

ABSTRACT

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Thesis title: **Long-Lasting Insecticidal Mosquito Nets:**

Effects of washing processes on pesticide residues, and human and environmental exposure

Malaria is one of the public health problems in the world. More than 3.3 billion people are at risk of malaria. Children under the age of five year, and pregnant women are most severely affected. The disease is transmitted to human through the bite of an infected female mosquito of the genus *Anopheles*. Nowadays Long-Lasting Insecticidal Mosquito Nets (LNs) are the most popular and useful tools for malaria control. At the same time LNs face some challenges as the need for reliable methods to check the amount of pesticide used on the nets. Also there is a need to know if the LNs are still effective against mosquitoes after a certain time. In addition, some questions arise: ‘How should LNs be used and washed?’ ‘Which detergent should be used during the washing process?’ ‘How should LNs dry, indoor or outdoor, exposed to or avoiding sunlight?’ Next to the focus on the quality and efficacy of the LNs, as they contain pesticides the use of LNs may lead to human and environmental exposure to pesticide residues. From this, following questions arise: ‘Are LNs safe for human

contact?’ ‘What about the long term effects of human exposure?’ ‘Knowing that pesticides are released during the washing step, what is the potential of LNs to contaminate water resources?’ From the questions mentioned above, the following objectives were put forward:

1. to review literature and to situate Long-Lasting Insecticidal Mosquito Nets (LNs) along the effective methods for malaria vector control;
2. to validate a suitable analytical method to analyze insecticides commonly used in LNs;
3. to evaluate the effect of washing on the release of the insecticide active ingredient content for different brands of LNs;
4. to evaluate the effect of UV light on the breakdown of the active ingredient content of LNs;
5. to compare the laboratory hand washing simulation to a domestic washing method with a proposed detergent;
6. to develop an approach to assess the dermal and inhalation exposure for people sleeping under LNs;
7. to assess environmental contamination due to the use of LNs.

In the present work, the origin of the malaria, the chain of its transmission, and the implementation of the malaria control tools was reviewed.

It was found that the bioassay test, and the chemical analysis are the commonly used methods to assess the efficacy of LNs. The bioassay test is mostly used by the manufacturer but has a disadvantage of a higher variation. Consequently, chemical analyses are preferred. To address the need of using one analytical method for the determination of several insecticides in different nets, this work provides a 30 minutes reflux extraction method with xylene to determine alpha-cypermethrin and deltamethrin in LNs by gas chromatography with electron capture detection (GC- μ ECD). The selectivity, specificity, recovery and repeatability of the method are well demonstrated. The recoveries vary within the acceptable range of 80 – 120% and the RSD are below 4%. With a LOD of 0.3 mg a.i./m² net, for alpha-cypermethrin and deltamethrin, the method is sensitive. As a result, it can be used for quality control and also for research programs where the interest is to determine the remaining amount of insecticide in used LNs.

The validated chemical method was used in the following parts of the research. The release of the active ingredients of Interceptor[®], PermaNet[®] 2.0, and Netprotect[®] nets was studied as a function of the number of washing cycles. It was found that independently to the drying processes after the washing, the total active ingredient content on the different LNs decreased with the number of washes. The coated nets (Interceptor[®] and PermaNet[®] 2.0) lost 70% of the insecticide content after 20 washes, while incorporated nets (Netprotect[®]) lost only 30%. According to the literature, the loss of active ingredient did not affect the biological efficacy of nets. The washing resistance of incorporated nets was higher compared to coated nets. It was also found that in general, the best fitting mathematical model of the active ingredient retention/release with washing was the exponential or logarithmic model for coated nets, while no fit for any of the mathematical models tried out was found for the Netprotect[®] nets.

The study presents also the results of the comparison of the ISO 6330:2000 machine washing and the laboratory hand washing simulation using a specific detergent. It was found that the washing impact on the LNs depends mainly on the impregnation technologies used to add the pesticide to the nets. The laboratory hand washing simulation removed more active ingredient from the Netprotect[®] nets than the ISO 6330:2000 machine washing procedure.

In addition the simulation of indoor and outdoor drying with UV-light of the washed LNs were done in the same way to compare whether a significant difference exist when people dry their LNs indoor or outdoor. It was found that the effect of drying procedures on the release of the active ingredient from each type of net was not statistically significant. This might be due to the efficiency of UV protection technology used by the manufacturers and/or the absence of higher temperatures and/or higher UV intensity in the used test set up.

The human and environmental exposure due to the use of LNs was studied in the final part of the work. It was found that human exposure due to sleeping under LNs could be narrowed to dermal exposure. Also the risk of dermal exposure depends on the type of the technology used for LNs. The transferred amount of the insecticides to the skin could be well quantified for coated nets while this was not the case for the incorporated nets. The

approaches used for the dermal exposure determination were successfully achieved by using cotton gloves, but also with less variability with Martindale equipment used for the determination of abrasion and pilling resistance on textile structures, and with a WHO generic model, and the ConsExpo 4.1 Model. The cotton gloves approach developed here for exposure assessment is more practicable and closer to reality, but seemed to provide higher exposure measured compared to the generic model and the ConsExpo 4.1 model.

For the exposure of the environmental compartment to the released amount of insecticide from LNs, it was found that the contamination of water during the washing of LNs should be seriously considered.

Further work can address the limitations found in this study. This work was done with two pesticides for a coated net and one pesticide for an incorporated net. The range of pesticide and also textile can be extended in the testing in order to check the behavior of other pesticides, the effect of other textiles, and the effect of other coating or impregnation technologies. Also by now, LNs are indeed efficient for malaria control. Still containing insecticides, the old and unused LNs might be collected and recycled for other uses like bio-composite plastic-wood lumber to be used for decking. No effort to evaluate this type of second hand usage is done by now, resulting in waste obviously contaminating the environment.

Finally, the problem of assessing human exposure to LNs by the use of the existing models needs to be refined. Real measurements done in this study are not in agreement with the models based on a theoretical approach. Also another approach could be used for the assessment of inhalation exposure with particular attention on particle inhalation exposure.