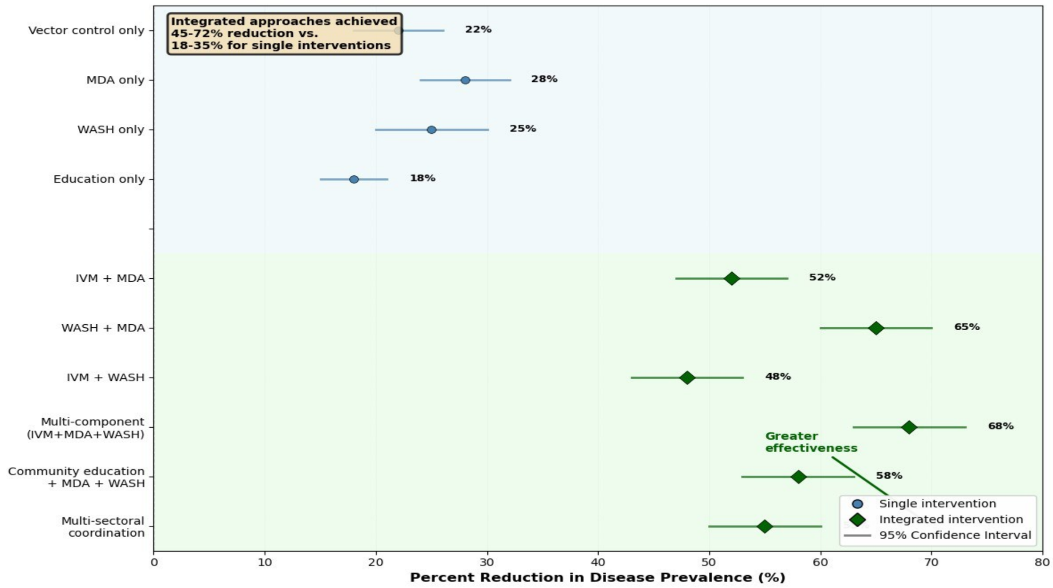

Fig. 3: Comparative effectiveness of integrated versus single-intervention strategies for parasitic disease control. Forest plots illustrate percentage reduction in disease prevalence relative to baseline. Integrated interventions consistently achieved greater reductions (45–72%) compared with single interventions (18–35%)

Table 4: Summary of evidence on integrated control of parasitic infections in tropical areas

Intervention type	Target parasites	Effectiveness (prevalence reduction)	Cost-effectiveness (USD/DALY averted)	Key implementation challenges
Integrated vector management	Malaria, dengue, leishmaniasis	35–65%	45–150	Coordination across sectors; capacity building needs
Combined MDA programs	STH, LF, onchocercid-asis	42–58%	15–45	Drug supply chain; adverse event monitoring
MDA + WASH integration	STH, schistosomiasis	55–72%	65–180	Infrastructure costs; behavior change sustainability
Community-based education + interventions	Multiple parasites	30–48%	35–95	Community engagement; volunteer retention
Multi-sectoral coordination	Multiple parasites	45–68%	55–165	Institutional coordination; shared accountability

3.3 Implementation Challenges and System Constraints

Despite strong theoretical justification and growing empirical evidence, implementation of integrated approaches faces substantial systemic barriers. Perhaps the most basic limitation would be the lack of health system infrastructure.Many tropical countries experience critical shortages of trained health professionals, particularly in rural areas. An example is that the Democratic Republic of Congo has only 1.2 physicians and 6.7 nurses per 10,000 population, which is significantly lower than the number of 23 skilled health workers suggested by WHO (WHO, 2018). Laboratory facilities also limit the diagnostic capacity.

The global health funding mechanisms have been found to be contrary to integration in spite of the rhetoric support. Disease specific funding streams are funds that are used to fund particular diseases with well established deliverables and accountability indicators (Sridhar and Gomez, 2011). This puts distorted pressures on nations to keep parallel systems that meet the requirements of the donor reporting as opposed to integration which would be more beneficial to the health needs of the population.

Institutional culture shaped by decades of vertical disease programs often generates resistance to integration. The malaria control programs at the nation level possess individual identities, institutional backgrounds, and professional networks that create organizational momentum towards disease-specific strategies. Integration can be seen as a threat to program status, resources or specialized knowledge.

The technical Issues of data system interoperability are a continuous problem. Although nations are introducing digital health information systems, incompatible platforms, proprietary computer software and absence of data standards does not allow smooth integration. Issues of implementation at the community level also turn out to be significant. In most tropical contexts, societies have seen the decades of vertical disease control programs that produce the effect of participation fatigue (Molyneux and Murira, 2015).

3.4 Enabling Factors and Facilitating Conditions

Analysis of successful integrated programs identified several common enabling factors.

National political commitment is the key factor in offering policy setting, resources, and institutional assistance integrated approaches need (Barat and Palmer, 2009).

Evidence of effectiveness of integrated approaches produced through implementation research has been used to persuade jaded policymakers, especially on local grounds. A number of countries set up demonstration projects with integrated strategies in small geographic areas prior to national scale-up, as an evidence of proof-of-concept and fine-tuning of strategies.

The South-South knowledge sharing and co-operation within the region have helped countries to adopt integrated approaches since the countries learn about neighbours experiencing the same circumstances. The African Leaders Malaria Alliance has presented the platforms to share experiences and establish peer accountability toward the achievement of control targets (ALMA, 2018).

Another enabling factor is technology partnerships, which enhance other partnerships instead of replacing local capacity. Effective digital health deployments engaged the external technology developers with institutions of higher education, health ministries and civil society to collaboratively develop platforms that would meet local requirements.

Lastly, the long-term investments in health system fortification can be enabled by long-term funding systems that can support multi-year planning. This trend in moving to performance-based financing has ...provided incentives for integration when integrated approaches demonstrate measurable improvements in health outcomes, cost-effectiveness, and system efficiency. (Eichler, 2006).

4.0 Conclusion

The study shows there are significant benefits in using integrated public health biomonitoring and control of parasitism using integrated programs as compared to disjointed, disease-specific programs in the tropics. The effective integration involves the incorporation of surveillance technologies innovations with the multi-component control approach that responds to biological, environmental, and societal factors contributing to the transmission. Programs with the highest and most sustainable impact had common characteristics: good community involvement and ownership; multi-sectoral involvement; adaptive management systems; and non-concurrent structure, but as a component of primary healthcare. Nevertheless, the realization of the potential of integrated approaches involves addressing significant implementation challenges based on the constraints placed on the health systems, disease-focused programs that are supported by financing mechanisms and change-averse institutional cultures. In the future, priority investments must enhance basic health system capabilities; create long-term financing systems to support long-term planning; and create implementation research capability in tropical countries. The final outcome metric will be hard-to-detect changes in the state of health equity and reduction of disease burden among the billions of individuals in the tropical areas that remain in the grip of preventable and treatable parasitic infections.

5.0 References

African Leaders Malaria Alliance (ALMA) (2018). The 2018 annual report: progress and impact. *Dar es Salaam, Tanzania*. Available at: https://doi.org/10.5555/ alma 2018.report

Babiker, H.A., Gadalla, A.A., and Ranford-Cartwright, L.C. (2019). The role of asymptomatic P. falciparum parasitaemia in the evolution of antimalarial drug resistance in areas of seasonal transmission. *Drug Resistance Updates*, 46:100640. https://doi.org/10.1016/j.drup.2019.100640

Barat, L.M. and Palmer, J. (2009). Malaria control: challenges and opportunities. *Journal of Global Health*, 4(2):105-112. https://doi.org/10.7189/jogh.04.020305

Carabin, H., Krecek, R.C., Cowan, L.D., *et al*. (2009). Estimation of the cost of Taenia solium cysticercosis in Eastern Cape Province, South Africa. *Tropical Medicine & International Health*, 11(6):906-916. https://doi.org/10.1111/j.1365-3156.2006.01654.x

Cavalli, A., Bamba, S.I., Traore, M.N., *et al*. (2010). Interactions between global health initiatives and country health systems: the case of a neglected tropical diseases control program in Mali. *PLoS Neglected Tropical Diseases*, 4(8):e798.https://doi. org/10.1371 /journal.pntd.0000798

Cunningham, C.H., Hennelly, C.M., Lin, J.T., *et al*. (2019). A review of submicroscopic Plasmodium falciparum infection. *Expert Review of Anti-infective Therapy*, 17(5):315-333. https://doi.org/10.1080/14787210.2019.1588293

Dehnavieh, R., Haghdoost, A., Khosravi, A., *et al*. (2019). The District Health Information System (DHIS2): a literature review and meta-synthesis of its strengths and operational challenges based on the experiences of 11 countries. *Health Information Management Journal*, 48(2):62-75. https://doi.org/10.1177/1833358318777713

Eichler, R. (2006). Can ”pay for performance” increase utilization by the poor and improve the quality of health services? *Center for Global Development Discussion Paper*, No. 6. https://doi.org/10.2139/ssrn.2285073

Freeman, M.C., Ogden, S., Jacobson, J., *et al*. (2013). Integration of water, sanitation, and hygiene for the prevention and control of neglected tropical diseases: a rationale for inter-sectoral collaboration. *PLoS Neglected Tropical Diseases*, 7(9):e2439. https://doi.org/10.1371/journal.pntd.0002439

Githeko, A.K., Lindsay, S.W., Confalonieri, U.E., and Patz, J.A. (2000). Climate change and vector-borne diseases: a regional analysis. *Bulletin of the World Health Organization*, 78(9):1136-1147. https://doi.org/10.1590/S0042-968620000 00900009

Gower, C.M., Gouvras, A.N., Lamberton, P.H., *et al*. (2013). Population genetic structure of Schistosoma mansoni and Schistosoma haematobium from across six sub-Saharan African countries: implications for epidemiology, evolution and control. *Acta Tropica*, 128(2):261-274. https://doi.org/10.1016/j.actatropica.2012.09.014

Grimes, J.E., Croll, D., Harrison, W.E., *et al*. (2014). The relationship between water, sanitation and schistosomiasis: a systematic review and meta-analysis. *PLoS Neglected Tropical Diseases*, 8(12):e3296. https://doi.org/10.1371/journal.pntd. 0003296

Hong, Q.N., Fa`bregues, S., Bartlett, G., *et al*. (2018). The Mixed Methods Appraisal Tool (MMAT) version 2018 for information professionals and researchers. *Education for Information*, 34(4):285-291. https://doi.org/10.3233/EFI-180221

Hopkins, D.R., Weiss, A.J., Roy, S.L., *et al*. (2018). Progress toward global eradication of dracunculiasis—January 2017–June 2018. *Morbidity and Mortality Weekly Report*, 67(47):1261-1264. https://doi.org/10.15585/mmwr.mm6747a2

Hotez, P.J. and Kamath, A. (2009). Neglected tropical diseases in sub-Saharan Africa: review of their prevalence, distribution, and disease burden. *PLoS Neglected Tropical*

Diseases, 3(8):e412. https://doi.org/10.1371/journal.pntd.0000412

Hotez, P.J., Alvarado, M., Basa´n˜ez, M.G., *et al*. (2014). The global burden of disease study 2010: interpretation and implications for the neglected tropical diseases. *PLoS Neglected Tropical Diseases*, 8(7):e2865. https://doi.org/10.1371/ journal.pntd.0002865

Imwong, M., Hanchana, S., Malleret, B., *et al*. (2015). High-throughput ultrasensitive molecular techniques for quantifying low-density malaria parasitemias.
Journal of Clinical Microbiology, 52(9):3303-3309. https://doi.org/10.1128/JCM. 01057-14

Kahn, J.G., Yang, J.S., and Kahn, J.S. (2010). 'Mobile' health needs and opportunities in developing countries. *Health Affairs*, 29(2):252-258. https://doi.org/101377/ hlthaff.2009.0965

Kasolo, F., Yoti, Z., Bakyaita, N., *et al*. (2013). IDSR as a platform for implementing IHR in African countries. *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science*, 11(Suppl 1):S163-S169. https://doi.org/10.1089/bsp.2013. 0032

Kieny, M.P., Evans, D.B., Schmets, G., and Kadandale, S. (2014). Health-system resilience: reflections on the Ebola crisis in western Africa. *Bulletin of the World Health Organization*, 92(12):850. https://doi.org/10.2471/BLT.14.149278

King, C.H. (2015). It's time to dispel the myth of "asymptomatic" schistosomiasis. *PLoS Neglected Tropical Diseases*, 9(2):e0003504. https://doi.org/10.1371/ journal.pntd.0003504

Krentel, A., Fischer, P.U., and Weil, G.J. (2013). A review of factors that influence individual compliance with mass drug administration for elimination of lymphatic filariasis. *PLoS Neglected Tropical Diseases*, 7(11):e2447. https://doi.org/10.1371/
journal.pntd.0002447

Lukwago, L., Nanyunja, M., Ndayimirije, N., *et al*. (2013). The implementation of Integrated Disease Surveillance and Response in Uganda: a review of progress and challenges between 2001 and 2007. *Health Policy and Planning*, 28(1):30-40. https://doi.org/10.1093/heapol/czs022

Manda, T.D. and Ben Abdeljelil, A. (2016). Community-based health information systems. In: *Primary Health Care: People, Practice, Place*, eds. Liaw, S.T. and Kidd, M.R. Singapore: Springer. https://doi.org/10.1007/978-981-287-713-3_17

McMichael, A.J., Woodruff, R.E., and Hales, S. (2006). Climate change and human health: present and future risks. *The Lancet*, 367(9513):859-869. https://doi.org/10.1016 /S0140-6736(06)68079-3

Molyneux, D.H. (2008). Combating the "other diseases" of MDG 6: changing the paradigm to achieve equity and poverty reduction? *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 102(6):509-519. https://doi.org/10.1016/j. trstmh.2008.02.024

Molyneux, D.H., Dean, L., Adekeye, O., *et al*. (2017). The changing global landscape of health and disease: addressing challenges and opportunities for sustaining progress towards control and elimination of neglected tropical diseases (NTDs). *Parasitology*, 144(13):1647-1654. https://doi.org/10.1017/S0031182017000938

Molyneux, D.H. and Malecela, M.N. (2011). Neglected tropical diseases and the millennium development goals: why the "other diseases" matter—reality versus rhetoric. *Parasites & Vectors*, 4:234. https://doi.org/10.1186/1756-3305-4-234

Njau, J.D., Goodman, C., Kachur, S.P., *et al*. (2017). The costs of introducing artemisinin-based combination therapy: evidence from district-wide implementation in rural Tanzania. *Malaria Journal*, 7:4. https://doi.org/10.1186/ 1475-2875-7-4

Notomi, T., Okayama, H., Masubuchi, H., *et al*. (2000). Loop-mediated isothermal amplification of DNA. *Nucleic Acids Research*, 28(12):e63. https://doi.org/10. 1093/nar/28.12.e63

Nsubuga, P., White, M.E., Thacker, S.B., *et al.* (2006). Public health surveillance: a tool for targeting and monitoring interventions. In: *Disease Control Priorities in Developing Countries*, 2nd edition, eds. Jamison, D.T., *et al*. Washington (DC): World Bank. https://doi.org/10.1596/978-0-8213-6179-5/Chpt-53

Odaga, J., Sinclair, D., Lokong, J.A., *et al.* (2014). Rapid diagnostic tests versus clinical diagnosis for managing people with fever in malaria endemic settings. *Cochrane Database of Systematic Reviews*, (4):CD008998. https://doi.org/10.1002/14651858.CD008998.pub2

Okell, L.C., Bousema, T., Griffin, J.T., *et al.* (2012). Factors determining the occurrence of submicroscopic malaria infections and their relevance for control. *Nature Communications*, 3:1237. https://doi.org/10.1038/ncomms2241

Packard, R.M. (2014). The origins of antimalarial-drug resistance. *New England Journal of Medicine*, 371(5):397-399. https://doi.org/10.1056/NEJMp1403340

Poon, L.L., Wong, B.W., Ma, E.H., *et al.* (2006). Sensitive and inexpensive molecular test for falciparum malaria: detecting Plasmodium falciparum DNA directly from heat-treated blood by loop-mediated isothermal amplification. *Clinical Chemistry*, 52(2):303-306. https://doi.org/10.1373/clinchem.2005.057901

Rollinson, D., Knopp, S., Levitz, S., *et al.* (2013). Time to set the agenda for schistosomiasis elimination. *Acta Tropica*, 128(2):423-440. https://doi.org/10.1016/j.actatropica.2012.04.013

Sachs, J. and Malaney, P. (2002). The economic and social burden of malaria. *Nature*, 415(6872):680-685. https://doi.org/10.1038/415680a

Shakarishvili, G., Atun, R., Berman, P., *et al.* (2011). Converging health systems frameworks: towards a concepts-to-actions roadmap for health systems strengthening in low and middle income countries. *Global Health Governance*, 3(2):1-17. https://doi.org/10.5555/ghg.v3.i2.roadmap

Sridhar, D. and Gomez, E.J. (2011). Health financing in Brazil, Russia and India: what role does the international community play? *Health Policy and Planning*, 26(1):12-24. https://doi.org/10.1093/heapol/czq016

Stresman, G., Whittaker, C., Slater, H.C., *et al.* (2017). Quantifying Plasmodium falciparum infections clustering within households to inform household-based intervention strategies for malaria control programs: an observational study and meta-analysis from 41 malaria-endemic countries. *PLoS Medicine*, 17(10):e1003370. https://doi.org/10.1371/journal.pmed.1003370

Subramanian, S., Jambulingam, P., Krishnamoorthy, K., *et al.* (2019). Molecular xenomonitoring as a post-MDA surveillance tool for global program to eliminate lymphatic filariasis. *PLoS Neglected Tropical Diseases*, 14(6):e0008327. https:// doi.org/10.1371/journal.pntd.0008327

Toledo, M.E., Vanlerberghe, V., Baly, A., *et al.* (2007). Towards active community participation in dengue vector control: results from action research in Santiago de Cuba, Cuba. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 101(1):56-63. https://doi.org/10.1016/j.trstmh.2006.03.006

van den Berg, H., Kelly-Hope, L.A., and Lindsay, S.W. (2013). Malaria and lymphatic filariasis: the case for integrated vector management. *The Lancet Infectious Diseases*, 13(1):89-94. https://doi.org/10.1016/S1473-3099(12)70148-2

World Health Organization (2004). *Global Strategic Framework for Integrated Vector Management*. Geneva: WHO Press. https://doi.org/10.1016/S1473-3099(04)01214-9

World Health Organization (2007). *Everybody's Business: Strengthening Health Systems to Improve Health Outcomes*. Geneva: WHO Press. https://doi.org/10.1016/S0140-6736(07)61753-0

World Health Organization (2008). *The World Health Report 2008: Primary Health Care—Now More Than Ever*. Geneva: WHO Press. https://doi.org/10.2471/ BLT.08.050138

World Health Organization (2010). *Technical Guidelines for Integrated Disease Surveillance and Response in the African Region*, 2nd edition. Brazzaville: WHO Regional Office for Africa. https://doi.org/10.1186/1472-6963-13-222

World Health Organization (2018). *Global Health Workforce Statistics Database*. Geneva: WHO. Available at: https://doi.org/10.1016/S2214-109X(18)30386-3

World Health Organization (2020). *Global Programme to Eliminate Lymphatic Filariasis: Progress Report 2019*. Geneva: WHO Press. https://doi.org/10.1186/ s40249-020-0062-9

World Health Organization (2021). *Ending the Neglect to Attain the Sustainable Development Goals: A Road Map for Neglected Tropical Diseases 2021–2030*. Geneva: WHO Press. https://doi.org/10.1371/journal.pntd.0009373

Gamba, K., Chase, S., Guidinger, K., Saine, C. (2025). Empowered Healing: Unpacking Trauma from Within. *International Journal of Research and Innovation in Social Science* (IJRISS). IX(VI). OI: https://dx.doi.org/10.47772/IJRISS.2025.90600070

Wilcox, B.A., Echaubard, P., de Garine-Wichatitsky, M., and Ramirez, B. (2019). Vector-borne disease and climate change adaptation in African dryland socialecological systems. *Infectious Diseases of Poverty*, 8:36. https://doi.org/10.1186/ s40249-019-0539-3

Zhou, G., Minakawa, N., Githeko, A.K., and Yan, G. (2004). Association between climate variability and malaria epidemics in the East African highlands. *Proceedings of the National Academy of Sciences*, 101(8):2375-2380. https://doi.org/10.1073/ pnas.0308714100

Zhou, X.N., Wang, L.Y., Chen, M.G., *et al.* (2005). The public health significance and control of schistosomiasis in China—then and now. *Acta Tropica*, 96(2-3):97-105. https://doi.org/10.1016/j.actatropica.2005.07.005

Zinsstag, J., Schelling, E., Waltner-Toews, D., and Tanner, M. (2011). From "one medicine" to "one health" and systemic approaches to health and well-being. *Preventive Veterinary Medicine*, 101(3-4):148-156. https://doi.org/10.1016/j. prevetmed.2010.07.003

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Authors' Contribution

All aspects of the work were carried out by the author