Exploiting the potential of vector control for disease prevention

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Abstract Although vector control has proven highly effective in preventing disease transmission, it is not being used to its full potential, thereby depriving disadvantaged populations of the benefits of well tried and tested methods. Following the discovery of synthetic residual insecticides in the 1940s, large-scale programmes succeeded in bringing many of the important vector-borne diseases under control. By the late 1960s, most vector-borne diseases — with the exception of malaria in Africa — were no longer considered to be of primary public health importance. The result was that control programmes lapsed, resources dwindled, and specialists in vector control disappeared from public health units. Within two decades, many important vector-borne diseases had re-emerged or spread to new areas. The time has come to restore vector control to its key role in the prevention of disease transmission, albeit with an increased emphasis on multiple measures, whether pesticide-based or involving environmental modification, and with a strengthened managerial and operational capacity. Integrated vector management provides a sound conceptual framework for deployment of cost-effective and sustainable methods of vector control. This approach allows for full consideration of the complex determinants of disease transmission, including local disease ecology, the role of human activity in increasing risks of disease transmission, and the socioeconomic conditions of affected communities.

Keywords Insect control; Insect vectors; Community networks; Intersectoral cooperation (*source: MeSH, NLM*).

Mots clés Lutte contre insecte; Insecte vecteur; Réseaux coordonnés; Coopération intersectorielle (*source: MeSH, INSERM*).

Palabras clave Control de insectos; Insectos vectores; Redes comunitarias; Cooperación intersectorial (*fuente: DeCS, BIREME*).

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Introduction

Vector-borne diseases account for approximately 17% of the estimated global burden of infectious disease (1) (Table 1). Although well planned vector control can contribute significantly to the reduction of this burden (2), the preventive power of vector control is grossly underutilized in public health. Insecticide-treated bednets (3) and indoor spraying of houses with residual insecticides (4) are highly effective in preventing malaria transmission, and thus in reducing malaria morbidity and mortality. Yet, it was estimated that in 2002, coverage of the target population stood at 31% for malaria treatment, while that for prevention was only 2% (5). To achieve the goal of 50% coverage for prevention by 2007 (5), investment in vector control would need to be significantly increased.

For diseases such as dengue (6) and Chagas disease (7–9), vector control is the only means of protecting populations from infection. For leishmaniasis (10–16) and African trypanosomiasis (17, 18), where current methods of chemotherapy are far from perfect, vector control currently offers the greatest potential for large-scale reduction in the burden of disease. For those vector-borne diseases where preventive chemotherapy is the principal control strategy, such as lymphatic filariasis, vector control can accelerate the reduction in disease transmission, thereby increasing the likelihood that programme goals will be met (19–21), and lessen the risk of drug resistance (22). Furthermore, vector control can add sustainability to strategies of preventive chemotherapy, and may be the most cost-effective option when unit costs of individual case detection and treatment become progressively greater as case numbers drop. For malaria, a reduction in the parasite reservoir cannot be sustained without a reduction in vectorial capacity brought about through vector control (23).

The role of vector control in the major vector-borne diseases is summarized in Box 1.

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Vector control clearly has an important role to play in the intensified control of tropical diseases. The question arises: if vector control is so effective, why has it been so neglected? Factors that have contributed to this neglect include technical complexity, costs and logistic needs, complacency and environmental concerns about pesticides. Certainly, one factor has been the "legacy of failure" of major, time-limited campaigns in the mid-twentieth century. The campaign for global malaria eradication, for example, suffered from an overambitious objective.

In some countries with malaria, such as India and Sri Lanka, disease-control programmes had a strong emphasis on vector control and were highly effective. However, as the incidence of malaria dropped dramatically, political will to continue funding also declined and successful organizational structures for vector control were allowed to break down.

Lessons from this example should be heeded by workers on other infectious disease programmes that rely on mass chemotherapy. Programme sustainability tends to become more difficult as the public health problem subsides. In a similar fashion, the programme for the hemispheric eradication of *Aedes aegypti* in the Americas was initially highly effective, but success generated apathy and an unwillingness to provide funds once the distribution of the vector had dramatically receded. After two decades of diminishing interest and dwindling expertise, national capacities to implement vector-control programmes have been severely weakened and in some cases have almost disappeared. These years of neglect have had serious consequences for health and socioeconomic development.

After the discovery and effective use of residual insecticides in the 1940s, large-scale and systematic control programmes succeeded in bringing most of the important vector-borne diseases under control in many areas of the world. By the late 1960s, most vector-borne diseases were no longer considered to be major public health problems outside Africa. Resources dwindled, control programmes collapsed, and fewer specialists were trained and employed (25).

Within two decades, many important vector-borne diseases, including malaria, dengue, African trypanosomiasis and leishmaniasis, had re-emerged or spread to new regions. These diseases returned to a world that was now characterized by accelerating population growth, rapid urbanization, and land-use trends conducive to the spread of vector-borne diseases. Moreover, specialists in vector control were frequently replaced by health-care managers, thus greatly diminishing the pool of technical expertise that is essential for vector control (26).

Positive trends: good tools and a promising new way to use them

Against this apparently gloomy background, several positive developments are opening up new opportunities to exploit the power of vector control to prevent disease transmission.

Insecticide-treated bednets

The renewed drive to bring malaria under control has resulted in the development of insecticide-treated bednets as the first major new tool for vector control in more than 50 years (3). New technologies for producing long-lasting insecticide treatment are now being developed through partnerships with private companies (27), and offer improved prospects for controlling transmission of malaria and other diseases, including leishmaniasis, anopheline-transmitted lymphatic filariasis, and Chagas disease. A problem in the deployment of insecticide-treated bednets for malaria control has been low re-treatment rates (28). Although mass campaigns and free re-treatment of bednets through local health services may help to increase rates of re-treatment (29), a better solution to the problem is the production of bednets with insecticidal properties that persist throughout their useful life (30).

Other new tools include long-lasting insecticidal traps for the tsetse fly to prevent transmission of African trypanosomiasis. For dengue there are treated covers for water storage jars, treated curtains and controlled-release larvicides, although the efficacy of these has yet to be determined on a wide scale. With the dearth of other effective ways of controlling dengue — there is no vaccine — measuring their efficacy under operational conditions must be a high research priority.

Table 1. **Estimates of the global burden of disease caused by major vector-borne diseases** (1)

Disease	million DALYs[a]
Mosquito-borne infections	
Malaria	46.5
Lymphatic filariasis	5.8
Dengue	0.62
Japanese encephalitis	0.71
Yellow fever	no data
Others[b]	
Onchocerciasis	0.48
Leishmaniasis	2.1
African trypanosomiasis	1.5
Chagas disease	0.67

DALY = disability-adjusted life year.

[a] Total of DALYs for these diseases represent 17% of the global disease burden due to parasitic and infectious diseases.

[b] Synanthropic flies play a major role in the transmission of trachoma and diarrhoeal diseases, but the attributable burden is not readily estimated; other arboviruses and typhus organisms may be of major public health significance but accurate data are not available.

Health sector reform, collaboration and community mobilization

Another positive development has been a move towards decentralization and intersectoral collaboration in the health sector. These trends promote an enabling environment for vector control activities in the communities affected by disease and also allow management of programmes to take place at the most proximate operational level, which in most cases will be the district, municipality or local community. The distribution and incidence of vector-borne diseases are strongly determined by local ecological conditions, while human behaviours — from farming practices to sleeping habits to waste disposal — directly affect transmission risk. Vector control interventions that incorporate social mobilization of communities and principles of community ownership are more likely to have a significant and sustainable effect on vector densities. In the long term, such bottom-up approaches will be more cost-effective than exclusively top-down programmes (31–33).

Vector-control programmes must also be integrated with other public health and development activities. For example, broadly based environmental programmes to improve public

Box 1. **The role of vector control in major vector-borne diseases** (24)

African trypanosomiasis. Imperfect drugs make control of the tsetse fly vector the main hope for preventing transmission. New long-lasting treatments may extend the capacity of communities to deploy simple traps and screens treated with pyrethroid insecticide.

Chagas disease. Vector control, mainly through indoor residual spraying, remains the only practical option for control of the domestic triatomine bug vectors.

Dengue. In the absence of an effective vaccine, control of the *Aedes* mosquito vectors is the only preventive intervention. This requires community participation for effective and sustained implementation.

Leishmaniasis. Vector control, through indoor residual spraying, has proven effective in controlling indoor transmission of visceral and cutaneous leishmaniasis in Europe, the Middle-East, South Asia and Africa. Insecticide-treated bednets show promise in experimental trials but have yet to be deployed in large-scale programmes. They may be the only means of preventing infection with kala-azar (visceral leishmaniasis) in rural communities.

Malaria. The uptake of vector control as a preventive strategy lags far behind the deployment of curative drugs. With the emergence of resistance to first-line drugs, greater priority needs to be given to preventive strategies based on vector control. The control of malaria vectors can also indirectly contribute to control of other diseases.

Onchocerciasis. Vector control was a major factor in the successful Onchocerciasis Control Programme in West Africa for more than 25 years. In the later stages of the programme, vector control was successfully combined with mass drug administration to consolidate the gains. This success underscores an important historical lesson: campaigns for the control of vector-borne diseases have the best chance of success when multiple interventions that target different points in the disease cycle are implemented concomitantly.

health afford opportunities to bring about permanent reductions in vector breeding; these are preferable to time-limited campaigns focused solely on vectors.

In rural areas, where vectors may be associated with agricultural practices, collaboration with farming groups could bring significant benefits (34). Examples include the agriculture extension networks and successful Farmer Field Schools promoted by the Food and Agricultural Organization of the United Nations (FAO) to improve pest management in environmentally benign ways, empower farmers and tap indigenous knowledge. These innovative approaches could also bring substantial public health benefits and fit well with the holistic approach to rural development being advocated to achieve the Millennium Development Goals (35).

Effective vector control will continue to require national level support in order to provide strategic direction, technical expertise and training, to develop national control policies and set norms and standards, and to develop indicators to monitor the progress of operational activities. The long-recognized need to include vector-borne disease hazards in impact assessments for new infrastructure projects such as dams and irrigation schemes (36, 37), roads, and urban development (38) will also require action.

Social marketing

Fortunately, the need for greater community engagement in vector control is being addressed by a third trend. Sophisticated methods of social mobilization and communication, through the application of the principles of private sector marketing, have been developed and have been shown to promote behaviours that contribute to sustained vector control, particularly for dengue (39). These methods offer good prospects for strengthening community-based activities against other vector-borne and communicable diseases. Additionally, partnerships with the commercial sector have been valuable in promoting insecticide-treated bednets for malaria control (40).

Many targets, one approach

An additional strength of vector control is that it is suited to the simultaneous control of multiple diseases. Vectors that transmit different diseases may share similar habitats. Single vectors may transmit more than one disease, as is the case with malaria and anopheline-transmitted filariasis. Several vectors may rest indoors or bite indoors at night. Hence, single interventions can be effective against more than one disease, as with indoor residual spraying for malaria and leishmaniasis (41, 42). This multi-target attribute can help make the most of scarce human and financial resources and organizational structures.

New mapping technology

The increasing use of geographic information systems for public health purposes and the development of powerful mapping tools have improved the capacity to locate and visualize ecological features that favour specific vector habitats, allowing rapid identification of at-risk communities. Spatial and temporal patterns of vectors are strongly affected by environmental factors, including vegetation, which can be sensed remotely by earth-observing satellites. For example, the use of satellite imagery has made it possible to identify the geographical location of human populations at greatest risk of contracting African trypanosomiasis. To identify, characterize and map the patterns of tsetse fly habitats over an area in excess of 10 million square kilometres where almost 50 million people are at risk would have been impossible before the advent of satellite imaging techniques and geographical information systems (43). Such advances provide considerable support for strategies that rely on targeted, selective application of measures for vector control.

Integrated vector management

All of these trends converge in a new approach to vector control — "integrated vector management" — that is now being endorsed as the recommended strategy to exploit the preventive power of vector control in sustained and ecologically-sensitive ways (44). Integrated vector management relies on packages of evidence-based interventions, tailor-made for local settings, and provides a way to coordinate and refocus resources for vector control, while at the same time reducing reliance on insecticides. This approach aims to control, manage and monitor vector-borne diseases at all relevant points in the life-cycle and transmission-cycle of the vector. Integrated vector management can incorporate the twin goals of reducing vectorial capacity and minimizing opportunities for human–vector contact.

A collaborative approach

A key feature of integrated vector management is the recognition that reduction in the burden of vector-borne disease cannot be seen as exclusively the responsibility of the health sector. There are two fundamental reasons for this. First, major development programmes, including irrigated agriculture, hydroelectric dam construction, forest clearance, road building, housing development and industrial expansion can all lead to increased transmission of vector-borne disease unless potential risks are addressed at the planning stage. In fact, disease could negate the very social and economic developments that such projects are designed to bring. Second, mobilization of vector control activities requires human and financial resources beyond those currently available in a health sector that is struggling with demands of other infectious diseases, particularly human immunodeficiency virus (HIV) and tuberculosis.

Thus, integrated vector management seeks to engage with communities and foster collaboration within the health sector and with other relevant public and private sectors. Fortunately, there are some excellent examples of how the public and private sector can work together to reduce vector-borne disease and produce not only improved health benefits but also significant economic returns (45–47). A notable example of such collaboration is the Lubombo Spatial Development Initiative in Mozambique, Swaziland and KwaZulu-Natal, South Africa (46). This initiative graphically illustrates how investment in vector control can contribute to regional development and thereby bring wider economic benefits.

Combination of interventions

Integrated vector management is an evidence-based, bottom-up approach in line with trends in health sector reform and is compatible with community action and management at the district level. It starts with an assessment of the local epidemiology — the incidence and distribution of infection; local vector species; ecological, social and other factors influencing infection and disease. The approach then draws on existing knowledge of the vector, its biology and ecology, and then selects the most economical and feasible combination of methods to achieve control. In building up the combination of interventions, the approach follows a clear sequential hierarchy. Consideration is given to locally suitable environmental management and personal protection methods, and there may be a role — albeit usually a limited one — for biological control. For some vector-borne diseases, chemical interventions are essential to achieve the required reduction in transmission risk, but wherever feasible, these must be used in combination with methods of source reduction and non-chemical means of reducing human–vector contact.

Integrated vector management also considers all options for intersectoral action and places responsibility for decision-making at the lowest possible administrative level — i.e., closest to communities affected by the problems. It includes not only the delivery of vector control interventions but also the regulation of activities of other public and private sectors that may affect transmission risks, such as those arising from irrigation schemes, road construction, and urban development.

Moving forward

Although the integrated vector management approach has been endorsed by WHO, few programmes are currently in a position to take full advantage of the preventive features of vector control. It could be argued that in terms of political prioritization, there is too great an emphasis on single-issue campaigns and quick fixes, at the expense of the more mundane and routine processes involved in integrated vector management. Furthermore, quick fixes do not address the major problem of building capacity in health systems, a problem highlighted recently by Haines & Saunders in their discussion of the obstacles to achieving the Millennium Development Goals (48). Effective vector control will require improvements in the human resources devoted to control, by building up a cadre of technical, managerial and operational staff able to support these activities. It will also require an improved policy framework.

The effectiveness of vector-control interventions in easing the burden of major diseases is indisputable. Scientific knowledge about vector biology and ecology is extensive. New tools allow identification of at-risk populations for targeted interventions with unprecedented speed. Other tools have enhanced the chances for successful and sustainable community-based control activities. The widely endorsed operational approach of integrated vector management is available to capitalize on these trends.

The stage is thus set to maximize the preventive power of these interventions. The most pressing challenge is to strengthen the managerial and operational capacity of health systems (48, 49) for vector control in the affected countries, in order to extend population coverage and achieve a greater reduction in disease transmission. All this comes at a cost, but the new international financing initiatives for health and development could, if realized, be targeted into sustainable capacity development.

If we grasp the opportunities available to us now, integrated vector management could make an important contribution to the attainment of the Millennium Development Goals, through reduction of child mortality and improved maternal health, through consequent improvements in economic productivity, and by an emphasis on methods that help sustain the environment. ■

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Résumé

Exploitation des possibilités de la lutte antivectorielle dans la prévention des maladies

Bien que la lutte antivectorielle ait fait la preuve de son efficacité dans la prévention de la transmission des maladies, ses possibilités ne sont pas pleinement exploitées, ce qui prive des populations défavorisées des bénéfices de méthodes bien éprouvées et testées. Après la découverte, dans les années 40, des insecticides résiduels de synthèse, des programmes à grande échelle ont réussi à endiguer un grand nombre des maladies à transmission vectorielle importantes. A la fin des années 60, la plupart des maladies à transmission vectorielle, - à l'exception du paludisme en Afrique -, n'étaient plus considérées comme des problèmes de santé publique majeurs. En conséquence, les programmes de lutte ont cessé leurs activités, les ressources dévolues à la lutte antivectorielle se sont amenuisées et les spécialistes de ce domaine ont disparu des services de santé publique. En l'espace de deux décennies, on a assisté à la réémergence ou à la propagation à de nouvelles zones de nombreuses maladies à transmission vectorielle importantes. Il est temps maintenant de rétablir le rôle clé de la lutte antivectorielle dans la prévention de la transmission des maladies, en accordant toutefois une importance plus grande aux mesures multiples, qu'elles fassent appel à des pesticides ou à des modifications environnementales, et en renforçant les capacités de gestion et de mise en œuvre des programmes. La lutte antivectorielle intégrée offre un cadre conceptuel solide au déploiement de méthodes peu onéreuses et durables de lutte contre les vecteurs. Cette approche permet de prendre pleinement en compte les déterminants complexes de la transmission des maladies, y compris l'écologie locale de celles-ci, le rôle des activités humaines dans l'augmentation des risques de transmission et les conditions socioéconomiques des collectivités touchées.

Resumen

Aprovechar el potencial de la lucha antivectorial como medio de prevención de enfermedades

Aunque ha demostrado ser muy eficaz como medio de prevención de la transmisión de enfermedades, la lucha antivectorial no se explota al máximo, y eso priva a las poblaciones desfavorecidas de los beneficios de algunos métodos de probada eficacia. Tras el descubrimiento de los insecticidas sintéticos de acción residual, en los años cuarenta, los programas a gran escala emprendidos consiguieron controlar muchas de las más importantes enfermedades de transmisión vectorial. A finales de los años sesenta, la mayoría de esas enfermedades -exceptuando la malaria en África- dejaron de ser un problema relevante de salud pública. El resultado fue que los programas de control cayeron en desuso, los recursos menguaron, y los especialistas en lucha antivectorial desaparecieron de las unidades de salud pública. En el término de dos décadas, muchas enfermedades importantes de transmisión vectorial reaparecieron o se propagaron a nuevas zonas. Ha llegado el momento de restituir a la lucha antivectorial su papel clave en la prevención de la transmisión de enfermedades, si bien es necesario hacer más hincapié en la adopción de múltiples medidas, basadas ya sea en el uso de plaguicidas o en la ordenación del medio, y en el refuerzo de la capacidad administrativa y operacional. El control integrado de los vectores brinda un marco conceptual sólido para desplegar métodos costoeficaces sostenibles de lucha antivectorial. Mediante este enfoque es posible abordar de forma exhaustiva los complejos determinantes de la transmisión de enfermedades, entre ellos su ecología local, el papel de la contribución humana a los riesgos de transmisión, y la situación socioeconómica de las comunidades afectadas.

Arabic

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