Overview of developments in 2013 – Albert Kilian, Tropical Health LLP, Spain

Over the past five years the Work Stream has focused its work on (1) behavioural aspects of LLIN durability including care and repair, (2) research on durability, (3) methods of laboratory textile testing of LLINs in order to predict field performance and (4) methods to measure LLIN survival in the field.

1. Behavioural aspects of durability:
   a. Recent publications (e.g. Wills et al., 2013. Malaria Journal, 12: 242, working in Ethiopia) confirm very low repair rates.
   b. An ongoing study in Nigeria (Nasarawa State) suggests that changing repair behaviour can be challenging but after one year of follow up there was a significant increase in the proportion of households repairing holes in nets. A second year of data collection will allow net condition (integrity) to be assessed.
   c. Quantitative research shows that people are able to determine the need for replacement and express a demand for replacements (Loll et al., 2013, Malaria Journal, 12: 337).

2. Research on durability:
   a. Ongoing work, yet to be published, indicates that the locations of the holes are important for mosquito entry, and that there are differences among species in finding and entering through these holes.
   b. Work on mosquito entry related to both hole size and insecticide level is planned in Tanzania.

3. Textile testing of unused LLINs in order to predict field performance:
   a. WHO (GMP-WHOPES) is testing recommended LLIN brands using currently existing textile tests. An initial meeting was held in August 2012 to discuss preliminary data with the final results expected in early 2014.
   b. The Bill & Melinda Gates Foundation has funded the Results For Development (R4D) and Non-woven Innovation & Research Institute (NIRI) and TropHealth Studies http://www.trophealth.com/?page_id=2

4. Field data net survival:
   a. A number of 2013 studies have reported on aspects of net survival in the field:
      - Mutuku et al., 2013. Malaria Journal, 12: 46 (Kenya): a cross-sectional survey of existing nets routinely used was conducted. Physical condition and use were assessed and nets considered ineffective with a hole surface >500cm².
The proportion of effective nets decreased until the third year and then stabilised at 30%.

- Mejía et al., 2013. Malaria Journal, 12: 158 (Kenya): a study was conducted within a Millennium Village to assess Olyset survival 4.5 years after distribution. A mean survival of 5.5yrs was estimated, with a more likely survival time of 4.5yrs when missing households are accounted for.
- Haji et al., 2013. Parasites & Vectors, 6: 82 (Zanzibar): three year old Olyset nets were analysed and 68% found damaged (however a low-cut off was used).
- Wills et al., 2013. Malaria Journal, 12: 242 (Ethiopia): a multiple cross-sectional survey was conducted to assess PermaNet 2.0 after 3-32 months of use. No attrition was reported; 30% LLINs were ‘torn’ after 26-32 months.
- Odhiambo et al., 2013. Journal of Tropical Medicine, 2013: 563957 (Kenya): Netprotect was evaluated in two villages. Attrition after 3 years was 21% with 90% nets still effective in cone assays.

a. Methodology for survival estimate:


- It was decided that insecticidal effectiveness will not be included in the recommended measure of median LLIN survival until a field test is available that does not necessitate removing or destroying the net, and until a better understanding of the minimal effectiveness is available (i.e. the insecticide level at which no extra clinical protection is achieved).
- A median survival analysis tool in a MS Excel spread sheet format will be made available online, which will allow survival outcomes to also be plotted.

b. Preliminary data from ongoing studies were presented:

- An ongoing retrospective durability study in three regions of Nigeria: preliminary results indicate that the way in which nets are used has a large bearing on survival.
- Two cross-sectional surveys 12-36 months after a LLIN campaign in the Eastern Region of Ghana which indicates that median survival of the 75D polyester nets used is around 5 years.
- A prospective LLIN study in Uganda of seven brands, showing on general a 3.5-4 year median survival with very little differentiation between brands.

In summary:

- There are too few publications with sufficient data to make a judgement on survival.
- Unpublished data suggests that median net survival in some sites is closer to 4-5 years (or more) than 3 years.
• There is a need to disseminate new guidelines and build capacity for the application of these guidelines.

Discussion
The following points were raised by participants:

• The overall goals of durability research are to produce an ideal LLIN product specification and to make recommendations on the ideal frequency of LLIN redistribution. There are insufficient data on these at present to make firm recommendations.
• The 'net survival tool' is useful and simple, however it must be remembered that the assessment of net quality is subjective.
• Much data on net durability has been, or is being, collected through prospective studies. These results may not be generalizable, since study participants may take better care of their nets. To account for this bias, it is important to consider both integrity and attrition when analysing prospective studies. This bias should not be problematic in retrospective studies.

Current studies of LLIN durability – Steve Smith, Centers for Disease Control (CDC), USA
Much work is ongoing to collect data and analyse LLIN survival, as recommended by the 2013 WHO Guidance Note, with at least 21 ongoing field studies in 19 countries. Preliminary results from Malawi, Kenya and other PMI sites were presented at MIM Durban in October 2013; one brand of net was found to perform considerably less well because of the knitting pattern and the manufacturer has now resolved this. At least four laboratory studies are also ongoing, coordinated by WHO, CDC, RD4 and Leeds University among others. Issues for discussion include how best to collect and disseminate information about ongoing research and whether the Durability Work Stream can provide technical expertise to assist the planning and design of studies.

Discussion
Results of studies ongoing with the old design of Olyset® net need to be treated with caution given the new knitting pattern. There was also discussion of the number of nets required to maintain 100% coverage.

Tanzania ABCDR study – Lena Lorenz, London School of Hygiene & Tropical Medicine, UK
The overall aim of ABCDR is to investigate LLIN durability in Tanzania by measuring the Attrition, Bioefficacy, Chemical residue, physical Degradation of LLINs and insecticide Resistance. The study comprises a prospective and retrospective study. The prospective study began in October 2013 when community sensitisation, household enrolment, a baseline questionnaire and net distribution (collection of old nets and distribution of sufficient new nets) were conducted. There are 8 participating districts, within which 10 villages and 45 households in each are enrolled. Approximately 9000 nets (Olyset® with the new knitting pattern, PermaNet® 2.0 and Netprotect®) were distributed at baseline. The retrospective study is an analysis of Olyset® nets distributed by the National Malaria Control Program (NMCP) campaign for children under five years old in 2009-10 and a universal campaign for all age groups in 2010-11. Preliminary results from the baseline survey and next steps for the study were presented.

Discussion
Net durability in low-endemic settings should be considered.
**Measuring insecticide levels in the field - Karl Malamud-Roam, Rutgers, The State University of New Jersey, USA**

This research originated to solve the problem of conducting chemical assays of permethrin-treated clothing without destruction, and the absence of a reliable, non-destructive method for routinely measuring the concentration of pesticides on LLINs in the field. Analytical extraction and quantification is destructive and expensive. Other measurements might include: electro-magnetic spectra (x-ray fluorescence, x-ray in lab and field, IR absorption, UV fluorescence or indicator dye) or non-destructive chemical assays such as minor extraction and colorimetry or ELISA. Pesticide estimation might use the following proxies: bioassays, wash count, use/deployment time and wear, abrasion or fabric weight loss. The pros and cons of currently available methods were discussed alongside the challenges in using chemical assays, including difficulties in standardising the extract, variability of pesticide on nets and reagent stability. Criteria for a reliable test include sensitivity, being effective for all fabrics, acceptable to users, inexpensive and durable in the field.

**Causes and mode of deterioration - Steve Russell, University of Leeds, UK**

Current projects aim to understand the actual cause and modes of physical deterioration of LLINs in field settings, and to lay a foundation for improved LLIN textile testing methods that can be used in LLIN procurement and to encourage innovation in net technology. In this study 526 used LLINs (12-36 months use) were collected from sites in Uganda, Nigeria, Kenya, India and Mozambique and a direct analysis conducted to determine damage mechanisms resulting from use in the field. A total of 41,294 damage sites were inspected along with the entire LLIN structure (e.g. seams). Of all damage sites, 57.2% were pulls, 41.3% were holes and 1.5% were other defects. Photographs were presented to illustrate each damage mechanism. Seven primary and three secondary mechanisms leading to holes were described. Damage mechanism profiles by hole frequency were presented by country. Mechanical damage is the most widespread and consistent source of holes. Improving snag resistance will likely improve durability. LLINs are also particularly susceptible to holes that are caused by cutting, thermal (fire) and rodent damage. Damage mechanisms affect subsequent hole size; tearing and seam failure produce the largest holes. Preliminary analysis indicates a relationship between laboratory tests for “hook strength” and the corresponding number of snags and tears per net observed in the field. The next phase in this research is to develop a suite of new LLIN textile testing methods and specifications to reflect actual modes of damage found in the field and to improve the linkage between lab test performance and long-term field durability.

**Discussion**

It was queried whether some net brands are more attractive to rodents or if it was more a matter of net cleanliness (i.e. no food residue) and storage. Given the large extent of rodent damage, messages can already be given out alongside net distribution to raise awareness of protecting from this damage. Understanding the origin of holes will help plan distribution and design future nets. The trade-off between net strength and price was highlighted.

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- Developing assays for pesticides on nets is not only relevant for duration of effectiveness but also for considerations of disposal of netting fabric beyond their effective lifetime.
• Given the close relationship between laboratory tests for “hook strength” and the corresponding number of field snags and tears, WHOPES should perhaps adopt this as a criterion.

• Current data is not sufficient to make recommendations on which brand of net is best; the user aspect and the environment where the net is deployed is important.

• It was queried whether used nets could be recycled and made into pit latrine covers, for example. Polyethylene material can be recycled, but the feasibility and practicality of collection of nets from the field for recycling currently lacks guidance; it is also unknown if there is any residual pyrethroid present that may affect the saleability of the end product.

• Issues were raised over the development of ultra long-lasting nets, e.g. a decade, including: price, uncertainty over how long nets are needed, possible problems inherent in using the same insecticide on a net for an extended period and how to demonstrate that a net will last for a decade given the long testing time needed for WHOPES approval.

A draft 2014 Work Plan will be circulated for input.