



# THE USEFUL LIFE OF BEDNETS FOR MALARIA CONTROL IN TANZANIA: ATTRITION, BIOEFFICACY, CHEMISTRY, DURABILITY AND INSECTICIDE RESISTANCE

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## 2. Acronyms

|                          |   |
|--------------------------|---|
| <b>ASTMH</b>             | American Society of Tropical Medicine and Hygiene         |
| <b>CI</b>                | Confidence Interval                                       |
| <b>CIPAC</b>             | Collaborative International Pesticides Analytical Council |
| <b>CRA-W</b>             | Walloon Agricultural Research Centre                      |
| <b>GIS</b>               | Geographical Information System                           |
| <b>HPLC</b>              | High Performance Liquid Chromatography                    |
| <b>IHI</b>               | Ifakara Health Institute                                  |
| <b>IRB</b>               | Institutional Review Board                                |
| <b>KD60</b>              | Knock-down after 60 minutes                               |
| <b>LLIN</b>              | Long-Lasting Insecticidal Net                             |
| <b>LSHTM</b>             | London School of Hygiene & Tropical Medicine              |
| <b>NIMR</b>              | National Institute for Medical Research                   |
| <b>NMCP</b>              | National Malaria Control Program                          |
| <b>PCA</b>               | Principal Component Analysis                              |
| <b>RCN</b>               | Research Council of Norway                                |
| <b>SES</b>               | Socio-economic Quintile                                   |
| <b>SOP</b>               | Standard Operating Procedure                              |
| <b>SSA</b>               | Sub-Saharan Africa  |
| <b>Swiss TPH</b>         | Swiss Tropical and Public Health Institute                |
| <b>U5</b>                | Under-5 Campaign  |
| <b>UCC</b>               | Universal Coverage Campaign                               |
| <b>UMB, now<br/>NMBU</b> | Norwegian University of Life Sciences                     |
| <b>WHO</b>               | World Health Organization                                 |

### **3. Project Summary**

#### **Rationale**

Long-Lasting Insecticidal Nets (LLINs) are the front line malaria vector control tool in sub-Saharan Africa (SSA), with most countries adopting universal coverage campaigns with free or subsidised nets. It is essential to understand the effective life of LLINs, i.e. the cost per year of protection that they provide. Public health policy makers may then use this information to select the most cost effective nets (rather than the cheapest that may not last very long), and estimate the timing of repeated distribution campaigns to ensure maximal health gains. However, there is only limited knowledge from few countries of the effective life of LLINs under user conditions.

#### **Objectives**

This study investigates LLIN effectiveness in eight districts of Tanzania, selected for their demographic, geographic and ecological representativeness of the country. Our household selection for LLIN distribution, questionnaire study and LLIN sampling over time is based on households already enrolled in the sentinel panel of districts.

LLIN effectiveness is being evaluated by measuring Attrition (the physical presence of nets), Bioefficacy (the ability of nets to knock-down and kill mosquitoes), Chemical content ( $\text{g}/\text{cm}^2$  of insecticide available on the surface and within the net fibres) and physical Degradation (measured by holes and tears in the net). We are also extending the current NIMR mosquito Insecticide Resistance monitoring program into additional districts and create GIS maps for use in health surveillance and decision making by the National Malaria Control Program (NMCP).

#### **Methods**

We are using a two-stage approach: Firstly, LLINs from recent net campaigns (Under 5 and Universal Coverage Campaign) were evaluated retrospectively. Those sampled households were then provided with one of three leading LLIN products (Olyset<sup>®</sup>, Permanet<sup>®</sup>2.0 or Netprotect<sup>®</sup>) that will be followed up for three years in a prospective study to compare the performance of the three LLIN brands under user conditions. We will also develop a GIS database to understand potential spatial reasons for LLIN loss and deterioration and to monitor insecticide resistance across the country.

#### **Relevance to Tanzanian Public Health**

The data collected will be of importance to policy makers and vector control specialists both in Tanzania and the SSA region to inform best practice for the maintenance of cost-effective coverage and to maximise current gains in malaria control. We will make the data available to stakeholders including NMCP and their collaborators on a 12 monthly basis throughout the life of the project to ensure that decision-making can be made in a timely fashion as data become available. We have brought together a highly skilled multi-disciplinary team that will support Tanzanian vector control both now and in the future through the development of the GIS database and training of two Tanzanian students to PhD level.

## 4. Objectives

### *Main objective*

To determine the useful life of LLINs from 1) a **retrospective survey** of Olyset® nets distributed by the Tanzanian Government two-to-four years previously; and 2) a **prospective study** of three different LLIN products (Olyset®, Permanet®2.0 or Netprotect®) over three years using a nation-wide sampling framework across eight districts in Tanzania.

### *Specific objectives*

1. Determine **Attrition** (net loss) of LLINs.
2. Determine **Biological efficacy** of LLINs by assessing mosquito mortality through WHO-approved methods and new alternative methods (for validation of WHO methods). Determine **Chemical residues** in LLINs through High Performance Liquid Chromatography (HPLC).
3. Determine physical **Degradation** and fabric integrity of LLINs through measuring holes and tears in the fabric.
4. Determine insecticide **Resistance** in the main malaria vectors in study locations in collaboration with the NIMR insecticide resistance monitoring scheme using WHO susceptibility assays.
5. Develop a GIS model for use by NMCP for insecticide resistance monitoring, with flexibility to be applied to other functions such as disease incidence or LLIN coverage
6. Using the GIS model, identify geographical variations in ABCD & R components to determine specific problem areas for potential success/failure of each and combinations of the components.
7. Training two Tanzanian students to PhD.

The project will use a retrospective study to assess operational effectiveness of Olyset® bednets distributed three years ago, and a prospective study to investigate the effective life of three LLIN products (Olyset®, Permanet®2.0 or Netprotect®) under user conditions at 10, 22, 30 and 36 months post-distribution.

## 5. Major Changes to the Study Protocol (April 2013)

1. The number of districts was reduced from 15 to eight for the ABCD components of the bed net study. The following districts were dropped from the study:
  - Ruangwa
  - Mtwara Urban
  - Songea Urban
  - Arusha
  - Kondo
  - Singida Rural
  - Kasulu

The Southern zone was excluded completely from this study after consultation with partners from NMCP due to current ongoing activities for a school-based pilot study of a LLIN keep up campaign.

2. The number of households per district was increased from 330 households per district to 450 households per district. This was to account for the loss of households in the seven districts that were dropped.  
In each district, we will continue to select 10 villages. Thus, 45 households from each village will be randomly selected to participate in the study (450/10=45). Each of the three net products will be given to 15 households per village (45/3=15) rather than 11 households as described in the initial study protocol.
3. The Long-Lasting Insecticidal Net LifeNet<sup>®</sup> (Bayer) was replaced by Netprotect<sup>®</sup> (BestNet) due to delivery problems. We will now compare Netprotect<sup>®</sup>, which contains 63 mg/m<sup>2</sup> of deltamethrin incorporated into polyethylene fibres, against Olyset<sup>®</sup> and PermaNet<sup>®</sup>2.0 (Table 1).

**Table 1 – Summary of LLIN products used in ABCDR study**

| <b>Product name</b>       | <b>Product type</b>                                | <b>Insecticide concentration</b> | <b>Denier</b>    | <b>Manufacturer</b>  | <b>WHO approval</b>   |
|---------------------------|--|----------------------------------|------------------|----------------------|-----------------------|
| Olyset <sup>®</sup>       | Permethrin <b>incorporated</b> into polyethylene   | 1000 mg/m <sup>2</sup>           | >150 denier      | Sumitomo Chemicals   | Full                  |
| PermaNet <sup>®</sup> 2.0 | Deltamethrin <b>coated</b> on polyester            | 55 mg/m <sup>2</sup>             | 75 or 100 denier | Vestergaard Frandsen | Full                  |
| Netprotect <sup>®</sup>   | Deltamethrin <b>incorporated</b> into polyethylene | 63 mg/m <sup>2</sup>             | 110 denier       | BestNet              | Temporarily withdrawn |

4. The timing of the follow-up field work was changed slightly. The 6 month follow-up was dropped and replaced by an additional follow-up after 30 months. Therefore, the durability of LLINs will be measured after 10 months, 22 months, 30 months and 36 months of field use.
5. We had initially relied upon the provision of a master list of households that received Olyset<sup>®</sup> LLINs during the U5 and UCC campaigns from MEDA. However, we were informed that no such household list exists and we therefore had to change the methodology so that all households in each selected village would have an equal chance of being selected to be included in the study. The questionnaire was then adapted in a way that will make it easier to identify which nets came from government campaigns and which nets had come from different sources.
6. The methodology to measure the C-component (chemical residue analysis) was changed from sonication at London School of Hygiene & Tropical Medicine to a CIPAC (Collaborative International Pesticides Analytical Council) approved methodology which allows extraction of active ingredients from incorporated nets (<http://www.cipac.org/>). This will now be performed at a WHO Collaborating Centre for Quality Control of Pesticides (Walloon Agricultural Research Centre; CRA-W).
7. In the previous protocol, assessment of the physical degradation of LLINs (D-component; holes and tears in nets) was only performed on a sub-sample of 75 LLINs for each net product. We have changed this methodology so that the field staff will be trained to perform hole index analyses in the field using a recently developed tool kit

by USAID/NetWorks-supported K4Health. Now, all nets will be investigated for D-component at all four follow-up time points.

8. The Tanzanian NMCP are preparing a new Global Fund-sponsored mass distribution campaign from April 2015, distributing double-sized blue Olyset® nets. Our study households will not be excluded from the national net campaign, and our questionnaire will reflect the choice to householders to investigate consumer behaviour when a choice of nets is given (colour and textile preference; when is it time to replace an older net?) This changes the research question of the ABCDR study and the donors RCN will be informed of this unavoidable change.

## 6. Completed Activities – Timeline

|                       |   |
|-----------------------|---|
| <b>April 2012</b>     | Project submitted to GLOBVAC.   |
| <b>June 2012</b>      | Funding awarded. Revised budget sent to RCN upon request.   |
| <b>July 2012</b>      | Start drafting of Consortium Agreements.  |
| <b>Aug-Sep 2012</b>   | Revised project and budget under review by RCN.   |
| <b>September 2012</b> | PhD students assigned: Mr. Dennis Massue and Ms. Zawadi Mageni.   |
| <b>October 2012</b>   | Consortium agreement under development. Budget deliberations.   |
| <b>November 2012</b>  | <ul style="list-style-type: none"> <li>– Agreements with Bayer, Vestergaard-Frandsen, and Sumitomo to donate 5000 nets each of identical colour (white), size (190x180x150cm<sup>3</sup>) and without brand labels.</li> <li>– Pre-meeting between three consortium partners at the Annual Meeting of the American Society of Tropical Medicine and Hygiene (ASTMH), Atlanta, USA.</li> <li>– Planning to increase number of districts from 5 to 15.</li> <li>– Contract signed between RCN and UMB.</li> <li>– Project exempted from ethical review by REK Norway.</li> <li>– Material and Data Transfer Agreements between IHI and LSHTM signed.</li> </ul> |
| <b>December 2012</b>  | <ul style="list-style-type: none"> <li>– Ethics protocol submitted to LSHTM, NIMR, and IHI institutional review boards (IRBs).</li> <li>– Consortium Agreements signed.</li> </ul>  |
| <b>January 2013</b>   | <ul style="list-style-type: none"> <li>– Project inception workshop held in Bagamoyo, Tanzania.</li> <li>– Decision to remove 5 districts from the Southern Zone because the project will interfere with another NMCP school net delivery project</li> <li>– Insecticide resistance work will remain in all 15 districts.</li> <li>– Decision to start field work in June 2013 (original plan April).</li> <li>– Project presented at the 8<sup>th</sup> Roll Back Malaria Vector Control Working Group meeting in Geneva, Switzerland.</li> </ul>  |
| <b>February 2013</b>  | <ul style="list-style-type: none"> <li>– Ethical approval obtained from LSHTM.</li> <li>– Individual financial agreements signed between UMB and LSHTM, IHI, and NIMR.</li> <li>– Study protocol and SOPs development starts.</li> </ul>  |

|                       |   |
|-----------------------|---|
|                       | <ul style="list-style-type: none"> <li>– Start planning field work logistics, equipment, etc.</li> </ul>  |
| <b>March 2013</b>     | <ul style="list-style-type: none"> <li>– Continued field work planning, Standard Operating Procedures (SOPs), questionnaires, auditing and monitoring, etc.</li> <li>– Study protocol completed and sent to net companies.</li> </ul>   |
| <b>April 2013</b>     | <ul style="list-style-type: none"> <li>– Ethical approval obtained from NIMR.</li> <li>– Bayer informs us of technical problems with their net production.</li> <li>– ABCDR shared platform established at LSHTM, <a href="https://teaming.lshtm.ac.uk">https://teaming.lshtm.ac.uk</a>.</li> <li>– Comments by net companies on study protocol</li> <li>– Agreement with Swiss Tropical Institute of Public Health to audit the project</li> </ul>   |
| <b>May 2013</b>       | <ul style="list-style-type: none"> <li>– Ethical approval obtained from IHI.</li> <li>– Budget change request to RCN (also requiring a contractual change between UMB and RCN).</li> </ul>  |
| <b>June 2013</b>      | <ul style="list-style-type: none"> <li>– Bayer informs us that their technical problems are of a kind that requires further lab testing of nets and they cannot say until the end of June if they will be able to deliver nets by September.</li> <li>– Contact alternative net company, BestNet, who are willing to donate 5000 nets for the study.</li> <li>– Meanwhile, Olyset nets shipped within Tanzania to our safe container storage facility with controlled temperature and exclusion of rodents in Bagamoyo.</li> </ul>  |
| <b>July 2013</b>      | <ul style="list-style-type: none"> <li>– Agreement with BestNet to send nets for trial. Nets will be shipped from India and will arrive Tanzania end of August.</li> <li>– Realistic decision made to start up field work on Monday 30 September.</li> </ul>  |
| <b>August 2013</b>    | <ul style="list-style-type: none"> <li>– Unexpected increase in field costs due to higher costs incurred by field work.</li> <li>– Decision to reduce number of districts from 10 to 8.</li> <li>– Questionnaires completed and field tested. Prepared for digital versions for use on tablets in the field.</li> <li>– Ethical clearance amendments submitted to respective IRBs.</li> <li>– Amendment of ethical approval obtained IHI.</li> <li>– Netprotect and PermaNet2.0 arrive in Tanzania.</li> </ul>  |
| <b>September 2013</b> | <ul style="list-style-type: none"> <li>– Amendment of ethical approval obtained from LSHTM.</li> <li>– Completion and updates of all SOPs.</li> <li>– Write training package for field enumerators.</li> <li>– Blinding of nets – type “1”, “2” and “3”. Bar code system and nets packaging.</li> <li>– PhD enrolment of Ms Mageni at LSHTM.</li> <li>– PhD enrolment of Mr Massue at Swiss TPH.</li> <li>– Contract completed with Walloon Agricultural Research Centre in Belgium for HPLC chemical analysis of nets.</li> <li>– Training of field workers.</li> <li>– Retrospective field work starts on 30th September in Bagamoyo district.</li> </ul> |
| <b>Oct - Dec 2013</b> | <ul style="list-style-type: none"> <li>– Continuous field work moving through 8 study districts (in order): Bagamoyo, Kinondoni, Kilosa, Iringa Urban, Mbozi, Kahama, Geita, Musoma Rural by field</li> </ul>   |

|                   |   |
|-------------------|---|
|                   | <p>team comprising 15 field enumerators, 2 field managers and 2 drivers plus 1 technical support staff (based in Dar) and 1 logistics manager (based in Bagamoyo).</p> <ul style="list-style-type: none"> <li>– Field work completed 10 days ahead of schedule.</li> <li>– Target: 450 households visited in 7 districts + 270 households visited in Kinondoni (only 6 ‘villages’) = 3,420 in total.</li> <li>– Total household completion rate: 3,398/3,420 (99.4%).</li> <li>– Nets collecting: 6,832 used nets (not all from government campaigns)</li> <li>– Nets distributed: 10,598 new nets (3,529 “type 1”, 3,519 “type 2”, 3,550 “type 3”).</li> </ul> |
| <b>Jan 2014</b>   | <ul style="list-style-type: none"> <li>– Data cleaning of survey data collected with tablet questionnaires.</li> <li>– Initial data exploration and trouble-shooting.</li> <li>– Ms Mageni started PhD training at LSHTM in London by attending two MSc modules between Jan – March 2014.</li> </ul>  |
| <b>Feb 2014</b>   | <ul style="list-style-type: none"> <li>– Presentation of study updates at the 9<sup>th</sup> Roll Back Malaria Vector Control Working Group meeting in Geneva, Switzerland.</li> <li>– ABCDR annual meeting in Geneva, Switzerland.</li> <li>– WHO baseline tests of 10 “type 1”, “type 2”, “type 3” nets for bioefficacy.</li> <li>– Amendment of ethical approval obtained from NIMR.</li> </ul>  |
| <b>March 2014</b> | <ul style="list-style-type: none"> <li>– Study coordinator Dr Lorenz in Tanzania.</li> <li>– Logistics planning of first prospective follow-up in August 2014.</li> <li>– Development of prospective questionnaire and informed consent.</li> <li>– Presentation of ABCDR project at Malaria Retreat 2014 (LSHTM Malaria Centre) in Brighton, UK by Ms Mageni.</li> </ul>   |

## 7. Timeline 2014 (Appendix 1)

|                          |  |
|--------------------------|--|
| <b>April 2014</b>        | <ul style="list-style-type: none"> <li>– Final SOP development and translation for bio-efficacy and physical degradation testing in the laboratory.</li> <li>– Training of IHI technicians using SOPs.</li> <li>– Questionnaire development and field testing.</li> <li>– Re-application for ethics amendments: IHI, NIMR, LSHTM.</li> <li>– Upgrading of PhD student Mr Massue at Swiss TPH.</li> </ul> |
| <b>April – July 2014</b> | <ul style="list-style-type: none"> <li>– Analysis of retrospective data.</li> <li>– Publication of study protocol.</li> <li>– Ordering of equipment for field work.</li> <li>– Planning logistics for field work.</li> <li>– Questionnaire programming using ODK open software by IHI data central.</li> </ul>   |
| <b>April – Sept 2014</b> | <ul style="list-style-type: none"> <li>– Retrospective laboratory analyses of U5 and UCC Olyset nets (N=200) in Bagamoyo, Tanzania. <ul style="list-style-type: none"> <li>○ D component: Hole index using a frame.</li> </ul> </li> </ul>   |

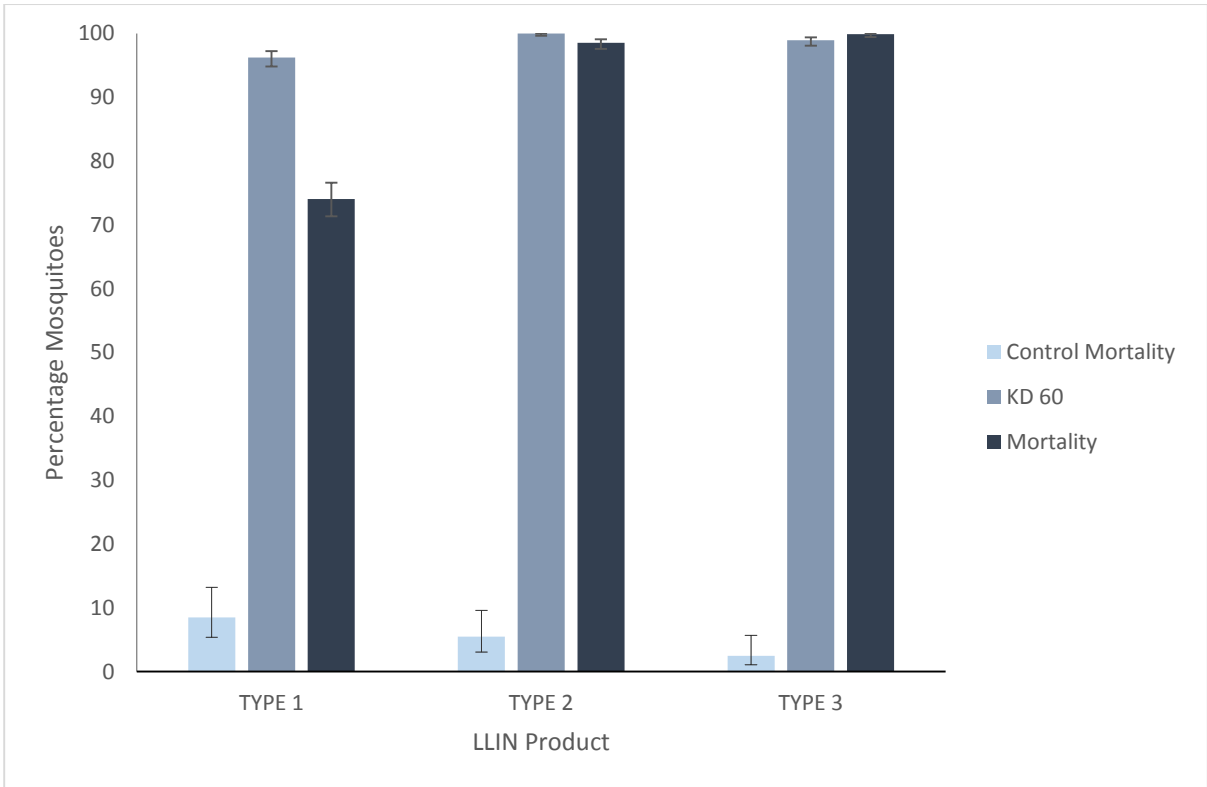


|                       |  |
|-----------------------|--|
|                       | <ul style="list-style-type: none"> <li>○ B component: <ul style="list-style-type: none"> <li>▪ Whole net blood-feeding inhibition and mortality of <i>An. gambiae</i> s.s. in the Ifakara Tunnel Test (ITT).</li> <li>▪ Sample knock-down and mortality of <i>An. gambiae</i> s.s. using WHO cone tests, and sample blood-feeding inhibition and mortality using WHO tunnel tests on failed samples.</li> </ul> </li> </ul>  |
| <b>July 2014</b>      | <ul style="list-style-type: none"> <li>– Set up logistics for first prospective census.</li> <li>– Training of field enumerators in Bagamoyo.</li> <li>– Ms. Mageni will attend a course in the Netherlands “Using GIS in disease control programmes”. Funding was obtained by the candidate through sponsorship by the programme.</li> </ul>  |
| <b>Aug – Oct 2014</b> | <ul style="list-style-type: none"> <li>– Beginning of first prospective census in Bagamoyo.</li> <li>– Continuous field work for 3 month by field enumerators throughout the 8 study districts.</li> <li>– Continuous quality assurance by monitoring of the survey data as it gets uploaded to the data server.</li> <li>– Following field enumerators, a second IHI team will visit randomly sampled households and collect prospective LLINs for further BCD testing in the laboratory in Bagamoyo.</li> <li>– Quality assurance by performing a second household questionnaire on sub-sampled households.</li> </ul> |
| <b>Oct 2014</b>       | <ul style="list-style-type: none"> <li>– Ship retrospective LLIN samples to Walloon Agricultural Research Centre (CRA-W) for HPLC analysis.</li> <li>– The GLOBVAC programme board of the RCN to visit the project, preliminary date 22 October. Hans Overgaard will oversee the visit.</li> </ul>   |
| <b>Oct – Dec 2014</b> | <ul style="list-style-type: none"> <li>– PhD candidate Mr Massue will take courses at Swiss TPH in Basel.</li> </ul>   |
| <b>Nov 2014</b>       | <ul style="list-style-type: none"> <li>– Study coordinator Lena Lorenz may present ABCDR results at ASTMH, New Orleans, USA</li> </ul>   |
| <b>Nov – Dec 2014</b> | <ul style="list-style-type: none"> <li>– Prospective laboratory analyses of sub-sampled LLINs (48 per LLIN product).</li> <li>– Upgrading of PhD candidate Ms Mageni at LSHTM.</li> </ul>  |

## 8. Baseline LLIN Results

### 8.1 WHO cone bioassays

Ten nets from each of the three LLIN products were randomly chosen from the batches provided by the manufacturers. WHO guidelines were followed and five samples from each LLIN were tested against *An. gambiae* sensu stricto (Ifakara strain) in Bagamoyo. The results are presented in Figure 1. Net samples that resulted in knock-down below 95% or mortality below 80% failed the WHO cone bioassay and were subsequently tested using the WHO tunnel test (Section 7.2). All nets from net products “type 2” and “type 3” passed the WHO criteria of knock-down above 95% and mortality above 80%. However, six “type 1” nets failed the WHO cone test and the net samples closest to the average mortality for each of the six failed nets were tested in the WHO tunnel tests.



**Figure 1 – Mean percentage knockdown and mortality of *An. gambiae* mosquitoes from ten nets of each LLIN product (type 1, type 2, type 3 and control). The error bars represent 95% confidence intervals around the mean proportions. KD60 = Mosquito knock-down after 60 minutes. Mortality was adjusted with the Abbott’s formula.**

## 8.2 WHO tunnel bioassays

Six “type 1” net samples were tested using WHO tunnel tests with rabbits as baits and *An. gambiae* s.s. (Kisumu strain) in Muheza following WHO guidelines. Samples from all six nets passed the WHO tunnel test, with  $\geq 90\%$  blood-feeding inhibition and  $\geq 80\%$  mortality (control blood-feeding inhibition was 15% and mortality 8%).

## 9. Preliminary Results from Retrospective Survey

### 1. Household net ownership

Bed net ownership was determined by including all the nets that were collected in the retrospective survey.

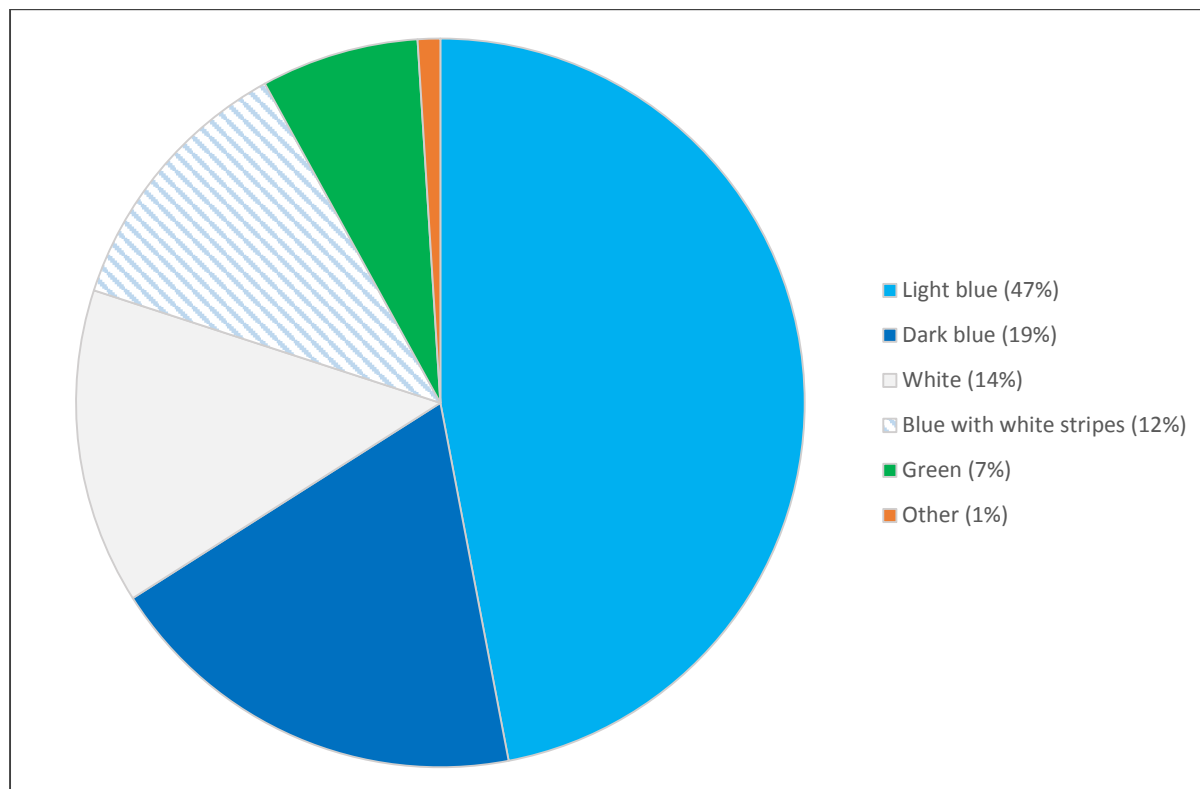


Figure 2 – Percentage distribution of textile colours of retrospective bed nets collected during Oct-Dec 2013 in all 8 districts in Tanzania – N (total) = 6,831

Table 2 – Three measures of household net ownership by each of the 8 study districts in Tanzania. Data presented in the table is the mean percentage  $\pm$  95% confidence intervals (CI).

| District         | % households with at least 1 net (95% CIs) | % households with at least 1 net per sleeping place (95% CIs) | % households with at least 1 net per 2 people (95% CIs) |
|------------------|--|---|---|
| <b>BAGAMOYO</b>  | 93 (79-98)                                 | 66 (51-78)  | 59 (47-71)  |
| <b>KINONDONI</b> | 83 (68-91)                                 | 42 (30-56)  | 48 (37-59)  |
| <b>KILOSA</b>    | 88 (77-94)                                 | 51 (40-63)  | 46 (36-56)  |
| <b>IRINGA</b>    | 88 (84-92)                                 | 41 (32-51)  | 54 (49-59)  |
| <b>MBOZI</b>     | 75 (64-84)                                 | 29 (21-38)  | 33 (24-43)  |
| <b>KAHAMA</b>    | 80 (71-87)                                 | 31 (22-42)  | 29 (20-40)  |
| <b>GEITA</b>     | 86 (78-92)                                 | 33 (24-44)  | 26 (21-31)  |
| <b>MUSOMA</b>    | 86 (81-90)                                 | 35 (25-47)  | 30 (21-42)  |

**Table 3 – Three measures of household net ownership by SES quintile. Data presented in the table is the mean percentage  $\pm$  95% CI. SES quintiles were established by PCA<sup>1</sup>.**

| SES quintile      | % households with at least 1 net (95% CIs) | % households with at least 1 net per sleeping place (95% CIs) | % households with at least 1 net per 2 people (95% CIs) |
|-------------------|--|---|---|
| 5<br>(Wealthiest) | 87 (82-91)                                 | 58 (52-64)  | 66 (63-69)  |
| 4                 | 89 (85-92)                                 | 56 (51-61)  | 59 (54-64)  |
| 3                 | 88 (84-91)                                 | 53 (48-59)  | 52 (48-57)  |
| 2                 | 83 (79-86)                                 | 55 (51-59)  | 48 (44-53)  |
| 1 (Poorest)       | 78 (71-84)                                 | 57 (52-62)  | 49 (44-55)  |

<sup>1</sup>Parameters included in PCA were: highest level of education, source of income, material of roof, wall, floor, electricity source, access to water and toilet, ownership of household assets, transport, animals and farm land.

## 2. Household LLIN ownership

LLIN ownership was determined by only counting the nets that were of light blue colour or white with blue stripes as LLINs. All other net colours (white, green, dark blue or other) were assumed to be commercially available untreated nets.

**Table 4 – Three measures of household LLIN ownership by each of the 8 study districts in Tanzania. Data presented in the table is the mean percentage  $\pm$  95% CI.**

| District  | % households with at least 1 LLIN (95% CIs) | % households with at least 1 LLIN per sleeping place (95% CIs) | % households with at least 1 LLIN per 2 people (95% CIs) |
|-----------|---|--|--|
| BAGAMOYO  | 43 (31-56)                                  | 30 (22-39)   | 27 (20-36)   |
| KINONDONI | 28 (17-44)                                  | 16 (9-27)  | 17 (10-28)   |
| KILOSA    | 51 (41-60)                                  | 26 (21-32)   | 25 (18-33)   |
| IRINGA    | 38 (28-50)                                  | 17 (11-24)   | 23 (17-30)   |
| MBOZI     | 58 (44-71)                                  | 21 (15-30)   | 25 (18-35)   |
| KAHAMA    | 55 (40-70)                                  | 20 (14-29)   | 18 (11-28)   |
| GEITA     | 62 (45-77)                                  | 25 (16-35)   | 18 (13-25)   |
| MUSOMA    | 60 (44-74)                                  | 24 (16-35)   | 20 (13-30)   |

**Table 5 – Three measures of household LLIN ownership by SES quintile. Data presented in the table is the mean percentage  $\pm$  95% CI. SES quintiles were established by PCA<sup>2</sup>.**

| SES quintile      | % households with at least 1 LLIN (95% CIs) | % households with at least 1 LLIN per sleeping place (95% CIs) | % households with at least 1 LLIN per 2 people (95% CIs) |
|-------------------|---|--|--|
| 5<br>(Wealthiest) | 34 (29-40)                                  | 17 (13-21)   | 21 (18-26)   |
| 4                 | 51 (44-57)                                  | 24 (20-29)   | 25 (21-31)   |
| 3                 | 57 (52-63)                                  | 26 (22-30)   | 26 (22-30)   |
| 2                 | 60 (53-66)                                  | 26 (22-30)   | 21 (18-25)   |
| 1 (Poorest)       | 51 (43-60)                                  | 20 (16-26)   | 16 (13-21)   |

<sup>2</sup>Parameters included in PCA were: highest level of education, source of income, material of roof, wall, floor, electricity source, access to water and toilet, ownership of household assets, transport, animals and farm land.

### 3. Household net use

We could only calculate the household net use the night before the survey for the general population rather than by children under the age of 5 versus use of the general population as we did not collect this information in our questionnaire in the retrospective survey.

**Table 6 – Percentage of people who slept under any bed net or an LLIN the night before the survey by each of the 8 study districts in Tanzania. Data presented in the table is the mean percentage  $\pm$  95% CI.**

| District         | % people who slept under a net the night before survey (95% CIs) | % people who slept under an LLIN the night before survey (95% CIs) |
|------------------|--|--|
| <b>BAGAMOYO</b>  | 82 (72-92)   | 38 (27-50)   |
| <b>KINONDONI</b> | 67 (54-79)   | 24 (14-35)   |
| <b>KILOSA</b>    | 70 (58-82)   | 43 (34-51)   |
| <b>IRINGA</b>    | 72 (68-77)   | 31 (23-38)   |
| <b>MBOZI</b>     | 50 (41-60)   | 39 (28-49)   |
| <b>KAHAMA</b>    | 57 (46-67)   | 39 (28-50)   |
| <b>GEITA</b>     | 62 (54-70)   | 45 (33-58)   |
| <b>MUSOMA</b>    | 62 (56-67)   | 42 (32-52)   |

**Table 7 – Percentage of people who slept under a bed net the night before the survey by SES quintile. Data presented in the table is the mean percentage  $\pm$  95% CI. SES quintiles were established by PCA<sup>3</sup>.**

| SES quintile          | % people who slept under a net the night before survey (95% CIs) | % people who slept under an LLIN the night before survey (95% CIs) |
|-----------------------|--|--|
| <b>5 (Wealthiest)</b> | 72 (67-77)   | 28 (24-33)   |
| <b>4</b>              | 71 (66-75)   | 41 (36-46)   |
| <b>3</b>              | 67 (62-71)   | 44 (40-49)   |
| <b>2</b>              | 60 (56-64)   | 44 (39-49)   |
| <b>1 (Poorest)</b>    | 54 (48-60)   | 36 (29-42)   |

<sup>3</sup>Parameters included in PCA were: highest level of education, source of income, material of roof, wall, floor, electricity source, access to water and toilet, ownership of household assets, transport, animals and farm land.

### 4. What is the reason for non-net use the night before the survey?

From the 6,832 nets collected, 1,844 (27%) were reported not to have been used the night before the survey. The main reasons reported for non-net use were that there were no mosquitoes (32%), that the primary user did not sleep at home that night (21%) and that the net was too old (18%). Other reasons reported for non-use were that the user was too hot (11%) and that the net was too dirty (7%). Unavailability of the net (2.5%), no malaria (2%), small net size (1.5%) and adverse reactions (1%) were not reported frequently.

## 5. What happened to nets that are no longer present in the household?

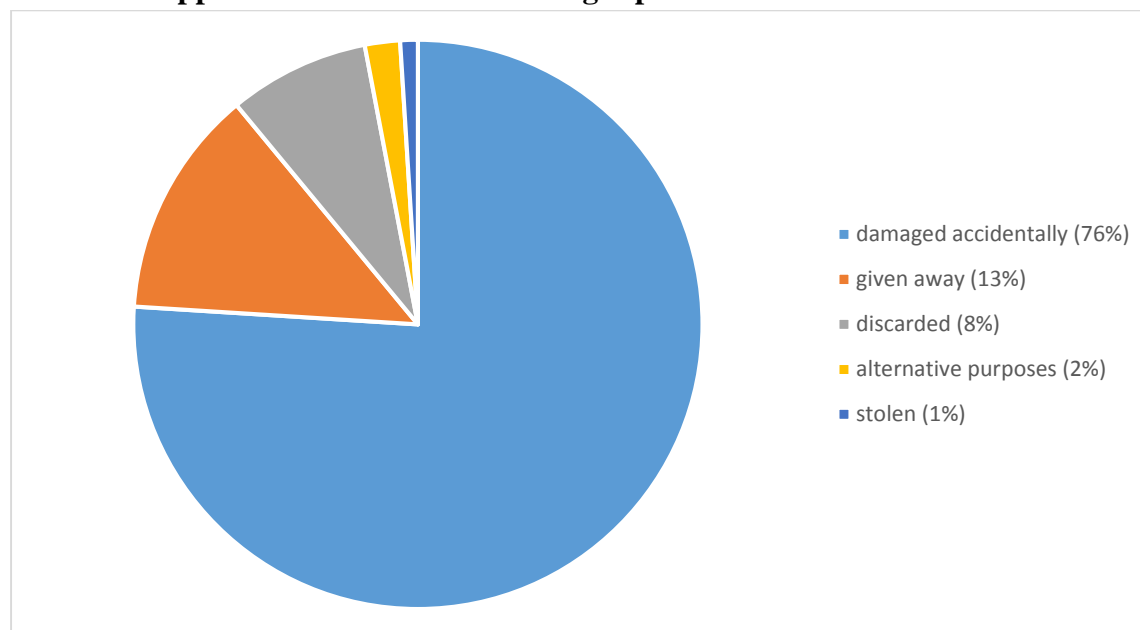


Figure 3 – Reported reasons for the absence of nets that used to be in the household. The number of households responding to this question was 779.

## 6. Net disposal

Table 8 – Ways of disposing of old nets as reported by householders during the retrospective interview. In total, 3,398 households answered the question of how they dispose of old unwanted bed nets.

| Disposal of old nets     | Frequency    | Percent     |
|--------------------------|--------------|-------------|
| Throw nets away as waste | 1,896        | 55.8%       |
| Burn nets                | 1,031        | 30.3%       |
| Other uses <sup>4</sup>  | 219          | 6.4%        |
| Use in garden            | 175          | 5.2%        |
| Give to children to play | 43           | 1.3%        |
| Bury nets                | 31           | 0.9%        |
| Send to be recycled      | 3            | 0.1%        |
| <b>TOTAL</b>             | <b>3,398</b> | <b>100%</b> |

<sup>4</sup>Other ways of net disposal included: fence (bathroom & keep poultry); house screen (window, door); mattress/pillow; (goat) rope; agriculture (dry cassava); fishing

