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Inhabitants' Knowledge on Mosquito Proliferation and Control in the Wetland Ecosystem of Wadi Gaza, Gaza Strip, Palestine

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Abstract: The wetland ecosystem of Wadi Gaza is a major source of mosquitoes (Diptera: Culicidae) in the Gaza Strip due to its water content that comes from different sources including wastewater. Local inhabitants usually complain from mosquito proliferation and ask the responsible parties for urgent solutions. The escalating situation in the study area promoted the conduction of this study, which aims at documenting the inhabitants' knowledge on mosquito proliferation and control in the wetland ecosystem of Wadi Gaza, Gaza Strip. One hundred and twenty people (N=120) were selected randomly to fill a questionnaire especially designed to conduct the current study. The findings of the study showed that most participants (85.0%) ranked stagnant wastewater as the main cause of mosquito proliferation and the emission of offensive odors that affect the life of Wadi Gaza residents. Of the study population, 72.5% linked mosquito proliferation to many of the prevailing diseases in the area, of which fever, skin rashes and inflammations and itching were a part. To control mosquitoes and to avoid their biting at the personal level, several means with variable scores were reported to include burning mats, light traps, indoor insecticides, mosquito bed nets (Namosiah), window and/or door wire screens, and self-hygiene. Some people limit their outdoor activities after dark during peak mosquito seasons. At the public level, mosquito control means included the spraying of kerosene and pesticides, burning and clearing of vegetation around the wetland ecosystem, and burial and desiccation of stagnant water pools in the area. As far as the use of the biological control agent "*Bacillus thuringiensis israelensis"* (Bti) is concerned, 57.5% of the participants demonstrated their knowledge on its use and sometimes on its efficacy. Only 20.0% of participants ensured their attendance to different health and environmental awareness campaigns concerning mosquitoes and their associated health problems. Finally, the authors recommend the different parties to coordinate their efforts to further alleviate the problem of mosquito proliferation and to find suitable control

methods. The conduction of educational and awareness health programs to all levels of the Palestinian society is highly recommended.
Key words: Mosquito proliferation, mosquito control, wetlands, Wadi Gaza, Gaza Strip, Palestine

معرفة المواطنين بانتشار و مكافحة البعوض في النظام البيئي الرطب لوادي غزة، قطاع غزة - فلسطين

ملخص: يعتبر النظام البيئي الرطب لوادي غزة مصدرا رئيسا للبعوض (Diptera: Culicidae) في قطاع غزة بسبب أن محتواه المائي يأتي من مصادر متعددة تشمل المياه العادمة، حيث يشكو السكان المحليون عادة من انتشار البعوض و يسألون المحافل المسئولة لوضع حلول عاجلة. لقد شجع الوضع المتفاقم في منطقة الدراسة على عقد هذه الدراسة التي تهدف إلى توثيق معرفة المواطنين حول انتشار و مكافحة البعوض في النظام البيئي الرطب لوادي غزة في قطاع غزة، حيث تم اختيار 120 مواطنا (N=120) بشكل عشوائي لتعبئة استبانة صممت خصيصا لهذا الغرض. أوضحت نتائج الدراسة أن معظم المشاركين (85.0%) اعتبروا أن المياه العادمة الراكدة هي السبب الرئيس لانتشار البعوض و انبعاث الروائح الكريهة التي تؤثر على حياة المواطنين في وادي غزة، كما و ربط 72.5% من عينة الدراسة بين انتشار البعوض و الأمراض الشائعة في المنطقة التي تتضمن الحمى و طفح و التهابات الجلد و الهرش. على المستوى الشخصي، تم خلال الدراسة تسجيل عدة طرق لمكافحة البعوض و تجنب عضه بدرجات متباينة لتشمل أقراص البعوض الكهربائية و المصائد الضوئية و المبيدات الحشرية المستعملة داخل البيت و ستائر النوم (الناموسيات) و الشاشات السلكية الشبكية في الأبواب و الشبابيك و العناية الذاتية. يلجأ بعض الناس أيضا لتقييد نشاطاتهم خارج البيت في الليل خلال الفصول المثلى لانتشار البعوض. أما على المستوى الشعبي فقد شملت طرق المكافحة رش الكيروسين و المبيدات و حرق و إزالة النباتات المحيطة بالنظام البيئي الرطب لوادي غزة و كذلك ردم و تجفيف برك المياه الراكدة في المنطقة. أبدى 57.5% من المشاركين معرفتهم باستخدام المكافحة الحيوية لمشكلة البعوض بواسطة النوع البكتيري (*Bacillus thuringiensis israelensis*, Bti) و أحيانا حول فاعليته، كما أكد 20.0% من المشاركين حضورهم لبرامج توعية بيئية و صحية حول البعوض و المشاكل الصحية المتعلقة به. ختاما، يوصي الباحثون بضرورة تنسيق الجهود بين المحافل المختلفة لتخفيف مشكلة انتشار البعوض و لإيجاد طرق مناسبة لمكافحتة، كما يوصون بشدة على ضرورة عقد برامج صحية تعليمية و توعوية حول البعوض و مشاكله لكافة شرائح المجتمع الفلسطيني.

الكلمات المفتاحية: انتشار البعوض، مكافحة البعوض، الأراضي الرطبة، وادي غزة، قطاع غزة، فلسطين.

1. Introduction

Although ecosystems with their variable biodiversity provide indefinite values to human beings [1, 2, 3, 4, 5], some still have the capacity to harbor disease-infecting agents such as microbes, parasites and insects like mosquitoes, which may pose harmful impacts on humans. Such impacts may include nuisance, bites, transmission of diseases …etc. [6, 7, 8, 9].

As far as natural and constructed wetland ecosystems are concerned, they contain both aquatic and terrestrial environments, which generate high biodiversity [10]. However, they seem to be a major shelter for annoying and feral animals and pests [11] especially the families of higher Diptera [10]. Mosquitoes (Diptera: Culicidae) are the most entomofauna in wetlands that are usually regarded as negative by humans because they can cause nuisance and transmit diseases [11, 12, 13]. The aquatic nature of wetlands provides good microhabitats for larval growth and production. Walton [12] pointed out that the emergent macrophytes of wetlands have been associated with high levels of mosquito production. In addition, these dense stands of emergent vegetation reduce the effectiveness of mosquito control agents by inhibiting the penetration of aerial or water-based applications of standard larval mosquito control agents. Removal or burning of dense vegetation stands and the use of petrol derivatives and pesticides for mosquito control also have negative impacts on the total environmental and ecological integrity of wetland ecosystems through pollution and species decline or even disappearance [11, 12]. The proliferation of mosquitoes in such ecosystems is usually accompanied by intensive use of pesticides to minimize risks of mosquito-borne diseases and this further pollutes the environment and may have adverse health impacts [14, 15]. In endemic malarious areas of Venezuela where *Anopheles aquasalis* is the main vector, the control of mosquitoes seemed very difficult and more expensive due to the vast areas the wetlands cover [16].

Personal protection to minimize risk of mosquito-borne diseases using different tools or methods could achieve good results and hence it should be promoted [15]. For example, the use of a kerosene oil lamp to vaporize transfluthrin (a volatile pyrethroid insecticide) gave 50-75% reduction in mosquito biting in Dar es Salaam, Tanzania [17]. Moreover, Sharma and Ansari [18] pointed out the role of burning neem oil in kerosene for providing personal protection from mosquito bites in Delhi, India. The use of insecticide-treated nets for personal protection against malaria vector *Anopheles* mosquitoes was applied in many countries and gave good results as well [19, 20, 21]. Biological control techniques for mosquito proliferation in wetlands seemed safer using various mosquitofish species including

Gambusia spp. and the bacterium *Bacillus thuringiensis israelensis*, which is commonly referred to as Bti as shown by many studies [11, 22, 23, 24, 25, 26]. The Bti is a bacterium found naturally in soils. Since 1982, it has been used successfully worldwide as a biological pest control agent to combat mosquitoes and blackflies [23]. Although Bti has been proclaimed to be relatively highly specific, some studies showed that some non-target organisms are affected either by single or repeated Bti treatments [7].

Mosquitoes are very important vectors and ectoparasites for humans and animals. They are by far the most important of the blood sucking arthropods worldwide. They are found throughout the world except the Antarctic. About 3,450 species of mosquitoes have been described worldwide [27]. They serve as intermediate hosts in the transmission of 4 important human diseases: Malaria; yellow fever; dengue and filariasis [28]. Among these diseases, the death rate caused by malaria is quite high. Currently, an estimated 2,073 million people living in 103 countries are at risk of malaria [29]. In 1950s, the Lake Hula of Palestine and its surrounding wetlands were drained partly to reduce the risk of malaria transmitted by mosquitoes [30]. Ornithophilic mosquito species, predominantly of the genus *Culex* are principal vectors of West Nile virus in the Old World [8, 31]. Especially in recent years, the distribution space of both mosquitoes and mosquito-borne diseases has been changing and expanding for reasons such as increasing rates of environmental corruption, climatic changes, vector and pathogen resistance to insecticides and drugs, progressive urbanization and population movement [32, 33, 34].

The literature on mosquitoes is extensive and the following general description of mosquito ecology is based on a number of references [27, 35, 36]. Mosquitoes undergo complete metamorphosis; they go through four distinct stages of development during a lifetime. The four stages are egg, larva, pupa and adult. The full life-cycle of a mosquito takes about a month. Mosquito species can lay their eggs on the water surface (e.g. *Culex* or *Anopheles* species) or on moist soil that is subsequently flooded (e.g. *Aedes* or *Ochlerotatus* species). These eggs hatch within 24-48 hours releasing larvae that are commonly called "wrigglers" because they are usually seen wriggling up and down from the surface of the water. The larvae are truly aquatic and feed mainly on bacteria, algae, protozoa and detritus. However, larvae of the genus *Ochlerotatus* are predacious and feed on other insects. The mosquito pupa is also aquatic and, in contrast to pupae of many other insects, rather mobile. The adults finally leave the aquatic habitat and occupy the terrestrial environment. Mating occurs shortly after adult emergence. In most mosquito species, females need a blood meal to complete development of eggs, but in some species (e.g. in the genus *Ochlerotatus*) females produce eggs without blood intake. Most mosquito species take blood primarily from mammals (including humans) or birds, but some bite reptiles, amphibians, or even fish. The need for a blood meal is accompanied by an elaborate host-seeking behavior as well as dispersal. As an energy source for flight, both female and male mosquitoes are dependent on plant nectar.

Work on mosquitoes in terms of survey, proliferation, disease transmission and control using various methods is intensive and extensive worldwide. This was apparent from the magnitude of literature surveyed. However, the scientific handling of the subject in the Arab countries seemed not sufficient and discrete. Of the 12 mosquito species identified recently in Lebanon, *Culex pipiens* was the most common species collected indoors and outdoors [37]. In Egypt, *Culex* species were the most common among mosquito species surveyed in some Egyptian governorates. Similar to mosquitoes of Lebanon, *Culex pipiens* was the most common species identified in Egypt [38]. However, the biological activities of *Bacillus thuringiensis* isolates in Egypt were pathogenic to both field and laboratory strains of *Culex pipiens* [39]. Amr *et al.* [40] reported the presence of 19 species of anopheline and culicine mosquitoes in northern Jordan and the Jordan Valley. The use of some insecticides to control adult females of the mosquito *Culex pipiens molestus* was effective in the Amman area of Jordan [41]. In Sudan, the prevalence and transmission of malaria seemed to be very high particularly in the aftermath of seasonal flooding where *Anopheles arabiensis* was the most malaria vector encountered in different localities of Sudan including Khartoum [42, 43]. Rainfall was the significant climatic variable in mosquito proliferation and transmission of malaria, whereas heavy rainfall was found to initiate epidemics in Sudan [44]. In the Kingdom of Bahrain, the low level of vector breeding spots with *Anopheles* mosquito suggests low potential of local malaria transmission [45].

Work on mosquitoes in the Palestinian territories seems to be unclear and not specific. Denotes to people complains from mosquito proliferation in the Gaza Strip were associated with wastewater-laden ecosystems such as the Beit Lahia wastewater treatment plant and its huge effluent pond in North Gaza [46] and Wadi Gaza [1, 47, 48]. In spite of the current attention made by the local, regional and international parties to Wadi Gaza and its wetland ecosystem, the environment of the system is deteriorating day by day in an alarming rate and fashion. This situation causes pollution to soil and groundwater resources and imposes public health risks to neighboring inhabitants such as mosquito proliferation and prevalence of intestinal parasites [49, 50]. Although there was no malaria transmission, public surveys showed that mosquitoes represent the major nuisance in Wadi Gaza [1, 47]. No studies were performed in neither the Gaza Strip nor Wadi Gaza on mosquito survey, proliferation and control prior to this study. Hence, this is the first study to be conducted in the area, which aims at documenting the inhabitants' knowledge on mosquito proliferation and control in the wetland ecosystem of Wadi Gaza, Gaza Strip.

2. Methodology

2.1. Study Area

Wadi Gaza is considered the biggest in Palestine, if the Jordan Valley is excluded. It springs from the Negev Mountains and the Southern Heights of Hebron City. Its catchment or drainage area is about 3500 km^2 [51]. The total length of the Wadi is 105 km from its source to its end. The final portion of the Wadi, which lies in the Gaza Strip, extends 9 km from the Truce line in East Gaza to the coast where it discharges into the Mediterranean Sea. The width of the Wadi varies from one place to another, and is widest near its mouth where it reaches about 100 meters. It is bordered in the north-west by the Mediterranean Sea, the south-east by Al-Bureij Camp, the south-west by Al-Nuseirat Camp, and the north by Al-Zahra City (Figure 1). The total population of Wadi Gaza area was estimated to be 10,000 people in 2001 and it will jump to more than 14,000 people in 2010 as indicated by the Project for the Conservation of Wetland and Coastal Ecosystems in the Mediterranean Region - MedWetCoast [52].

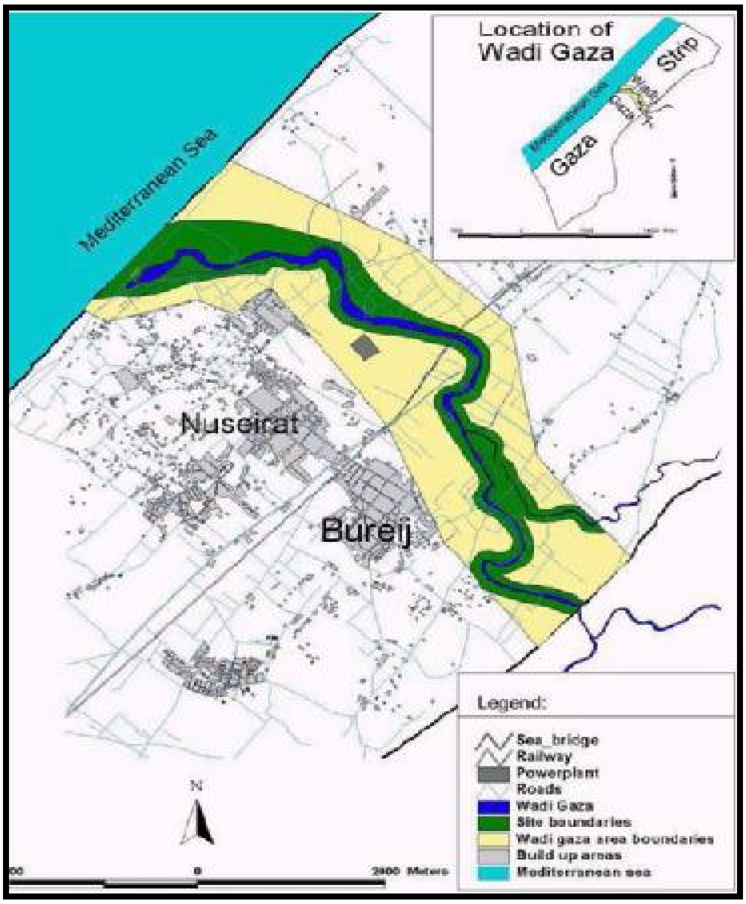

Figure 1: Wadi Gaza area and site boundaries

The wetland ecosystem of Wadi Gaza, which covers 10.14 hectares, is unique in coastal Palestine and has many ecological values [1, 2, 3, 52]. The water table of the aquifer at the wetland intersects with the topography and emerges at the surface. The amount of groundwater feeding the wetland ecosystem is estimated to be from 65,000 to 81,000 m^3 [53]. Another source of freshwater supplying the wetland ecosystem is storm water that accumulates during the rainy season. Untreated wastewater is discharged in Wadi Gaza and hence its wetland from the adjacent residential masses [48]. The total quantity of this wastewater ranges between 5000-7000 m^3 per day. In recognition of its importance as a natural area and as the only coastal wetland in Palestine, Wadi Gaza was declared as a nature reserve in June 2000. Wadi Gaza is historically rich in its biodiversity. The aquatic and semi-aquatic nature of the system attracts avifauna and other biodiversity elements [1, 54, 55, 56, 57] including invertebrates and as a result, the system could provide ecotourism and recreation values to interested parties [1, 58]. However, the current situation of pollution of the Wadi Gaza by both solid wastes and wastewater and the proliferation of annoying pests including mosquitoes have reduced its attractiveness and use for recreation (Personal Communication).

2.2. The Study Design

The total population of Wadi Gaza area was estimated to be 10,000 people in 2001 and it will jump to more than 14,000 people in 2010, and about 50% of the population are refugees [52]. The study design comprises two methods; questionnaire application and field observations. From this population, 120 people were selected randomly to fill a questionnaire especially designed to conduct the current study. The draft questionnaire was validated by experts in the fields of environmental, health and biological sciences. The questionnaire was piloted and modified as necessary. Most of the people interviewed were either native-born or had been living in the vicinity of Wadi Gaza for more than 10 years. All meeting interviews were conducted *face to face*. The interviews were conducted with local people while practicing their normal activities in the study area. Local municipalities' workers who were usually engaged in cleaning activities and spraying of gasoline and pesticides in the wetland to combat mosquitoes were also involved in the questionnaire filling. The questionnaire included questions related to personal profile of the respondents, knowledge on the mosquito problem and control in the wetland ecosystem of Wadi Gaza. Mix of yes/no; multiple choice and open-ended questions were included in the questionnaire [59]. During the survey, the investigator explained to the respondents any questions that were not clear to them. Field observations included meetings with local people and surveying the field for mosquito control-related activities. This method permitted the surveyors to obtain endless information that enrich the study. It is worth mentioning that Wadi Gaza inhabitants were cooperative during the succeeding stages of this study. Many photos were taken to document the situation on site. Finally, data obtained were computer analyzed by descriptive statistical method using SPSS/PS (Statistical Package for the Social Sciences Inc, Chicago, Illinois) program version 11. Graphs were plotted using Microsoft Excel program version 6.

3. Results

3.1. Personal Profile of the Sampled Population in Wadi Gaza

Table 1 illustrates the personal profile of the sampled population (N=120) in Wadi Gaza, Gaza Strip. The age frequency showed that 58.3% of the respondents were 21-40 years old. The majority of the interviewed people (76.7%) were married while 20.8% were single. Eighty (87.0%) of the married people have children. Analysis of the educational status of the participants showed that 31.6% had university or diploma degree, 42.5% had finished secondary school, 17.5% had finished preparatory school, 4.2% had passed primary school, and only 4.2% were illiterate.

Table 1: Personal profile of the study population (N=120)

Variable	No.	%
Age distribution (year)		
≤20	5	4.2
21-30	33	27.5
31-40	37	30.8
41-50	28	23.3
>50	17	14.2
Marital status		
Single	25	20.8
Married	92	76.7
have no children	12	13.0
have children	80	87.0
Widowed	1	0.8
Divorced	2	1.7
Educational status		
Illiterate	5	4.2
Primary school	5	4.2
Preparatory school	21	17.5
Secondary school	51	42.5
University or diploma degree	38	31.6

3.2. Proliferation of Mosquitoes in Wadi Gaza

Health problems are usually associated with wetlands and neglected areas rich in wastes including primarily the liquid wastes. In case of Wadi Gaza Nature Reserve, the problem of mosquitoes and other annoying insects is getting worse and worse. This was clear from the verbal and nonverbal expressions of the interviewed people. Table 2 showed that stagnant wastewater was ranked by most participants (85.0%) as the main cause of the proliferation of mosquitoes and the emission of offensive odors which affect the life of Wadi Gaza residents. Other causes were ranked by participants but with low scores such as the solid wastes (2.5%), trees and shrubs surrounding the wetland ecosystem of Wadi Gaza (2.5%) and the lack of sanitation and self-hygiene (1.7%). However, 8.3% of participants had multi-answers where they selected many factors contributing to mosquito proliferation in Wadi Gaza. 72.5% of participants linked the proliferation of mosquitoes to many of the prevailing diseases in the area, of which fever, skin rashes and inflammations and itching were a part. Although malaria is absent in the Gaza Strip, as many as five participants claimed that mosquitoes transmit malaria to Wadi Gaza inhabitants.

Table 2: Proliferation of mosquitoes in Wadi Gaza

Variable	No.	%
Factors contributing to mosquito proliferation in Wadi Gaza		
Stagnant wastewater	102	85.0
Garbage and solid waste	3	2.5
Trees, shrubs and herbs	3	2.5
Lack of public hygiene	2	1.7
Multi answer	10	8.3
Relation between common diseases and proliferation of mosquitoes		
Yes	87	72.5
No	33	27.5

3.3. Personal Protection Measures Against Mosquitoes in Wadi Gaza

Protection from mosquitoes can be attained in several ways in Wadi Gaza. At the personal level, 35.8%, 32.5% and 9.2% of respondents demonstrated that they used burning mats and light traps, indoor insecticides and mosquito bed nets (*Namosiah*) respectively to control mosquitoes or to avoid their biting (Table 3). In spite of that, many participants who used to use bed net when sleeping said that we are sill bitten from mosquitoes … we do not know how? Complains of participants are very painful; they usually cry, "*Mosquitoes eat us up every night*". Participants who used burning mats and light traps to control mosquitoes claimed that this method is safer than the application of pesticides, which may pollute the indoor environment and cause health problems. Only few participants (6.7%) ranked self-hygiene as a control means for mosquitoes. The rest of respondents used other preventive techniques including window and/or door wire screens to limit the entrance of mosquitoes and other arthropods into their houses. Screens are usually constructed of various metals or plastic and they are tight-fitting over window openings. Other choices were also mentioned in separate discussions with local people inhabiting the area of Wadi Gaza. They avoid mosquitoes through limiting their outdoor activities after dark during peak mosquito season. People who must be outdoors wear long sleeves and long pants to physically limit mosquito biting. Furthermore, few people tried to use mosquito repellents to avoid biting. They claimed that these creams could be harmful to human health specially children.

Table 3: Personal means for mosquito control in Wadi Gaza

Variable	No.	%
Personal protection measures against mosquitoes in Wadi Gaza		
Insecticides	39	32.5
Burning mats and light traps	43	35.8
mosquito bed nets (*Namosiah*)	23	19.2
Self and public hygiene	8	6.7
Others	7	5.8

3.4. Public Means for Mosquito Control in Wadi Gaza

With regard to mosquito control in Wadi Gaza, many public means were used. At the public level, 81.7% of the sampled population indicated that the local municipalities were the principal bodies for mosquito control in Wadi Gaza. Other mosquito control bodies including the Ministry of Health, Environment Quality Authority (EQA), Non-governmental Organizations (NGOs) and local commissions have marginal roles in solving the problem in question. However, many people were said to cooperate in the control of mosquitoes. At Al-Nuseirat, the municipality sprayed kerosene and burnt the vegetation on the banks of the wetland at Wadi Gaza. Table 4 showed that 47.5% and 40.8% of the sampled population indicated that petrol derivatives and pesticides respectively were the main means used for mosquito control in Wadi Gaza. Other means including public hygiene principles, burial and desiccation of stagnant water pools and vegetation and waste clearing were also practiced in Wadi Gaza but in small scales. The nature of the wetland ecosystem of Wadi Gaza and the various means used to control mosquitoes there were photographed and are illustrated in figure 2.

In the last couple of years, a new method of mosquito control; notably biocontrol (biological control) was adopted in Wadi Gaza by the use of Bti. When asked about what does the term “biocontrol” mean?, only about one-fifth of the participants defined it in a way that could be scientifically accepted, and some were able to give examples. Table 4 showed that 57.5% of the participants demonstrated that they knew about Bti use in Wadi Gaza and some participants were uncertain about its effectiveness. They claimed that the Bti use was effective in the first year of application, but after that

the effectiveness was debatable among Wadi Gaza inhabitants. The researchers took a photo while a worker was applying the Bti to control mosquito larvae in wetland ecosystem of Wadi Gaza in April 2005 (Figure 2).
Finally, when asked about their attendance of awareness courses or campaigns regarding mosquito control in Wadi Gaza area or in other localities of the Gaza Strip, only 20.0% of participants indicated that they attended such courses in the clinics of the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA), governmental and non-governmental institutions and agencies (Table 4). They mentioned that they were given brochures and booklets discussing various health issues among which were mosquitoes and mosquito-transmitted diseases.

Table 4: Control of mosquitoes in Wadi Gaza area

Variable	No.	%
Who controls mosquitoes in Wadi Gaza?		
Local municipalities	98	81.7
Ministry of Health	6	5.0
Environment Quality Authority	4	3.3
NGOs and local committees	8	6.7
others	4	3.3
Methods used for mosquito control at public level		
Pesticides	49	40.8
Petrol (oil) derivatives	57	47.5
Public hygiene	5	4.2
Burial and desiccation of water pools	5	4.2
Others	4	3.3
Knowledge of mosquito control using the bacterium Bti		
Yes	69	57.5
No	51	42.5
Reception of awareness courses on mosquito control in Wadi Gaza		
Yes	24	20.0
No	96	80.0

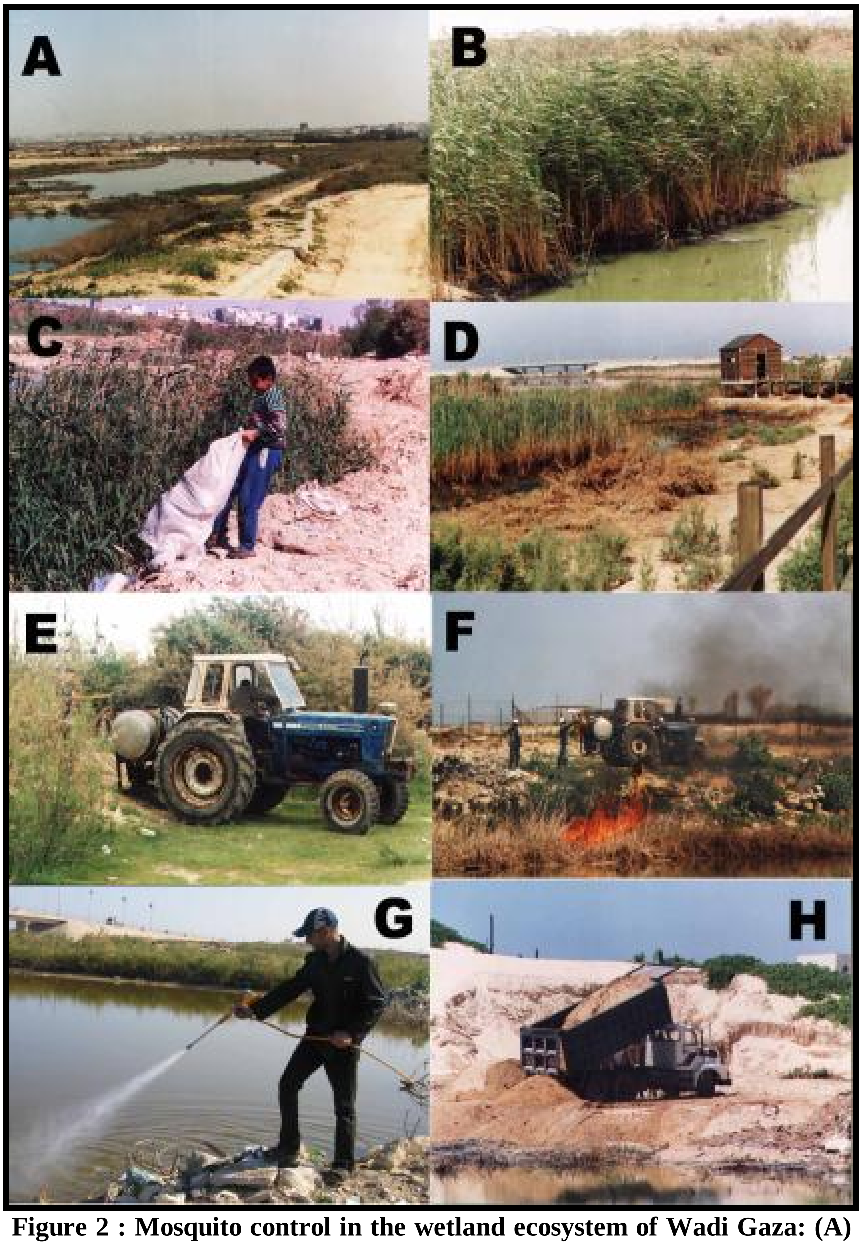

Figure 2 : Mosquito control in the wetland ecosystem of Wadi Gaza: (A) Parts of the wetland ecosystem of Wadi Gaza, (B) Monostands of *Phragmitis australis* in the wetland, (C) Solid waste disposal in Wadi Gaza, (D) Clearing of *Phragmitis australis* in the wetland, (E) Spraying of oil derivatives and pesticides to combat mosquitoes, (F) Burning of vegetation to control mosquito proliferation in the wetland (G) Spraying of Bti to combat mosquito larvae and (H) Burial of great parts of the wetland ecosystem of Wadi Gaza

4. Discussion

The study showed that 91.6% of the respondents finished the intermediate level of education, while 4.2% were totally non-educated (Table 1). These results illustrate that the education level of the respondents is generally good, which means that over 90% of the interviewed people can read and write. This of course will help in any training courses or campaigns to be held in the future aiming at dealing in a responsible manner with the different environmental health risks associated with Wadi Gaza including mosquito-related issues. Such results are normally expected in the Palestinian society as a whole, since the majority of the Palestinians in Gaza are educated due to the political, social and economic pressure prevailed during the last 4-5 decades.

The proliferation of mosquitoes (Diptera: Culicidae) seems to be in strong correlation with wetlands and aquatic ecosystems where the larvae play an important role as filter-feeders [11, 12, 16] and the problem exacerbates in ecosystems where raw sewage is drained as figured out by most participants of Wadi Gaza who admitted that the huge quantities of raw sewage drained to Wadi Gaza course promote mosquito proliferation. This was confirmed by studies, which indicated that discharging of raw municipal wastewater into shallow vegetated wetlands can result in mosquito larval abundance higher than discharging primary or secondary pretreated wastewater [12]. The larval and pupal stages of the mosquito life cycle are aquatic and it is only the adult mosquito that is regarded as a pest. Adult female mosquitoes require a blood meal in order to obtain the necessary protein required to produce a large numbers of eggs (usually between 100 – 500 eggs) [11], and for this reason Wadi Gaza inhabitants usually complain from mosquitoes and their biting that may produce fever, skin rashes and inflammations and itching symptoms.

At public level, petrol derivatives and pesticides were ranked by most participants as the favorite methods for mosquito control in Wadi Gaza. Vegetation clearance or burning was mentioned to happen intermittently as well. These control techniques may impose health problems on the wetland ecosystem as many wildlife species are very sensitive to pesticides and vegetation clearance [12, 60, 61]. With regard to emergent macrophytes of wetlands, there was an association between these plants and the high levels of mosquito production. However, the dense stands of emergent vegetation were found to reduce the effectiveness of mosquito control agents by inhibiting the penetration of aerial or water-based applications of standard larval mosquito control agents [12]. Although the mosquitofish (*Gambusia spp*.) was commonly introduced and reared in freshwater ponds and wetlands to biologically control mosquitoes worldwide [11, 12, 62], it is not used in case of the wetland ecosystem of Wadi Gaza. Instead, the Bti is used as the biological control method. Breakdown of the function of the mosquito's gut epithelium is the primary cause for the lethal action of the Bti. Field efficacy of Bti has been demonstrated in many countries and most impressive results were obtained in West Africa where this microbial larvicide has been included in a large field program to control blackflies, the vector of river blindness [63].

The results of the current study showed that more than half of the participants knew about the Bti use in Wadi Gaza for mosquito control. They claimed that the application of Bti was effective in the first year, and then it was ineffective. The ineffectiveness of Bti use in the second year of application in the wetland ecosystem of Wadi Gaza was attributed by most inhabitants to the long period of time the Bti load stayed at the checkpoint between the Gaza Strip and Israel as the quantity was imported from Israel at times of total closure to the occupied Palestinian territories. This justification by local inhabitants seems to be of low consideration because the formulation of Bti products usually contains spores that are tolerable to wide ranges of environmental conditions. On the other hand, the lack of resistance to Bti by mosquito larvae could be ensured since laboratory attempts to induce resistance by continual exposure to Bti have generally failed to detect resistance [64]. According to Becker and Margalit [65], the lack of resistance development to Bti could be due to its complex mode of action, involving synergistic interaction between up to four proteins. The effect of other aquatic organisms on the efficacy of Bti could not be ignored. Becker *et al.* [66] pointed out that the competition in food intake by filter feeding *Daphnia curvirostris* resulted in lower mortality of mosquito larvae after Bti applications. Inoculum and host density may also play a role in Bti efficacy. As demonstrated with many host systems, the higher the host density, the greater the Bti dose required to kill [66]. The wetland ecosystem of Wadi Gaza is very polluted with different pollutants that seem to affect the efficacy of Bti application. According to Becker and Margalit [65] again, organic pollution apparently results in less Bti being ingested, resulting in reduced efficacy. Essen *et al.* [67] revealed that the presence of soil significantly reduced larval mortality, probably by assisting sedimentation and unavailability of Bti.

Despite of some improvement in primary health care, water supply services, sewerage systems and sanitation conditions, the Gaza Strip and the study area are still suffering a high proliferation of mosquitoes and a prevalence of a diverse spectrum of intestinal parasites. Therefore, coordinated efforts are needed to further alleviate this problem; of which educational and awareness health programs and campaigns to all levels are highly recommended.

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