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MOSQUITO (DIPTERA: CULICIDAE) AS A BIOINDICATOR OF ENVIRONMENTAL HEALTH AND DISEASE OUTBREAK

[Nyamuk (Diptera: Culicidae) Sebagai Bioindikator Kesehatan Lingkungan dan Kejadian Luar Biasa Penyakit]

Sugeng Juwono Mardihusodo
Department of Parasitology Faculty of Medicine
Center for Environment Studies
Gadjah Mada University, Yogyakarta
sugengjuwono42@yahoo.com

Abstract

Quality of public health is greatly influenced by a lot of environmental factors, especially biotic factors among wich is a group of haematophagous mosquitoes (Diptera: Culicidae) showing high competence as disease vector(s). The vector mosquitoes belong to different species of different genera: *Anopheles, Aedes, Culex,* and *Mansonia*. In hypersensitive individuals, mosquito bites may induce pain and itching on the skin where the mosquito suck blood, allergic dermatitis leads up to dermatosis, even persistently, causing nuisance. Through the mosquito bites, man may risk to being infected with pathogens causing Malaria, Dengue Haemorrhagic Fever (DHF), Chikungunya, Japanese Encephalitis (JE), and Lymphatic filariasis, specifically in areas where the mosquito-borne disease (MBD) is (are) endemic. Survival of a mosquito vector species of disease vector is much dependent on its environment, mainly on the availability of a number of suitable habitats for its preadult stages, larvae and pupae. Number, type and size of the larval habitats as well as quality of water in the mosquito breeding places apparently determine rates of survival and density of the mosquito breeding in it which generally positively correlate with the increase of the MBD transmission. Therefore, mosquito mainly a disease vector could be used as one of the bioindicators of environment health and its significant increase in density is predictive of the probable occurrence of a MBD epidemic in a community living in an endemic area.

Key words: mosquito, biotic environment, bioindicators, mosquito-borne disease, epidemics, environmental health

Abstrak

Kualitas kesehatan masyarakat sangat dipengaruhi oleh banyak faktor lingkungan, di antara fakor-fakor itu adalah sekelompok nyamuk hematofagosa yangs angat berkompeten sebagai vektor penyakit. Nyamuk vektor penyakit termasuk banyak spesies dari genera Anopheles, Aedes, Culex dan Mansonia. Pada individu-individu yang hipersensitif, gigitan nyamuk bisa menimbulkan nyeri dan gatal-gatal di kulit tempat nyamuk menggigit dan mengisap darah itu, berupa dermatitis alergika sampai dermatosis, bahkan mungkin juga menyebabkan stress dan rasa jengkel yang berkepanjangan. Lewat gigitan nyamuk, manusia berisiko terinfeksi dengan patogen penyebab Malaria, Demam Berdarah Dengue (DBD), Chikungunya, Japanese Encephalitis (JE) dan Filariasis limfatik. Keberlangsungan hidup nyamuk vektor penyakit sangat bergantung kepada lingkungannya, terutama kepada tersedianya habitat-habitat yang cocok untuk stadia pradewasanya, larva dan pupa. Jumlah, Tipe dan ukurah serta kualitas air tempat perkembangbiakan nyamuk secara nyata menentukan laju kelangsungan hidup dan densitas

nyamuk yang berkembangbiak di habitatnya itu yang umumnya berkorelasi positif dengan kejadian dan peningkatan penularan penyakit bawaan nyamuk (PBN). Karena itu, nyamuk yang vektor penyakit bisa digunakan sebagai salah satu bioindikator kesehatan lingkungan dan peningkatan densitas nyamuk yang sangat nyata, serta bisa digunakan sebagai bioindikator untuk prediksi kejadian luar biasa (KLB) PBN pada masyarakat yang tinggal di wilayah endemik.

Kata kunci: nyamuk, lingkungan biotik, bioindikator, penyakit bawaan nyamuk, kejadian luar biasa, kesehatan lingkungan

INTRODUCTION

Background. Mosquito (Diptera: Culicidae) of medical importance is a group of insect that belongs to Tribus Anophelini and Culicini with a number of species classified in the genera *Anopheles, Culex, Aedes, Mansonia, Coquilettidia, Psorophora, Haemagogus* and *Sabethes* (Service, 1996). They may affect human health due to their preference for biting and sucking human blood. Certain species of anopheline and culicine mosquitoes, apart from their significance as pests they may also inoculate dangerous pathogens while feeding on human blood. Such mosquito-borne diseases as malaria, Dengue Haemorrhagic Fever (DHF), and Lymphatic filariasis with elephantiasis. up to the present time still constitute public health problems in many parts of the world, including Indonesia (WHO 1998; Abednego and Suroso, 1998). In the ongoing Twenty First Century, malaria and DHF seem to be on the increase in their incidence and prevalence, due to their mosquito vector survival and abundance are closely related to the dynamics of global ecological or environmental changes (Mardihusodo, 1999). The physical changes of landscapes, chemical aquatic medium of pre-adult stages of the mosquitoes, hydrological and climatological factors, as well as biotic factors such as vegetations, and vertebrate animals which serve as the mosquito's blood source, greatly influence directly the dynamics of vector population, and indirectly the dynamics of MBD transmission. The ongoing global warming, El Nino, La Nina, ozon layer depletion, deforestation, huge irrigation development project, mining openings without good reclamation, all affect human health including the increased MBD incidence (Mardihusodo, 1999).

Rational. MBDs, notably malaria and DHF, more frequently produce epidemics in a certain season during the year compared to the other MBDs along with the changes of environmental variables. Endemicity status and epidemics of DHF, for example, are greatly influenced by their epidemiological components (Pant and Self, 1993): (a). human or people (in terms of density, demographic composition, behaviour, socio-economy, immunity status); (b) Dengue virus (type, virulence); (c) environment (climatology, larval habitats in case of their number, type and distribution of the water containers, and (d) mosquito vetors (*Aedes aegypti* and *Ae. Albopictus)* that respectively serve as the main vector and co-vector. The incidence of DHF being common on the increase in an endemic area seems to be correlated with the rainy season. Such situation is thought to be in correspondence with the significant increase in the number of the natural breeding places of *Ae. albopictus* mosquito outdoors, such as banana leaves and other plant axils, bamboo stumps, and others, which have the potentials to contain water whenever the rain is coming.

The status of endemicity and epidemic occurrence of malaria, being analogous with DHF, are closely related with the following epidemiological component (Bruce-Chwatt, 1985). Human acting as the donor of malaria parasites, or gametocyte carrier, or as the intermediate host of malaria parasites; (b) the causative agent, malaria parasite that is *Plasmodium* (*P. falciparum, P. vivax, P. malariae* and *P. ovale*); (c) mosquito vector, female

anopheline mosquito which is anthropophylic, acting as the final host of the malaria parasites, and as vector transmitting sporozoites of the plasmodium to human, and (d) environmental factors, that include physical, hydrological, climatological and biotic factors. The biotic factors include vegetations where the mosquitoes, male and female, take a rest outdoors, vertebrate animals and human as the blood source of the anopheline mosquitoes, and also include the human population or community in the aspects of immunity to malaria infection, demography, behaviour, and socio-economic (Bruce-Chawatt, 1985).

Environmental factors are well recognized as the main determinants of health status; in malaria, taken as an example, the factor greatly influence the other epidemiological components: human, mosquito vector, and the disease agent (Bruce-Chwatt, 1985; Mardihusodo, 1999). Therefore, for the control of MBDs, the intervention on the environmental factors, for example in the locality point of breeding place of a certain mosquito species of disease vector with a friendly environmental approach is one of the many applicable methods to drop of the vector population. As an example of that is the programme on Dengue control through the practice of mosquito source reduction in Indonesia (called "Pemberantasan Sarang Nyamuk/ PSN) by launching large campaign at a national scale. The habitats of *Aedes* larvae are urged to be eliminated in order that the actions could reduce the *Aedes* population, thus reduce the disease transmission and subsequently disease incidence.

Learning from the understanding on MBD control based on their epidemiology respectively, changes of parameter on one or integration of a number of epidemiological components which is (are) significant as disease determinant(s), could be used as indicator of disease occurrence or outbreak.

Problem formulation. Based on the epidemiological background of MBDs, with DHF and malaria as the examples, the mosquito vectors which play the main role on the disease transmission, moreover in an episode of disease outbreak, seem to be the appropriate bioindicator of environmental health status and predictive to possible occurrence of a disease outbreak.

Objective. The objective of this paper writing is to present an descriptive analysis and theoretical discussion on that subject matter, to come to a conclusion and offer some recommendation.

DISCUSSION

Bioindicator. In the comment sense, a bioindicator is a plant or an animal the presence, abundance and health condition of which reflects or indicate general condition of its habitat (Anonym, 2005) including the occurrence (incidence) of a related disease inflicting the biotes as well as human. It is already well known that environment is the major factor that affect health status of a community dwelling in a certain area (Blum, cited in Slamet, 2004). In another word, the decrease of environmental health status of a certain housing, for example, due to degradation of the environment will indirectly influence the health status of the community living there. For MBDs affecting human, apparently transmitted by mosquito, in the concept of bioindicator, mosquito vector whether infected or not infected with a certain pathogen at a certain time, can be categorized as bioindicator.

In case of MBDs, the presence, abundance and population fluctuation of the disease vector indicate condition (perhaps also type) of the larval habitat of the vector that play important role in the disease transmission. For DHF as the example, the presence and increased population of *Ae. aegypti* as well as *Ae. albopictus* in a certain community dwelling at a certain time found during an entomological surveillance indicate the presence of water containers in the housings that may prove positive for the *Aedes* larvae either indoors or outdoors and the underlying factors influencing. Such situation warrants to possible conse-

quent, e.g. Dengue outbreak.

Because of the presence of reversal relationship between health status of the environment and that of human, thus disease occurrence (incidence) in human could be used as the bioindicator of the environmental health status (Cook *et al.*, 2004). In case of MBDs, pathogens infecting human naturally must be through mosquito bites which serve as the competent vector of the pathogens, e.g. malaria, which is endemic in a certain area through bites of certain species of *Anopheles* mosquito.

The environmental health that is also called as ecosystem health or ecological health is greatly influenced by human activities (Cook *et al.*, 2004). Human activities on development project or land-use change, for example, may result in the increase of vector population and subsequently in the increase of transmission and spread of the MBDs. The presence of mosquitoes, specially confirmed as disease vectors, and their increasing density, that increase the mosquito-pathogen-human contact (entomological inoculation rate/EIR) can be used as the bioindicator of the poor environmental health or health sanitation. Taken as example is, the presence and abundance of *Culex quinquefasciatus*, one of the house mosquitoes in a certain urban area could be used as a bioindicator that in the area there are many stagnant waters in small ditches or water canals, due to arbritarily disposing organic garbage materials by the local people, or others. The presence and increased population of *Ae. aegypti*, e.g. House Index (HI) is more than 10, or Breteau Index (BI) is more than 50, can be used as the bioindicator of poor environmental health due to the presence of many permanent water containers in the houses polluted with *Aedes* larvae, where the people will be at a risk of suffering a dangerous ravage of DHF. Thus, the presence and abundance of *Ae. aegypti* can be used as the bioindicator or even predictor of possible DHF outbreak in a certain public housings moreover Dengue virus proves to be circulating not only in human but also in the *Aedes* mosquito.

Changes in the global and regional environmental factors such as global warming may be related to climatological changes in many parts of the world which is very difficult to predict accurately, and may produce an impact on many environment-related disease. More so any change in environmental factors in a specific locality such as changes in land-use, drastic environmental changes due to development projects, increased urban population and people mobility among cities and countries, changes in life-style and behaviour of the people living in endemic areas, result in different health impacts on the occurrence and spread of the MBDs. Changes in environmental variables result in either direct or indirect health impacts on human as the host of the pathogenic agent and the mosquito or vector. Thus, human health is frequently dependent upon environmental variables operational in nature, including mosquitoes, as one of the biotic environmental factors of human. The significant increase of vectors from time to time means that the environmental health surroundings is poorer and poorer. The environmental health is environmental condition with complex subfactors which at a certain level raise certain probability supporting the optimization of the human health status, or, even conversely, to inhibit improvement of the human health status or to drop it off.

An environment with the presence and persistently high density of mosquito vectors is apparently considered as not healthy, because such condition increase increase the risk of transmission of pathogens infective to human. Apart from high density, the vectors may increase in their activities on biting human due to in the increase of the air temperature and relative humidity. Number of people being bitten by the mosquito vectors may be increasing in a certain area due to increased birth rate or people immigration or the number of immigrants exceed the number or the emigrants.

Mosquito as a bioindicator of ecosystem health or ecological health seems to be appropriate and fulfill one of the criteria of measurable bioindicators as described in more detail

by Rapport *et al.* (1986). The need for bioindicator and its development including that is prescribed by Rapport et al. (1986) has been emphasized its importance by Burger and Gochfeld as cited by Cook et al. (2004) in the terms of the following criteria.

Bioindicators in general should fulfill 4 main criteria: (1) applicable for integrated evaluation of ecologic health and public health; (2) readily measurable and understandable its meaning; (3) cheap and easy to practice, and (4) easy to be guidance for the executives and readily memorized, and gain support by the public. Disease incidence or occurrence may be used as indicator due to such indicator fulfill 4 criteria of a bioindicator, but there is still lacking for a certain point. That lacking may lie on a number of probabilities, for instance, the possibility that there are many procedures in the research methodology, in collection of data, including data on new cases the criteria of which may be false negative or false positive. Disease incidence bioindicator in a community as described by Cook *et al.* (2004) is potential for being used in the early warning system (ESW) and also usable in identification and decision making for disease intervention based on the ecologic health.

It is, however, recognized that mosquito as a bioindicator is not as popular as that of disease incidence. Out of 4 criteria of the needs of a bioindicator, only criterium 1 is fulfilled, added with many facts that the presence and abundance of mosquitoes (vectors) and the increase in vector population , as that of the increase of disease incidence, mosquito bioindicator is relevant to degradation of the ecosystem. However, it would be already late, if the incidence bioindicator in an epidemic situation, taken DHF or malaria as the examples, whenever applied in real situations like that, that is the use of environmental management for vector control, it is apparently late. In such situation, mortality and sufferings of the people affected have been already ongoing to the peak of the epidemics!. Therefore, surveillance on mosquito presence and density with methods that fulfill the criteria high sensitivity, high specificity, high validity, and high reliability should be used either as the bioindicator of environmental health or predictor of an epidemic.

Taken as an example is Breteau Index (BI) in DHF vector surveillance. BI is a number obtained from number of water containers positive for *Aedes* larvae per 100 houses surveyed. BI shows the presence and abundance or density of Aedes mosquito, thus it is potentially used as the bioindicator of DHF. Pant and Self (1993) proposed a general guide the indices with interpretations as the followings (Table 1).

The six bioindicators as proposed by Pant and Self (1993) cited above are based on many, repeated entomological measurements matched with the presence and level of disease incidence

Table 1. A number of entomological parameters with its interpretation in relation to potential in Dengue transmission

Entomological Parameter	Interpretation in Relation to Dengue Transmission
1. Breteau Index (BI) > 50	High risk
2. Breteau Index (BI) < 5	Low risk
3. House Index (HI) > 10%	High risk
4. House Index (HI) < 1%	Low risk
5. Biting rate (BR) > 2 per man hour	High risk
6. Biting rate (BR) < 0.2 per man hour	Low risk

Note: BI = number of water containers positive for *Aedes* larvae per 100 houses surveyed
HI = number (%) houses surveyed with water containers positive for *Aedes* larvae.
BR = number of *Aedes* mosquito found biting human bait, in average, per hour

in many parts of the world, so that in term of bioindicator development they do not fulfill all criteria proposed by Burger and Gochfeld (Cook *et al.*, 2004).

Similar situation is the same with malaria. Entomological bioindicator which involves mosquito vector, *Anopheles* sp., for example by using EIR (entomological inoculation rate) as described by Onori and Grab (1980) it is sufficiently difficult to obtain the entomological data periodically although only for a unit endemic area. That is because for calculation of EIR (h') the entomological data on number of mosquito biting human for one night ($m.a$ where m is number of a mosquito species biting a human bait per hour, while a is number of human bitten by a species of mosquito per night), gametocyte rate ($g.x$), duration of sporogonic cycle in one species of vector (n), and daily survival rate (p). Such numbers are absolutely needed to obtain EIR data mathematically as formulated as the following: $h' = m.a^2.g.x.p^n / a.g.x - \ln p$.

Result of h' calculation and its data components is more or less difficult to understand and to be memorized by the executives or decision makers, as well as by the community members. The result seems to be more important to entomologists who assist planners of control programme of malaria, and to consultants or expert committee of the Department of Health or, at lower level, of the provincial health office.

Integration of bioindicator of disease occurrence and entomological bioindicators and multiple approaches for the intervention of ecosystem is applied in Dengue and malaria control. For DHF, the presence of various serotypes of Dengue virus (virDen) inter-endemic areas in the tropical countries (Thongcharoen *et al.*, 1993), and for malaria that spreads differently in accordance with its different vector species distribution (Mardihusodo, 1999), both show poor health level of the ecosystem.

In case of vector control of either DHF or malaria, intervention based ecosystem is frequently overlapping either in local, regional or global level. In a local level, vector control through source reduction directed to controllable containers (water bath basin, etc.), and/or disposable containers (unused old tyres, etc.) in public housings. In regional level, drainage of small water canals, to eliminate mosquito breeding places, that may include that of *Aedes*. In global level, a lot of effort is directed to lessen the impact of global warming, whenever it is not successful, the raising air temperature in the earth will greatly influence abundance and biting activities of mosquitoes including vectors of DHF and malaria.

CONCLUSION AND RECOMMENDATION

Out of descriptive analysis and discussion above it is concluded that:

(1) Mosquito larva is a biological pollutant of hydrological environment, thus mosquito can be considered as a bioindicator of the environmental health; its significant increased abundance will risk to public nuisance and annoyance;

(2) Mosquito vector can be used as bioindicator of the environmental health, and its significant increase in density will risk to disease transmission subsequently to disease outbreak subsequently leading to disease.

Out of the conclusions it is recommended as the following:

(1) Entomological parameter specifically for malaria, that is highly sensitive, specific, valid and reliable, should be used as the bioindicator of environmental health status;

(2) The presence and abundance of mosquito, in general, should be used as bioindicator of disease vector should be used as bioindicator of possible disease occurrence and packed in the early warning system, especially for DHF and malaria.

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REFERENCES

Abednego, H.M, Suroso, T. 1998. Mosquito-borne diseases: status and control in Indonesia. National Seminar on mosquito-borne diseases by molecular approaches. Yogyakarta: Center for Tropical Disease, Gadjah Mada University.

Anonym, 2005. World Factbook: Notes and definitions. Bioindicators. Central Inteligence Agency, Washington DC.

Bruce-Chwatt, L.J. 1985. Essential Malariology, 2nd edit. ELBS/William Heinemann Med Books Ltd: London. .....

Cook, A., Jardine, A., Weinstein, P. 2004. Commentary. Using human disease as a guide to multilevel ecosystem interventions. Envir. Health Perpect .112(11): 1143-1146.

Mardihusodo SJ. Malaria: Status kini dan pengendalian nyamuk vektornya untuk abad XXI. (*Malaria: Recent status and control of its vector for the 21st Century*).Pidato Pengukuhan Jabatan Guru Besar pada Fakultas Kedokteran. UGM Yogyakarta. (Professorship oral speech at The Faculty of Medicine in Medical Parasitology, Gadjah Mada University, Yogyakarta).

Onori, E, Grab, B. 1980. Indicators for forcasting of malaria epidemics. Bull. Wrld Hlth. Org. 58: 91-98.

Pant, C.P. and Self, L.S. 1993. Chapter 8. Vector ecology and bionomics. In: P. Thongcharoen : Monograph on Dengue/ Dengue Haemorrhagic Fever. Regional Pub SEARO No. 22. New Delhi: WHO SEARO.

Rapport, D.J, Begier, H.A, and Hutchinson, T.C. 1986. Ecosystem behaviour under stress. Am. Nat. 175: 617.

Service, M.W. 1996. Medical entomology for students. Chapman & Hall: London.

Slamet JS. 2004. Kesehatan lingkungan (Environmental Health). Gadjah Mada University Press: Yogyakarta.

Thongcharoen, P., Wasi, C., and Puthawathan, P. 1993 Chapter 7. Dengue viruses. In: : P. Thongcharoen : Monograph on Dengue/Dengue Haemorrhagic Fever. Regional Pub. SEARO No. 22. WHO SEARO: New Delhi.

WHO Director-General. 1998. The World Health Report 1998. Life in the 21st Century. A vision for all. WHO: Geneva.