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Source Reduction Practices for Mosquitoes (Diptera) Management to Prevent Dengue, Malaria and Other Arboborne Diseases

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Abstract

Progress in control of arboborne (arthropod bites to person) diseases focuses mainly on chemical interventions like residual sprayings and insecticide treated nets, so problems of using pesticides continue to exist in many countries. Non-chemical control program using source management for mosquitoes control has been promoted or tested in several experimental projects. Source reduction primarily aims to prevent development of aquatic stages of mosquito's larvae by reducing breeding source primarily involving methods like filling, drainage, drains and drainage in irrigation schemes. But sustained implementation of source reduction practices is uncommon and insufficient support available is as well. This paper presents case studies from various states, which demonstrates that source reduction to prevent mosquitoes is cost-effective to fight against dengue, malaria and other arboborne diseases effectively in rural and urban areas, and can underpin economic development in prone areas. After identifying principal breeding sites responsible for diseases transmission, it is urgent to apply selective larval control action, which has been called species sanitation. Housing conditions might be improved, and water supply and sanitation facilities can also be taken as a primary step to establish source management. Many breeding sites can be identified along nearby banks of river, sea, or other water holding bodies for modification and vegetation clearance. Environmental management strategies might prove to be sustainable over the long-term enabling development of state by effectively controlling diseases. Comprehensive and integrated mosquito management program including use of adulticides or larvicides, source management, zooprophylaxis, aerial space spraying and using coils, screens and repellents are essential. During epidemics, indoor and outdoor residual sprayings are generally conducted, commonly using insecticides against adults and larvae. Mosquito days can be initiated to activate the local community for source management through draining pools and canals, filling pools of stagnant water, and personal protection. But interest in developing non-pesticidal approaches has been growing especially as mosquitoes have developed resistance. This recommends, motivates and introduces to citizens to reduce mosquito-borne diseases through environmentally sound strategies that require no cost outlay. Arboborne diseases control based on source management can be non-toxic, feasible and cost-effective, and demonstrates the feasibility of sustainable bioenvironmental vector control. Key points of success are combination of multiple interventions adapted to local conditions, community participation, awareness raising, surveillance, decentralisation, local capacity building, intersectoral collaboration, improvement of public health system, income generation, involvement of civil society organizations, regional cooperation and support by local research.

Keywords

Source Reduction, Mosquito Control, Sustainable Vector Control, Dengue, Malaria

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1. Introduction

Incidences of dengue, malaria and other arboborne diseases are showing increasing trend from the past few years. In view of this, peoples are well aware that dengue, malaria and other vector borne diseases are transmitted through the bites of Aedes and Anopheles mosquitoes which breed mainly in water, in addition to this, there are no specific drugs for these diseases. Hence, prevention and control of arboborne diseases should mainly be aimed at source reduction which is not possible without the active involvement of the community. Under integrated vector control measures more emphasis has been given to public-private partnership through the involvement of local committees (Beaty et al., 1996; Sarwar, 2014 a; 2014 b).

Out of more than 3 000 known mosquito species, however, of the 150 species that are potential vectors, only 30 are considered dangerous. The principal problematic species associated with three genera Anopheles, Aedes and Culex, from three sub-families, are mainly diseases relevant. The immature stages such as eggs, larvae and pupae require an aquatic environment, whereas adult mosquitoes live in terrestrial ecosystems. The quality and quantity of water, whether it is running or standing, shallow or deep, clean or polluted, sweet or brackish, shaded or sunlit, permanent or seasonal, and finally the climate will determine which particular species can breed (Fritsch, 1997).

2. Source Reduction

Anti-larval operations causing the reduction or permanent elimination of mosquito breeding places or sites are recognized as source reduction methods. Source reduction primarily aims to prevent development of aquatic stages of mosquito larvae or reducing breeding source. These methods are atmosphere pleasant, inexpensive in the long run with least conservation and surveillance needs. Source reduction measures undertaken can solve the problem of vector borne diseases in an area but also would bring socio-economic and financial benefits to the communities. Habitat modification includes harbourage alteration and source reduction can be used for mosquito control. Harbourage alteration renders the sites unsuitable for resting of adult mosquitoes and source reduction changes the larval habitat so that mosquito oviposition, hatching and larval development are prevented (Sarwar, 2014 c; 2014 d).

Source reduction step is with the objectives of creating awareness in the community regarding the transmission of vector borne diseases and their prevention, educating the community on proper water storage practices to bring about behavioural change and communication, environment improvement through proper solid waste management involving local municipality, and changing people’s attitude, behavior and life style through social mobilization and motivation. For gaining the above objectives funds are needed to carry out the activities on identification of teams for source reduction, advocacy meetings. conduction of advocacy meeting to the teams of local volunteers, survey and identification of Aedes breeding sites and elimination through source reduction measures, maintenance of fish hatcheries and the sustaining fishes in the breeding sources, release of larvivorous fishes in identified water bodies in the selected areas, and creation of community awareness through motivation activities (Gerberich and Laird, 1985).

A source reduction team has to be identified, which may include one health worker and local worker members. House to house survey may be carried out to identify the Aedes breeding in cement tanks, barrels and any other water storage containers inside the houses, also in tyres, and solid domestic wastes which can hold water in peri domestic situation. Eliminate the same by emptying, scrubbing and advising habitants to keep the containers closed always with plastic lid or sheet and application of Temephos at a final dilution of 1 ppm wherever the containers cannot be emptied. This activity has to be carried out every month in selected areas and such localities have to be considered as Model. A summary of the source reduction factors is given below:-

2.1. Source Reduction at Door Step

Preferred breeding sites of both *Anopheles stephensi* and *Aedes aegypti* are ornamental tanks and fountains. Containers with high breeding potential for both malaria and dengue vectors in construction sites and high breeding potentials in residential areas with broken lids or cover of overhead tanks must be managed in and around the houses for Aedes mosquito control. The source reduction program adopted in this study is a structured set of activities practiced by the community health nurse along with the family members during home visit for elimination of mosquito breeding places or for making the breeding places unsuitable for mosquito breeding or for preventing mosquitoes from reaching the breeding places in and around the houses as well as motivating the family towards practicing these activities. The need of the time is sensitization and mobilization of the family and community as well as the field health workers towards mosquito control through source reduction which is the potentially ideal and most environment friendly method for controlling mosquitoes. The control interventions can change the spatial and temporal dispersal of Aedes mosquitoes and perhaps the pattern of habitat utilization. Hence, entomological studies should be conducted before any vector control operations, especially against Aedes mosquitoes (Kishorekumar and Mujeeb, 2015).

Source reduction includes elimination of breeding sites by removing potential breeding places like water bottles, solid waste, coconut shells and tyres. Weekly cleaning or drying of water containers, room coolers and extensive activities for social mobilization of the community on preventive measures and destroying breeding habitats. Minor engineering measures are like proper placing of lids of overhead tanks and underground tanks, repairing of leakage from pipeline and preventions of over flowing tanks, channelizing of water collections in roof, cleaning of gutters and water outlets, and overall general sanitation in and around domestic environment. The source reduction program adopted in this study is a structured set of activities practiced by the community health nurse along with the family members during home visit for elimination of mosquito breeding places or for making the breeding places unsuitable for mosquito breeding or for preventing mosquitoes from reaching the breeding places in and around the houses as well as motivating the family towards practicing these activities. This intervention is the independent variable in the study. The effectiveness of this intervention is tested using reduction in the entomological monitoring parameters of Aedes mosquito control (Konradsen et al., 1998; Kusriastuti et al., 2004).

Modification of human habitation has been shown to reduce the risk of malaria. Poorly constructed houses are found to harbour significantly higher numbers of mosquitoes and screens can prevent mosquitoes entering to houses. Mosquito nets can reduce the human vector contact and provide, even untreated, a certain degree of protection against malaria infection. Covering eaves and repairing cracks and holes may reduce disease transmission. Clearing vegetation around houses may remove the breeding and resting sites of mosquitoes. Personal protection can be achieved through the use of long sleeved shirts and pants as well as repellents that are the most universal of mosquito control practices to deter nuisance bites. Some societies use smoke, while some communities have built their houses on stilts, above the flight patterns of mosquitoes. Domesticated animals can reduce the malaria cycle of infection through a process called zooprophylaxis (parasites die when an infected mosquito injects parasites into the bloodstream of an animal, but livestock may also increase the density of mosquito populations. This increase has been documented in a few areas where livestock are kept in a compound where people sleep outside (Florida Mosquito Control, 1998; Foster and Walker, 2002).

2.2. Source Reduction at Outdoor Step

Filling up of cavities of fences and fence-posts made from hollow trees such as bamboo should be cut down to the node, and concrete blocks should be filled with packed sand or cement to eliminate potential Aedes larval habitats. Source reduction includes elimination of breeding sites by removing potential breeding places like water bottles and solid waste. Weekly cleaning or drying of water containers, room coolers and extensive activities for social mobilization of the community on preventive measures and destroying breeding habitats are encouraged. Minor engineering measures are like proper placing of lids of overhead tanks and underground tanks, repairing of leakage from pipeline and preventions of over flowing tanks, channelizing of water collections in roof and cleaning of gutters and water outlets, and overall general sanitation in and around domestic environment. Used automobile tyres are of significant importance as breeding sites for urban Aedes, and are therefore a public health problem. Tyres in depots should always be kept under cover to prevent collection of rainwater. New technologies for tyre recycling and disposal are continually coming into use, but most of them have proved to be of limited application or cost-intensive. It is recommended that each community should look at ways to recycle or reuse the used tyres so that they do not become breeding habitats (Yohannes et al., 2005).

Participants are voluntarily conducting ecosystem management activities in their paddy fields including, levelling land to reduce the number of puddles, cleaning and water management of irrigation systems to make the current measures faster to avoid mosquito breeding, draining fields to prevent mosquito larvae reaching the adult stage, clearing coconut shells and containers, covering water containers at regular time intervals, and minimizing pesticide use to conserve natural enemies of pests and mosquito vectors. In addition, participants can eliminate breeding sites, apply oil, salt or fish to wells and water storage tanks, and improve environmental sanitation in the residential areas. Discarded receptacles namely tins and buckets or any other consumable packaged items such as plastic cups and waste materials scattered around houses should be removed and buried in landfills. Scrap materials in factories and warehouses should be stored appropriately until final disposal. Household and garden utensils (bowls and watering devices) should be kept upside down to prevent accumulation of rain water. Similarly, in coastal areas canoes and small boats should be emptied of water and turned upside down when not in use. Plant waste (cocoa husks) should be disposed of properly (Sivagnaname et al., 2005).

Water-storage facilities at construction sites should be mosquito-proof and housekeeping should also be stepped up to prevent occurrence of water stagnation. The design of buildings is important to prevent Aedes breeding wherein drainage pipes of rooftops, sunshades or porticos often get blocked and become breeding sites for mosquitoes. Likewise, roof gutters of industrial or housing sheds also get similarly blocked. Where possible, the design of such features should minimize the tendency for mosquito breeding. There is a need for periodic inspection of such structures during the rainy season to locate potential breeding sites. Accessibility of water to adult mosquito can be altered or eliminated by ditching, draining, and covering and filling of water bodies. Shredding of disused tires, proper disposal of water containers, alteration of flow rate of water, disturbance of water surface, removal of shelters such as vegetation and refuse in water bodies can interfere the breeding of mosquitoes. Larval habitats vary in size, some of the water bodies cannot be covered, filled or drained because of ecological or technical reasons, and it may be too costly to drain or fill the water bodies. Converting sloping edges of ponds/ pools with exposure of muddy areas to almost vertical banks with deep water (impoundment) can reduce the breeding of Aedes mosquitoes. Increase sunlight on water by trimming overhanging vegetation can prevent breeding of mosquitoes which prefer shaded habitats. Removal of rooted and floating vegetation reduces breeding of mosquitoes such as the species of Mansonia which require plants to obtain their oxygen supplies (World Health Organization, 2011).

Emphasis on environmental modifications including straightening of watercourse and maintaining a sunlit water surface have been made for prevention of malaria vectors breeding. Proper management of small containers, clearing of choked drains, filling of small holes etc., are the methods adopted and promoted for preventing the breeding of dengue fever vectors locally. Draining of water and keeping ditches and ponds free from aquatic vegetation are the methods used for controlling the vectors of encephalitis breeding in the territory. Environmental source management is the planning, organization, carrying out and monitoring of activities for the modification and manipulation of environmental factors or their interaction with man with a view to prevent or minimize vector propagation and reducing man-vector pathogen contact. There are three categories of source management, environment modification; manipulation to target the larval stages of the mosquito life-cycle, and non-pesticidal personal protection. Environmental modification aims to create a permanent or long-lasting effect on land, water or vegetation to reduce vector habitat. It has been successfully implemented in large scale interventions in some countries, for example, draining wetlands by the creation of ditches or drains, land levelling, and filling depressions or covering with soil and sand (World Health Organization, 1988).

Reconstructing a drainage canal in order to provide a permanent waterway promoting the free-flow of water through a malaria-prone region creates a permanent effect. Stagnant water is among the approaches applied to prevent, eliminate or reduce the vector habitat. Initially, these interventions require significant costs but they contribute to the reduction or elimination of mosquito breeding habitats. Any such interventions should be critically evaluated to protect biodiversity as large-scale draining projects could adversely affect natural wetlands and ecosystems that are in decline worldwide. Several trial schemes in recent times have been initiated to implement more sustainable and less pesticide-intensive approaches. Small-scale modifications that concentrate on human-made breeding habitats have been successfully put in place in combination with other interventions, for example, filling puddles, drying out stagnant pools, covering of water containers, filling pits and low lying areas, and clearing out standing pools of water. On the other hand the development of irrigation schemes and construction of dams can increase the risk of malaria transmission. Under such circumstances, the risks have to be evaluated at the design stage to mitigate or avoid them. Reduction of mosquito breeding sites can be achieved through planting trees with high water requirements. Planting local water-intensive tree-species like eucalyptus can help to reduce the surface water and create a source of income for local peoples. However, these interventions should also be critically evaluated to protect biodiversity. Polystyrene beads have been used to prevent mosquito breeding in small confined water collections by hindering larvae respiration and preventing adult mosquitoes from laying their eggs on the water surface. Environmental source manipulation also refers to activities that reduce larval breeding sites through temporary changes. The regular clearing of vegetation from water bodies or depending on the vector species, elimination of shade or planting of shade trees may prevent egg deposition (vegetation management). Flushing streams, periodically changing the water level of reservoirs or changing water salinity can eliminate breeding sites, but the impact on non-target organisms must be critically evaluated (World Health Organization, 1989).

Malaria epidemics associated with irrigated rice lands can be minimized by introducing intermittent irrigation to control breeding sites. Periodic draining of the fields prevents the mosquito larvae from completing their development cycle and may increase the crop yield (water management). Environmental manipulation is best implemented at the community level with assistance from educational institutions. Non-pesticidal personal protection strategies for malaria prevention have historically been practiced, particularly by locating houses away from breeding sites to reduce the human-vector contact. A distance of 1.5 to 2 km from major breeding sites may significantly reduce disease transmission. Female Anopheles mosquitoes are attracted by the exhalation of carbon dioxide and other human odours and they can be discouraged by improved ventilation, effective rubbish disposal strategies and setting aside a defined space for domestic animals (World Health Organization, 1996).

3. Long Term Source Reduction Operations

For long term environmental operations as basic vector control measures for prevention of vector borne disease are management of water bodies and drainage to discourage the breeding of disease vector. Urban legislative body and all Municipal Corporations are to develop and implement program for water supply, sewerage, drainage and solid waste management to keep the environment free from vector breeding. Cover storm water drainage system and maintain them periodically and properly by way of regular cleaning, desilting and maintain adequate velocity for flow of water. Water stagnation in construction areas must be prevented and over flow from overhead water tanks must be controlled through proper floating valves. Proper sanitation in community toilets and drainage facility must be provided for slum areas with proper supply of potable water. Leakage of water tanks, water supply pipes and fountains must be repaired and reinstalled to prevent water stagnation and mosquito breeding. A memorandum between Municipal Corporations and contractors may be formulated and incorporated as a clause in the line of public bye-laws for prevention of breeding during construction of developmental projects. Anti-larval measures must be taken by construction authorities and completion certificate only to be issued after proper disposal of storage tanks or dismantling such structures so that no rain water can accumulate. Vegetation in and around ornamental tanks and swimming pools should be removed to limit the breeding potential. Stagnated water in dumps or junk yard should be drained out or disposed before monsoon starting to discourage mosquito breeding. Lids of overhead tank are to be repaired to prevent entry of mosquitoes. Orientation training of junior Engineers, public health engineering departments and other engineering staff about vector control measures and preventive measures on water stagnation can sow excellent results. Urban planners and engineers should assume responsibility for creating master plan with comprehensive vector control activities (Jobin, 1987).

The construction of buildings and building codes designed to minimize site of mosquitoes breeding, the registration and regulation of construction sites to prevent mosquito breeding and coordination are the crucial elements for prevention of mosquitogenic potential. Flower pots and cooler require special attention as potential breeding spots in community situations like government buildings, hospitals, schools, religious places, public places, cinema halls, theatres, malls, and entertainment venues. Anti-larval measures with Temephos granules may be applied fortnightly and wherever possible these potential breeding spots be dried up once in a week. Special attention must be given for mosquito free environment in hospitals. Development of inter-sectoral linkages by roping all government and nongovernment agencies or institutions for behaviour change and adoption of approaches are important. Health educational messages to the community on weekly cleaning of containers or covering of such containers holding water for more than seven days and disposal of solid waste materials and dumps are imperative. All developmental projects in urban and semi-urban or peri-urban areas should have clearance on anti-mosquito preventive measures after assessment by national vector borne disease control program. Development of skilled manpower for the control of breeding of vector mosquitoes and regular surveillance on potential breeding sources and their reduction in metro cities, urban, peri-urban, semi-urban areas decrease the risk of diseases transmission (Hespanhol, 1990).

4. Integrated Mosquito Management Approaches

Integrated mosquito management approaches should be adopted for getting an effective and efficient control on mosquito with minimal impact on the ecological system. It starts from identification of the species of mosquito causing the problem. One or more measures could be selected from the biological, environmental and chemical categories for controlling the target species. The primary goal to control mosquitoes and other vectors is by preventing them from breeding before they are built as permanent treatment problems. The removal of debris and non-protected vegetation can decrease water retention, thus eliminating or reducing mosquito breeding. Another important aspect of prevention is education of the residents through contact with field staff. Field staff can reduce breeding sources by removing debris and vegetation and by pumping and filling sources. When staff inspects an area, technician has to make every effort to personally speak to the residents to explain the need for mosquito control activities and how to eliminate mosquito breeding sources around their homes (Sarwar, 2015 a; 2015 b).

For an attempt to eliminate breeding sources, the need for biological and chemical control of mosquitoes is necessary.

When a breeding source is found that cannot be permanently stopped, the technician can determine the best method of treatment. The *Bacillus thuringiensis* is a microbial agent formulated as crystalline bacterial spores that are ingested by mosquito larvae and causes the cell walls of the larval digestive system to burst. Methoprene is a synthetic insect growth regulator which mimics with naturally occurring hormones in the mosquito's body. It disrupts the mosquito's normal life cycle causing the adult mosquito to fail to emerge from the pupae. If the breeding source is active with pupae, staff will initially treat the source with molecular film which suffocates the mosquito pupae and larvae, and since pupae do not feed, they must be killed by suffocation. Fish stocking for mosquito control is a useful strategy in freshwater ecosystems and choosing the right fish is important. Source modification for mosquito control, reducing moisture including flooded areas, standing water and untreated stagnant ponds around residences can make a significant difference in mosquito populations (Sarwar, 2015 c; 2015 d).

In any community, if the classes of containers with the highest rates of adult emergence are known, their selective targeting for source reduction or other vector control interventions can be the basis for the optimized use of limited resources. Control programs using integrated strategies do not require sampling at frequent intervals to assess the impact of the applied control measures. This is especially true where the effect of the alternative strategies outlasts residual insecticides (larvivorous fish in large potable water storage containers, source reduction or mosquito-proofing of containers) or when larval indices are high (greater than 10%). Meteorological data are important as well because such information aids in planning targeted source reduction and management activities, as well as in organizing epidemic interventions measures. In summary, the vital integrated mosquito management approaches are biological control, bacterial larvicides, predators (larvivorous fish), botanicals including repellents, larvicides (neem), biological insecticides, medicinal herbs, nematodes, fungi, aquatic plant Azolla and sterile mosquitoes (O'Neill, 1997; Sarwar, 2015 e).

5. Conclusion

An important fact is that the arboborne diseases can be easily controlled by man through source modifications. A comprehensive and integrated mosquito management program including source reduction, chemical control with resistance management and biological vector control is essential. The key factors for the success of dengue and malaria control are a holistic approach based on extensive communication campaigns, public education and promoting of prevention strategies. The strategy can be established on active leadership at all levels of government, mobilized and trained communities in diseased areas, provided technical support and ensured sufficient funding. Pesticides resistance in vectors might be monitored and epidemiological surveillance should be strengthened through mobile teams. As a result, the interventions can become more targeted with decision making based on data gathered. Since human and animal faces attract mosquitoes, and vegetation offers them shelter, the family hygiene and housing conditions might be improved, walls be painted with an insecticidal paint, dirt floors be covered with cement, space be set aside for domestic animals, ventilation be improved, vegetation around homes be pruned and additionally trash be disposed. It is reasonable to conclude that repeated recharge of freshwater wetlands by urban type storm water runoff would have a significant and cumulative adverse impact upon that wetland environment. These destructive impacts include the loss of natural mosquito predators and fluctuating wetland water levels. These conditions often create mosquito producing habitat which may be in close proximity to residential areas. The preservation of healthy freshwater wetlands, unpolluted by excessive urban storm water runoff or sedimentation is, therefore, of vital concern to mosquito control. Subsequently, source reduction by clean-up campaigns can be promoted widely to achieve sustainability of a successful vector control program. It is essential to focus on the larval source reduction while closely cooperating with non-health sectors such as nongovernmental organizations, civic organizations and community groups to ensure community understanding and involvement in plan implementation. Therefore, there is a need to adopt an integrated approach to mosquito control by including all appropriate methods (environmental, biological and chemical) that are safe, cost-effective and environmentally acceptable. Distributers of the larvicide should always encourage house occupants to control larvae by environmental sanitation i.e., source reduction. The characteristic feature integrated mosquito management includes methods based on knowledge of local vector biology, disease transmission and morbidity, use of a range of interventions often in combination, synergistically collaboration within the health sector and with other public and private sectors that impact vector breeding, engagement with local communities and other stakeholders, and a public health regulatory and legislative framework.

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