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Assessment of Environmental Management as Method of Malaria Vector Control in Khartoum State

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Dedication

To my fathers' soul …

To the soul of my brother Alshaheed Awad…. .

To my kind mother…

My wife………….

My brothers & sisters….

& to my colleagues….

I dedicate this work.

Acknowledgment

I greatly appreciate the help of Dr. Ahmmed Hussein for his guidance. My great thanks go to my dear friend Musab Briar Musa Briar and all the people who assisted me in this work.

Abstract

This study was conducted in Khartoum State during the year 2007,with the objective of assessing the environmental management activities for malaria vector control. The source of data was the records of Khartoum State, Ministry of Health. The respondents to the questionnaires were the malaria control personnel. The study revealed that there were significant differences between the sources of breeding sites and the positive breeding sites during the years 2004 and 2005. The study showed significant correlation between the environmental management and the reduction of the breeding places in the new buildings and cisterns. It was observed that (1042089) of mosquito breeding sites resulting from agriculture schemes and (25414) of mosquito breeding sites from broken pipes increased in the year 2005, due to weakness in applying intermittent irrigation program and pipe maintenance. The respondents regarded intermittent irrigation as the most efficient method (83.8%), also the respondents regarded (78.8%) of the community members as involved in intermittent irrigation. The major mosquitoes breeding sites in Khartoum State reported in the study were agricultural block, bricks factories, broken pipes, cisterns, construction ponds, rain and river pools, public gardens, cesspits, private public building, water kiosk houses, zaraib (dairy farms) and sewers.

The dryness (95.3% - 93.8%) applied in agricultural schemes, the repairing of broken pipes (18.9% - 13.5%), and the repairing of cisterns (0% - 85.9%) and the demolishing of construction ponds (34% - 95%), during (2004 – 2005) frequently led to the reduction of mosquito breeding sites in Khartoum State (11.4% - 8.5%) & (2.7% – 2.7%) & (0.7% - 0.7%) & (1.7% - 2.7%) respectively.

ملخص الدراسة

أجريت هذه الدراسة بولاية الخرطوم خلال العام 2007 ، لتقييم المكافحة البيئية لناقل الملاريا بالولاية للعام 2004-2005 م . وقد إعتمدت الدراسة نوعين من مصادر جمع المعلومات ، السجلات وإستطلاع قادة العمل الصحى (مدراء الملاريا وضباط الصحة) بمكافحة الملاريا بولاية الخرطوم . وقد توصلت لعلاقة واضحة فى نتائج البحث للأهمية بين مصادر التوالد – مشاريع زراعية وبرك أمطار وشاطئ النيل ومواقع من صنع الإنسان – ومواقع التوالد خلال العام 2004-2005 م، كما أوضحت الدراسة العلاقة الواضحة بين المكافحة البيئية وإنخفاض أماكن التوالد فى كل من احواض المبانى والصهاريج وذلك عندما تم تكسير أحواض المبانى وصيانة الصهاريج والمواسير المكسرة . إرتفع عدد أماكن توالد البعوض فى كل من المشاريع الزراعية إلى (1042089) موقع توالد للبعوض، والمواسير المكسرة إلى (25414) موقع توالد للبعوض خلال العام2005م نسبة للتدنى فى نسبة تجفيف المشاريع الزراعية وصيانة المواسير المكسرة مقارنة بالعام 2004م.

83.8% من مدراء الملاريا وضباط الصحة بولاية الخرطوم عبَروا عن آرائهم بأن تجفيف المشاريع الزراعية من اكثر الطرق فعالية ، كما عبروا عن أن 78.8% من المجتمع شارك فى طريقة تجفيف المشاريع الزراعية . أوضحت السجلات فى الدراسة أن معظم أماكن توالد البعوض بولاية الخرطوم تتمثل فى المشاريع الزراعية وكمائن الطوب والمواسير المكسرة وأحواض المبانى وبرك شاطئ النيل وبرك الأمطار والحدائق العامة والبلاعات والصهاريج والمؤسسات العامة والخاصة وأكشاك توزيع المياه بالأحياء السكنية والمنازل والزرائب والسبايل لشرب المياه ومصارف الأمطار واخرى مثل البراميل وإطارات السيارات التالفة وعلب الصلصة والأوانى المهملة .

تجفيف المشاريع الزراعية (95.3% - 93.8%) وصيانة المواسير المكسرة (18.9% - 13.5%) وصيانة الصهاريج(Zero% - 85.9%) وتكسير أحواض المبانى(95% - 34%) للأعوام (2004-2005م) على التوالى أدى إلى إنخفاض واضح فى نسبة توالد البعوض بولاية الخرطوم ، (11.4%- 8.5%) & (2.7%-2.7%) & (0.7%-0.7%) & (1.7%-2.7%) على التوالى.

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Introduction

Objectives

1.1 Introduction

All previously documented successes of larval control against African Malaria vector have depended on vigorous surveillance for aquatic stage mosquitoes to enable suppression and even elimination. To have sustainable malaria control in Africa cities, integrated vector management needs to be implemented through community-based systems. Operational research is required to develop surveillance systems that are practical, affordable, effective and acceptable, **(Vanek J & etal, *2006*).** It is postulated that more than half of the African population will be living in urban areas by the years 2030. It is anticipated that the challenge and opportunity for tackling Malaria burden in urban areas will also grow.

The increased problem of insecticide resistance and the expansion in towns which is sometime unplanned led to serious environmental problem, such as:

- Limited proper drainage systems.
- Limited proper sewage disposing system.
- Presence of many broken pipes.

The inability of community members to detect mosquito larval habitats in urban farming areas were minimal supervision in operational urban malaria control program.

The interventions against the vectors of diseases are essential for the control of these diseases. There are many methods used for vector control such as chemical, physical, biological and environmental methods. Environmental modification refers to the long–lasting or permanent changes of breeding sites in method of irrigation.

Environmental manipulation refers to a temporary effect and need to be repeated. The term source reduction refers to any measures that prevents the breeding of mosquitoes or eliminates their breeding sites ***(Rozandaal, 1997).*** The control of breeding places must be carried out around human settlements in an area with a radius greater than the flight range of the target mosquito species and for many species, this is about (1.5-2) km. Control measures that are not permanently effective have to be maintained throughout the period when the mosquito acts as a disease vector. Therefore, larval control is more costly per person in sparsely populated areas than in density populated ones, ***(Rozandaal, 1997)***. Compared to rural setting, Malaria in urban Africa is generally characterized by lower intensities and more focal distribution of transmission, resulting in weaker immunity in the afflicted population and distribution of disease burden across older age groups. Compared to rural setting, urban areas usually offer more Malaria Control options because relatively good transport, communication, educational and health infrastructure is available to large populations in small geographic areas. Through the relatively easy access to most urban areas breeding sites, interventions, such as an environmental control and application of larvicide's may be cost-effective, but remains to be vigorously evaluated in the modern African context,(Vanek J & etal, ***2006)***.

In places with intense transmission of malaria all ***anopheline*** breeding sites need to be eliminated in order to achieve a reduction in the prevalence of malaria. Across–sectional entomological survey was conducted in Kisumn and Malindi, Kenya .in Kisumn, 98 aquatic habitats were indentified, 65% of which are human – made and 39% were positive for Anopheles larvae. In Malindi, 91 aquatic habitats were identified; of which 93% were human made and 65% were harboring anopheline larvae (Joseph, 2003).

In Khartoum State during the year 2004, 12 aquatic habitats were indentified 75% of which were human-made, and 16% were positive for anophenline mosquitoes.

In 2005, 15 aquatic habitats were indentified, 80% of which were human-made, 14% were positive for *anopheline* larvae (Annul Statistic Report, M .of .H. 2005).

1-2 Objectives

General objective

Assessment of environmental Management as method of Malaria Vector in Khartoum State.

Specific objectives

1. Evaluation of environmental management for Malaria Vector Control in Khartoum State.
2. Identification of breeding sites of Malaria Vector in Khartoum State.
3. Evaluation of methods of control used in Khartoum Malaria Free Initiative in 2004 – 2005.
4. Assessment of source reduction method compared to other methods, applied in Khartoum State.

Chapter Two

Literature Review

Literature Review

Malaria Control

The Global Strategy for Malaria Control, adopted in 1992 at the Amsterdam Ministerial Conference, outlines four strategic technical elements, including prevention and vector control. As efforts intensified following the 1999 launch of the Roll Back Malaria Initiative by WHO, The World Bank, UNICEF and UNDP, the outside observer may have come to the conclusion that the global campaign against this killing disease relied exclusively on stepped-up case detection and treatment, and on the scaling up of the use of insecticide-treated nets (ITNs), (Lindsay & et al, 2004)

The factors that govern the ecology of malaria are many and varied and depend on local conditions. These factors are known as the contextual determinants of malaria and fall into three broad categories- environmental, socio-economic and biological. These broad areas operate at a range of spatial and temporal scales, further increasing the complexity of the local ecology of malaria. What is fundamental here is the overwhelming importance of economic factors that drive malaria. Much of malaria is man-made, where the breeding habitats of vector mosquitoes are created by human activity, such as road building and the construction of irrigation networks. Those at greatest risk of malaria are the poor and vulnerable that live in poorly constructed housing that often increases their risk of infection, and who have poor nutrition and poor access to effective health care, (Lindsay & et al, 2004).

Malaria control is a big challenge due to many factors: There is the complexity of disease control process; the complexity of the vectors and expensiveness of the control program. There is a variation of disease patterns and transmission dynamics from place to place, by season and according to climate and environmental circumstances. Since malaria varies from season to season and from place to place within a country, approaches will also differ in the planning and implementation of vector control. The circumstances of each region's will influence the organization of practical programmes to identify local problems and priorities, and the design and implementation of appropriate interventions. Therefore, selection of suitable, sustainable and cost-effective interventions must be based on local analysis, (Ministry of Health Addis Ababa, March 2002).

Malaria Vectors

There are about 380 species of Anopheles mosquitoes .forty or so species of which can transmit malaria, and of these only 15 are of major importance as vectors. Some anopheline mosquitoes prefer to bite animals and thus either do not normally transmit malaria parasite to humans or do so very rarely. Some others do not live long enough for the parasite to develop in the them. In other anopheline mosquitoes the parasite does not seem to be able to develop ,(WHO , 2002)

History of Malaria Vector

Early control programmes included the screening of houses, the use of mosquito nets, the drainage or filling of swamps and other water bodies used by insects for breeding, and the application of oil or Paris green to breeding places,(Rozendaal,1997). The discovery of the insecticide dichlorodiphenyltrichloroethane (DDT) in the 1940s was a major breakthrough of the control of vector-borne diseases. In the 1950s and early 1960s, programmes were organized in many countries which attempted to control or eradicate the most important vector-borne diseases (malaria, chagas disease and leishmaniasis) by the large scale application of DDT, (Rozendaal,1997).

Larval Habitats

Larval habitats vary from species to species, but are frequency exposed to sun light and commonly found in association with emergent vegetation, such as grass or mats of floating vegetation or algae, (Rosendale, 1997) There is a great diversity in the type of water utilized by different anopheline species. Some larval habitats may be temporary, such as small ponds, pools and puddles, other may be more permanent, such as marches, and borrow pits (depression created by excavating soil), (Warrell & Gilles, 2002). The most preferred breeding sites are pools , seepage , quiet places in slow running streams , rice field , leaf axils of certain epiphytic plants and puddles of rainwater , (Rozendaal,1997) . Most aquatic habitats are fresh-water, while some Anopheline species breed in saline water, but most anopheline avoid organically polluted waters, such as those contaminated with human or animal faeces or rotting vegetation, (Warrell & Gilles, 2002) .Many anophelines are found in freshwater ponds and small collections of water such as pools and puddles that lack vegetation (e.g.A.gambiae in Africa and A.stephensi in India). Artificial containers such as pots, tubs, cisterns and overhead tanks are not usually suitable, except in the case of Anopheles stephensi in south-west Asia, (Rozendaal, 1997). Malaria has major and multifaceted linkages with agriculture, both in a rural and peri-urban context, (Klinkenberg, et al 2005 & Wang, 2005). Agricultural environments provide conditions well suited for anopheline breeding, with clear, temporary water bodies coinciding with the time of crop cultivation, and human and animal hosts at flying distance. Clearing of land for agriculture opens up breeding habitats for heliophilic vectors, whereas "informal" smallholder farming systems located near natural water sources, such as streams and rivers, open up vector breeding opportunities , Moreover, mounting evidence indicates that the widespread agricultural use of broad-spectrum insecticides contributes to insecticide-resistance in mosquito vectors, (Georghiou, et al 1990). In Africa , the larvae of A, gambiae can be found in roadside pools , small puddles and hoof prints as well as in borrow pits and rice field and , very occasionally , in water-filled village pots, (Warrell & Gilles, 2002). In the cities, the other sites for mosquito breeding are the water tanks.

Shortage of water supply in large cities makes it necessary to have these tanks in virtually every building.

Overhead tanks, sump tanks, storage tanks, ornamental tanks etc, are often left uncovered and this provides chance for mosquito breeding. Potential breeding sites of mosquitoes include:

- Small rain pools, hoof-prints, drain ditches, where the entire surface of water should be examined.
- Brackish water, e. g at sites where fresh water and salt water mix. Streams, should be searched at the edges where there is vegetation and the water moves slowly.
- Ponds and lakes, where larvae usually occur in vegetation around the edges but can sometimes be found far from the shore among floating vegetation.
- Swamps and marches, where larvae occur in places similar to those described for ponds and lakes.
- Special sites, such as wells and water containers made of cement, where the entire surface of the water should be examined, (WHO, 2002).

Larval Collection

Mosquito larvae are disturbed by shadows and movement of the water, which cause them to swim down-wards; therefore, the collector should wait for them to resurface before attempting to collect those, (Warrell & Gilles, 2002). Essential equipments for collecting larvae and pupae are dipper , larval net , large tray , pipette , stopper specimen tubes (vials) , 70% alcohol solution , cotton wool , a pencil , and safety match or lighter,(WHO , 2002) . The dipper should be gently lowered into the breeding place and the larvae allowed to flow into it. The number of dips depends on the size and diversity of the habitat and on weather simple detection of breeding places or some measure of larval density is required , probably about 10 dips are appropriate for small ponds up to 4 cm in diameter . Aquatic nets are useful in detecting anopheline breeding when larval density is low, (Warrell & Gilles 2002). For very small collections of water such as in cattle hoof prints and puddles visual inspection should reveal whether larvae are present. The larvae can then be collected by direct pipette, (Warrell & Gilles, 2002).

Types of mosquito survey

- Preliminary survey

Preliminary survey is original, basic, short-term surveys used to gather baseline data for planning vector control measures. They provide information on identity of the specific vector species , their resting and feeding habits , seasonal densities and longevity, type of water bodies used as breeding sites ; and sensitivity to available insecticides to facilitate the selection of most effective insecticide, (WHO , 2002) .

- Regular or trend observation:

Provide information on changes in vector density-Infection rates, behavior, and susceptibility of vectors to insecticides, (WHO, 2002).

- Spot checks:

Spot checks are carried out in localities chosen at random. Since the fixed stations often used to monitor mosquito populations may not be representative of all areas , spot checks may be conducted randomly in selected areas to supplement routine observations or obtain a clear indication of the effects of control measures , (WHO , 2002) .

- Foci investigations

These are undertaken in areas of new or persistent malaria transmission to determine why there is transmission or why the disease is not responding to the measures being applied , and to identify the best approaches to control , (WHO , 2002) .

- Malaria Vector control

Vectors

Vectors carry and transmit of infection.

Vector competence:

Biological and/or mechanical ability to transmit infection, (WHO, 2004 -2010).

Vector control

Interventions targeting vectors to reduce their vectorial capacity, (WHO, 2004 -2010).

Vectorial capacity

- Mathematical expression to measure vector efficiency, used to assess risk and impact of interventions, (WHO, 2004 -2010).
- **Objective of Vector Control**

The objective of vector control in a malaria control programme is to reduce levels of transmission, thus reducing malaria morbidity and mortality, (Ministry of Health Addis Ababa, March 2002).

Indications for Vector Control

- Prevention and control of malaria epidemics;

- Elimination of new foci of infection in malaria-free areas;
- Prevention of seasonal peaks of malaria transmission;
- Control of transmission in high-risk situations;
- Reduction of transmission in areas of high drug resistance;
- Control of endemic malaria, (WHO, 2002).

AVAILABLE TECHNICAL INTERVENTIONS

* Personal protective measures

1. Repellents

These may be applied either directly on the skin (as a cream, lotion or aerosol) or on clothes. The use of repellents is also only a measure of individual protection In epidemics, repellents have been distributed in some malaria control programmes, although their cost-effectiveness remains doubtful, (WHO,2004) .

2. Protective Clothing

Clothing can offer protection from biting insect when it is of a thickness and texture through which insects cannot easily bite, (Rozendaal 1997).

3. Use of mosquito nets

The introduction of net treatment with pyrethroid insecticides of residual action has considerably increased their effectiveness by adding to the barrier effect of the net the repellent and killing actions of the insecticide. In particular, the repellent effect of pyrethroids prevents feeding through the net and often also the penetration of mosquitoes through holes in the net, (WHO, 2003).

4. Aerosols

The spray can be directed against flying or crawling insects or sprayed into room, once the aerosol has settled out of the atmosphere insects can again enter the area with impunity, (Rozendaal, 1997).

5. Coils, vaporizers and anti-mosquito plants

(Fumigant insecticide dispensers)

These are widely used throughout the tropical regions for individual protection, particularly in the form of mosquito coils and, in urban areas, electrically heated dispensers, (WHO, 2003).

6. House screening/proofing

This is an effective method if properly implemented and maintained. It remains an almost exclusive method of individual and family protection, since it requires a high investment and has high care and maintenance costs, (WHO, 2003).

7. Prevention of breeding in and around dwellings

Preventing egg lying: The easiest, cheapest and most environment-friendly method to control malaria is by preventing the mosquito from laying eggs. This is done by avoiding or eliminating the clean water collections. Most such collections are artificial, temporary and man-made. It is common habit to throw the unutilized utensils, buckets, bottles, tyres, tender coconut shells etc. into the open. During the rains, water gets collected in these containers and provides ample breeding locations for the female Anopheles mosquito, (Kakkilaya's, 2006).

Prevention of breeding around dwelling involves the removal of possible breeding sites near homes by filling ditches, borrow pits and holes where water collects, burying empty tins and other containers where water may be collected and act as breeding sites. Individuals or communities in rural or urban areas may apply this measure to reduce mosquito populations.

Advantages

- Easy to apply and cost almost nothing
- Helps to keep home environment clean

Disadvantages

- Have little effect on malaria transmission except when widely applied, (Ministry of Health Addis Ababa, March 2002).

*** DISEASE CONTRO-TRANSMISSION CONTROL**

Disease control in the community, on the other hand, requires more concerted efforts and needs to be applied on a larger scale. Measures applied to reduce transmission aim at reducing breeding and survival of the mosquito vectors. Some of these measures require particular expertise and specialized equipment to apply and almost all measures requires good knowledge of local vectors, especially their breeding and resting behavior, (Ministry of HealthAddisAbaba, March2002).

These interventions include:

Environmental management / sanitation.

Use of chemical insecticides.

Biological Control

1. Use of Chemical insecticides

1.1. Larviciding

Larvicides are applied to mosquito breeding sites to kill larvae. Larvicide's are used on breeding sites that cannot be drained or filled and where other source reduction methods or the use of larvivorus fish would be too expensive or impossible, (Rozendaal, 1997). Larviciding is most useful where breeding sites are accessible and relatively limited in number and size. Targeting the most important vector breeding sites may improve operational efficiency and cost-effectiveness. Larviciding, using insecticides, should be considered as a complementary measure to environmental management. Larviciding exerts more selection pressure on the vector than IRS and ITNs, since it affects both sexes Residual effect of larvicides varies considerably with the water quality. The higher dosages are indicated for polluted water. Some larvicide formulations have rather long residual effect on standing water. But, most natural breeding sites are likely to be disturbed and other breeding places formed, so larviciding programmes may use cycles which may vary between two and ten weeks . Larviciding should avoid the treatment of water that could be used for drinking of human and domestic animals or that which could contaminate food stuff, (WHO, 2002.)

1.2. Space Spraying

The space spraying technique can be a valuable method to reduce the numbers of mosquitoes rapidly, not only in dwelling, but also temporarily in outside breeding ground. It is also generally well accepted by the community as it has a broad action against mosquitoes in general, (Warrell & Gille., 2002).

1.3. Indoor Residual House Spraying

Indoor residual spraying is useful to reduce the number of infections caused by malaria-carrying mosquitoes quickly; it has proven to be just as cost-effective as other malaria prevention measures, and DDT presents no health risk when used properly, (WHO, 2006) .

House spraying is still important in some tropical countries but in others its significance is diminishing because of a number of problems, which, in certain areas, have led to the interruption or termination of malaria control programmes, (Rozendaa, 1997). However, a number of problems were eventually encountered, among which are the following:

- Development of resistance by the targeted insects to DDT and other insecticides.

- Outdoor biting and resting habits of some vector mosquitoes;
- Inadequate sprayable surfaces in some houses.
- Customs of people in some areas who sleep outside during hot season.
- Poor acceptance of the method by the community, (Rozendaal, 1997).

1.4. Insecticide Treated Materials (ITMs)

Insecticide Treated Materials (ITMs) is one of the most up coming malaria control strategy, which combines a physical barrier with an insecticide against adult vectors. Insecticide treated materials are important in malaria control when used widely in the community. ITMs have been shown to reduce transmission of the disease. The evidence from several studies showed that the use of insecticide treated materials reduced severe malaria cases in children by about 45% and all cause mortality by about 20% compared to those not protected by any net, (Lengeler, 1998).

A wide range of materials can be treated with insecticides e.g. window/door curtains, wall mats, cloth etc. In selecting materials for ITMs multi-filament synthetic materials are preferred because they are relatively cheaper than cotton, durable, easier to treat and takes in less insecticide, (Ministry of Health Addis Ababa, March 2002).

1.5. Insect Growth Regulators (IGRs)

Insect growth regulators (IGRs) are chemical compounds that are highly toxic to mosquito larvae by preventing their development into adults. They have very low toxicity to mammals, birds, fish and adult insects, but are toxic to crustaceans and immature stages of aquatic insects. Their use has generally been limited by their high cost and inefficiency, but may be of particular interest where target species have developed resistance to organophosphate larvicides or where these compounds cannot be used because of their effect on the environment. IGRs can be divided into:

(a) Juvenile hormone analogues

Which prevent the development of larvae into viable pupae or of pupae into adults (they do not kill larvae);

b) Chitin synthesis inhibitors

Which interfere with the molting process, killing the larvae when they molt, (WHO, 2003).

1.6. Polystyrene beads

These have been used in controlling culicinae by the treatment of abandoned wells and latrines. Although anophelines may breed in the former, this method is not normally suitable for treating anopheline breeding places. It has been used in India against An. stephensi in water tanks, (WHO, 2003).

2. Biological Control

For anophelines, this is practically limited to the use of predators (mainly larvivorous fish), which are most effective in man-made breeding sites (e.g. ponds, cisterns or irrigation systems). Although such predators suffer from the same problems of incompleteness as all the other anti-larval measures, they may become established in a more permanent form although, as with most natural interacting populations, they will tend to establish an equilibrium with their prey, which will have to be disturbed by frequent seeding of the predator or pathogen concerned, (WHO,2002) .

2.1. Use of Larvivorous Fish

Fish are exceptionally good predators of mosquito larvae, and an increase in fish stocking has been correlated with a decrease in malaria incidence over the same time period. The economic benefits of fish may also encourage community participation in mosquito control. Gambosia spp have been effective for the control of anopheline larvae, (Lindsay & etal, 2004)

2.2. Use of Bactericides

Bacterial larvicides are preferred because they specifically control mosquito larvae, (WHO, 2004-2010). Bacillus thuringiensis var israelensis H-14 (Bti) and B. sphaeriesis, bacteria producing a toxin that kills mosquito larvae, could be efficiently cultured in coconuts (which are plentiful in some malarial regions). Bti, which is harmless to humans and livestock, could be used to reduce populations of mosquitoes dramatically, (Wu, 1997).

3. Environmental Management

Environmental management for vector control aims to induce changes in ecosystems that help reduce their receptivity to the propagation of disease vectors, (Lindsay & et al, 2004).Environmental management involves the modification of the environment to make it unfavorable for the vectors to breed. These include draining or filling up of ponds and borrow pits, intermittent draining of irrigated areas and maintenance of irrigation channels. Construction of drainage channels. Environmental management can effectively be used in urban settings to control mosquito breeding, (Ministry of Health Addis Ababa, March 2002).

Source Reduction

The term "source reduction" refers to any measure that prevents the breeding of mosquitoes or eliminates their breeding sites, (Rozendaal, 1997).

Therefore, unless these breeding sites (most of which are man-made and temporary) are taken care of, it is impossible to control mosquito breeding and hence malaria and it is impossible to achieve this without the participation of the general public. Education of the people is thus very important for any meaningful action. The following measures are called for to minimize mosquito breeding and these measures require only a trifle of human efforts:

- Do not throw utensils, vessels, buckets, tyres, bottles, tender coconut shells etc. in the open. They should be either destroyed or buried or at least kept inverted so that water cannot collect in them. All such things should be cleared during the rainy season.
- All tanks should be kept tightly closed. A black plastic sheet can be used for the purpose. Also, all tanks should be emptied, cleaned and allowed to dry for at least half an hour once every week.
- Terraces and roofs should ideally have a slope, particularly in places where monsoon tends to be heavy. All such roofs/terraces should have adequate drainage for water. Any collection of water on these surfaces should be cleared at least once a week.
- At construction sites, all the care should be taken to avoid collection of water at one place for more than a week. The layer of water on the surface of the concrete, used for concrete curing, should be cleared at least once a week and allowed to dry for half an hour. All other puddles should be cleared regularly. Collections of water in the toilets and closets under construction should also be cleared. All tanks should be kept snugly closed. All laborers should be frequently checked for parasitemia and adequately treated. They should also be provided with mosquito nets.
- All unused wells and tanks should be closed or destroyed. Engine oil or kerosene has been used as a larvicidal on these collections. Another method to prevent egg lying on unused wells is by adding EPS polystyrene beads onto the surface of water. These beads are

non-toxic, cheap and long-lasting. They coat the water surface and prevent the mosquito from laying eggs. Finally, Wells that are being used and ornamental tanks can be treated with biological larvicides that do not harm the quality of drinking water. Also, these wells should be covered with either mosquito-proof nets or with plastic sheets, (Kakinada's, 2006).

3.1. Environmental Modification

Environmental modification, means infrastructure development, to make changes to the environment as a periodic routine (Lindsay & etal, 2004). By measures are long-lasting or permanent changes in method of irrigation, (Rozendaal, 1997).

3.1.1. Impoundments

Impoundments are reservoirs for the storage of water behind dams and its subsequent release for power generation, irrigation and other uses. The flooding of a large area following the construction of a dam may have a beneficial effect in controlling the mosquito population if, instead of innumerable , scattered breeding foci there is a large , well-defined water surface , more amenable to supervision and control, (Warrell & Gilles, 2002). When dams are constructed mosquito numbers generally fall, if large numbers of small water bodies are combined into one large area of water as the reservoir fills. Mosquito larvae occurring within dam reservoir are usually confined to the shoreline, not in the main body of water, since many fishes are rapacious predators of mosquito larvae. Only when there is floating vegetation shielding the aquatic stages of mosquitoes will vector populations expand. There are a number of ways for reducing the threat of malaria from dams that are related to their design and operation, (Lindsay & et al 2004). Mosquito control related to impoundments should be based on the following considerations:

- Proper preparation of the reservoirs sites and particularly the clearance of trees and other vegetation at all levels between high and low water.
- Provision for fluctuating water level of the reservoir.
- Appropriate marginal drainage to avoid pools along the margins of the reservoir.
- Maintenance of shoreline vegetation control and drift removal, (Warrell & Gilles, 2002).

Canal lining

Lining irrigation canals with concrete makes good facilities, not just to reduce seepage and thus save water, but also to reduce the risk of creating mosquito-breeding sites. Lining will increase waterflow, washing the aquatic stages of mosquitoes out from canal networks. If they are well maintained, plants will not become established to offer shelter for some species of mosquitoes. Since there is less seepage with lined canals, this results in less need for drainage, which may also reduce mosquito breeding. In cases where vector mosquitoes become established in the canals it be comes easier to control mosquitoes either by water management or by targeted use of insecticides. People and domestic cattle should be prevented from crossing canals or drainage channels in order to prevent the formation of hoof or foot prints that can make ideal breeding habitats for some mosquitoes. Construction of bridges or placing large stones or rocks in such areas may also help alleviate the problem, (Lindsay &et al, 2004).

3.1.2. Filling

Filling is permanent measures of mosquito control, resulting in complete elimination of waterlogged areas; if the source of fill material can be obtained without creating borrow pits that can not drain, (Warrell. & Gilles, 2002). Abandoned ditches, borrow pits and ponds should be filled to remove potential mosquito breeding sites and these measure are particularly important if situated close to human habitation, although it should be recognized that heavily polluted water is often inimical to anophelines, (Lindsay & et al, 2004). On a small scale , no special expertise is needed and communities can carry out work with shovels , picks , wheelbarrows , carts and other simple equipment, (Rozendaal,1997).Filling on a large scale makes use of the spoil from such operations as harbour dredging , demolition , mining, etc. Sanitary land-fills using refuse disposal for depressions of the ground are acceptable as a method of mosquito control, provided that nuisance and fly-breeding are avoided by compaction and earth cover, (Warrell & Gilles, 2002) & (Rozendaal, 1997).

A special type of filling is that of hydraulic fill, when slurry of silt or sand mixed with water is pumped in estuaries, lagoons and creeks into the coastal swamp, which is gradually filled and converted into valuable land, (Warrell & Gilles, 2002).

3.1.3. Drainage

Drainage is the removal of unwanted water from the land surface or below. The purpose of a drainage system is the opposite to that of irrigation but otherwise the hydrological concepts and techniques of the two systems are the same, (Warrell & Gilles, 2002) .The drainage of water can be accomplished by constructing open ditches and dykes with tidal gates, subsoil drainage and pumping. Proper drainage reduces mosquito breeding. However, the drainage systems used in agriculture or for the transportation of sewage and rainwater in cities are often an important source of breeding sites because of poor design and maintenance, (Rozendaal, 1997). A well-constructed drainage system can prevent the formation of small water bodies suitable for the aquatic stages of mosquitoes. The straightening of streams and the removal of vegetation from banks can reduce mosquitoes by washing the aquatic stages away and allowing larvivorous fish access to the mosquitoes, (Thevasagayam, 1985). Surface-drainage requires improving water courses and the construction of ditches. In all cases, these need to be built following the path of water flow that exists in the area to prevent pooling of water along the drainage channels. Lining drains with concrete, stone or brick will allow faster water flow, reduce silting and weed growth, but will add substantially to the costs of implementation. Integrated control of breeding sites by improving drainage, filling and leveling and planting eucalyptus trees has been used to convert a once prolific area of mosquito breeding in a peri-urban area into a public park in Zambia, (Bae, 1999). Tree planting to drain boggy ground has also been used as part of an integrated programme to reduce malaria transmission and help reforestation for the provision of wood and improvement of water management in Gujarat, India, (Sharma, & et al1986).

a. Open ditches

Open earth drains are the simplest to construct. They are used to prevent the accumulation of excess rainwater in depressions in the ground and to dry out marshy area, borrow-pits, ground pools and other accumulations of surface water, (Rozendaal, 1997).

b. The ‘Lido system

In areas of extensive water covered with vegetation where drainage is impractical, the area can be deepened to the extent that plants cannot grow. If the banks of the impoundment are also steepened and stabilized, the introduction of larvivorous fish can reduce mosquito production dramatically, (Lindsay & et al, 2004).

Subsoil drainage

Subsoil drainage is more expensive than open drainage and, therefore ,of limited value in the control of mosquito. It is used where the ground surface has to remain unbroken by ditches to allow free movement and use of the land and where the earth is so unstable that open ditches cannot be maintained, (Rozendaal, 1997).Subsoil drains (also known as subsurface drains) are widely used for irrigated area; they prevent water-logging and improve aeration and leaching out of salts.

c. Design of drainage schemes

The design of drainage systems can be relative simple in small areas, but can be extremely complex over large areas. Generally, a system of grid-iron drainage, with few junctions, is preferred to the herring-bone arrangement with many junctions since blockages tend to occur at junctions, thus, increasing mosquito breeding, (Lindsay & et al, 2004).

d. Coastal swamp drainage

Constructing embankments to prevent the inundation of seawater at high tides can assist drainage of some coastal swamps. Pipes fitted into the embankments with an automatic outflow gate will allow water from the lagoon to be drained at low tide. A saltwater marsh drainage project, combined with larviciding and antimalarials for case treatment was used to control a malaria epidemic in Haiti epidemic in Haiti, (Takken, 1994).

e. Vertical drainage

In flooded areas lined with silt or clay over permeable bedrock, shafts can be sunk through the impermeable layer to allow water to leak into the permeable strata below, (Lindsay & et al, 2004).

3.1.4. Drinking Water Provision

Provision of safe drinking water and ensuring the related infrastructure is not causing seepage, leakage or standing water is an important environmental management measure in itself. This is particularly so since it allows people to move their settlements away from water bodies on which they would otherwise rely for their drinking water, (Lindsay & et al, 2004).

3.1.5. Reduction of man-mosquito contact

a) Housing (Site selection)

Mosquitoes do not tend to fly far from their breeding habitats, about 2-4km. Thus positioning houses1.5 to 2 km from large breeding sites will result in a substantial reduction in transmission. Similarly, villages at higher elevations and exposed to the wind will also have fewer mosquitoes than sites situated in the lowlands where it is less windy and small water bodies abound. Where the land within the mosquito flight range is sparsely populated or in areas flooded during dam construction, it may be possible to persuade people to move away from mosquito-breeding habitats. In rice-growing areas, where prodigious numbers of adult mosquitoes are often produced, it has also been suggested that areas immediately next to the rice fields should not be inhabited in order to reduce exposure to malaria, filaria and lieshmania parasites. This practice of dry belting villages in rice-cultivation areas is theoretically sound, but in reality, as with the previous examples, encouraging people to move away from water is extremely difficult to achieve and is not widely applicable as an intervention measure, (Lindsay & et al, 2004).

b) Raising buildings off the ground

Since most mosquitoes when searching for blood are flying close to the ground, (Snow, 1976). One of the simplest ways of avoiding mosquito bites is to build homes off the ground. In the early 1900s it was recommended that around Rome the floor of a house should be raised off the ground and be built at least two storey's high to provide bedrooms for the occupants on the top floor and reduce biting by mosquitoes. Even today people can reduce biting by sitting in the evening on raised platforms as in rural Gambia. Field studies in Papua New Guinea, and The Gambia, have even demonstrated that simply keeping the feet off the ground protects from biting mosquitoes, (Lindsay & et al, 2004).

c) Mosquito-proofing of dwellings

In the early 20th Century housing screening were regarded as one of the main methods to control malaria. Mosquito-proofing houses to demonstrate the role of mosquitoes in malaria transmission and modification house structure was used to protect people from malaria in Italy, Greece, Panama and the USA. There is an ample evidence that house screening contributed to the elimination of malaria from many parts of the world. More recently, risk factor surveys for malaria have shown that well-built homes and those with ceilings or closed eaves are protected from mosquitoes and malaria. A recent study using experimental huts in The Gambia demonstrated that installing a ceiling made of netting reduced transmission by 80% , (Lindsay & et al).This reduction compares favorably with that seen with ITNs in the same huts and need not be expensive, (Lindsay & et al , 2004) .

3.2. Environmental Manipulation

Environmental manipulation requires individuals/communities to make changes to the environment as a periodic routine, (Lindsay & et al, 2004). Measures have a temporary effect and need to be repeated, (Rosendale, 1997).

3.2.1. Controlling water level

Agricultural environments provide conditions well suited for anopheline breeding, with clear, temporary water bodies coinciding with the time of crop cultivation, and human and animal hosts at flying distance. Clearing of land for agriculture opens up breeding habitats for heliophilic vectors, whereas "informal" smallholder farming systems located near natural water sources, such as streams and rivers, open up vector breeding opportunities. Moreover, mounting evidence indicates that the widespread agricultural use of broad-spectrum insecticides contributes to insecticide-resistance in mosquito vectors, (Georghiou &

Diabate , 1990) .The Farmer Field School (FFS) has one of the most impressive track records in participatory community approaches, (Sanchez Pedro, 2005), with 2–3 million farmers graduated on the agricultural subject of Integrated Pest Management(IPM) during the past 15 years,(Braun et al, 2006), mainly in Asia, but more recently also in Africa, the Middle East and Latin America. A review of 25 impact studies indicated a range of positive outcomes of IPM Farmer Field Schools including drastic reductions in agro-pesticide use, economic benefits and empowerment effects. The FFS approach evolved from the need to strengthen the ecological basis of Integrated Pest Management (IPM) to deal with the variability and complexity of agro-ecosystems whilst reducing reliance on pesticides. The ecology of opportunist insects (which include mosquitoes) is highly localized and dynamic, with populations fluctuating manyfolds both spatially and temporally. Accordingly, most tropical smallholder agro-ecosystems require management decisions that are tailored to local and contemporary conditions. This implies the need to decentralize expertise to the field level by educating local people to analyze field situations and to make appropriate management decisions. The Farmer Field School is a form of education which uses experiential learning methods to build farmers' expertise, (Pontius, 2002). In sessions at weekly intervals during a crop cycle, a group of 15–30 neighboring farmers meet in an open-air situation to take observations of the agro-ecosystem. Several sub-groups of farmers sample the populations and characteristics of harmful and beneficial Organisms, plants, soil and environmental conditions. These observations are analyzed and presented on newsprint for group discussion, which provides an opportunity for speculation (for example, "what if, instead of spraying, we drain the water to control plant hoppers in rice"), leading to decision-making on experimental action to be evaluated in the following week. These weekly completed learning cycles result in strengthened skills and increased confidence of farmers. Several additional observations or experiments are conducted during the field school to study life cycles, insect behavior, and plant damage. Group dynamics and communication exercises are conducted to strengthen group cohesion, maintain motivation and help participants to develop organizational skills. Group building is important in approaches such as IPM and disease vector management, which benefit from coordinated management by many farmers over a large area. Post FFS support has been given in a number of countries to facilitate the emergence of local project initiative, (Pontius et al, 2002).

3.2.2. Stream sluicing or flushing

A regular discharge of a large volume of water into a stream, by releasing water held behind a dam across the stream, can flush out mosquito larvae from the stream bed pools. Existing irrigation infrastructures have been manipulated in tea and rubber plantations in South- East Asia, where *An. minimus and An. maculatus* prefer the relatively still water at the edges of streams, (Lindsay & et al, 2004).

3.2.3. Changes of water salinity

The Kochi Corporation in Kerala tried out a novel and cost effective method of reducing the mosquito population at the larvae stage itself. It has conducted experiments suggested by the retired National Institute of Oceanography (NIO) scientist, Dr. U.K. Gopalan, where the salinity of water in canals and stagnant pools is increased by adding sea water. The experiment was successful and mosquito larvae were found morbid in the canal portions where salinity was increased. When the salinity level reaches 30 parts per thousand or PPT (the normal percentage of salt in the sea), mosquito larvae cannot survive beyond 3 hours. Even at lower concentrations of 15 PPT, they are dead in 12 hours. And when the concentration is upped to 60 PPT, the larvae perish within the hour, (Kakkilaya's, 2006).

3.2.4. Shading of stream banks

This method of control was used to control An. maculatus in Assam, India, where it prefers open areas of water. Such approaches have also been used against An. fluviatilis and An. sundaicus. Under dense shade, no vegetation grows near the edges of the. Stream so that the current takes away mosquito larvae and renders them more susceptible to predation by fish, (Lindsay & et al, 2004).

3.2.5. Vegetation clearing

Clearing of vegetation has been used to control An. balabacensis in Sabah and may have an effect on An. minimus that prefers larval habitats along the edges of streams in the shade. Alternatively large-scale clearance of forest may result in increases of An. minimus. In general clearing of vegetation removes resting places for outdoor sheltering mosquitoes and increases water evaporation contributing to a reduction in breeding sites. On the other hand, such exposed sites may favour other vector species. Planting trees with high water requirements, such as Eucalyptus rousts, can also help reduce surface water, (Lindsay & et al, 2004).

3.2.6. Water pollution

Pollution of water has been used as a deliberate method for the control of An. fluviatilis and An. maculatus in India and Malaysia. Vegetations such as grass clippings and other vegetable composition added to water to increase anaerobic decomposition that can deter some mosquitoes from laying eggs. This procedure may favour some culicine mosquitoes, by increasing biting locally. Pollution with industrial waste is clearly not an option because of the damage to the environment and human health, (Lindsay & et al, 2004).

4. Integrated vector management

Integrated vector management is a process for managing vector populations in such a way as to reduce or interrupt transmission of disease.

Characteristic features of IVM include

• Methods based on knowledge of factors influencing local vector biology, disease transmission and morbidity.

• Use of a range of interventions, often in combination and synergistically.

• Collaboration within the health sector and with other public and private sectors that impact on vectors.

• Engagement with local communities and other stakeholders;

• A public health regulatory and legislative framework, (WHO 2004-2010).

An IVM approach takes into account the available health infrastructure and resources and integrates all available and effective measures, whether chemical, biological or environmental. IVM also encourages effective coordination of the control activities of all sectors that have an impact on vector borne diseases, including health, water measure, solid waste and sewage disposal, housing and agriculture. Commensurate benefits for non-health-sector partners make it more likely that IVM approaches will be effective. For example, alternate wet/dry (intermittent) irrigation, combined with other vector control methods, has been effective in controlling the vectors of malaria and Japanese encephalitis in China, India, Indonesia and Sri Lanka. It also allows a more economical usage of irrigation water, thereby reducing farmers' costs, (WHO 2004-2010).

Chapter Three

Materials &Methods

Study Design

The study is a retrospective study for assessment of environmental management as method of Malaria Vector control in Khartoum State 2004-2005.

Area of Study

The study was conducted in Khartoum State that lies between longitudes (34.24 east – 31.35 West) and between latitudes (15.9 S - 16.45 N) with a total area of 20.14 Km. The total population in the State is estimated at 5.752.425 million inhabitants .The climate of the State is semi-desert, with maximum temperature reaching as much as 45 C in the hot season (April – July) with average temperature of about 30 C. The rainy season is usually during July and October with high relative humidity (RH) suitable for mosquito breeding and multiplication. The average annual rain fall is 200 mm. In the cool season (November to March) the minimum temperature decreases to 16C in January, with an average of 25C (Ibrahim, 2004). 70% of the people in Khartoum State live in urban areas, 19% in rural areas and 11% are in displaced camps (Ministry of Health, 2005).

Study Population

The study was done among the health officers and Programme leaders of Khartoum Malaria Free Initiative Project. In Khartoum STATE, there are 33 public health officers distributed in seven localities and twenty five mosquito control units affiliated to malaria administration. Each unit is divided into many sectors and has a daily control program in which environmental management is an important component. Assistants and workers contributed in malaria control program.

The leader of malaria program and public health officers was determining:

1. All the types of mosquitoes breeding sites in Khartoum state in report during the years 2004 – 2005, in monthly report Appendix (1). The information in these forms was analyzed monthly to evaluate the effect of the different control measures on larval densities Appendix (4).
2. The position, distribution and types of breeding sites were determined by the use of GIS, Appendix (2).
3. All the methods used for larval control in these sites were identified (chemical, physical, biological and environmental).
4. The efficacy of each method as source reduction was evaluated according to certain interview prepared for these reason, Appendix (3).
5. Larval densities were determined according to WHO measures, (Rozendaal, 1997).

Sample Size

Total coverage leaders and public health officers.

Data Collection

The data in this study was collected from:

1. Records.
2. Observation.

Data analysis

Data analysis was performed using **SPSS** (Statistical Package for Social Science) program version 11.5.

Chapter Four

Results

Results

Table No. (1): The distribution of mosquito control units in Khartoum State:

N=26

Distribution	No	%
Urban	7	28
Rural	8	32
Semi-Urban	11	40
Total	26	100

In this table there are 26 mosquito control units in Khartoum State, 28% of which are urban, 32% rural and 40% semi-urban.

Table No. (2): The respondents views on the best environmental management measures used in Khartoum State, 2004-2005:

N=33

Method of environmental management	No	Respondents view (%)
Intermittent Irrigation	27	81.8
Water Drainage	2	6.1
Removal and Filling of Breeding Places	4	12.1
Others	0	0
Total	33	100

The respondents regarded intermittent irrigation as the best method among environmental methods used for mosquitoes larval control.

Table No. (3): Environmental activities carried out by the community members in Khartoum State, 2004-2005:

N=33

Methods of environmental measured	No	%
Intermittent Irrigation	26	78.8
Water Drainage	3	9.1
Removal and Filling of Breeding Places	4	12.1
Others	0	0
Total	33	100

Similarly, 78.8% of the community members involved in mosquitoes control participated in applying this method in their farms.

Table No. (4): Respondents opinions on obstacles facing source reduction of malaria vector in Khartoum State, 2004-2005:

N=33

Obstacles	No	Respondent's opinion (%)
Limited financial , moral& political support	16	48.5
Un-sustainability of control measure	8	24.2
Acceptability of community	0	0
Limited response to voluntary work	2	6.1
Limited level of people awareness	7	21.2
Total	33	100

The respondents regarded financial, political and moral support as major obstacles that face source reduction method of mosquitoes control which lead to un-sustainability of this control measure.

Table No. (5): Promotion of community involvement in mosquitoes source reduction of malaria vector in Khartoum State, 2004-2005:

N=33

Suggestions	No	Respondent's percentage (%)
Raise awareness of people	29	87.8
Motivate volunteers	4	12.2
Sustainability	0	0
Encourage community participation	0	0
Total	33	100

The respondents suggested raising of public awareness and motivation of volunteer as tools to encourage community involvement in mosquitoes source reduction activities.

Table No. (6): Respondents views on environmental management as source reduction of malaria vector in Khartoum State, 2004-2005:

N=33

Respondent view on environmental management	No	Respondents view (%)
Excellent	10	30.3
Good	19	57.6
Moderate	3	9.1
Un-successful	1	3
Total	33	100

Most of the respondents consider environmental management as source reduction for mosquitoes control in Khartoum State.

Table No. (7): The measures of control of mosquito breeding sites in Khartoum State, 2004:

No	Potential breeding places	Places inspected by workers	Breeding places found	% of breeding places	Mosquito species		Mosquito densities	
					Cu	An	cu	An
1	Broken Pipes	816283	21695	2.7	15881	7739	6	4
2	Houses	1277126	3381	0.3	3066	388	6	3
3	Agricultural Blocks	7919977	902151	11.4	768924	148888	7	4
4	Construction Ponds	166030	2797	1.7	2692	210	6	3
5	Rain & River Pools	355988	6015	1.7	4307	2329	6	4
6	Brick Factories	146513	3164	2.2	2122	1453	5	4
7	Swears	656483	27727	4.2	26500	2251	7	3
8	Cisterns	186100	1325	0.7	984	444	5	3
9	Private&Puplic Building	2180868	17781	1	16708	1406	7	3
10	Public Gardens	88679	800	o.9	731	105	5	7
11	Cesspits (Animal farm)	616122	7313	1.2	7237	110	6	5
12	Water Kiosks	64508	84	o.1	78	23	4	3
13	Others	1324694	7613	0.6	7302	1077	6	3
Total		**15799371**	**1001846**	**0.9**	**856532**	**166423**	**6**	**4**

Table No. (8): The measures of control of mosquito breeding sites in Khartoum State, 2005:

No	Potential breeding Places	Places inspected by workers	Breeding places found	% of breeding places	Mosquito species		Mosquito densities	
					Cu	An	cu	An
1	Broken Pipes	943850	25414	2.7	19863	6636	7	7
2	Houses	1027611	2690	0.2	2474	296	5	3
3	Agricultural Blocks	12204639	1042089	8.5	936965	166704	7	5
4	Construction Ponds	49843	1331	2.7	1298	59	5	3
5	Rain & River Pools	561531	9835	1.8	5548	4845	6	4
6	Brick Factories	219047	2204	4.9	1619	694	5	4
7	Swears	867307	42697	0.1	35637	1360	7	4
8	Cisterns	172512	1145	0.7	905	353	5	3
9	Private&Puplic Building	3935854	21849	0.6	20094	2379	7	4
10	Public Gardens	121430	1548	1.3	1475	114	5	3
11	Cesspits	541653	5058	0.9	5051	39	6	2
12	Water Kiosks	138257	870	o.6	615	335	4	2
13	Zaraib (Animal farm)	266399	527	0.2	488	89	5	3
14	Water Sabeel	946964	320	.03	255	74	3	1
15	Others	1648421	48517	2.9	42804	907	6	4
Total		**23645318**	**1206094**	**5.1**	**1075091**	**35250**	**5**	**4**

The measures of control of mosquito breeding sites in the years 2004-2005 in Khartoum State are shown in table No. (7) & (8) respectively. The measures of control of mosquito breeding site in the State were found to be the irrigated agricultural projects of the State.

Table No. (9): Breeding sites & mosquitoes larvae densities in agricultural irrigated projects in Khartoum State, 2004-2005:

	YEAR		Total
	2004	2005	
Breeding places Inspected	7919977 39.3%	12204639 60.7%	20124616 100%
Breeding places found	902151 79.7%	1042089 20.3%	1132304 100%
Culex SPP collected	768924 45.1%	936965 54.9%	1705889 100%
Culex larval density	7	7	-
Anophline SPP collected	148888 47.2%	166704 52.8%	315592 100%
Anopheline larval density	4	5	-
Total	9739940 41.8%	14350397 58.2%	23278401 100%

There was a significant increase of mosquitoes breeding places in agricultural irrigated projects, in the year 2005 compared to 2004, (P>0.05). This resulted in an increase in the densities of both Culex & anopheline larvae in Khartoum State during 2005.

Table No. (10): Breeding sites & mosquitoes larvae densities in broken water pipes in Khartoum State during 2004-2005:

	YEAR		Total
	2004	2005	
Breeding places Inspected	816283 46.4%	943850 53.6%	1760133 100%
Breeding places found	21695 46.1%	25414 53.9%	47109 100%
Culex SPP collected	15881 44.4%	19863 55.6%	35744 100%
Culex larval density	6	7	-
Anophline SPP collected	7739 53.8%	6636 46.2%	14375 100%
Anopheline larval density	4	7	-
Total	861598 46.4%	995763 53.6	1857361 100%

Also, there was a significant increase in mosquitoes breeding places resulting from broken pipes in the year 2005, which gave significant increase in larval densities of both Culex & anopheline in Khartoum State during 2005 compared to 2004.

Table No. (11): Breeding sites & mosquitoes larvae densities in rain & river pools in Khartoum State during the season 2004-2005:

	YEAR		Total
	2004	2005	
Breeding places Inspected	355988 20.2%	561539 79.8%	1760133 100%
Breeding places found	6015 37.9%	9835 62.1%	15850 100%
Culex SPP collected	4307 43.7%	5548 56.3%	9855 100%
Culex larval density	6	7	-
Anophline SPP collected	2329 32.5%	4845 67.5%	7174 100%
Anopheline larval density	4	7	-
Total	368639 38.8%	581767 61.2%	950406 100%

The result showed that rain & river pools were significantly higher in mosquito breeding places in the year 2005, which led to significant increase in the densities of both Culex & anopheline compared to 2004, ($P < 0.05$).

Table No. (12): Breeding sites & mosquitoes larvae densities in man-made places in Khartoum State during 2004-2005:

	YEAR		Total
	2004	2005	
Breeding places Inspected	6122107 36.1%	10805909 63.9%	16928016 100%
Breeding places found	88059 44.3%	110589 55.7%	198648 100%
Culex SPP collected	72040 43.7%	93799 56.3%	165839 100%
Culex larval density	6	7	-
Anophline SPP collected	14544 52.3%	13253 47.7%	27797 100%
Anopheline larval density	4	7	-
Total	6296750 36.4%	11023541 63.6%	17320291 100%

The results showed that man-made places were significantly higher in mosquito breeding places in the year 2005 compared to 2004, mainly in Culex species ($P < 0.05$).

Table No. (13): Comparison between breeding places & mosquitoes larvae densities in agricultural projects, man-made places and rain & river pools in Khartoum State 2004-2005:

Types of breeding sites	YEAR		Total
	2004	2005	
Anopheline breeding places of agricultural scheme	148888 14.7%	166704 13.8%	315592 28.5%
Anopheline breeding places of rain & river pools	2365 0.2%	4845 0.4%	7210 0.6%
Anopheline breeding places of man-made places	13253 1.3%	14544 1.2%	27797 2.5%
Total number of Breeding places	1001843 45.4%	1206595 54.6%	2208438 100%

During this study, the densities of Anopheline mosquitoes increased significantly in all types of mosquito breeding places in the year 2005 when compared to 2004, ($p<0.05$) .

Table No (14): Percentage of dryness in agricultural schemes in Khartoum State 2004-2005

Year	Number of agricultural Blocks	Number of dried of agricultural blocks	%
2004	375992	358146	95.3%
2005	380928	357486	93.8%

Table No. (15): The repairing of broken pipes in Khartoum State, 2004-2005

Year	Total number of broken pipe	Number of repaired pipes	%
2004	201732	30908	18.9%
2005	242652	32854	13.5%

Table No. (16): The percentage of demolished construction ponds in Khartoum State, 2004-2005:

Year	Total number of construction ponds	Number of construction ponds demolished	Demolishing (%)	Number of sites	
				Cu	An
2004	4260	1456	34%	2692	210
2005	3104	2957	95%	1298	59

Table No (17): Percentage of cisterns repaired in Khartoum State 2004-2005:

Year	Total number of cisterns	Number of cisterns repaired	%	Number of Breeding places		%
				Cu	An	
2004	**716**	**0**	**0%**	**3042**	**1043**	**0.7%**
2005	**941**	**809**	**85.9%**	**905**	**353**	**0.1%**

The dry day practice applied in agricultural schemes, the repairing of broken pipes, the repairing of cisterns and the demolishing of construction ponds have played an important role in reducing mosquito breeding places in Khartoum State. The results were shown in table No. (14), (15), (16) and (17).

Chapter Five

Discussion

Discussion

Larval control was an effective method of controlling malaria prior to insecticide era (1930-1950) when malaria control depended mainly on mosquito larval control. This study revealed that, the potential breeding places in Khartoum State include broken pipes, houses, irrigated agricultural blocks, construction ponds ,rain & river pools, brick factories, sewers, cisterns, private and public buildings, public gardens, cesspits, water kiosks, Zariab (animal farms), water sabeel and others. Similar potential breeding sites were listed by WHO,(2002).

The study showed that the most important breeding places in Khartoum State are the irrigated agricultural projects (11.4%) in 2004 & (8.5%) in 2005.The same finding were reported by Ahmed (2005). It is known that agricultural environments provide conditions well suited for anopheline breeding, with clear, temporary water bodies coinciding with the time of crop cultivation, and human and animal hosts at flying range of mosquito. Clearing of land for agriculture opens up breeding habitats for heliophilic vectors, whereas "informal" smallholder farming systems located near natural water sources, such as streams and rivers, open up vector breeding opportunities, ***(Georghiou, G.P, 1990).*** Also, the study indicated that there was significant increase in breeding places in agricultural irrigated projects during 2005 compared to 2004, ($P>0.05$). Similarly a significant increase in mosquito larval densities in other man-made breeding sites (broken pipes, public garden, ect) was observed in the year 2005 compared to 2004. This might be due to expansion in new residential areas in Khartoum State such as Dar Alsalam & Mayo. Also it might be due to the increase in defective network of drinking water pipes in the State.

The results showed that the environmental management activities such as intermittent irrigation, maintenance of broken pipes have a significant effect in reducing mosquito breeding places in 2004. When those activities decreased in 2005 the mosquito breeding places increased in those breeding site in 2005. As for activities such as maintenance of cisterns and demolishing of construction ponds, which increased in 2005, the results showed a decrease in mosquitoes breeding places in those sites significantly when compared to that of 2004. The annual rainfall was higher in 2005 and this might has added to the availability of the breeding sites in the State (rain pools), as observed by Ahmed (2005). A good coverage for the breeding places in Khartoum State in the form of intermittent irrigation, insecticides treatment of breeding places, demolishing construction ponds, repairing of broken pipes and cisterns, were reducing breeding sites in Khartoum State.

Eighty one point (1% of the respondents) considered intermittent irrigation as the best method to be used in environmental management for mosquito control in the State. It is evident that, in this method the community of the farmers is the main stakeholder. The farmers in Khartoum State received intensive training on mosquito control as part of the activities of KMCP. This form of Farmer Field School (FFS) has one of the most impressive track records in participatory community approaches **(*Sanchez Pedro*, *2005*).** Such training was given to farmers in Asia and Central America where 2–3 million farmers were graduated on the agricultural subject of Integrated Pest Management (IPM) during the past 15 years ***(Braun et al, 2006).***

The Farmer Field School is a form of education which uses experiential learning methods to build farmers' expertise**, *(Pontius etal, 2002).***That might be the reason for 78.8% of the farmers to participate in intermittent irrigation. The most common mosquito larval control method used in Khartoum State is integrated pest management (IPM) method as indicated by the respondents (93.3%).The respondents indicated that the major obstacle facing environmental management in Khartoum State is the limited financial, support. Although Sudan was included in Roll Back Malaria initiative (Lindsay et al, 2004) and is receiving considerable support, the magnitude of problem is very huge and need more financial support from Sudan government to bring the problem under control.

Fifty seven point (6%of the respondents) believed that environmental management is the best method for mosquito larval source reduction. This agrees with policy made by Khartoum Malaria Control Program regarding the control of malaria vectors in Khartoum State.

Chapter Six

Conclusion

Recommendations

Conclusion

Most of breeding places in Khartoum State reported in this study were man-made. Environmental management is sufficient in the new buildings and cisterns, but low in the agricultural scheme and broken pipes due to lack of awareness of people.

Recommendations

1. Encouraging environmental management programmes for controlling malaria vectors in Khartoum State.
2. Strengthening of legislations to improve environmental management in KMCP.
3. Intersectoral collaboration in management of water problem between related sectors such as Water Corporation and Ministry of Agriculture are important in source reduction.

Chapter Seven

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Appendixes

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Appendix No (1)

N	Potential breeding places	Places inspected by workers	Breeding places found	% of breeding places	Mosquito species		Mosquito densities	
					cu	An	cu	An
1	Broken Pipes							
2	Houses							
3	Agricultural Blocks							
4	Construction Ponds							
5	Rain & River Pools							
6	Brick Factories							
7	Sewers							
8	Cisterns							
9	Private&Puplic Building							
10	Public Gardens							
11	Cesspits							
12	Water Kiosks							
13	Zaraib (Animal farm)							
14	Water Sabeel							
15	Others							
16	Total							

بسم الله الرحمن الرحيم

جامعة الخرطوم

كلية الصحة العامة وصحة البيئة

مرفق رقم (2)

بيانات التعرف الجغرافي لأماكن توالد البعوض

محافظة:..............محلية:............حي:.............قطاع رقم:............

م	نوع المكان	اسم صاحب المكان	بئر	حوض			مواسير	بلاعة	صهريج	أكشاك	كماين	مصارف	براميل	حفر	مستنقعات	مشاريع	اخر	ملاحظات
				مباني	زراعي	للشرب												

اسم القائم بالعمل : ــــــــــ التوقيع: ــــــ التاريخ: / /2008م

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Appendix No (4)

Daily report of field check:

Date… **Area: ………………**

No	Location	Inspected number	Positive breeding places	Types of breeding		Density of breeding	
				Cu	An	Cu	An

Cu = Culex.
An = Anopheles.