

Novel malaria control by strategic net-hoisting with S/O channel/grip devices

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Abstract

Background. Hoisting of netting screens with battens on windows/vents suffers from unsightly gathering of dust and allergens, which may provoke respiratory diseases and therefore lack popularity as a mosquito/malaria control tool. Furthermore, installing them in high-rise buildings can be cumbersome and risky. An S/O channel/grip device was, therefore, conceived to eliminate impediments to screening windows/openings in houses.

Methods. Thin sheet metal strips were transformed into s-shaped channels. The lower ends provided for attachment to buildings while the upper ends allowed net attachments with O-rubber pipes. Effectiveness was ascertained by applying these to screen a room against adult *Anopheles* and *Aedes* mosquitoes. Net hoisting/de-hoisting periods were measured for windows at various locations, and opinions of bystanders were obtained.

Results. The device maintained a firm grip of metal, fabric or natural nets placed on them. Over a 7-day period, 1036 mosquitoes could not enter rooms protected by either the novel or the traditional methods. Placement/removal of nets with the new device on experimental windows had a mean of 4.5/1 min, respectively, with all the nets intact, hence being reusable; whereas the traditional method had a mean of 4.25/8.75 min with all the nets torn/not-reusable. In high-rise buildings, employing ladders/scaffolds to mount nets were unnecessary: period of hoisting/removal on windows was 1 1/2 min irrespective of the location of windows whereas the traditional method hoisting period increased substantially as the height of the window increased.

Conclusion. S/O channel/grip devices can improve mosquito control through screening because it engenders net hoisting on windows that is simple, effective, affordable, accessible and convenient, especially on high-rise buildings. The intact removal and recovery of used nets creates opportunities for cleaning them, retreatment with insecticide, regular maintenance, etc. which underline its potential roles in control of asthma and insect-borne diseases.

1 Introduction

Insect-borne parasitic diseases such as malaria, leishmaniasis, onchocerciasis, and sleeping sickness afflict humans and/or animals around the world. The consequences of these disorders result in reduced economic growth due to losses sustained, lack of effective or dwindling labour force or man hours, high cost of treatment, and rising death tolls, especially in children and pregnant women. The World Health Organization [1] indicates that sub-Saharan Africa bears the brunt of malaria worldwide and loses about one million persons to malaria yearly, or 90% of all global deaths due to this disease. The parasite burden in the region may be associated with cerebral malaria and their neurological consequences [2]. Unfortunately, governments in the region whose responsibility include vector control [3] are inactive - the bane of Sub-Saharan politics. The net result is that basic control measures cannot be enforced or implemented. It is therefore not surprising that, in the region, beyond efforts undertaken by NGOs, everyone is for himself with respect to vector or parasite control. It is therefore appropriate to strengthen vector control by updating everyone

at risk with options that one may choose from.

Literature is replete with the use of bednets, insecticide-treated or untreated [4,5]. Long-lasting insecticide treated nets are recommended to be used as personal protection [6,7]. Unfortunately, uptake of bednet technology has not been universal and with great enthusiasm. In the tropics many people don't like sleeping under bednets because of heat. In parts of Nigeria, people attribute their dislike for bednets to its causing *achubu* (nightmares). In other cases, sleeping under bednets is not feasible such as when a crowd of people sleep in one room or open halls, in churches, or in the open where they sleep on mats [8]. Culture in some parts of Africa does require a number of people to stay and sleep close together during marriages, burials, age-grade and other festivals when sleeping under bednets is impractical.

Placement of insect screening across openings in houses such as windows, vents and eaves are regarded as personal protection measures against vector-borne diseases and constitute an integral part of integrated malaria management [9]. Nets are effective because they physically prevent animal pests from gaining entry into protected spaces on ac-

count of their mesh sizes. The traditional method of placement of these screens, which essentially are of metal, fabric or polypropylene nets, consists of placing them across the required spaces and securing them with wooden battens nailed unto wooden frames or walls. The nets, with time, would rut or rust, gather dust and become laden with mites, spores and other allergens which may provoke allergy, asthma, and other respiratory illnesses. In addition, both wood and net materials degenerate to the extent that spaces emerge between the wooden frame and the battens. Ultimately, the nets are rendered insufficient and useless [10].

Replacements of such nets require that new nets, new battens and nails be purchased. In addition, skilled labour, acquired at great cost, will be required for the removal of old window screening materials and replacement with new ones. In bungalows, such labour is minimal; whereas, in high-rise buildings, such maintenance works are inconceivable because of the enormous labour cost and associated risks in putting scaffolds around the building and moving and manipulating tall ladders. This prevents occupants of such houses from employing any form of screening to prevent mosquito entry into their rooms. A cursory look at windows of high-rise buildings (in Nigeria for instance) confirms the observation that almost all such buildings have no window screens. The few that had them installed when the buildings were constructed now show nets in various stages of decay [10]. Consequently, insect vectors have unlimited access to occupants of such buildings.

Given the foregoing scenario, against a background of increasing urbanization [11] and indoor stay of large numbers of people, predisposition to respiratory and vector-borne diseases rises in areas where slums are increasing. These conditions also favour the breeding requirements of insect vectors and sewer rodents. Apart from increasing the intensities of diseases, which they peddle, they also cause intense irritations, destruction of food reserves and spoilage of foods. They increase the cost of living because additional cost of insecticides, rodenticides and other purchases will have to be met in view of the concurrent increasing pesticide resistance [12]. Some landlords in slum areas in attempt to minimize contact with insect vectors erect buildings nearly or completely devoid of any ventilation thereby exposing tenants to escalating risks of respiratory infections and asthma.

There is, therefore, an urgent need to extend the frontiers of indoor insect screening to occupants of any type of house, whether high-rise or not. This objective connotes that such screening should not only be affordable but also accessible to the rich and poor for wholesome protection of every man or domestic animal within. Such extensions would encourage builders to promote rather than impede ventilation to enhance reduction of allergens inherent in netting materials

fixed for long periods on windows or eaves. In this paper, a novel S/O channel/grip device is introduced and it is demonstrated that when the devices are applied with suitable netting materials, they are as effective as the traditional method of window screening in restraining mosquitoes from entry into protected rooms.

2 Materials and Methods

2.1 Construction of the S/O channel/grip devices

Several male and female dies longer than 240 cm in length were made to yield metal channels in the preferred shape of the letter S. Thin iron sheet metal stock which measured about 120× 240 cm (1mm thick) was marked according to the extent of the shape and size of the letter S. Rectangular pieces were therefore cut off from the main stock. Each work piece was folded along its length with a 9-ton hydraulic press which forced it into the dies to yield the required profile. The lower end of each of the channels was punched with holes for passing bolts, nails or screws for attachment to window frame or wall (Fig. 1). Nets were attached to the upper end of the channels and gripped with O-shaped firm rubber/plastic pipe which had a diameter greater than the internal diameter of that end of the channel such that when forced into place, strapped the net snugly in place (Fig. 2).

2.2 Application of the S/O channel/grip devices

The channels were applied for the protection of spaces in buildings. They were joined end to end to form the perimeter of the respective space (*e.g.* by chamfering the ends at 45°). The ends could be welded together or placed singly end to end and attached to the respective window frame by securing with screws, nails or bolts through the holes provided at the base of the S channels. Un-welded joints were sealed with rubber paste or suitable pieces of foam or cloth materials. Welded S channels, when desired to be placed on windows of high-rise buildings, were each lifted up by means of a rope.

For windows or spaces which exceed 65cm×130cm, crosses between the S channels were made with two iron bars about 2cm parallel to each other with the ends welded onto a strip of metal with projections at either end to permit attachment to the S channel with small bolts and nuts. The nets were borne by a plastic O pipe (with diameter slightly greater than 2cm) in a cul-de-sac manner, such that it opened on the outside (of the room whose window is to be screened). The plastic pipe bearing the nets was forced into the space between the two bars (Fig. 3A). Alternatively,

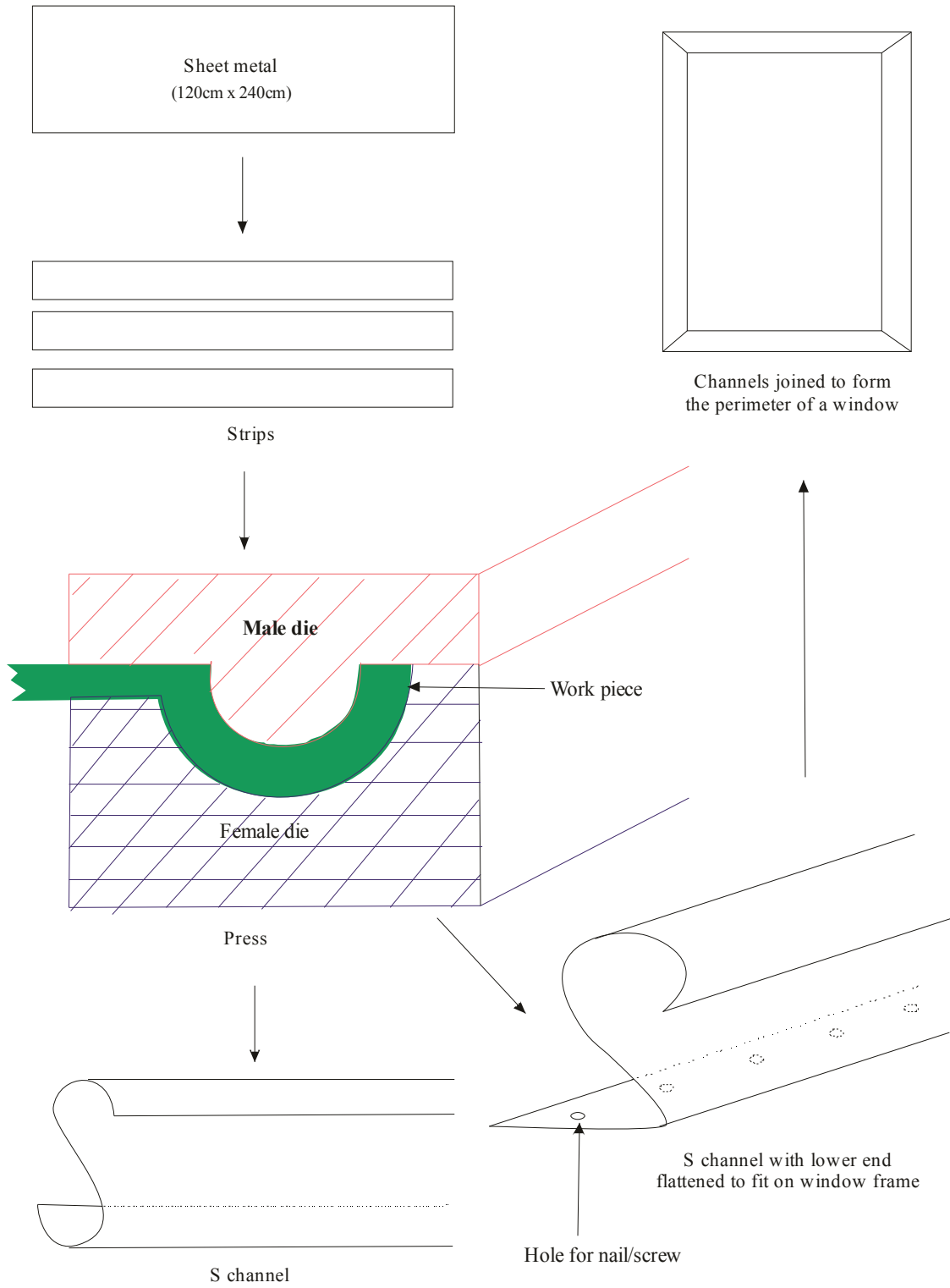


Figure 1. Production of S/O channel/grip device (not drawn to scale).

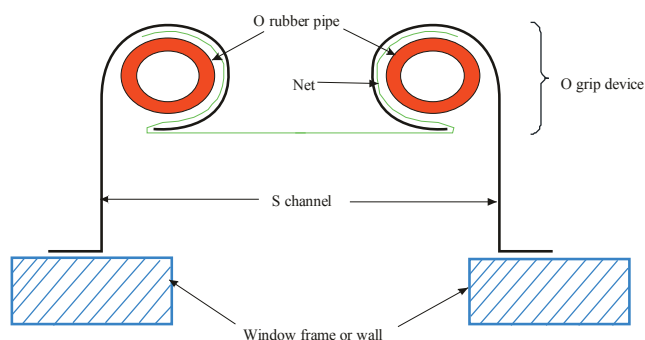


Figure 2. Cross section of S/O channel/grip devices on a single window (65cm×130cm). Note that the O rubber/plastic pipe fits snugly.

crosses of two S/O channels/grip devices could be joined side by side as mirror image of one another (Fig. 3B). Any spaces between the wooden frames and the S channel were closed with rubber paste (Abbo Silicon Sealant).

2.3 Effectiveness of the S/O channel/grip devices

The effectiveness of S/O channel/grip devices was tested by comparing a room of which the windows were protected with nets (100 holes/cm²) and hoisted with the new device with another room protected with the same netting material the traditional way with nails and battens. A house with three sealed rooms with white carpeted floors and 8 identical windows was constructed. The central room had two windows, one each opened into the adjacent room. Glass viewers were provided for the anterior and posterior sides of the breeding room. The rooms at either sides of the breeding room each had 3 extra windows, one on each side, and an entrance that consisted of a cylinder measuring 61 cm (diameter) by 183 cm. One end located inside the room was fitted with nets and a blower while the opposite end opened to the outside. Entry to the rooms was by creeping through the respective cylinder via a lid cut sideways just before the fan. The blowers were put on at least a minute before room entry/exit. Leather shoes and stockings (four pairs/room) worn throughout the day served as mosquito attractant [13] and were placed in each of the experimental rooms and replaced every evening. The placement of the attractants commenced two days after observing adult mosquitoes from the breeding room and was terminated 7 days later.

2.4 Breeding room

Deposits of water from *egba-ite* (earthenware pots lined up at the backyard that serve as water reservoirs, common in Nsukka, Nigeria, and its suburbs) dominated by culicine

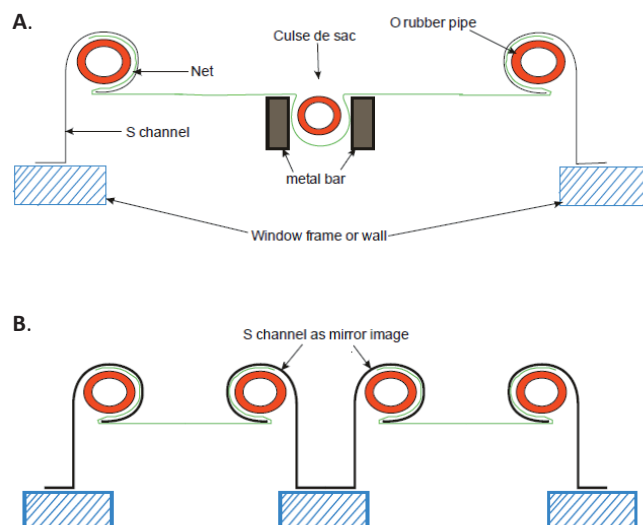


Figure 3. Cross section of S/O channel/grip devices showing arrangement of crosses on windows exceeding 65cm×130cm. A: Arrangement of crosses with metal bars. B: Crosses made with S/O channel/grip devices arranged as mirror image.

mosquito larvae were collected. A few larvae from the deposit (3-5) were placed in a beaker of water and their floating characteristics were used to select anophelines [14]. The larvae were placed into a large bowl in the center of the room. As soon as adult emergence was noted, cotton wool balls soaked in 6% glucose [15] were placed around the bowl with a long stick bearing a small nail at one end to serve as hook to pick/drop the cotton balls. Glucose cotton balls were replaced after 12 hrs. At the end of the experiment, all the openings were closed and pyrethroid based insecticide (Mortein) was sprayed into all the rooms and allowed to act for 20 minutes.

2.5 Installation on windows of a high-rise building

Convenience of the novel channel/grip devices was further ascertained by installing them on 3 windows (each 183 cm×122 cm) on each floor of one arm of a 3-story building following the above procedures. The traditional method was used to also install window nets on the same kind of windows on the other arm of the building. After 3 months the nets were recovered. A total of 33 bystanders' opinions were obtained during that interval of time.

3 Results

3.1 Gripping of various netting material

The upper end of the S channel when applied with a plastic/rubber showed that various netting materials such as silk, voile, cotton, polypropylene, iron and natural nets could fit in well (Fig. 4). Some of the materials like silk, cotton, voile and natural nets would rather tear when deliberately pulled than come out from the grip device showing that the gripping was very firm and likely to resist tugging by wind.



Figure 4. Natural net (from axiles of cocoa-nut tree) hoisted with welded S/O channel/grip device on a window. Note that each piece has a different hole size.

3.2 Hoisting and de-hoisting of net screens

Table 1 shows the time taken to install nets by both the traditional and novel method using identical number and lengths of battens or S/O channels and grip devices all chamfered at 45°. The data indicate that there was negligible difference in hoisting times of both traditional and novel method. However, the mean hoisting time of the traditional method was slightly less. Net recovery was conveniently faster with the novel channel - the average period taken was only a minute with all the nets intact. Removal of nets hoisted with the novel devices was effected with bare hands, with no tools required. On the other hand, the traditional method took an average of 8 minutes and 45 seconds with all the nets damaged and therefore not reusable. Some of the wooden battens were damaged during the net recovery of the traditionally hoisted nets as well. Also, some markings

were left on the wooden frames from scratches made on them with metal pincers.

3.3 Effectiveness of S/O channel/grip devices

No mosquito was seen resting anywhere in the experimental rooms indicating that both methods restricted the entry of insects from both the experimental rooms and from extraneous quarters. At the end of the experiments, after insecticide treatment, no dead mosquito was seen within the two experimental rooms confirming that the novel net hoisting method was equally effective in screening out mosquitoes as the traditional one. In the breeding room, 1036 dead mosquitoes (422 anophelines, 614 aedines) were counted.

3.4 Net hoisting on high rise buildings

The installation speed of the new device and the traditional method tested on windows of a high-rise building encumbered with previously installed glass louvers showed that time spent during installations increased in leaps with height by the traditional method but did not increase significantly with the novel device. The use of the novel devices did not require many hands unlike the traditional one that required increasingly more personnel and other ancillary services with rise in building height (Table 2). Like in the experimental rooms, all the net and the battens recovered in the traditional method were damaged and not reusable. Cost of labour, put at 20 Naira per minute showed that the novel device cost between N220 - N230 for that size of windows irrespective of height of the building; whereas the traditional method would take an average of N160/window for those on the ground floor, N900/window plus cost of hiring ladder, barrow and paying the assistant (usually paid a third of a workman's wage in the locality) for those on the 2nd story and an average of N2560/window for those of the 3rd story plus the cost of paying the assistants, hiring other labour and paying a truck driver.

3.5 Bystander's opinion

The S/O channel/grip devices hoisted windows appeared from the outside as ordinary small metal frame surrounding the perimeters of windows (Fig. 4). They were more noticeable than the traditional ones, an observation confirmed by 87.9% (29 out of 33) of bystanders. All the respondents were unanimous in their preference for the novel channels because they felt it was cheaper on the long run. However if they were to pay and install window net immediately, only 69.7% would apply the channels on the ground floor while 10 respondents (30.3%) said they would use the traditional method because it would be cheaper. On the second floor

Table 1. Time taken to install/remove nets on windows (65cm×130cm) of an experimental house.

Window	Traditional Method with Battens		Novel S/O Channel/Grip Devices	
	Net Hoisting Time [min]	Net Removal Time [min]/State of Net	Net Hoisting Time [min]	Net Removal Time [min] /State of Net
1	4	8 / Damaged	4	1 / Intact
2	4	10 / Damaged	5	1 / Intact
3	4	8 / Damaged	4	1 / Intact
4	5	9 / Damaged	5	1 / Intact

Table 2. Time taken to install/remove window nets (183cm×122cm) on a 3-story building.

Location of window	Traditional method with battens			Novel S/O channel/grip devices		
	Sundry requirements	Mean net hoisting time [min]	Mean net removal time [min]/state of net	Sundry requirements	Mean net hoisting time [min]	Mean net removal time [min]/state of net
1 st Story	Nil	8	15/destroyed	Nil	11.5	2/intact
2 nd Story	1. Ladder	45	65/destroyed	Nil	11	2/intact
	2. Barrow					
	3. An assistant					
3 rd Story	1. Scaffolds	128	148/destroyed	Nil	11	2/intact
	2. Truck					
	3. Loaders					
	4. 2 Assistants					

and beyond, all agreed that the novel S/O channels/grip devices would be the only option.

4 Discussion

Personal activities to reduce host-vector contact include the use of untreated or insecticide-treated nets [16, 17]. A number of investigators reveal that use of bed-nets can be hampered by: poverty [18], what people think the season is [19], insecticide resistance [5], irregularities in re-treating nets, unwillingness by those at risk to use them, especially in hot seasons, when transmission of the parasite is high, and net deterioration with holes [16] to those that have been rendered ineffective by the gaping holes in them. Galvin *et al.* [20] listed some constraints against the use of bednets in the Niger Delta as local beliefs, danger for children's comfort, not satisfying sleeping arrangements, consumption of family space, arduous set up and usage which is made worse when there is electricity failure. Window nets, by their locations on buildings, are relatively far from the human host (as compared to bednets) so do not lend themselves the kind of criticism ascribed to the bednet. For instance, heat or nightmares are not ascribed to window nets in my locality. Hoisting of nets with the new device on windows would offer some respite to some of the above-listed problems because, in addition to its effectiveness as the traditional types, it permits corrective interventions whenever desired: if a hole is observed for instance, the net could be quickly removed for amendment.

The channels allowed nets to be placed and removed without damage to the nets or fabrics quite unlike the traditional method where battens and nets would be destroyed to effect any change. In the traditional method, the frame of the window might be damaged as well during attempts to remove the nails used in fixing nets and batten thereby necessitating use of specialized skilled labour at high cost to accomplish such task. When O pipes were used to strap the nets to the channel or to the crosses, no marks were left on them so the nets will remain intact for many future cycles of hoisting/removal, cleaning, treatment/re-treatment with insecticide. The channel could allow other kinds of attachments. They may be fitted with tiny holes to permit attachment of nets to the channel with threads and needle passed through them. Other options are possible such as the use of an 'Ash Wednesday' clip (u-clip with the two arms perforated by a tiny hole for passage of a securing pin which could traverse both the nets and the S channels). These possibilities are essential in sustaining vector control at the individual level because everyone could apply any appropriate technique convenient whenever required.

Sirinivas *et al.* [21] indicated that people exposed to organic dust experience respiratory diseases like asthma and

acute bronchitis. Reduction of accumulated allergens on nets would be an important outcome of the new hoisting device because at the slightest sign of accumulation of dust, the nets could be removed, washed and replaced thereby keeping aeroallergens below the threshold levels. Moreover, fabrics and nets with finer holes such as those made of silk and voile would trap more dust particles than conventional ones of say 144 holes /inch². Rooms protected this way will certainly contain less aero-irritants than those without or covered with coarser netting materials. This affords the occupants two steps ahead of asthma. First, the allergens in air are prevented from entering the screened room; secondly, the trapped allergens could be safely removed by those who show no reactions to dust thereby protecting those occupants allergic to them. Thus, the novel method obviates the risk inherent in the traditional method where attempt to control malaria creates the risk of respiratory problems.

The channel will open up new possibilities to reduce host-vector contact. There were no additional requirements or differences in the installation times of the new device in high-rise building (Table 2), therefore houses where nets were not usually installed can now do so because it will no longer matter with respect to cost where the space required to be covered is located. That is, expected cost of hoisting net across similar spaces will be the same irrespective of the number of stories of the building. For those living in high-rise buildings to install window nets by the traditional method, the time between decision and implementation could progress to months and years, or may never be installed as commonly observed because of the high cost of labour. On the other hand, the new device will afford the convenience of installing them the same day someone decides to do so. Moreover, the device can be made to fit any type of window. Even those that have burglary proofs would still be protected if they have a clearance of up to 4 cm from the window frames. Therefore the novel S/O channel/grip devices would invite generalized usage to check house entry of insect vectors.

Owing to the ease of monitoring houses that have installed house in-let screens, window screening could recommend itself to public health law for adoption. Unlike bednets, installation of house in-let screens implies that a mosquito control application is effectively in place. In communities where governments provide free medicare to children under 5 years or pregnant women, house screening could be made a precondition to access such welfares. It is reasonable to enforce a law that seeks to ensure that all people living in endemic areas provide window nets for their own protection just as it is compulsory to put on a crash helmet while riding a motorcycle in most countries for personal protection. Compliance may not present much problems because S/O channel/grip device itself is simple to manu-

facture. Moreover, the infinite industrial creativity of man may supply simpler manufacturing tools such that individuals could make them on their own. In the same vein, the installation of the channels and net hoisting/removal processes do not appear to require specialized tooling or training so can serve as attractive inducement to ensure that every hand is involved in malaria control. Owing to the fact that the channels are made of metal, it is expected that it would confer the advantages of stability and strength over wood which retract, expand, bend, degenerate, rut, volatilize etc. in the face of climatic pressure. The novel device, currently made of iron would rust. This can be prevented or delayed by rust-resistant oil paints. Where the device is made with aluminium or galvanized iron, it would further extend the life span of the device. The net benefit is that the novel method would offer longer periods of protection from disease vectors when effectively deployed in both houses and animal shelters.

The modification of buildings to control vector contact is an established practice in vector control: the use of ceiling and covering of eaves or installation of air conditioner and painting of houses is known to reduce insects in houses [5,10]. The contours of the novel channel can be incorporated in window frames when the frames are being manufactured so that it could allow occupants to place and remove nets at will without having to install additional channels or wooden battens to strap netting materials. The novel method is capable of spiraling further innovations to enhance mosquito control in more convenient ways at lower cost generally.

The foregoing experiments suggest that where all openings to rooms are completely protected, and steps which discourage insects from entering rooms with hosts are also put in place, then host-vector contact can be largely overcome. In this age, growing proportions of the population remain indoors or engage in jobs that dictate they remain indoors most of the time. It is pertinent to argue that where commensurate house screening is also put in place, there will also be equivalent 'growing' protection from pathogenic flies, such that, with time, malaria transmission can be significantly reduced.

Elphick and Elphick [7] noted that 98.1% of their subjects knew about the use of bednets yet only 27% owned one: the reasons for not owning one could be the same reason why they do not install window nets or door nets. The S/O channel/grip devices tends to mitigate these problems because it affords those at risk to apply alternatives: even cocoa-nut nets can be strewn together and applied on the channel/grip devices (Fig. 4) when conventional nets are not available/affordable. Loincloths, commonly worn in Sub-Saharan Africa, could in emergency be employed to screen out mosquitoes with S/O channels/grip devices.

A major threat to house screening is mosquito entry

through doors even when door screens are in place because they must be opened to access the house. Kirby *et al.* [22] recovered mosquitoes from screened houses. They noted that screened doors were often propped open during the day. In the present study, house entry to mosquitoes through access routes to the rooms were prevented by the use of fans. This facility may be too costly and therefore not available for common use. Therefore, it is still safer to house-screen in addition to use of bednet. The National Greenhouse Manufacturers Association [23] listed increased sizing and fastening problems, reduced access, maintenance, less ventilation occasioning less airflow and higher temperatures as some of the bane of house screening. The novel channel would be expected to contend with these challenges. The difficulties associated with fastening screens led to the development of the channel which has simplified the process with O rubber/plastic pipes that is easy to place or remove. Sizing problems (like changing from larger holed nets to smaller holed nets) actually underlines the usefulness of the novel channels because it would accept any size or kind of nets. The ease of changing these nets implies that when the need for increased ventilation arises, larger holed nets could be applied to increase air in-let, thus reducing the temperature within houses provided the holes do not exceed the limit necessary to prevent house entry by insect vectors; conversely, when it is desired to warm up the room, smaller net sizes could also be applied. It has been indicated earlier that the novel channels allow nets to be removed and cleaned from dust. The removal of trapped dust particles would restore air entry into the house. Except for door screen, house screens do not pose any access problems within houses. However the flexibility of the novel channels are perceived, they must bow to the submission of Gimnig and Slutskia [24] that only robust evidence of equivalence or superiority would sway the global commitment to LLINs to house screening.

5 Conclusion

It was shown that where all openings to rooms were completely protected with nets, entry of mosquitoes could be totally prevented thereby completely breaking host-vector contact. Nets hoisted with S/O channel/grip devices were shown to offer effective services of preventing house entry by mosquitoes like the traditional counterpart but in a form that would be more stable to resist climatic pressures. Net hoisting process was simplified, requiring no specialized skills or possession of complicated instruments. In addition, it engendered net hoisting on windows that could be de-hoisted with its structures intact and could thus be cleaned, re-used or treated/retreated with insecticide over and over again. This quality earmarks its potential of mul-

multiple roles in control of asthma and other insect vectored diseases. Its application on high-rise building proved that it was preferred on account of cheapness and convenience as no ladder or scaffolds were required. The novel channel debuts another option at the disposal of everyone at risk of vector borne diseases and will engage epidemiologists/researchers in the battle to keep vectors in check and eradicate malaria in particular.

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