Journal of Communicable Diseases
Volume 54, Issue 2 - 2022, Pg. No. 1-11
Peer Reviewed & Open Access Journal

Research Article

An Opinion based on a Retrospective Study on Vector Management for the Elimination of Visceral Leishmaniasis and its Sustenance

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DOI: https://doi.org/10.24321/0019.5138.202264

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How to cite this article:
Kumar V, Rama A, Sharma SN. An Opinion based on a Retrospective Study on Vector Management for the Elimination of Visceral Leishmaniasis and its Sustenance. J Commun Dis. 2022;54(2):1-11.

Date of Submission: 2022-05-16
Date of Acceptance: 2022-06-28

A B S T R A C T

Background: Visceral leishmaniasis (Kala-azar, VL) is a vector-borne illness that affects people all over the world. Indoor Residual Spray (IRS) has been recognised as a tool for eliminating the illness. In the context of Kala-azar elimination, it is critical to address evidence-based studies on IRS success and failure.

Methodology: For the literature search, the Internet was used. The following websites were visited: PubMed, Google Search Engine, ResearchGate, NVBDCP sites, and WHO/TDR sites. We utilised keywords like leishmaniasis vector, indoor residual spray, eradication of visceral leishmaniasis, and sand fly ecology in our search, and we also visited the library of ICMR-RMRI for the journals which we could not find on the internet.

Result: The success of IRS may be shown in the progress made in controlling kala-azar in Assam via vector control. This accomplishment, however, could not be duplicated in Bihar. We looked at all of the studies that dealt with insecticides and vector control. In addition, policies and papers produced by the Indian government and the World Health Organization (WHO) from time to time were included. Suboptimal pesticide usage, a lack of effective IRS M&E, and the use of resistance insecticides have all been concerns in vector control, resulting in failure to meet elimination objectives.

Conclusion: It is suggested that strong Monitoring and Evaluation (M&E) is needed particularly during the low transmission period. Restrictive use of insecticide associated with other control measures will be helpful. Determination of infectivity rate in vector and accordingly application of intervention will stop the unscrupulous use of the insecticide.

Keywords: Visceral Leishmaniasis (VL), Phlebotomus Argentipes., Indoor Residual Spray, Monitoring and Evaluation (M&E), VL Vector Control

Introduction

The protozoan illness visceral leishmaniasis (VL), also known as Kala-azar (KA), is spread by the bite of an infected sand fly. Sand flies (Diptera: Psychodidae) are quite little, measuring 1.5 to 3.5 millimetres in length and about one-third the size of a mosquito. Phlebotomus spp. in the Old World and Lutzomyia spp. in the New World are the main vectors. VL is spread in the Indian subcontinent through the biting of infected female Phlebotomus argentipes. VL is present in more than 80 countries, with Brazil, Eritrea, Ethiopia, India, Kenya, Somalia, South Sudan, and Sudan accounting for 90% of the illness. According to a recent report by WHO, leishmaniasis is endemic in 98 countries, with 71 being endemic for both Cutaneous Leishmaniasis (CL) and VL and 8 being endemic for VL. More than 1 billion people worldwide are at risk of contracting the disease. An estimated 30000 and more than 1 million new cases of VL and CL respectively occur annually.[1] Amajor share of the disease is contributed by Brazil, East African countries, and India. Both East Africa and India have more or less similar Kala-azar epidemiology having ahistory of frequent outbreaks,[2,3,4] and both territories having anthroponotic transmission and manifesting thepost Kala-azar dermal leishmaniasis (PKDL) in 5-10% of VL cases. Hence, in the sustenance phase, PKDL and resurgence of VL must be taken into strict vigilance to sustain the elimination. Despite its high severity, VL has been given the least importance in the tropical disease priorities list.[5]However, the National Health Policy, in the year 2002, was dedicated to the elimination of Kala-azar, with the goal of elimination set for 2010. Since 2003, the Government of India has been fully committed to the elimination of Kala-azar. Political commitment was regarded to be vital for the illness's eradication because it was a disease of the poorest with a high prevalence among the impoverished and marginalised group. As a result, in 2004, a ministerial-level conference between India, Bangladesh, and Nepal was conducted in the Maldives, and a tripartite Memorandum of Understanding was signed for the eradication of Kala-azar. For SEAR, first-time elimination was defined as a decrease in yearly case incidence of less than one per 10,000 population at the block level. Thailand and Bhutan eventually joined the group. The vector has an unusual behaviour in that it is endophilic and endophagic, cannot fly but exhibits hopping or jumping movements of less than 0.5 meters, and is susceptible to most insecticides. Because of these characteristics, it was assumed that could be easily eliminated; however, this hypothesis proved to be a nightmare, and targets set for its abolition in the years 2010, 2015, 2017 and 2020 failed and now 2023 has been set as a new goal to reach elimination.

In the Accelerated Plan for the Kala-azar elimination 2017, Guidelines by the Directorate National Vector Borne Disease Control Programme (NVBDCP),[5] New Delhi, have identified five pillars for Kala-azar elimination. They are early case detection, Integrated Vector management, supervision, monitoring and evaluation, capacity building, and IEC/BCC. Kala-azar control in India heavily relied on the use of insecticide through indoor residual spray (IRS). Some publications have voiced misgivings about the declining trends of Kala-azar owing to the restricted IRS, suggesting that the drop might be related to the leishmaniasis' natural cycle.[6] Another worker concurred with this point of view.[7] Muniaraj[8] had a similar sentiment, stating that IRS had a beneficial influence, despite the fact that it was cautioned about the major flaw in vector management procedures due to its limited effect on case occurrence after 2011. More crucially, the authors of a meta review[9] have concluded that based on the current information, making recommendations for evidence-based vector management will be challenging. Several findings, on the other hand, clearly imply that IRS has a good influence on the control of VL, and the removal of Kaka-azar from Assam is a testimony of IRS's favourable impact.[10,11,12] As a result, the purpose of this work is to examine the role of vector control in Kala-azar removal and the path ahead for post-VL sustainability through a retrospective investigation. Since IRS has been the mainstay for vector management in the Indian subcontinent, hence IRS is the subject of this research. Approximately 80% of the money set aside for the Kala-azar eradication is spent on vector management. In this context, it's essentialto consider the importance of vector management for the disease's elimination and long-term viability.

Methodology

The PubMed database, Google Search Engine, and relevant websites such as ResearchGate, NVBDCP sites and WHO/TDR sites were visited and searched for combinations and variations of the following key terms: 'Phlebotomus', 'indoor residual spray','visceralleishmaniasis', 'sand fly distribution', and 'sand fly ecology'. Only papers that primarily focused on vector control methods for visceral leishmaniasis, i.e. by quantifying the impact of IRS on sand fly abundance and/or on the incidence of in-field settings, were considered eligible for inclusion although a few other papers addressing malaria control were also included. The susceptibility status of sand fliesshowed many results but only those that were relevant to the studywere selected. Papers which were not related to vector control were not included inthe study. Using IRS in vector control as a keyword, papers on malaria control were also searched and a few papers were selected from malaria control too. Some important papers were collected through cross-references. For sand fly ecology searches, 59 articles were found but among them, only those were selected which suitedour study. For this study,the ICMR-RMRIMS library wasalso consulted for the papers and books which we could not get on the internet search.

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202264

Results

Prior to the 1970s, India had no vector control programme for Kala-azar. However, as a result of the malaria control programme in the 1950s and 1960s, the worst infectious sickness could be brought under control. Kala-azar recurrence was found after DDT was removed in the 1960s, with a peak in 1977 when over 100,000 cases were recorded, regardless of the fact that the official number of VL cases was significantly lower.[13] As a result, all malaria control methods, such as two rounds of IRS using dichloro diphenyl trichloroethane (DDT) 50% WP @ 1 gm/m^2, were included for vector control. IRS cow barns were included in the research, which was in contrast to malaria control. Only barriers up to 6 feet were chosen due to the vector's endophilic, endophagic[14] and zoophilic[15] nature, as well as its weak flying ability and hopping speed. DDT requirements werereduced to half as compared to the requirementfor malaria control i.e. 37.5 MT for one round covering one million population. IRS operation was performed with traditional equipment, a stirrup pump. In 1977, IRS was started in September and continued till December.[10]

Due to a lack of political consensus, cases began to rise again after 15 years; a peak reached in 1992, with around 250000 cases reported.[13] Surprisingly, no instances have been reported in Assam. In 1991, the Planning Commission drafted a plan for a government-supported Kala-azar management campaign, recognising the disease's enormity,namely Kala-azar Elimination Programme (National Kala-azar Elimination Programme). The nodal agency for vector-borne illness control, NMEP, currently known as the National Vector Borne Disease Control Programme (NVBDCP), announced a vector control plan through IRS in 1991. The "insecticide of choice" remained DDT. The policy for the management of VBDs established two rounds of IRS spraying, with the first and second rounds occurring in February-March and May-June in Bihar, and May-July and August-October in West Bengal, respectively. This had a substantial impact on the incidence of VL, with cases dropping dramatically between 1993 and 1999.[16] Despite IRS's decline, the number of cases reduced to 12176 from 1995 to 2001. Although these approaches may help to manage VL in West Bengal, a rising trend of VL has been seen in Bihar's districts. The IRS schedule, which only protected disadvantaged individuals for five months, is the most likely factor of the rising tendency of KA cases in Bihar. The high-density phase of the sand fly,[17] as well as the epidemiological viable period, is October-November,[18] were remain unprotected. In a study, it was demonstrated that proper spacing between the two rounds of spray could give better results and June-July and October-November were suggested for the first and second cycle respectively.[19] Guidelines by the Directorate, NVBDCP[5] has proposed a new schedule for IRS which included the first round during March-April and the secondround during August-September which appears more realistic in the direction of elimination of Kala-azar from Bihar. This schedule is very much near to the Assam model.

Assam: The Model to be Replicated in Bihar for KA Elimination/ Eradication

When Kala-azar reemerged in the 70s and established itself till the90s, Assam remained free of Kala-azar. Assam has a very old history ofKala-azar. The earliest report of the epidemic was in 1882 and it was called Kala-azar or black sickness. Clarke, a Civil Medical Officer of Tura, headquarter of Garo Hills district in Assam, called it "Kala-hazar". Young TC[20] a sanitary commissioner in Assam, has documented more than 100000 cases of Kala-azar from the plain. In Bengal, there was a terrible epidemic of Kala-azar between 1871 and 1876. It was thought that kala-azar might be existing there in a sporadic form in 1869 in the Garo Hills of Assam but the state felt a severe epidemic in 1882-87.[21] The epidemic was so intense that one-third of the population lost their lives in Nowgong during the 1892-98 epidemic. This epidemic continued at different intensities in Assam till 1950. Till 1949, mass treatment campaign was the only method of control but drug resistance was an obstacle in the way. Hence, DDT was suggested as another means of control.[21] DDT spray started during 1949-52 for malaria control. The schedule of DDT spray in Assam wasApril-June for the first round and October-December for the second round. There is very little study regarding the cause of total elimination of Kala-azar from Assam. However,it was pointed out that though the spray wasmade for malaria interruption, it unintentionally and effectively covered the entire period of Kala-azar transmission resultingin the total elimination of Kala-azar from this area.[10] This fact was supported byBora D and Khan AM et al.[22,23]

In other words, epidemiology status remained at a minimum level and it was declared a Kala-azar free state.[24] Due to the outbreak of Kala-azar in Chiapadana village of Chandparna area of Kamrupmetro district in Assam, the entomological and medical team from ICMR-RMRC, Dibrugarh and ICMR-RMRIMS, Patna visited the area and collected P. argentipes which were identified up to species level as described in morphological taxonomic keys[25]and also reported 27 confirmed cases.[26]All confirmed cases were treated and supervised. IRS was performed resulting in total control of the disease. However, till 2012 in Assam, a total of 162 persons were found positive with rK-39 and 4 suspected cases of PKDL were identified.[12]

It can be said that after the epidemic of the nineteenth century which continued up to 1950, Assam remained free from Kala-azar, except for a small outbreak in 2008. For a better understanding of IRS in Kala-azar control, the situation of Assam provides an in sight in to the role of

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202264

IRS. On the other side, after stopping DDT in the sixties in Bihar for malaria control, Kala-azar came back after agap of 12-15 years in the early 70s whereas Assam was free from Kala-azar. Though DDT was stopped between 1962 and 1965, Assam and Bengal received DDT due to a high incidence of malaria but Bihar did not receive DDT because malaria was absent in Bihar. This contributed a lot tothe surge of cases in Bihar. From time to time, NVBDCP, WHO, and ICMR have developed policies for improvement in the control of visceral leishmaniasis, and translational research work has beendone to make the indoor residual spray more effective.

Mandate Committee Report

Due to a flood of reports about the development of resistance in vectors against DDT, a mandate Committee of GOI decided to evaluate the efficacy of DDT in Kala-azar and malaria control. In 2000, a multicentric study was initiated by ICMR, and ICMR-RMRIMS conducted the trial in Bihar for evaluation of IRS-DDT with the objective to determine the susceptibility status of P. argentipes to different insecticides. In the report, it was suggested to replace DDT for sometime with other insecticides and it was called "Insecticidal Holidays".

Joint Monitoring Mission Report, February 2007

The report mentioned the pitiable situation of the IRS in 2006. According to the report, the average coverage of IRS was only 50% in the first round and only 20% inthe second round. Nonetheless,complete coverage was only 7%. JMM had mentioned many shortfalls in the IRS performance; these were all indications that the 2010 elimination target was difficult.[26]

In 2007, an inter-country Training of Trainers Workshop for Kala-azar elimination was organised at ICMR-RMRIMS, Patna, as aninitiative of WHO, to give the Kala-azar eradication campaign a boost. The event drew participants from India, Bangladesh, Myanmar, Thailand, and Nepal. The workshop's goal was to improve national participants' knowledge of different technical and practical elements of Kala-azar eradication. The workshop was the first time the Kala-azar affected nations participated after signing the MoU, and they discussed the technical issues of the elimination of VL. In a multi-country research conducted by WHO/TDR in 2006 (phaseI), it was determined that IRS is the most effective control method.[27] In a multi-country study including Bangladesh,India, and Nepal, a monitoring and evaluation (M&E) toolkit comprising a set of indicators and processes for monitoring and evaluating a VL vector control programme using IRS as the principal technique was reviewed in 2007 (Phase II). The M&E toolkit was examined for national IRS programmes in India and Nepal in phase III of the WHO/TDR research initiative in 2008, with positive results. Based on the findings of Phase III, the created M&E was deployed through a programme in 2009 (Phase IV) to improve IRS implementation. In 2009 (Phase V),atoolkit was built with the goal of scaling up the usage of the newly developed M&E toolkit for tracking progress and identifying programmatic shortfalls.[28] In the WHO Regional strategic framework for the elimination of kala-azar from the South-East Asia Region (2011-2015), it has been strongly recommended that for the elimination strategy, the toolkit should be implemented for evaluation of IRS. WHO/TDR through the Agreement for Performance of Work (APW) in 2013 and 2016 organised an expert group meeting to remove the bottleneck in the progress of elimination. In 2020, in the Independent assessment of Kala-azar elimination in India,WHO pointed out the weakness in IRS and made recommendations to achieve elimination.

Operational Guidelines on Kala-azar (Visceral Leishmaniasis) Elimination in India -2015

The NVBDCP took various Kala-azar control actions as a result of these guidelines.[29] For the first time, the illness was formally recognised as a notifiable disease. The rules covered all of the characteristics essential for appropriate IRS. All villages with a Kala-azar history over the previous three years, as well as any new cases recorded during the current year, were included for full IRS coverage.

Report of National Advisory Committee (NAC)

In its 2017 report, the National Advisory Committee (NAC) recommended that the IRS requirement be improved. The investigation found six samples of synthetic pyrethroid to be substandard and recommended that the quality of pesticides be improved. On the logistical front, the committee reported procuring hand compressor pump accessories. According to the findings, even after 10 minutes of IRS, sand flies were spotted perched on the walls, indicating a major IRS flaw. SinceIRS is such a crucial component of vector control, it has to be greatly improved in order to have the intended effect on vector control.[30]

Health Society and Kala-azar Control

As a result of these developments, the Bihar government began a quality-based IRS training programme in 2007 for all of Bihar's 31 endemic districts. DMOs, Medical Officers, Malaria Inspectors, and all other personnel participating in IRS operations were trained by the ICMR-RMRIMS in Patna. It was a trainers' workshop. The training was given on all important aspects of IRS, such as prior information households, preparing DDT suspension, measuring discharge rate of pumps, cleaning 8002E nozzle tips in case of clogging, maintaining the distance between lance and wall, swath formation and overlapping of successive swaths, disposal of any leftover DDT suspension, washing

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202264

of stirrup and its storage, as well as the storage of DDT. The locals were made aware of the IRS by using microphones. The NVBDCP, Bihar Health Services Officers, and RMRIMS were in charge of IRS monitoring. The sand fly prevalence was examined, and considerable reductions were seen in the districts of Vaishali, Saran, and East Champaran. There was no substantial percent decline in Muzaffarpur. The percent reduction in VL cases ranged from 100 to 49.35 percent in 15 districts. It was another evidence-based report on the influence of IRS on both the disease vector and the disease.[31]

Vector Bionomics (Relevant to the Control Strategy)

Any cost-effective and focused management plan requires a deeper understanding of the ecology of the vector species. Cattle barns were also included for IRS for vector management since P. argentipes, the VL vector is generally endophilic, endophagic, and severely zoophilic. Another distinguishing feature of the vector is that it does not fly but rather jumps or hops. In terms of P. argentipes'vertical distribution, it was discovered that the highest height of occurrence of P. argentipes in cow sheds was 8.3 feet.[32] IRS up to 6 feetwas accepted based on its vertical distribution along with its hopping action. It was more realistic since owing to its hopping action, every sand fly that travels beyond 6 feetheight must come down to 6 feet and below. In another work amongthe Kani tribe at the western Ghat, a collection of P. argentipeshas been reportedat the level of >8 feet including ceiling level.[33] In astudy with impregnated fibrewith deltamethrin, popularly known as Durable Wall Lining (DWL), VestergaardFrandsen (India Private Ltd) aimed to compare the entomological efficacy of reduced wall surface coverage of 1.5 m DWLversus surface coverage of 1.8 m DWL. After a longitudinal study, it was reported that DWL up to a height of 1.5 meters is sufficient to obtain the same entomological efficacy in comparisonto the full wall coverage up to 1.8 m height.[34] Another behaviour which must be considered for adoption of any additional control measure is the exophilic behaviour of vector species.[7,33,35] Hence the role of these exophilic vectors in transmitting the disease to the persons sleeping outdoors, which is a common scenario in Bihar, must be taken into consideration. However, it is cautioned that before taking any major shift in the control measure, a pilot study is highly recommended.

Obstacles in the Way of Good and Effective IRS

Despite all the successes, many endemic areas in Bihar have not yet achieved optimal control. The major hurdle in the way of quality IRS is the lack of monitoring and evaluation resultingin under or overdose of insecticides on the walls. This led to serious consequences which jeopardised the kala-azar elimination programme. The development of resistance is another issue which has put the elimination programme on back foot. Lack of knowledge in vector ecology, particularly in the shifting behaviour of vectors under the impact of DDT, has not been studied. Another issue is a lack of human resources. Most of the IRS personnel (Malaria Inspectors, MI) have been retired and IRS is in the hand of untrained persons like sanitary inspectors etc. M&E is in a very poor state. Regarding the coverage, only 57.9% was found in Jharkhand which is far below the recommended 80% by WHO. However, in the Saran district of Bihar, IRS coverage was reported better than 80%. It is worth mentioning that in the Saran district, supervised IRS was performed by the research team of ICMR-RMRIMS. In a review to assess the performance of the programme for vector control strategy,[36] severe issues were reported which they confronted during their visit. The review has mentioned the tolerance to alpha-cypermethrin in P.argentipesof the Godda district of Jharkhand. This is a caution signal for periodical monitoring of insecticide resistance. The review suggested that there should be feedback by the partners regarding the entomological impact. This review has also mentioned thelow efficacy of alpha-cypermethrin,only 66.7% mortality after 4 weeks, and also serious technical issues like nozzle tips and ControlFlow Valve (CFV). On the initiative of NVBDCP,the Independent assessment of Kala-azar elimination[37] has also raised serious problematic issues in vector control, particularly in Jharkhand andBihar.

Resistance in the Vector Species

Resistance in vector specie against the insecticide had been amajor hurdle in the VL vector control. The tolerance in *P.argentipes* started developing during the 90s. This was the period when *P.argentipes* of different regions started showing different levels of susceptibility and tolerance against DDT.[38,39,40,41] From 2003 onwards, there were a series of publications about the development of resistance in *P.argentipes* against DDT.[42,43,44,45,46,47,48] Based upon these reports, NVBDCP, in the year 2016 withdrew the usage ofDDT from the IRS programme and alpha-cypermethrin 5% wasrolled out. More interestingly, *P.argentipes* of the Kanitribe has been reported to be 100% susceptible to DDT.[49]

Research for Improving the Quality of IRS

Replacement of conventional stirrup pump with hand compression pump (HCP) was a milestone in the direction of quality IRS. The stirrup pump had a lot of limitations in performing quality IRS. Hence in collaboration with TDR/WHO, a pilot study was conducted in the Vaishali district whichdemonstrated that with HCP, better coverage and quality spray could be achieved.[50] In another pilot study which was performed by ICMR-RMRIMS in collaboration with TDR/WHO to ascertain the concentration of insecticide on the walls, it was demonstrated that the insecticide concentration was only 73% i.e., the mean concentration

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202264

of insecticide was 0.73 gm/m^2. In the same study, the bio-availability of insecticides on the walls wastested as per standard test procedures.[51] The mortality was less than 80% which was below the standard set by the WHO. The inefficacy of insecticides on the walls may be due to the use of sub-standard DDT or due to thesub-optimal use of IRS.[52] A combination of the two may have far-reaching consequences in achieving the elimination target (Figure 1).

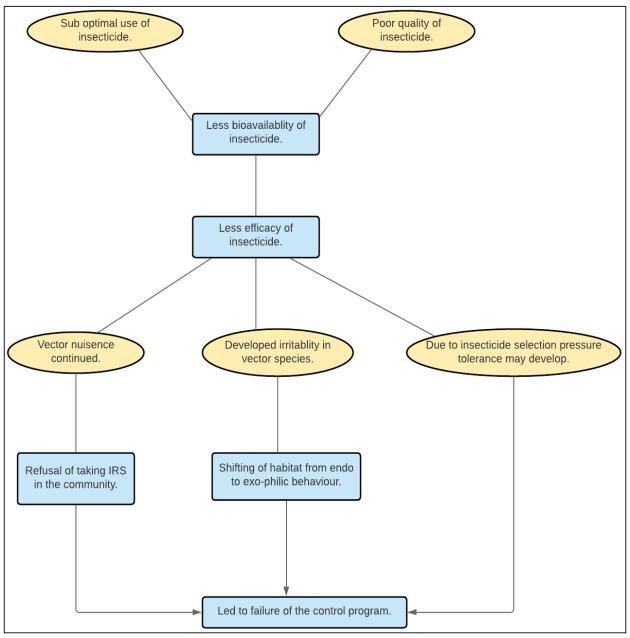

Figure 1.A Schematic Diagram for Reason of Development of Resistance in Sand Fly

Despite the fact that IRS has been the mainstay for the elimination of Kala-azar and DDT has been the insecticide of choice, IRS has been severely harmed due to a lack of proper monitoring and evaluation tools,[6,31,37,53,54] whilst a four-year assessment of IRS coverage revealed that while there has been progress, much more improvement is needed.[55] In 2009, TDR/WHO and German collaboration (BMZ/GIZ) developed an IRS toolkit for use in a multi-country study in India, Bangladesh, and Nepal. This tool set for IRS quality assurance included a number of indicators. It assists in the qualitative finding of the gaps and limitations of the IRS programme, as well as the implementation of relevant corrective actions.[54] The toolset was validated in three districts in Bihar: Muzaffarpur, Vaishali, and Samastipur. The study concluded that the main shortcomings were a lack of training among IRS employees and a lack of effective logistics. The tool kit revealed that 23.5% of the spray pumps were leaking. The bio-availability result was just 47.97%, which is below the WHO's 80% guideline. The significant degree of DDT resistance in vector species was mirrored in the tool kit. It had a 21.5% knockdown rate after one hour and 54% mortality after 24 hours. The tool kit can evaluate the IRS irrespective of the type of insecticide and evaluate the process qualitatively, but it cannot quantify the insecticide on the walls. Hence, for quality IRS, tools were urgently needed to quantify the insecticides on the walls so that any corrective stepcould be taken immediately.ICMR-RMRIMS in collaboration with LSTM, Liverpool developed an insecticide quantification kit (IQK) for a more precise quantitative analysis of DDT on sprayed surfaces. The principleof IQK was based on the measurement of Cl- (chlorine ion) through a deep stick assay on Quantab® test strips. The study also demonstrated that out of 1964 field samples collected, 81.1% were substandard. These experiments can be performed in the field. They do not require hi-tech laboratories and the results are comparable to HPLC. Theyprovide test results within an hour, hence any corrective measure in the performance of IRS canbe done without any delay.[53]

IRS and Vaishali Model

Based on the previous evidence, the IRS appears to be the backbone ofthe Kala-azar containment. The eradication goal remained a ghost, and many endemic locations in Bihar had not yet attained optimal management, despite various studies undertaken from time to time to enhance IRS effectiveness. A lack of knowledge of the changing situation in Kala-azar, particularly in terms of prevention, as well as poor IRS M&E were the causes. In view of these concerns, the DGHS and NVBDCP enlisted the help of ICMR-RMRIMS, a pioneer in Kala-azar research, to develop a Kala-azar elimination strategy. One of Bihar's 33 endemic districts, Vaishali, was chosen for this study since it is one of the most endemic. ICMR-RMRIMS started the work in Vaishali inJanuary 2015. Vaishali district is situated at 25.6833 ^{o}N, 85.2167 ^{o}E, and is bordered by the river Ganges in the south and river Gandak in the west. The district has 16 community development (CD) blocks and 1542 villages. The population of Vaishali district was 3.5 million and the number of house structures was 0.61 million. A complex strategy was implemented, capacity building was prioritised, and ASHAs, as the backbone of the health system at the village level, were provided on-the-job training for active case detection and prior notification to households for IRS. A compressor pump with Control Flow Valve (CFV) was introduced for the first time in the history of IRS in Bihar. For the formulation of the action plan, a new dynamic technique was used, which included spatio-temporal mapping of the VL case distribution. It was discovered that the majority of VL cases were recorded in the following year within a 500-meter radius of an existing VL case. Sincethe maximum flying range of P. argentipes[56] was 500 m, all endemic and non-endemic villages within the radius of 500 m of the index case were classified as high-risk villages under IRS. For identifying and choosing the villages and risk-prone households for implementation of the targeted IRS, a GIS-based spatial mapping approach was used. Any new case

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202264

report was covered by the district's focus spray. A layered monitoring and supervisory system was created to help with this massive task. One monitor was assigned to each squad. A supervisor was assigned to each of the eight squads. One officer was stationed at the block level to keep an eye on the IRS's activity. One district-level officer was assigned to keep track of the IRS's actions across the board. Toolkit aided in the qualitative assessment of IRS activities, while IQK was used for quantitative analysis. IEC and BCC, which are critical components of a high-quality IRS, were beefed up even further. To assess the influence of IRS, entomological indicators such as sand fly population and bioavailability testing using the WHO cone technique were used. Active Case Detection (ACD) was used for any case finding. All these efforts resulted in the effective elimination of Kala-azar, with the CIR (Case Incidence Rate) of less than one case per 10,000 inhabitants at the community block level in all 16 PHCs of Vaishali district. Using 2014 as a baseline, the CIR in Vaishali district fell by 75.45%, whereas it fell by 37.32% in the other 33 districts of Bihar. The Vaishali model's performance in eliminating Kala-azar was phenomenal.[57]

Evidence-based Study of Essentiality of IRS as a Tool for Kala-azar Elimination in Raghopur Block in Vaishali District

The CIR in Raghopur, a community block in Vaishali district, increased to 1.33 in 2017 and then to 1.41 in 2018. It indicates that after being in the elimination zone in 2016 with a CIR of 0.55 in 2016, Raghopur became kala-azar endemic once more. The block's topography will aid in the comprehension of kala-azar transmission. This block is 20 km from Patna, the state capital. The river Ganges encircled it on all sides, and it is connected to Patna by a seasonal Pontoons bridge known as "Pipa-pul". During the rainy season, the whole city of Raghopur was flooded, rendering the location impassable for the programme. This area had major flooding in 2017 and 2018, causing IRS to fail, resulting in an increase in CIR and a move into the endemic zone from the elimination zone, i.e. from 0.55 CIR in 2016 to 1.33 and 1.41 in 2017 and 2018 respectively. However, complete IRS was performed in 2019 and again CIR reduced to less than one in the Raghopur block. These observations point out that if IRS would have beenperformed with standard procedure, elimination could have been achieved much earlier[58] (unpublished report ICMR-RMRIMS).

Discussion

Based on the aforementioned findings, it can be concluded that IRS is a significant instrument for the effective elimination of visceral leishmaniasis, not with standing its flaws. One of the reasons for not meeting elimination objectives and, to some degree, for the formation of resistance in target species, is the inefficient usage of IRS.[53,54] With good monitoring and assessment, as well as the best use of IRS, the Vaishali model shows that elimination might be achieved. Another roadblock to Kala-azar elimination has been the quality of pesticides.[38,53] The study of pesticide bioavailability on walls remains a critical element for determining insecticide efficacy against the targeted insects. It helps to define the intervals between the two cycles as well as the frequency of the IRS cycle in order to protect the population from vector bites,but previous work demonstrated that though *P.argentipes* is highly susceptible to alpha-cypermethrin 5%, bioavailability results were not inconsistent with the WHO standards. It was satisfactory only up to 4 weeks when the corrected mortality was in the line with WHO standard i.e., more than 80%. After that mortality became much lower i.e only 55.6% after 12 weeks.[59] In her model, Rutte EA et al.[60] estimated that optimum IRS decreases VL incidence by roughly 25% in the first year and another 25% in the second year, regardless of endemicity. They also showed that due to the short lifetime of asymptomatic cases (about 1.4 years), VL incidence will retain its current rate due to the quick depletion of infection reservoirs. However, the author predicted that due to the prevalence of PKDL cases, the downward trend would moderate after two years. This model indicates that 4-6 years of optimum IRS will lower the incidence rate in low and medium endemic locations, but that it will be ineffective in low VL incidence areas, even if it can last up to 12 years. On the basis of his model, it was recommendedthat in high endemic regions, lengthier IRS will be necessary, and that in the case of sub-optimal IRS, extra interventions will be required. The earlier results[35,61] have backed up this conclusion. In a post-elimination setting based on the Rutte model, indiscriminate pesticide application will be useless. Villages that are hotspots should be given a lot of attention. The ideal approach would be a reactive IRS.[62] Another source of concern in terms of quality IRS is logistics.[51,55] Due to limited coverage, a suboptimal or defective spray may raise the cost of the programme and, as a result, the usage of insecticide.

In addition, because the same target location, the voltage-gated sodium channel (vgsc) kdr gene, is widely related toDDT and pyrethroid resistance,[63] a poor IRS may exacerbate the cross-resistance issue. The emergence of resistance/tolerance in the vector of Godda district[37] is a red flag. Regular insecticide susceptibility monitoring and supervised IRS are strongly suggested since they will only serve the aim of IRS. An undisclosed paper implies that K-Othrinefollowed by Actellic may be a useful proposition in the study of alternative insecticides (unpublished report of Kala Core project, ICMR-RMRIMS).[64] The new IRS schedule prepared by NVBDCP, which is quite similar to the Assam model, will aid in the complete elimination of Kala-azar if rigorously implemented. Monitoring and evaluation need to be enhanced even further, priority should be given to the

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202264

IRS monitoring and evaluation tool kit. IQK should be used for synthetic pyrethroid.[65] Effective surveillance instruments are essential throughout the maintenance/sustenance phase of kala-azar eradication, and xenomonitoring may be the most viable monitoring and surveillance approach for identifying Kala-azar endemicity and applying enough IRS in restricted locations. It is crucial to have a better understanding of VL transmission dynamics, particularly infectivity status in both vectors and hosts, so that control efforts may be focused on eliminating the disease.[66] This will not only help to minimise pesticide use, but it will also help to protect the environment by reducing the use of insecticide in unethical methods. In Bangladesh, concerns regarding a suboptimal IRS have been raised, as has the need for another acceptable control tool, especially when the number of cases is low.[67] As a consequence, it can be stated that IRS, when used in accordance with WHO and NVBDCP standards, can be a successful tool for Kala-azar eradication. According to the WHO expert consultation report on Kala-azar vector control,[68] IRS's goal is to achieve more than 80% coverage. Spray teams must be regularly supervised to ensure that proper spraying procedures are used and that the correct amount of product is applied evenly. According to the article, a faulty IRS insecticide may cause sand flies to have an excito-repellency reaction, which might be dangerous. Low-incidence case sites need special care to ensure that the elimination phase runs well. The 2017 Accelerated Plan for Kala-azar elimination emphasised the need of continuing to monitor blocks on the verge of elimination (0.8 to 1 case) and low endemic zones (less than 0.8 cases per 10,000 people). In Bihar's Kosra village,[3] a quick outbreak was documented in a low-level endemic region. An epidemic of Kala-azar cases has been detected in a low-endemic zone of Saran district's Isuapur block (personal communication). An epidemic was identified in a community-based study among the low socioeconomic category.[4]

Conclusion

It can be concluded that IRS vector management could be a powerful tool for eradicating VL, if it is implemented correctly, with proper vector ecology, logistics, standard insecticides, good monitoring and evaluation tools, additional methods of control, especially in the maintenance phase, and adhering to all the parameters outlined in WHO guidelines[69] and, most importantly, keeping a close eye on any possible outbreak in the low endemic zone.

Acknowledgement

Mr Narendra Kumar Sinha (STO), Mr SA Khan, and MrKundan Kumar provided invaluable assistance to the writers during the writing of this work. Last but not least, we are grateful to Dr Pradeep Das, Ex-Director, for overseeing the majority of the activities at ICMR-RMRIMS.

Conflict of Interest: None

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