UNHCR
The UN Refugee Agency

GREENING OPPORTUNITIES FOR **MOSQUITO NETS**

Long-Lasting Insecticidal Nets(LLINs) procured by UNHCR

EXECUTIVE SUMMARY

Reduction of the carbon footprint associated with the production and delivery of the Core Relief Items (CRIs) is one of the main objectives of UNHCR towards Climate Resilience and Environmental Sustainability. The Long-Lasting Insecticidal Nets (LLINs) are among the essential CRIs that are procured and distributed by UNHCR. UNHCR procures 1.6 million LLINs annually, equating to more than 6.5 kilo-tonnes of CO_2, as well as more than 800 tonnes of plastic released into the environment.

This Desk Review explores options for reducing the environmental impact of LLINs procured and distributed by UNHCR whilst ensuring refugees have access to quality LLINs to protect against malaria and other vector borne diseases.

Findings of this Desk Review:

1. The most viable option to reduce the carbon footprint of LLINs is to shift from virgin plastic to 100% recycled plastics used for LLINs production. Only within the UNHCR context, it would result in a yearly CO_2 reduction of ~3 kilo-tonnes.

2. However, several obstacles limit the immediate introduction of LLINs made of 100% recycled plastic to UNHCR practice:

   - ***Duration of the pre-qualification process of products by WHO.*** The product evaluation process conducted by WHO takes approximately 12 months which may delay the availability on the market of approved recycled LLINs.
   - ***Limited availability of suppliers in the market for the provision of 100% recycled LLINs.*** Only two companies have been identified that have recycled LLINs projects. One of them, Vestergaard (PermaNet 3.0™), proved a principal possibility to make net-to-net recycling without compromising the quality of the recycled LLINs. Another company, Shobikaa Impex GreenNet™ is already on the verge of mass production of bottle-to-net recycled LLINs (production capacity 40 000 LLINs per day). GreenNet™ recycled LLIN is currently in a WHO Prequalification Pipeline. Recycled LLINs might be available at the beginning of 2024. These companies may control the market prices and may also limit innovation due to the lack of competition.
   - ***Lack of motivation of the suppliers to shift towards recycled materials***, which can be attributed to: a) the relatively low market price of the current mosquito nets (approximately USD 2); b) a low demand for LLINs made of recycled materials; and c) the relatively small volume procured by UNHCR, out of overall demand, to attract sufficient suppliers to compete for contracts. There is no sufficient demand for recycled materials to create the market conditions.

3. The demand of UNHCR is only a small portion of the global demand (less than 1 per cent of the global demand). Therefore, UNHCR has limited leverage to influence the introduction of sustainable materials and to reduce the market price.

Recommendations:

1. A coordinated action of UN agencies is required to both reduce the price and improve the production capacity of LLINs made of recycled materials, which are becoming available on the market with the same quality and reduced carbon footprint.

2. The procurement of 100% recycled LLINs should ideally take place through UN aggregated demand, to increase the purchasing power of UN agencies due to the limited availability of suppliers in this market. Engagement with key sister agencies procuring LLINs is required to understand their environmental policies and directions and explore common objectives and procurement.

3. Close cooperation with WHO is required to understand their position regarding environmental policies / considerations and greener specifications as well as any other products in the prequalification pipeline. Unilateral action of UNHCR is not recommended as it would result in a higher price and be limited to 2 suppliers; lack of competition can also reduce the incentive to improve the product as the market is controlled by a small number of suppliers.

Expected Results:

- Coordinated approach of UN Agencies towards a more sustainable option for LLINs.
- Increased economies of scale of the suppliers resulting in reduced costs of LLINs made of 100% recycled plastics.
- Ensured standardization, leading to efficiencies in the procurement processes with lowered administrative costs of UN Agencies.
- Increased opportunity to shape the market of more sustainable products and reduce the emissions generated by this item.
- Increased efficiency in delivering humanitarian assistance.

Abbreviations

LLIN – Long-Lasting Insecticidal Net

WHO – World Health Organization

PBO – Piperonyl-butoxide

WHOPES – WHO Pesticide Evaluation Scheme

PPF – Pyriproxyfen

PET – Polyethylene Terephthalate plastic (In textile form, it is also known as polyester)

PE – Polyethylene

HDPE – High-density polyethylene

LDPE – Low-density polyethylene

WAP – Weighted average price

AMP – Alliance for Malaria Prevention

CO_2 – Carbon dioxide

CO_{2e} – Carbon dioxide equivalent

Definition of Terms

Bio-based plastics – plastics produced from renewable biomass sources, such as vegetable fats and oils, corn starch, straw, wood chips, sawdust, recycled food waste, etc. Bio-based plastics are not necessarily biodegradable or compostable.

Biodegradable and compostable plastics -- plastics produced from renewable biomass or non-renewable fossils. The main feature of these plastics is that they can be broken down by microorganisms into water, carbon dioxide, mineral salts and new biomass within a defined period. The rate of biodegradation or composting strongly depends on the conditions of exposition during disposal. These include temperature, duration, the presence of microorganisms, nutrients, oxygen, and moisture.

Chlorfenapyr – is a member of the pyrroles class of chemicals. This compound is a pro-insecticide, i.e. the biological activity depends on its activation to another chemical. For LLINs, chlorfenapyr is recommended for use in combination with pyrethroid(s).

Dalton (Da) – is an atomic unit of mass that is equal to one-twelfth of the mass of a free carbon-12 atom at rest.

Extrusion – is a plastic manufacturing process that involves forcing the base material through a pre-shaped die to create objects with a specific cross-sectional profile.

Extrusion die – is a metal channel that imparts a specific cross-sectional shape to a polymer stream.

Insecticides – are chemicals used to control insects by killing them or preventing them from engaging in undesirable or destructive behaviors.

Long-Lasting Mosquito Net (LLIN) – is a mosquito net that has been treated with insecticide during the manufacturing process.

Masterbatch – is a plastic formulation that contains additives that are essential for the appearance and/or performance of the final product. Usually, a masterbatch is comprised of plastic pellets that contain a concentrated number of additives such as processing aids, colorants, UV-stabilizers, oxi-biodegradable additives, fillers, etc.

Monofilament – is a single yarn made from molten polymer extruded through a die, and then drawn through a series of rollers to orient the molecules in order to obtain the desired characteristics.

Multifilament yarn – is a yarn that contains a multitude of fine, continuous monofilaments (often 5 to 100 individual filaments) usually with some twist in the yarn to facilitate handling.

Oxi-biodegradable plastics – ordinary plastics that include additive(s), which degrade through oxidation in the open environment until their molecular weight is low enough to be accessible to bacteria and fungi, who then recycle them back into nature.

Oxi-degradable plastics – ordinary plastics that include additive(s), which degrade through oxidation in the open and quickly create fragments, but do not necessarily become biodegradable except over a very long time.

Piperonyl-Butoxide (PBO) – is a chemical that enhances the potency of pyrethroids against pyrethroids-resistant mosquitoes. For LLINs, PBO is recommended for use in combination with pyrethroid(s).

Prequalification pipeline – is used to refer to finished pharmaceutical products (FPPs) and active pharmaceutical ingredients (APIs) accepted for and currently undergoing evaluation by WHO for prequalification.

Prequalified Vector Control Products – is a list that contains vector control products that have been assessed by WHO and found to be acceptable, in principle, for procurement by the United Nations and other international agencies and countries.

Pyrethroids – are synthetic derivates of pyrethrins, which are natural organic insecticides procured from the flowers of Chrysanthemums. Pyrethroids are used in many synthetic insecticides and are generally used against mosquitoes. Pyrethroids are cost-effective, widely studied and used for many years.

Pyriproxyfen (PPF) – is an insecticide that mimics natural hormones in insects, disrupting their growth. PPF is a type of insect growth regulator that affects mostly young insects and eggs. Although rarely toxic to adult insects, it prevents insects from multiplying. For LLINs, PPF is Recommended for use in combination with pyrethroid(s). PPF is low in toxicity to humans.

Recycled plastics – are plastic materials that have undergone a process of collection, cleaning, sorting and reprocessing after their initial use.

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Chapter 1. Long Lasting Insecticidal Nets, technical background

1.1 Background of LLINs

A five-year WHO investigation showed that LLINs remain the most effective intervention tool to control malaria[1][2]. They function as knitted polymer filaments that contain or are coated with insecticide allowing for this mosquito-killing effect to be maintained longer than alternative methods of protection. However, not all LLINs provide the same physical and biological protection from bites of infected mosquitoes. Nets differ in their material composition, insecticide used, and methods and means of production and processing. In the below sections, more details about the insecticides used for LLINs (Section 1.2), primary materials for LLINs (Section 1.3) as well as some treatment process details (Section 1.4) will be given.

1.2 Insecticide used for LLINs

The insecticide used for LLINs must comply with WHOPES (WHO Pesticide Evaluation Scheme), which carries out testing and evaluation of the product to ensure quality, safety and efficacy. A prequalification process is conducted that allows companies to provide products that are safe to use due to the content of insecticides. Currently, only four classes of insecticides are recommended by WHO:

1. Pyrethroids (Permethrin, Alpha-cypermethrin, Deltamethrin, others) – is the oldest type of insecticide used for LLINs. These insecticides are readily available, cost-effective, widely studied and used for many years. However, mosquitoes in many areas are now resistant to pyrethroids, and the effectiveness of these insecticides has decreased.

2. Combination of Pyrethroids and Piperonyl-Butoxide (PBO). WHO started to recommend this combination in 2017. PBO is a chemical that enhances the potency of pyrethroids against pyrethroids-resistant mosquitoes. Pyrethroids-PBO LLINs are more expensive than those with only Pyrethroids. Also, PBO is less wash-resistant than pyrethroids, therefore its bioavailability declines faster over the three-year lifespan of LLINs.

[1] *Five-year WHO investigation shows that LLINs remain a highly effective tool in the malaria fight. https://www.who.int/news/item/16-11-2016-five-year-who-investigation-shows-that-llins-remain-a-highly-effective-tool-in-the-malaria-fight*

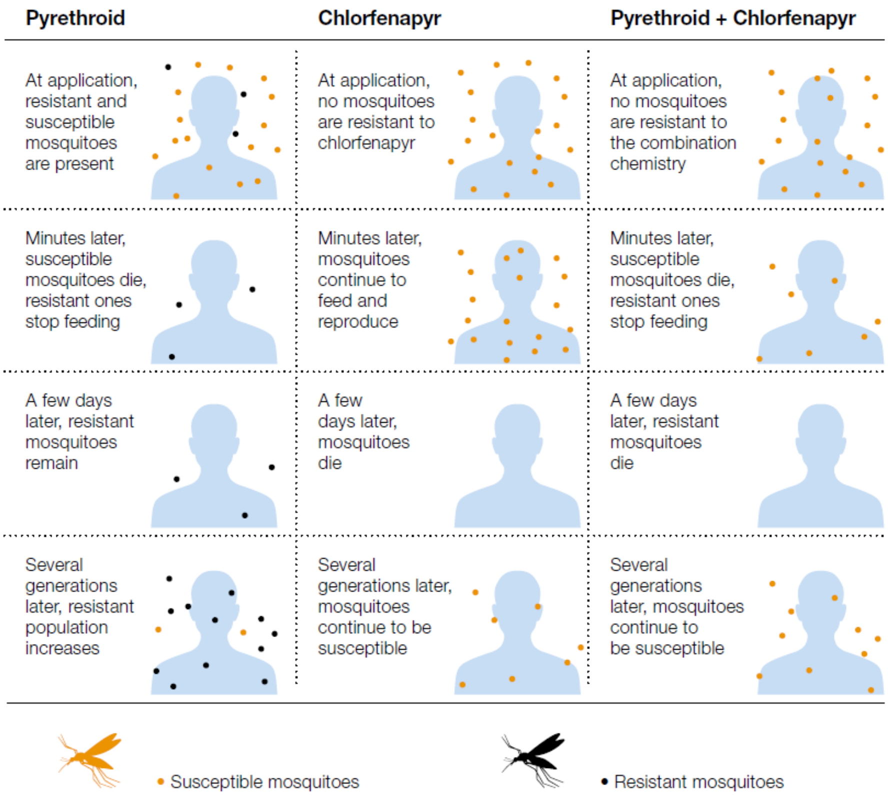
[2] *Kleinschmidt, I., Bradley, J., Knox, T.B., Mnzava, A.P., Kafy, H.T., Mbogo, C., et.al., 2018. Implications of insecticide resistance for malaria vector control with long-lasting insecticidal nets: a WHO-coordinated, prospective, international, observational cohort study. Lancet Infectional Diseases 18(6). 640-649. https://doi.org/10.1016/S1473-3099(18)30172-5*

3. Combination of Pyrethroid and Chlorfenapyr. WHO began recommending this combination in 2023. Pyrethroid-Chlorfenapyr LLINs are theoretically more effective and less harmful for humans than Pyrethroid-PBO LLINs. However, this evidence is from only one trial in Benin[3].

4. Combination of Pyrethroid and Pyriproxyfen (PPF). WHO began recommending this combination in 2023. PPF is a commonly used juvenile hormone mimic and growth inhibitor (i.e. an insect growth regulator) that sterilizes any mosquitos that survived contact with the LLINs, so they cannot multiply. PPF can also be effective at reducing the lifespan of mosquitos. Studies show that the mortality of mosquitos subjected to PPF-permethrin nets is 8.6 per cent higher than for nets with only permethrin (Pyrethroid class). The main drawback of this kind of LLIN is the high price (compared to pyrethroids-only LLINs).

LLINs with two insecticides (e.g. Pyrethroids + PBO, Pyrethroid + Chlorfenapyr, etc.) are called dual active ingredient LLINs. The mechanism of action of dual active ingredients is presented in Fig. 1.

Fig. 1. Mechanism of action of dual active ingredients (from BASF The New Nets Project[4])



[3] *Accrombessi, M., Cook, J., Dangbenon, E., Yovogan, B., Akpovi, H., et. al., 2023. Efficacy of pyriproxyfen-pyrethroid long-lasting insecticidal nets (LLINs) and chlorfenapyr-pyrethroid LLINs compared with pyrethroid-only LLINs for malaria control in Benin: a cluster-randomised, superiority trial. Lancet 401(10375). 435-446. https://doi.org/S0140-6736(22)02319-4.*

[4] *https://agriculture.basf.com/global/en/business-areas/public-health/our-partnerships/stories_partnership_countries/stories/manufacturing-a-new-generation-of-mosquito-net.html*

There are **25 LLINs in the Prequalified Vector Control Products**[5] issued by WHO (Table A1 in Annex 1). Additional four LLINs are in the Prequalification Pipeline[6] (Table A2 in Annex 1).

UNHCR can purchase only LLINs from the list of Prequalified Vector Control Products.

1.3 Materials used for LLINs

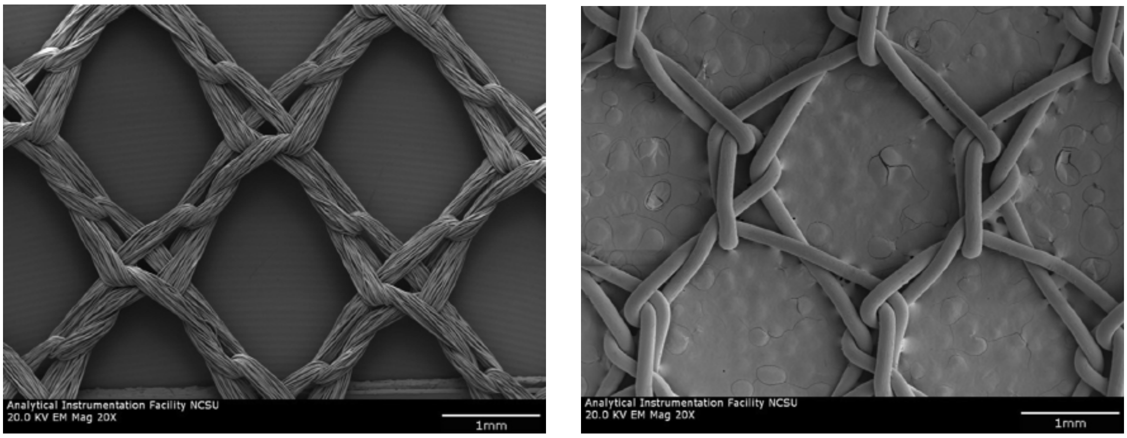
Currently, only 100 per cent polyester (PET) and 100 per cent polyethylene (PE), i.e. Low Density Polyethylene (LDPE) and/or High Density Polyethylene (HDPE) have been approved as per material for LLINs by WHO.

Polyester (Polyethylene Terephthalate, PET) LLINs are made of yarns which consist of multiple filaments (Fig. 2 a) (typically 48 in 100 denier yarns) that are twisted together in the yarn production process. LLINs made of PET are coated with insecticide (for more details, refer to Section 1.4). PET used for LLINs manufacture exists in many varieties and qualities.[7].

Polyethylene (PE) LLINs are typically made from single filament yarns (Fig. 2 b) that are extruded with additives, color, and insecticide. Therefore, the insecticide is located throughout the LLINs yarn, so the technology is called “incorporation” (for more details, refer to Section 1.4). PE yarns are typically made as a mix of high-density and low-density polyethylene (HDPE and LDPE, respectively).

Fig. 2. (a) Polyester multifilament LLIN coated with insecticide; (b) polyethylene monofilament LLIN with incorporated insecticide (reproduced from Peresin et al.[8])

(a) (b)



[5] https://extranet.who.int/pqweb/vector-control-products/prequalified-product-list?field_product_type_tid=100&field_pqt_vc_ref_number_value=&title=&field_applicant_tid=&field_active_ingredient_synergis_tid=
[6] https://extranet.who.int/pqweb/vector-control-products/prequalification-pipeline
[7] Skovmand, O., Dang, D.M., Tran, T.Q., Bossellman, R., Moore, S.J., 2021. From the factory to the field: considerations of product characteristics for insecticide-treated net (ITN) bioefficacy testing. Malarja Journal 20: 363, 1-13. https://doi.org/10.1186/s12936-021-03897-7
[8] Brake, S., Gomez-Maldonado, D., Hummel, M., Zohdy, S., Peresin, M.S., 2022. Understanding the current state-of-the-art of long-lasting insecticide nets and potential for sustainable alternatives. Current Research in Parasitology and Vector-borne Diseases, 2, 100101

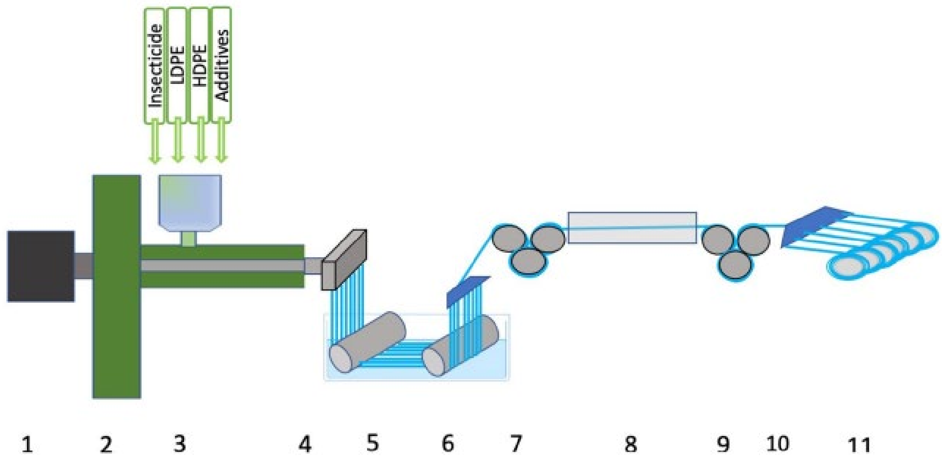
1.4 Manufacturing (treatment) process for LLINs

After the manufacture of the LLINs, insecticides are released by the fibers of the nets through diffusion to ensure slow release and long-lasting properties. There two main methods to incorporate insecticides to LLINs:

1. **Infusing, i.e. incorporation of insecticides** into the fibers during the production of fibers used for LLINs made of PE. The insecticide in the form of powder or liquid is mixed with the pellets of PE (LDPE, HDPE or mixture of both) and both components are co-extruded into a filament (Fig. 3 a). In this case, the insecticide can remain within the filament and migrate to the surface when needed. As shown in Fig. 3 b, the insecticide migrates from the bulk of a filament to its surface. The rate of this migration is dictated by the initial concentration of the insecticide, as well as the ratio of HDPE and LDPE in the mixture. HDPE and LDPE have different crystallinity level (80-90 per cent and 30-50 per cent respectively). Dense crystalline zones block the migration of insecticides and therefore HDPE has much lower migration rate of insecticide than LDPE (Fig. 4). HDPE is stronger than LDPE and therefore, an optimum LDPE/HDPE ratio is necessary to ensure enough strength, as well as appropriate insecticide migration in incorporated polyethylene LLINs. The ratio of LDPE and HDPE affects the release of insecticides from polyethylene LLIN. The data show the number of washes 20 experimental PE nets could resist before failing, according to WHO cone tests as a function of the HDPE per cent of the polymer total. The 80 per cent optimum mortality was used as a threshold (reproduced from Skovmand et al.).

Fig. 3. Production of incorporated LLINs[9]

(a)



(1) Extruder for yarn production (simplified drawing); (2) the motor driving the extrusion screw;; (3) the hopper containing mixture of polymer and insecticide; (4) the extruder tube with heating and cooling

[9] *Skovmand, O., Dang, D.M., Tran, T.Q., Bossellman, R., Moore, S.J., 2021. From the factory to the field: considerations of product characteristics for insecticide-treated net (ITN) bioefficacy testing. Malarja Journal 20:363, 1-13.* https://doi.org/10.1186/s12936-021-03897-7

bodies around a central tube with the extruder screw; (5) the die head where 150–300 yarns are extruded in parallel into a water bath; (6) a comb that arranges the yarns parallel drawn by the first set of rotating rollers (7); (8) a stretch zone where yarns are drawn by the difference in speed of rotation rollers (7) and (9); (10) a set of combs that guides the yarns to winding up on cones. (11) (b) Diffusion process of insecticides in a filament (schematically).

(b)

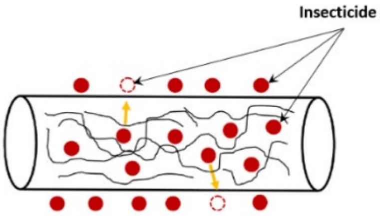
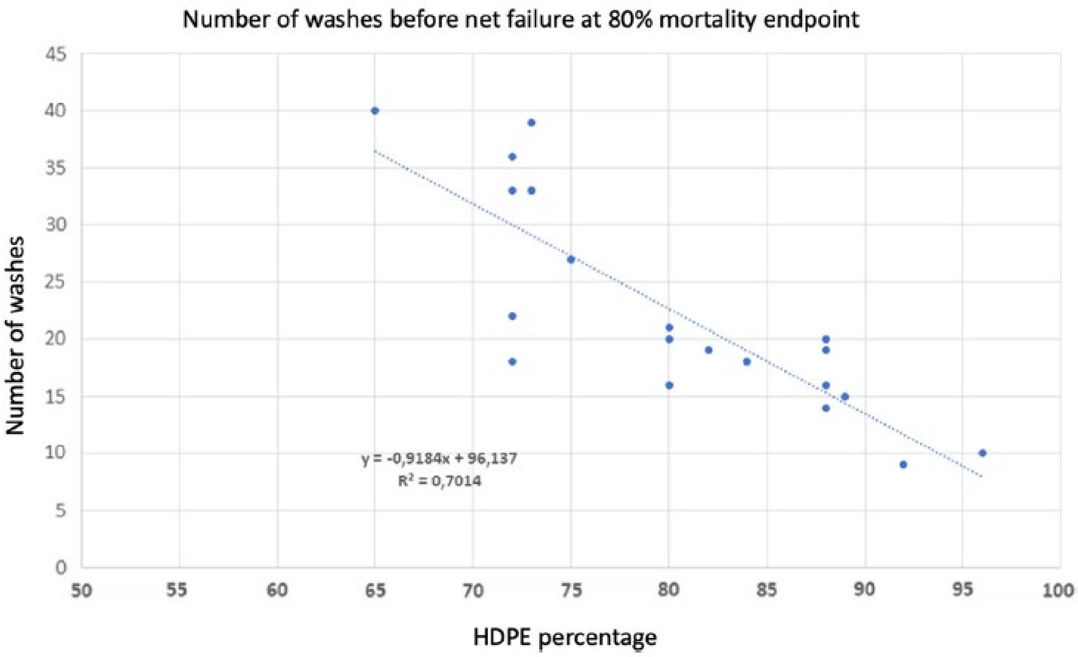


Fig. 4. Number of washes that nets could resist before failing by HDPE percentage (reproduced from Skovmand et al.[14])

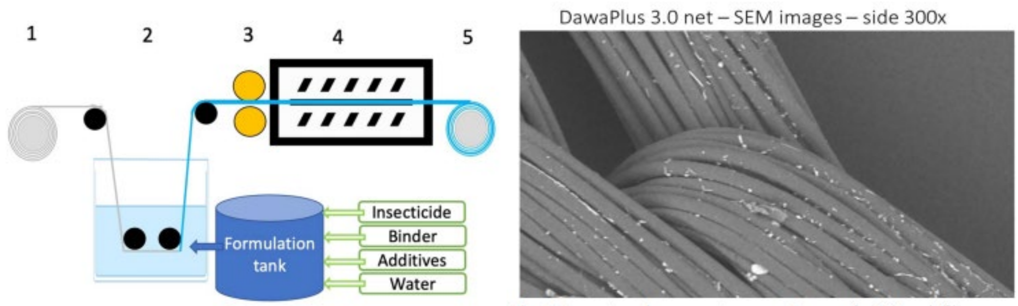


2. **Impregnation, i.e. coating** of LLINs made of polyester with a suspension that contains insecticide. Polyester is a highly crystalline material (with a crystallinity level of 60-85 per cent). Dense crystalline zones block the migration of insecticides in polymer, which is one of the reasons why the impregnation method is used for insecticide treatment in polyester LLINs. The process of impregnation of LLINs with insecticide is schematically represented in Fig. 5. Impregnation or coating with insecticide happens after the multiple polyester filaments are knitted into a fabric. A polymer and insecticide mixture are suspended in a bath, then the multifilament polyester yarn is run through the bath so the suspension can bond to the filaments' surface. Then, the net must be dried so the polymer can cure, and the insecticide can crystallize in the interfaces of the filaments. As shown in the microscope image of

impregnated LLIN (Fig. 5 b), the insecticide particles concentrate on the surface and in between filaments

Fig. 5. (a) Schematic representation of the impregnation process of polyester LLIN (reproduced from Skovmand et al.[14]): (1) roller with a LLIN; (2) a bath with insecticide suspension: (3) two pressing rollers for squeezing out excess fluid; (4) a drying and curing oven; (5) a roller for ready LLIN; (b) scanning electron microscope image of a multifilament polyester yarn coated with a dispersion of deltamethrin particles.

(a) (b)



1.5 LLINs currently prequalified by WHO

Out of the 25 LLINs currently prequalified by WHO, 14 of them incorporate insecticides, eight are coated and three use incorporated netting for the top part and coated netting for the sides. LLINs made of PE (usually a mixture of HDPE and LDPE) have incorporated insecticide, while LLINs made of polyester (PET) are impregnated with insecticide. While both polyester and polyethylene nets provide the same level of protection, several end-user factors other than the material of LLINs seem to drive net use. Based on a UNICEF report[10], the end-users' feedback indicates that polyester nets are lighter and softer compared to polyethylene.

Table 1. Summary of the main differences between polyethylene and polyester LLINs

Material of LLIN	100 per cent Polyethylene (mixture of LDPE and HPDE)	100 per cent Polyester (PET)	Roof – 100 per cent polyethylene; side walls – 100 per cent polyester
Filament type	Monofilament	Multi-filament	-
Insecticide treatment method	Incorporation, i.e. infusion	Impregnation, i.e. coating	-
Number of LLINs prequalified by WHO	14	8	3

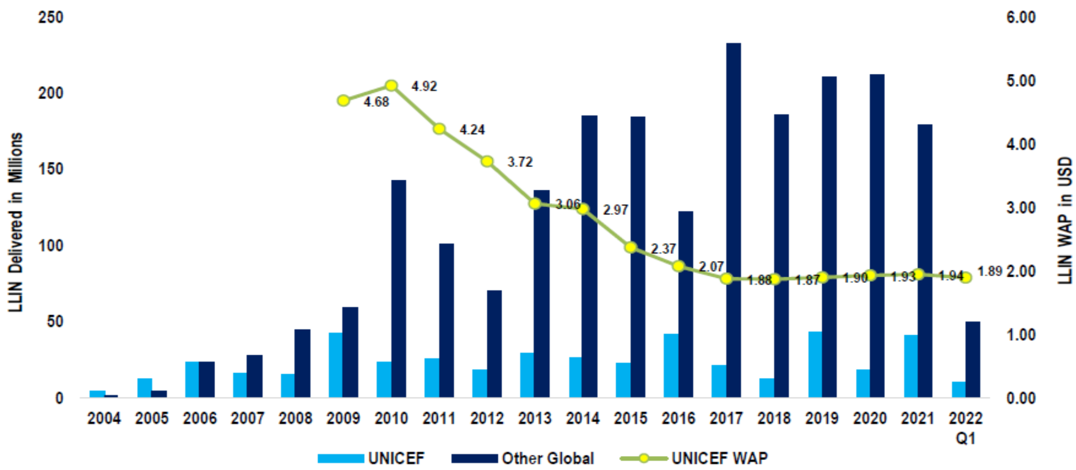
[10] *Long-Lasting Insecticidal Nets: Market and Supply Update. UNICEF Supply Division 2022. https://www.unicef.org/supply/reports/long-lasting-insecticidal-nets-market-and-supply-update*

Chapter 2. The global market of LLINs

2.1 The global deliveries of LLINs

The total global deliveries of LLINs have been gradually increasing since 2012, reaching over 250 million nets in 2017 and 2019 (Fig. 6).[11] At the same time, the Weighted Average Price (WAP) per LLIN steadily decreased from $ 4.92 in 2010 to $ 1.89 in 2022.

Fig. 6. Global LLIN deliveries 2004-Q1 2022 (reproduced from UNICEF Supply Division Report[16])



Approximately 90 per cent of all LLINs are delivered to African countries, of which Benin, Cameroon, Chad, the Democratic Republic of the Congo, Ethiopia, Mali, Mozambique, Nigeria and Sudan, accounted for 70 per cent of the overall LLINs distribution in 2022 (Fig. 7). Pakistan represents the largest recipient country outside of Africa and accounts for 2 per cent of the overall LLINs distribution. The demand for LLINs varies significantly from country-to-country and from year-to-year. This is due to the large-scale mass distribution campaigns that require countries to renew and procure LLINs on a two- to three-year cycle.

The Alliance for Malaria Prevention (AMP) developed a Net Mapping Project, the main goal of which is to monitor the delivery of WHO prequalified LLINs since 2004. The detailed interactive map that enables tracking the number and location of distributed LLINs in malaria-endemic countries is available online[12]. Based on the data of a Net Mapping Project since 2009, some 2 515 million standard (i.e. pyrethroid-treated) LLINS were distributed all over the world (Fig. 8).

[11] *Long-Lasting Insecticidal Nets: Market and Supply Update. UNICEF Supply Division 2022.* *https://www.unicef.org/supply/reports/long-lasting-insecticidal-nets-market-and-supply-update*

[12] *https://netmappingproject.allianceformalariaprevention.com/*

Fig. 7. WHO prequalified LLINs distribution by country in 2022 (based on Net Mapping Project[13])

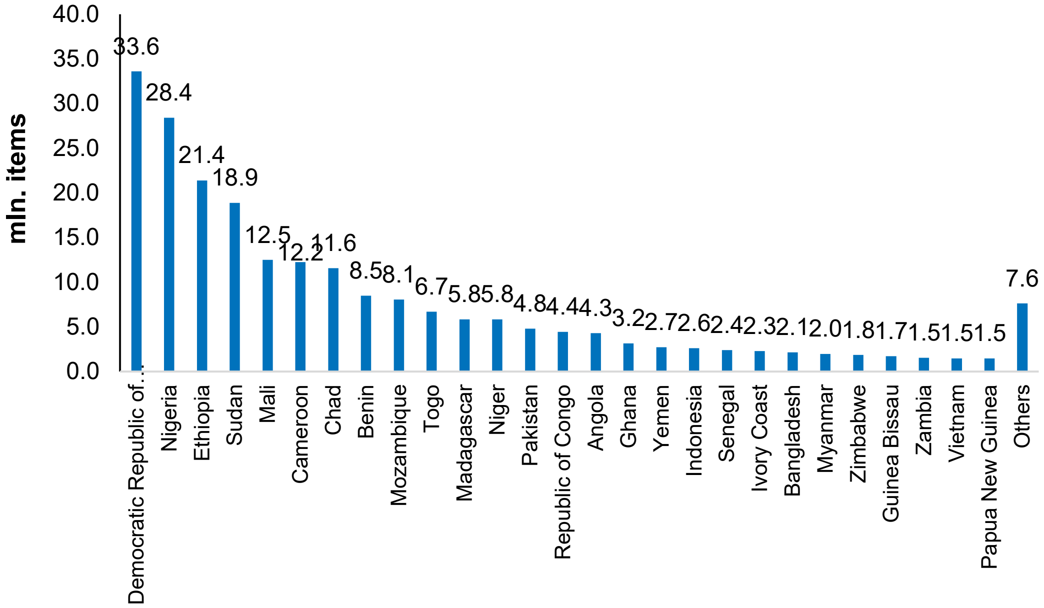
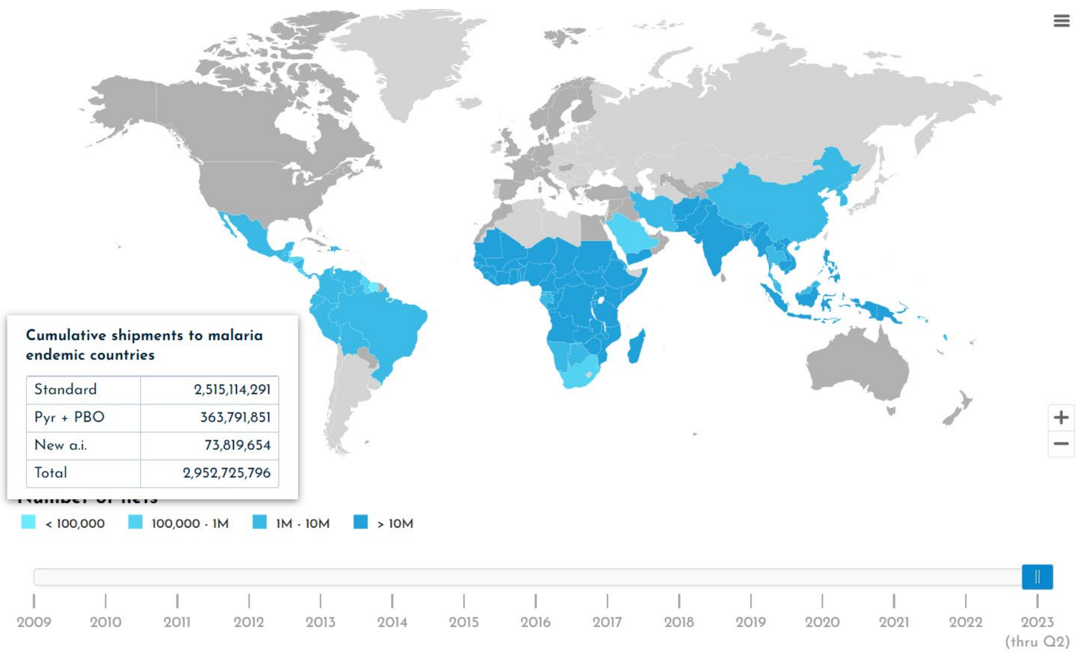


Fig. 8. The cumulative shipment of different types of LLINs from 2009 till 2023 (source: Net Mapping Project[19])



[13] https://netmappingproject.allianceformalariaprevention.com/

2.2. The supply of LLINs

Based on the UNICEF estimates, the LLIN industry production capacity is around 480 million nets per year, with a global supply of 240 to 270 million nets per year[14]. There are multiple LLIN variations in net size, color, mesh, shape, packaging and labelling. The most procured are rectangular nets with the following sizes: 190 x 180 x 150 cm, 180 x 160 x 150 cm; 190 x 180 x 170 cm.

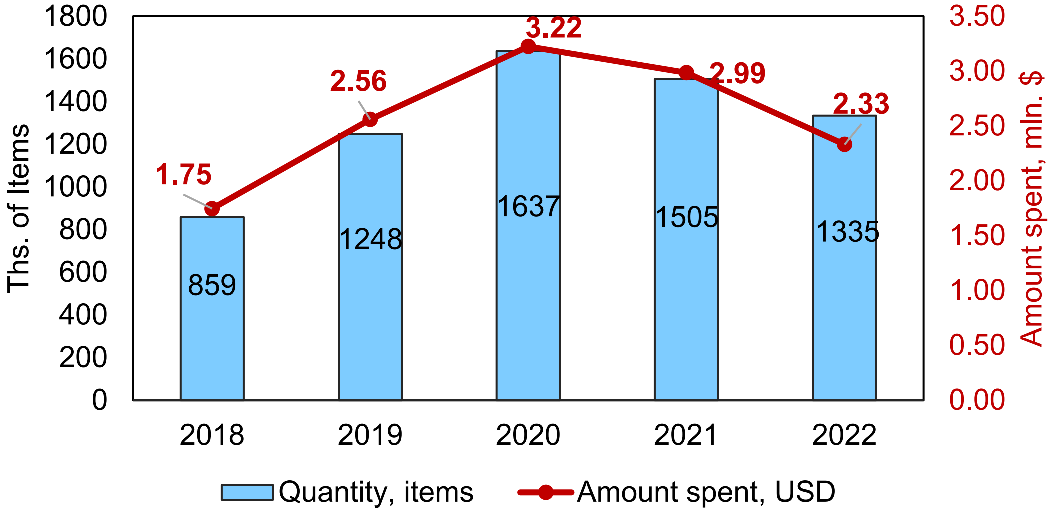
This report focuses on **LLINs from the list of Prequalified Vector Control Products.** Currently, there are **25 LLINs in the Prequalified Vector Control Products**[15] issued by WHO (Table A1 in Annex 1). Additional four LLINs are in the Prequalification Pipeline[16] (Table A2 in Annex 1). All the 29 LLINs are produced by 13 manufacturers (Table 2). Out of 29, two manufacturers are located in India, two in Africa, four in China, one in Vietnam and one in Germany (Table A3 in Annex 1).

2.2 UNHCR demand for LLINs

2.2.1 LLINs supply by UNHCR

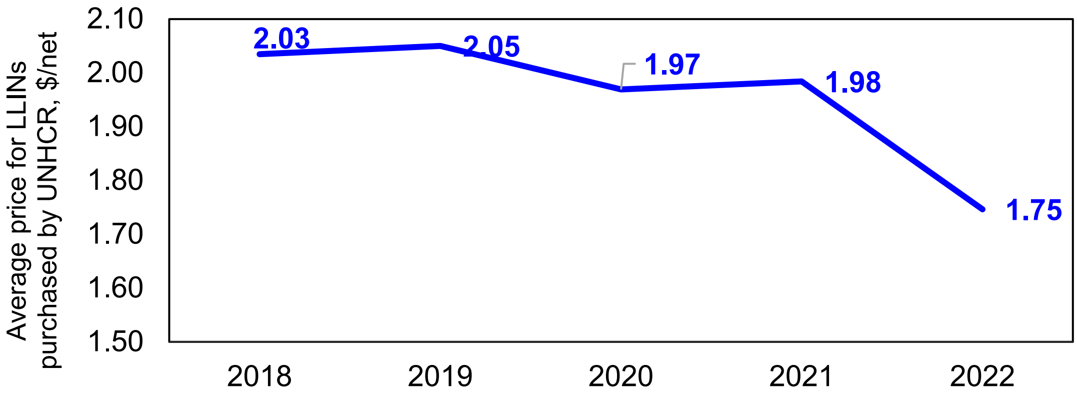
The results of an analysis of UNHCR's procurement of LLINs during the period 2018-2022 are presented in Fig. 9 to Fig. 11. The quantity of the LLINs purchased by UNHCR increased from 2018, reaching its maximum (1.6 million LLINs) in 2020 (Fig. 9), and slightly decreased in the following years. At the same time, the average price per LLIN steadily decreased from $2.03 in 2018 to $1.75 in 2022 (Fig. 10).

Fig. 9. The quantity of LLINs procured yearly by UNHCR and the related expenditures (2018-2022)



[14] *Long-Lasting Insecticidal Nets: Market and Supply Update. UNICEF Supply Division 2022.*
[15] *https://extranet.who.int/pqweb/vector-control-products/prequalified-product-list?field_product_type_tid=100&field_pqt_vc_ref_number_value=&title=&field_applicant_tid=&field_active_ingredient_synergis_tid=*
[16] *https://extranet.who.int/pqweb/vector-control-products/prequalification-pipeline*

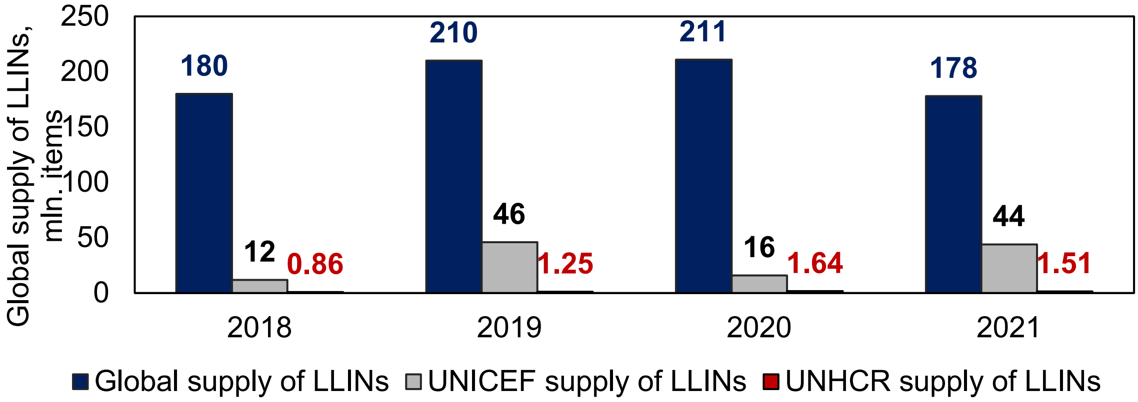
Fig. 10. The average price per LLIN (2018-2022)



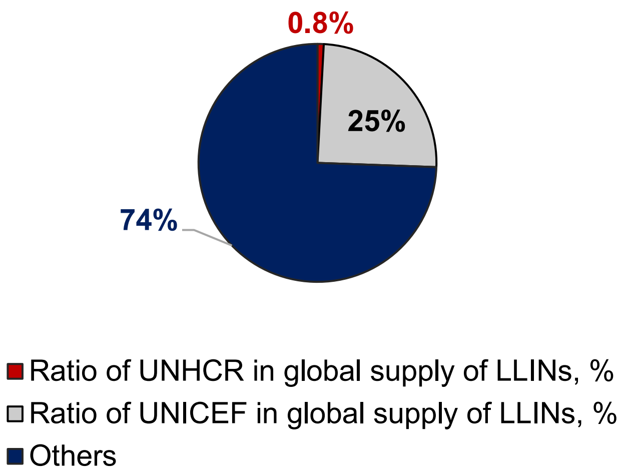
Compared to the global supply, the UNHCR share of LLINs is relatively small and does not exceed 1 per cent (Fig. 11). Thus, in 2021, UNHCR's supply of LLINs accounted for 0.8 per cent of the global LLINs supply. At the same time, UNICEF's ratio in LLINs supply in 2021 accounted for 25 per cent (Fig. 11 b).

Fig. 11. Comparison of the UNHCR supply of LLINs with the Global and UNICEF supplies: (a) in millions of items (2018-2021); (b) in per cent (2021)

(a)

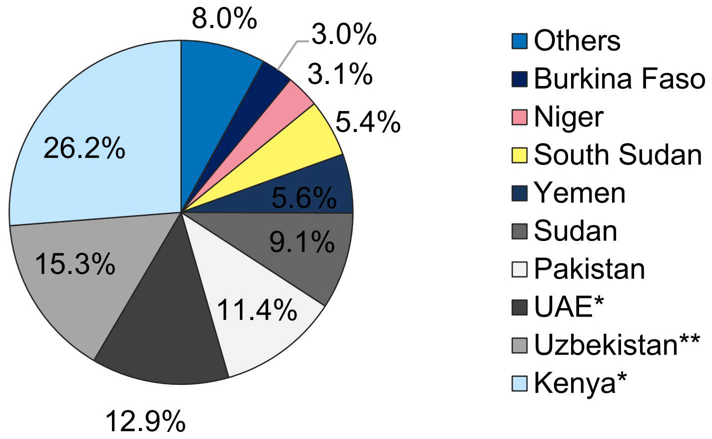


(b)



The distribution of LLINs supply by UNHCR in 2018-2022 sorted by country is presented in Annex 2 (Fig. A1 a-e). Most of the LLINs in 2022 were supplied to Kenya (26 per cent), Uzbekistan (15 per cent), United Arab Emirates (13 per cent), Pakistan (11 per cent) and Sudan (9 per cent) (Fig. 12).

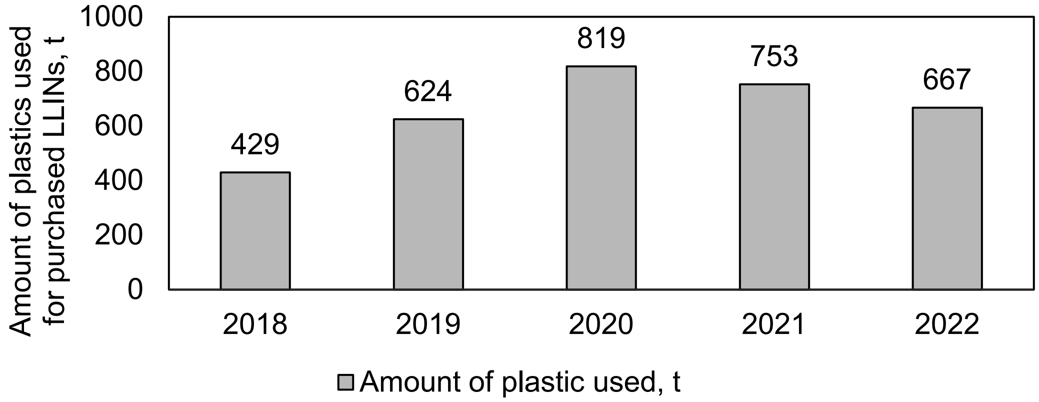
Fig. 12. UNHCR supply of LLINs by country in 2022



2.2.2 The amount of materials needed for the LLINs procured by UNHCR

The estimated amount of plastic (both PET and PE) necessary to produce the LLINs procured by UNHCR yearly ranges from 429 tonnes (in 2018) to 819 tonnes (in 2020) (Fig. 13). The estimation was done considering that 1 LLIN weighs around 0.5 kg.

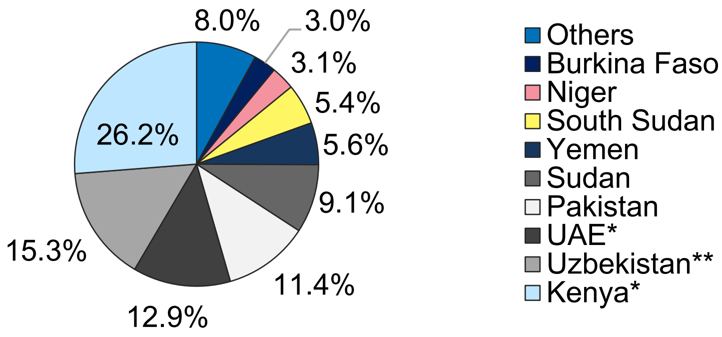
Fig. 13. The estimated amount of plastic used for the LLINs procured yearly by UNHCR (2018-2022)



In 2022, UNHCR procured around 1.33 million LLINs, out of which 96 per cent (approximately 1.28 million LLINs) were made of PET, while the other 4 per cent (which is 50 000 LLINs) were made of PE.

Most of the LLINs in 2022 were supplied to Kenya (26 per cent), Uzbekistan (15 per cent), United Arab Emirates (13 per cent), Pakistan (11 per cent) and Sudan (9 per cent) (Fig. 14).

Fig. 14. UNHCR supply of LLINs by country in 2022



Chapter 3. Sustainable opportunities for LLINs

Three feasible options to improve the sustainability of LLINs (reducing their carbon footprint) have been identified (listed in Table 2) and are discussed in detail in the sections below. Combinations of options (e.g., Option 1 + Option 2) are also possible.

Table 2. Feasible options to increase LLIN's sustainability.

Options	Description	Effect
Option 1	Shift towards **100 per cent recycled plastics** in LLINs production	- CO_2 reduction - Saving non-renewable resources - Reduction of plastic pollution
Option 2	**Remove individual packaging** from LLINs	- CO_2 reduction - Saving non-renewable resources - Reduction of plastic pollution
Option 3	Use **oxi-biodegradable plastics** for LLINs	Reduction of plastic pollution

3.1 Option 1: recycled plastic

In principle, LLINs can be made of 100 per cent recycled plastic (both polyethylene and polyester). However, **shifting towards recycled plastic in LLIN production may require suppliers to report the changes they make in material composition to the WHO and potentially undergo the prequalification procedure again.** Currently, there are **no fees** associated with the prequalification of LLINs nor the assessment for the development of specifications[17]. However, **the prequalification process takes from 6 to 12 months and consequently, shifting towards recycled plastic may cause additional difficulties for suppliers.**

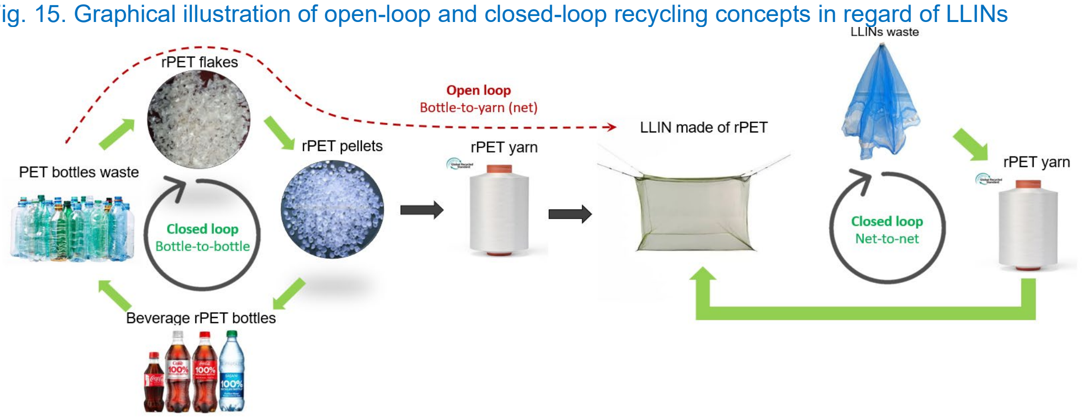
There two different recycling concepts -- open-loop and closed-loop recycling.

Open-loop recycling refers to the recycling of a product into a product for different application. For example, recycling of PET bottles to rPET yarn and consequently to some textile items (blankets, mosquito nets, etc.) is an open-loop recycling concept. The benefit of open-loop recycling is the reduction of environmental impact (e.g. reduced carbon footprint) of the final product. This is a feasible solution when the recycled material cannot be used for its original application (for example, ocean plastic scrap is very difficult to reprocess back to food-grade plastic), or when recycled material is widely available. However, the weak point of this concept is that the final product is very difficult to recycled again and return to the loop.

Closed-loop recycling refers to the recycling of a product into a same product category. Bottle-to-bottle recycling is a typical example of a closed-loop recycling. The benefit of this approach is that the plastic product can be recycled up to 10 times without significant properties degradation.

The discussed two concepts are in place for the recycled mosquito nets as well. Thus, mosquito nets can be made of recycled PET yarn, which can originate from two different sources: waste PET bottles (bottle-to-net recycling), or waste mosquito nets (net-to-net recycling). In both cases LLINs made of rPET have a reduced carbon footprint. Nevertheless, net-to-net recycling is more prospective due to a more prolonged lifetime of material, i.e. "longer staying in the loop". At the same time, due to the limited availability of old mosquito nets, finding enough raw material to implement net-to-net recycling is a challenging task. Oppose to this, rPET yarn made of PET bottle waste is more available in the market[18].

Fig. 15. Graphical illustration of open-loop and closed-loop recycling concepts in regard of LLINs



3.1.1. Vestergaard

Vestergaard has its headquarters in Switzerland, and its production facilities are located in Vietnam. The production capacity of the Vietnam factory is 50-60 mln. LLINs per year.

History of the "net-to-net" recycled LLINs project

[17] https://extranet.who.int/pqweb/vector-control-products/prequalification-procedures-and-fees-vector-control-products#:~:text=Fees%20for%20prequalification,been%20made%20at%20this%20time.

[18] https://textileexchange.org/knowledge-center/reports/materials-market-report-2022/

In 2020, **Vestergaard** announced the successful development and validation of their technology for manufacturing new LLINs from old nets without compromising quality[19]. The name of the product is PermaNet 3.0 (Fig. 16). At that time the company faced several problems with this project/product which did not allow them to proceed with the net-to-net recycled LLINs[20]:

Problem 1: the initial plan was to “close the loop” and to make LLINs from the old LLINs. But it turned out that it was difficult to collect enough old nets for recycling. Plus, the colour of the collected nets was assorted, so it was questionable for the company if the buyers would accept nets other than white colour.

Problem 2: the company also looked at recycled polyester yarn (from PET bottles) as the potential material for LLINs production. However, at that time (2020-2021) in Vietnam the price for recycled yarn was higher than virgin. This situation happened mostly because many brands were competing for recycled yarn, thus causing the price increase.

Problem 3: after realizing the problem with recycled yarn, Vestergaard considered the possibility of building a recycling line in their factory in Vietnam to ensure the need for recycled yarn. However, this solution needed considerable capital investments. Therefore, before making capex the company needs to be sure of the demand for recycled LLINs. That time (2020-2021) Vestergaard discussed this issue with the Global Fund (the main buyer of LLINs), and UNICEF. The result of these discussions is unknown.

Fig. 16. LLIN by Vestergaard made of 100 per cent recycled polyester mosquito nets

Current status of the net-to-net recycled LLIN project is unknown. No recycled LLINs by Vestergaard exists in the list of Prequalified Products, nor in the Prequalification pipeline.

[19] *https://vestergaard.com/towards-a-circular-economy-in-the-llin-industry/*

[20] *Personnal communication with the company representative*

3.1.2 Shobikaa Impex

History of the "bottle-to-net" recycled LLINs project
In 2023, this Indian company Shobikaa Impex announced the production of LLINs made of 100 per cent recycled PET bottles. The trade name of the new product is GreenNet™. which is currently in the prequalification pipeline of WHO.
Based on the discussion with the CEO of the company (dated back December 2023), Shobikaa Impex is positive about the result of WHO prequalification process (1 year) which is expected to come in January 2024. The production capacity of GreenNet™ is 40 000 nets per day. Company has its own recycling facility, and the raw material for recycling are waste PET bottles, including PET waste bottles collected from the ocean. Additional sustainable feature of the company is that 80% is of the energy used is renewable: windmills and solar.

More details about the "bottle-to-net" recycled LLINs project by Shobika Impex can be found in the video presentation available online[21].

Current status of the project: waiting the results of the WHO prequalification process (beginning of 2024).

3.1.3 Other suppliers

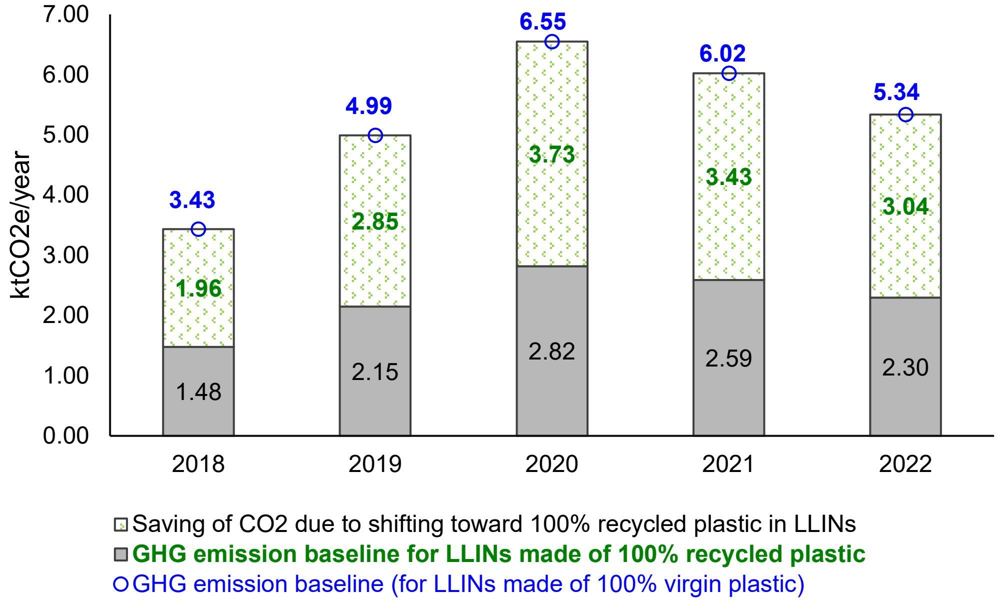
So far, recycled mosquito nets are not in the portfolio of other suppliers. The main challenge is most probably the price of recycled plastic. One of the suppliers (TsaraNets™, which is now supplied by PPP Hollandi DMCC, but previously was supplied by Moon Nettings) says that "mosquito net sales price is constituted by approximately 50 per cent material cost, and currently, the metric tonne price for quality recycled PET chips is approximately 1 200 $/MT vs. virgin grade at 900 $/MT." However, the price for recycled PET is volatile and depends on factors such as the region, the production volume and the purchase volume. Given that the mosquito nets are relatively lightweight (approximately 0.5 kg), and the annual demand for mosquito nets by UNHCR is relatively low (around 600 tonnes/year), the price of recycled plastic might be somewhat higher than virgin plastic due to the limited purchase volume). Nevertheless, this may not pose a significant challenge for companies engaged in both plastic recycling and LLIN manufacturing, such as Shobika Impex. Furthermore, **if all humanitarian organizations collectively commit to sourcing recycled plastic for LLINs, it can stimulate an increase in suppliers shifting toward recycled materials, leading to an inevitable decrease in the price of recycled plastic.**

3.1.4 GHG savings from shifting to 100 per cent recycled plastic in LLINs

Shifting toward 100 per cent recycled mosquito nets can potentially save the supply chain of UNHCR from 1.9 up to 3.7 ktCO2e/year (Fig. 17), and up to 800 tonnes of virgin plastic (depending on the procured quantity)

[21] *https://youtu.be/mnEIDuxs9o4*

Fig. 17. Potential effect on total GHG emissions (in kilo-tonnes per year) when shifting to 100 per cent recycled plastics in LLINs procured by UNHCR



Main findings:

1. **Limited availability of suppliers in the market for the provision of 100 per cent recycled LLINs**
   Only two companies have been identified that have recycled LLINs projects. One of them, Vestergaard (PermaNet 3.0™), proved a principal possibility to make net-to-net recycling without compromising the quality of the recycled LLINs. However, due to certain challenges that the company met, up to now the project has not moved from the R&D stage to the industrial implementation and mass production of recycled LLINs.
   Another company, Shobikaa Impex GreenNet^{T} is already on the verge of mass production of the bottle-to-net recycled LLINs (production capacity 40 000 LLINs per day). GreenNet™ recycled LLIN is currently in a WHO Prequalification Pipeline. Recycled LLINs might be available at the beginning of 2024.

2. **Long duration for products to be prequalified by WHO**
   The product evaluation process conducted by WHO lasts from 6 to 12 months. This creates additional barriers to making recycled LLIN available on the market.

3. **Lack of motivation to shift towards recycled materials**

It can be attributed to:
- the relatively low market price of the current mosquito nets (approximately $2);
- a low demand for recycled materials; and
- the small percentage of UNHCR's requirements, out of overall demand, to attract sufficient suppliers to compete for contracts.

Under the circumstances, without a coordinated action of UN agencies, improvement in the price and the production capacity of LLINs made of recycled materials are unlikely. Items produced especially for UNHCR might have a higher price and be limited to 2 suppliers, which can control the market price for the product.

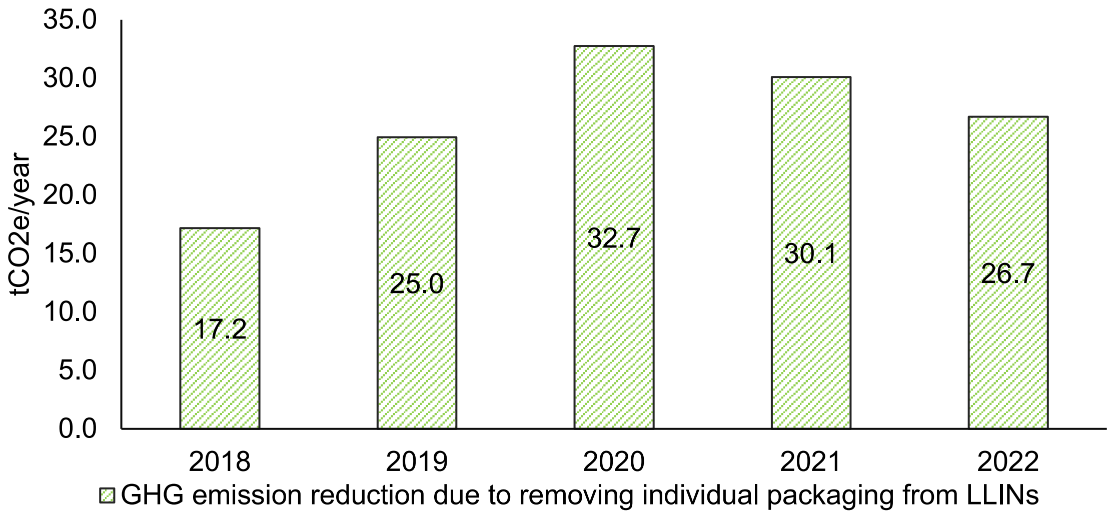
Possible solutions

1. Accept that price of LLINs in recycled plastic will be ~15 per cent more expensive than virgin ones.
2. Procure recycled LLINs only from the producers who manufacture nets, as well as recycled plastics (e.g. Shobika Impex)
3. Promote sustainability approach among UN and Humanitarian Agencies using common specifications of LLINs in recycled plastic

3.2 Option 2: Removing individual packaging from LLINs

The most common material for packing LLINs is single-use plastic, which is made primarily from fossil fuel–based materials and meant to be disposed of immediately after use.
Similar to the UNICEF initiative[22], UNHCR can promote bulk packaging of mosquito nets, e.g. 50 nets wrapped in a bale, as an alternative to individually packed nets. This will help to reduce the quantity of material required to pack items. This solution can save the UNHCR supply chain up to 32 tonnes (which is 0.032 kilo-tonnes) of CO_2 per year (Fig. 18), and up to 8 tonnes of single-use plastic packaging per year.

Fig. 18. Potential effect of removing individual packaging for LLINs procured by UNHCR (in tonnes of CO_2 per year)



Nevertheless, the use of bulk packaging would be limited to mass distribution of LLIN, e.g. when they are distributed in hospitals. When distributed to individuals, individual packaging is functional to avoid the use of other bags that might be later used for carrying food items.

[22] https://www.unicef.org/supply/stories/greening-unicefs-supply-chains-and-reducing-plastic-waste

Moreover, if not used right after the delivery, the LLIN without individual packages can be easily damaged, and the insecticide effectiveness might decrease over time.
To reduce the environmental impact of individual packaging made of single-used plastic, paper packaging might be an alternative option to test. However, more investigation is needed to test which sustainable packaging could assure sufficient protection against insecticide release to the outside environment.

3.3 Option 3: Use of oxi-biodegradable plastics

Currently, there is a notable degree of confusion and misunderstanding regarding the precise nature of "**oxi-bio**degradable plastics" and the extent of the environmental benefits they offer. Therefore, in Annex 3 a brief introduction to the topic is presented.

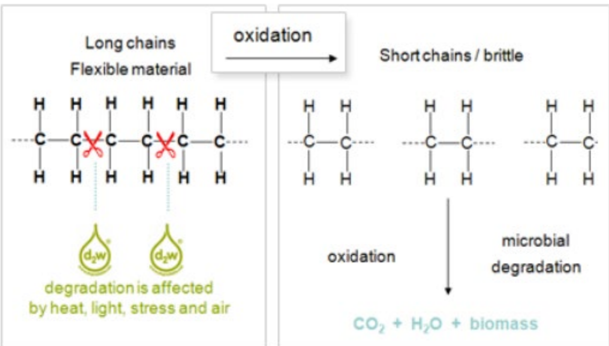
3.3.1 What is an oxi-biodegradable additive to plastics?

Oxi-biodegradable additives to plastics are metal-based catalyst(s), based on manganese, iron or cobalt, that are designed to speed up the breakdown of polymer molecules until they are reduced to a size that can be biodegraded. The masterbatch[23] is itself mostly polymer, with 1-3 per cent of the catalyst(s). Therefore, the amount of catalyst in the plastic product is low, and typically lower than other additives in conventional plastic such as colorants, UV-stabilizers, etc.

3.3.2 Mechanism of oxi-biodegradation

Polymers comprise long molecular chains in the region of 250 000 Daltons in mass. Polymers need to break down into around 5 000 Daltons before organisms can feed on them and achieve biodegradation. Conventional plastics eventually break down to this size, but oxi-biodegradable plastics are designed to achieve it much faster. Conventional plastics and oxi-biodegradable plastics are the same (apart from the addition of a small amount of catalyst in the case of oxi-biodegradable plastics), and the mechanisms of biodegradation are the same; oxi-biodegradable plastics are simply designed to achieve biodegradability more expediently. (Fig. 19).

Fig. 19. Mechanism of oxi-biodegradation (schematically)



[23] ***Masterbatch*** *– is a plastic formulation that contains additives that are essential for the appearance and/or performance of the final product. Usually, a masterbatch is comprised of plastic pellets that contain a concentrated number of additives such as processing aids, colorants, UV-stabilizers, oxi-biodegradable additives, fillers, etc.*

3.3.3 What is the time of oxi-biodegradation?

Various stakeholders offer differing opinions about how much faster degradation of oxi-biodegradable plastics occurs compared to conventional plastics. The somewhat limited research[24, 25, 26]that has been carried out to date shows that the speed range of degradation may range from marginally faster than normal plastics, to very significantly faster, depending on such factors as the formulation of the masterbatch and the extent to which the plastic is exposed to UV light and heat.

It may take up to a century for conventional plastics to reduce in size to 5 000 Daltons (the rate is highly variable depending on environmental conditions and other factors), whereas ***oxi-biodegradable plastics are likely to reach 5 000 Daltons significantly sooner -in the range of months and years.***

3.3.4 End-of-life options for oxi-biodegradable plastics

Recycling is the preferred end-of-life option for oxi-biodegradable plastic. However, once into the open environment, oxi-biodegradable plastic starts to degrade under the influence of oxygen and UV.
It is important to consider that oxi-biodegradable plastic:

- *It is **NOT a disposal route.*** Oxi-biodegradable plastics can be reused, recycled and disposed of like normal plastic. However, oxi-biodegradable adding will ensure that if the plastic accidentally gets into the open environment, the molecular weight will reduce rapidly[27] so it becomes biodegradable.
- *It is **not for LANDFILL***. Biodegradation of oxi-biodegradable plastics in anaerobic conditions (landfill) will generate methane, which is undesirable unless the landfill is designed to collect the gas.
- *It will **not DEGRADE in the absence of oxygen***.
- *It is **not for COMPOSTING.***

3.3.5 Legal restriction

Through European Union (EU) Directive 2019/904 Article 5, there is a restriction on products made from oxi-degradable plastics being placed on the market in the EU. Although oxi-biodegradable plastics are fundamentally different by virtue of their ability to biodegrade, they are nevertheless included in the blanket restriction.

By contrast, the Middle East region, with elevated temperatures and abundance of sunlight, is an ideal environment for oxi-biodegradation. As a consequence, Saudi Arabia and the United Arab Emirates have adopted laws that mandate disposable polyolefin plastics (e.g. HDPE, LDPE, PP, etc.) to be oxi-biodegradable[28].

[24] *Rose, R.-S., Richardson, K.H., Latvanen, E.J., Hanson, C.A., Resmini, M., Sanders, I.A. Microbial degradation of plastic in aqueous solutions demonstrated by CO2 evolution and quantification. International Journal of Molecular Science 2020, 21(4), 1176. doi:10.3390/ijms21041176*
[25] *https://www.biodeg.org/wp-content/uploads/2020/12/Report_20160727_final_corr-9-8-16-1.pdf*
[26] *https://anr.fr/Project-ANR-16-CE34-0007*
[27] *The degradation rate will strongly depend on the environmental conditions. Degradation id soil might take several months, while degradation in the ocean – years (up to 10 years)*
[28]*https://www.gulftic.com/ecasoxo.html#:~:text=The%20GCC%20region%2C%20with%20its,plastics%20to%20be%20oxo%2Dbiodegradable.*

3.4. Oxi-biodegradable LLIN

Currently only one company, **Real Relief**[29]**,** produces LLIN made of oxi-biodegradable LDPE, **Reliefnet Reverte™,** which is prequalified by WHO. The company promotes this LLIN as an environmentally friendly product, which can potentially prevent plastic pollution. The company announced that "If Reliefnet Reverte™ is wrongfully disposed of in the open environment or misused as for example fishing net, the sun will degrade the product to the extent that it becomes bioavailable allowing naturally occurring microorganisms to fully digest it. Reliefnet Reverte™ will disappear by itself if left in the environment. The oxi-biodegradable technology of Reliefnet Reverte™ is designed in such a way that it does not influence the lifetime of the net while in use". However, the company did not provide any evidence of the average degradation time (most probably due to the reasons discussed in the sections above). The price of Reliefnet Reverte™ is ~$2.5, which is significantly higher than ordinary LLINs purchased by UNHCR. However, the only visible difference in material composition between this LLIN and ordinary LLIN is the addition of 1-3 per cent of oxi-biodegradation component into the same LDPE plastic. This addition should not increase the price notably (see estimation given in Section 4.3.7). So, the possible reasons for this price increase can be either a small- or medium-scale production, which causes the higher price, or an increased company margin due to its "greening" feature.

Main findings:

1. Oxi-biodegradable plastics do not reduce GHG emissions related to LLINs. However, they might help to reduce plastic pollution.

2. Oxi-biodegradable plastics are not designed to be a disposal route, or to be composted or landfilled. The ideal end-of-life option for oxi-biodegradable plastics is still recycling. However, if these plastics are accidentally released into an open environment, after some time they will bio-degrade.

3. The degradation rate of oxi-biodegradable plastics strongly depends on the environmental conditions. However, compared to conventional plastics - which usually degrade within a century, oxi-biodegradable plastics are likely to degrade in the range of months or years.

4. Currently oxi-biodegradable plastics are banned in the EU and mandated in Saudi Arabia and the United Arab Emirates (for disposable single-use plastics).

5. Currently there is one WHO-prequalified LLIN made of oxi-biodegradable LDPE -- Reliefnet Reverte™ developed by Real Relief. Their price for the LLIN is $2.5, which is almost 30 per cent higher than the price of an ordinary LLIN.

[29] *https://www.realreliefway.com/products/reliefnet*

Conclusions

This report has identified several potential environmental benefits from the proposed greening options for the LLINS procured by UNHCR, as summarized in Table 3.

Table 3. Potential environmental effect of greening of LLINs procured by UNHCR

Options	Description	Effects	
Option 1	Shifting towards **100 per cent recycled plastics** for LLINs production	CO_2 reduction	**1.96 – 3.73 kilo-tonnes of CO_2/year**
		Saving non-renewable resources	**430-820 tonnes of virgin plastic**
		Reduction of plastic pollution	
Option 2	**Removing individual packaging** from LLINs	CO_2 reduction	**0.017 – 0.032 kilo-tonnes CO_2/year**
		Saving non-renewable resources	**4.3-8.2 tonnes of single-use plastic**
		Reduction of plastic pollution	
Option 3	Using **oxi-biodegradable plastics** for LLINs	Reduction of plastic pollution	TBD

Shifting towards 100 per cent recycled plastics for LLINs production (Option 1) would represent the most viable and effective way to reduce environmental footprint of LLINs. Within UNHCR context it would result in a yearly CO2 reduction of 1.96-3.73 kilo-tonnes. Nevertheless, the following obstacles would limit the immediate introduction of this action to UNHCR practice:

- The product evaluation process conducted by WHO lasts approximately 12 months. This creates additional barriers to making recycled LLIN available on the market.
- The demand of UNHCR is low in comparison with the global demand (less than 1 per cent of the global demand). Therefore, UNHCR has limited leverage to influence the introduction of sustainable materials and to reduce the market price. It is recommended that the procurement of LLINs goes through UN aggregated demand, to increase the purchasing power of UN agencies.
- As WHO pre-defined the specifications of LLINs and pre-qualified suppliers, all UN agencies can only choose among a limited supply of products. However, it is possible that different prices are being offered to different UN agencies as suppliers provide prices based on the demand of each agency.

To introduce recycled plastic for LLINs into UNHCR practice, it is necessary to foster collaboration among all UN agencies, preferably through joint procurement.
Standardized greener specifications should be developed by WHO and agreed upon among all UN agencies, preferably with one organization leading the overall procurement process

under the procurement rules and regulations of that UN entity. Synergy is required as resources are increasingly limited and effective action to reduce the effects of climate change is everybody's responsibility.

The aggregated demand of LLINs will help to:

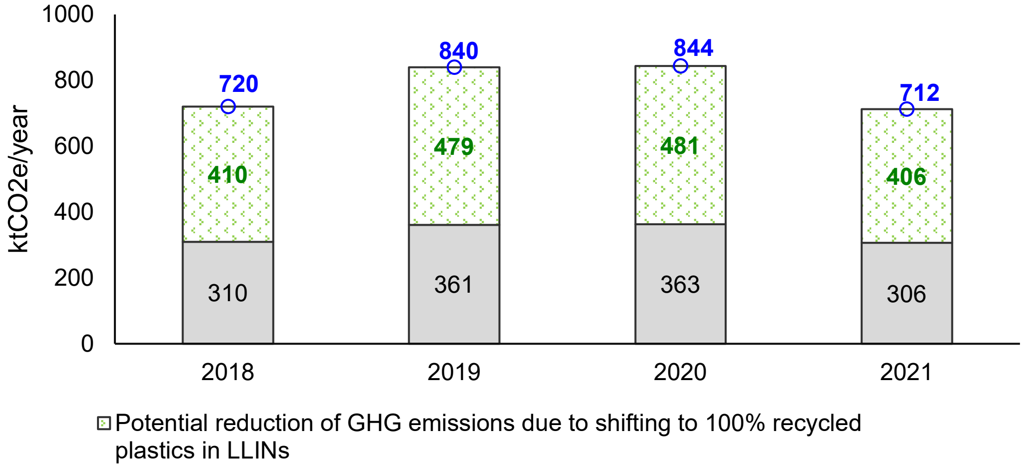
1. Increase the economy of scale of the suppliers and thereby reduce costs
2. Lower the administrative cost of the UN organization
3. Ensure a standardization that leads to efficiencies in the procurement processes
4. Increase the power to shape the market of more sustainable products and reduce the emissions generated by this item.

Moreover, the reduction of the time of the pre-qualification process conducted by WHO will also facilitate suppliers' motivation to shift towards recycled plastic for LLINs.

An evaluation of the impact of shifting to 100 per cent recycled plastic for all LLINs procured globally is presented in Fig. 21. Reduction in their GHG emissions would amount to 480 kilo-tonnes per year, which is equivalent to (based on the GHG equivalencies calculator by EPA[30]):

- More than 100 000 gasoline-powered passenger vehicles driven for 1 year.
- More than 200 million litres of gasoline consumed.
- More than 60 000 homes' energy use for one year.
- More than 7 million tree seedlings grown for 10 years, and so on.

Fig. 21. Potential effect on total GHG emissions (in kilo-tonnes per year) from shifting to 100 per cent recycled plastics in LLINs procured globally.



Although removing individual packaging from LLINs (Option 2) can help to reduce carbon footprint and plastic pollution, this solution is not recommended when LLINs are for individual distribution.

Introduction of oxi-biodegradable plastics for LLINs (Option 3) to UNHCR practice is not recommended yet, as more evidence and testing are required to assure the degradation time under the influence of certain environmental conditions.

[30] *https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator*

ANNEX 1

Table A1. List of LLINs prequalified by WHO

No	Product Name	Manufacturer	Material of LLIN	Active Ingredient/Synergist	Insecticide treatment method	Date of prequalification	Comment
1	DuraNet LN	Shobikaa Impex Private Limited	Polyethylene (HDPE+LDPE)	Alpha-cypermethrin	Incorporated	7-Dec-17	
2	DuraNet Plus	Shobikaa Impex Private Limited	Polyethylene (HDPE+LDPE)	Alpha-cypermethrin, Piperonyl Butoxide (PBO)	Incorporated	13-Aug-20	
3	Interceptor	BASF AGRO B.V. Arnhem (NL) Freienbach Branch	Polyester	Alpha-cypermethrin	Coated	8-Dec-17	
4	Interceptor G2	BASF AGRO B.V. Arnhem (NL) Freienbach Branch	Polyester	Alpha-cypermethrin, Chlorfenapyr	Coated	29-Jan-18	
5	MAGNet	V.K.A. Polymers Pvt. Ltd	Polyethylene	Alpha-cypermethrin	Incorporated	19-Feb-18	MAGNet® is packed in oxobiodegradable plastic bags
6	VEERALIN	V.K.A. Polymers Pvt. Ltd	Polyethylene	Alpha-cypermethrin, Piperonyl Butoxide (PBO)	Incorporated	29-Jan-18	
7	MiraNet	A to Z Textile Mills Limited	Polyethylene	Alpha-cypermethrin	Incorporated	21-Feb-18	
8	OLYSET Net	Sumitomo Chemical Co., Ltd	Polyethylene	Permethrin	Incorporated	7-Dec-17	
9	OLYSET PLUS	Sumitomo Chemical Co., Ltd	Polyethylene	Permethrin, Piperonyl Butoxide (PBO)	Incorporated	29-Jan-18	
10	Panda Net 2.0	Life Ideas Biotechnology Co. Ltd	Polyethylene	Deltamethrin	Incorporated	3-May-18	
11	PermaNet 2.0	Vestergaard Sarl	Polyester	Deltamethrin	Coated	8-Dec-17	

12	PermaNet 3.0	Vestergaard Sarl	Polyester	Deltamethrin, Piperonyl Butoxide (PBO)	Deltamethrin – coated; Deltamethrin + PBO – incorporates	29-Jan-18	Possibly made of recycled mosquito nets
13	PermaNet Dual	Vestergaard Sarl	Polyester	Chlorfenapyr, Deltamethrin	Coated	17-Mar-23	
14	Reliefnet Reverte	Real Relief Health ApS	Polyethylene	Deltamethrin	Incorporated	25-Jan-21	Oxi-biodegradable
15	Royal Guard	Disease Control Technology LLC	Polyethylene	Alpha-cypermethrin, Pyriproxyfen	Incorporated	29-Mar-19	
16	Royal Sentry	Disease Control Technology LLC	Polyethylene	Alpha-cypermethrin	Incorporated	7-Dec-17	
17	Royal Sentry 2.0	Disease Control Technology LLC	Polyethylene	Alpha-cypermethrin	Incorporated	6-Feb-19	
18	SafeNet	Mainpol GmbH	Polyester	Alpha-cypermethrin	Coated	19-Feb-18	
19	Tsara Boost	PPP Hollandi DMCC	Polyethylene for roof; polyester – for side walls	Deltamethrin, Piperonyl Butoxide (PBO)	Incorporated for roof; coated for side walls	29-Jan-18	
20	Tsara Net	PPP Hollandi DMCC	Polyethylene	Deltamethrin	Incorporated	14-Aug-20	
21	Tsara Plus	PPP Hollandi DMCC	Polyethylene for roof; polyester – for side walls	Deltamethrin, Piperonyl Butoxide (PBO)	Incorporated for roof; coated for side walls	29-Jan-18	
22	Tsara Soft	PPP Hollandi DMCC	Polyester	Deltamethrin	Coated	9-Oct-20	
23	Yahe LN	Fujian Yamei Industry & Trade Co. Ltd	Polyester	Deltamethrin	Coated	19-Feb-18	
24	Yorkool G3 LN	Tianjin Yorkool International Trading Co., Ltd	Polyethylene	Deltamethrin, Piperonyl Butoxide (PBO)	Incorporated	18-Apr-23	
25	Yorkool LN	Tianjin Yorkool International Trading Co., Ltd	Polyester	Deltamethrin	Coated	19-Feb-18	

Table A2. List of LLINs in a Prequalification Pipeline

Product Name	Manufacturer	Material of LLIN	Active Ingredient/Synergist	Comment
DuraNet Plus 2.0	Shobikaa Impex Private Limited	Polyethylene	Alpha-cypermethrin, Piperonyl Butoxide (PBO)	
GreenNet	Shobika Impex Private Limited	Polyester	Deltamethrin	made of recycled PET bottles
VectorGuard	Disease Control Technology LLC	N/a	Alpha-cypermethrin, Piperonyl Butoxide (PBO)	
YAHE 4.0	Fujian Yamei Industry & Trade Co. Ltd	N/a	Alpha-cypermethrin, Piperonyl Butoxide (PBO)	

Table A3. Thirteen manufacturers that are certified by WHO and obtained the supplier qualification of the Global Fund, UNICEF and the United Nations Global Procurement System

No	Manufacturer name	Location of production site	Material of LLINs	Production capacity	Comments
1	Shobikaa Impex Private Limited	India	PE PET	2.5 million. /month	The company has PET bottle recycling program and recycling line(s) for this. The company uses wind energy, and plans to enter solar energy as well[31]
2	BASF AGRO B.V. Arnhem (NL) Freienbach Branch	Eastern China, and Thailand	PET	N/a,	BASF is a German company, but they do not have textile manufacturing facilities. Therefore, LLINs from BASF are manufactured (under ISO9001:2015 standards) by specialized textile companies in eastern China and Thailand[32]
3	V.K.A. Polymers Pvt. Ltd	India	PE	N/a	V.K.A Polymers is an ISO 14001:2015 certified company and takes its environmental sustainability seriously. To assure customers that the products sourced are produced using 100 per cent renewable green energy, the company invested in a 4.0 mega-watt (one-million-watt) windmill farm in the district of Tirunelveli in southern India. The wind turbines of the world-renowned Suzlon company have been installed in the windmill farm location. The power generated from the wind energy generators is fed to the Tamil Nādu State Electricity Board's grid and adjusted in the power consumption of various companies in the group, including V.K.A Polymers. Surplus electric power produced from windmills is sold to the Tamil Nadu State Electricity Board[33]. The company also uses oxi-biodegradable bags for packing mosquito nets.
4	A to Z Textile Mills Limited	Tanzania, Africa	PE	2.5 million/month	ISO 9001:2008 certified[34]

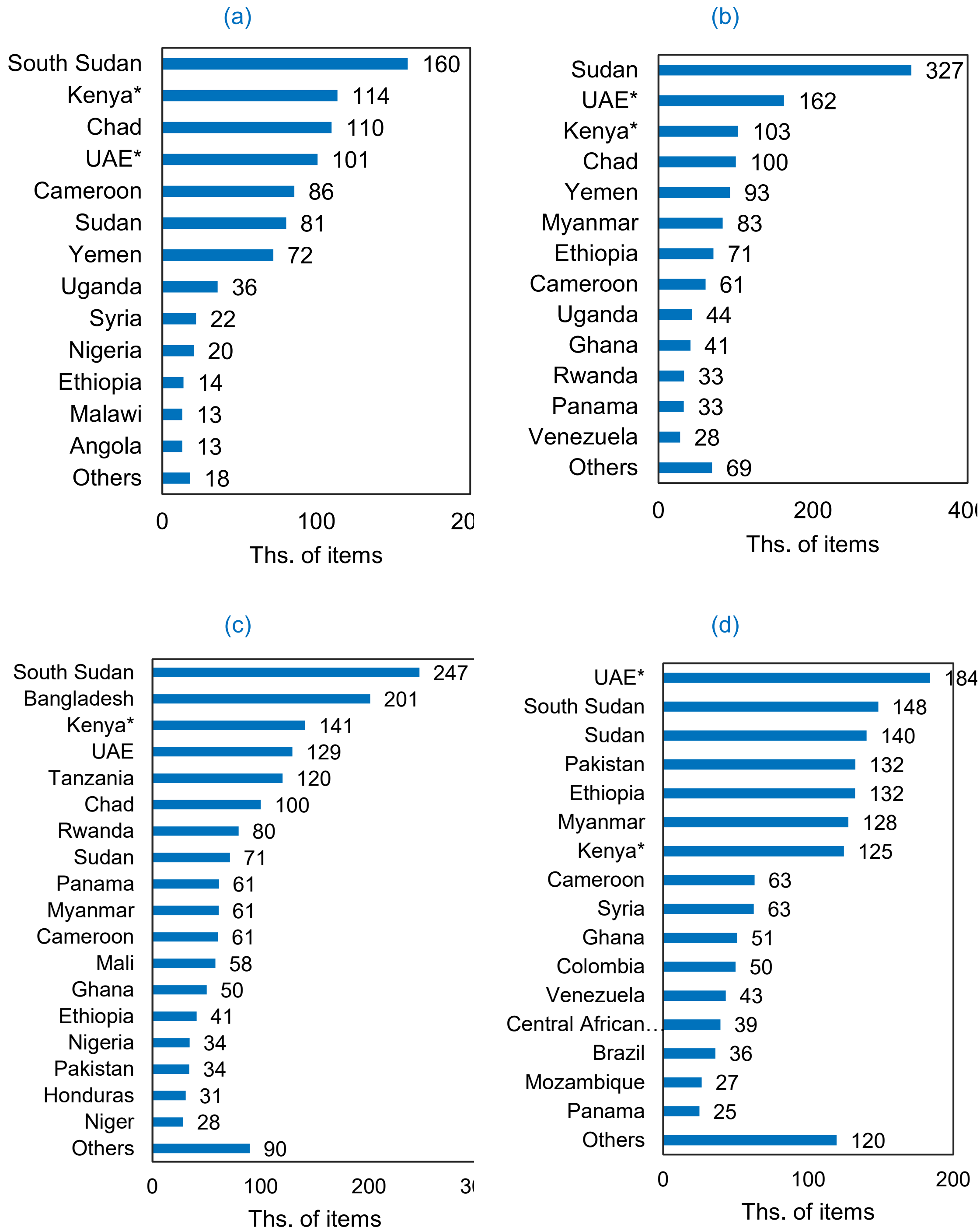
[31] http://www.aidforum.org/directory/shobikaa-duranet/#:~:text=Experience%3A%20Shobikaa%20is%20in%20the,2.50%20million%20nets%20per%20month
[32] https://agriculture.basf.com/global/en/business-areas/public-health/our-partnerships/stories_partnership_countries/stories/manufacturing-a-new-generation-of-mosquito-net.html
[33] https://www.vkapolymers.com/sustainability
[34] https://www.azpfl.com/index.php/en/profile/company-profile

5	Sumitomo Chemical Co., Ltd	Tanzania, Ethiopia	PE	N/a	A Japanese company which produces nets in Ethiopia[35] and the United Republic of Tanzania.[36]
6	Life Ideas Biotechnology Co. Ltd	China	PE	N/a	-
7	Vestergaard Sarl	Vietnam	PET	N/a	The company's headquarters are in Switzerland, and its manufacturing sites are located in Vietnam. The company initiated a program of collecting old nets[37].
8	Real Relief Health ApS	N/a	PE	N/a	The headquarters are in Denmark
9	Disease Control Technology LLC	N/a	PE	N/a	The company is based in the United States of America.
10	Mainpol GmbH	Germany	PET	N/a	-
11	PPP Hollandi DMCC	HQ -- UAE Manufacturing facility – N/a	PE PET	N/a	
12	Fujian Yamei Industry & Trade Co. Ltd	China	PET	2,5 mln/year	-
13	Tianjin Yorkool International Trading Co., Ltd	China	PE PET	N/a	-

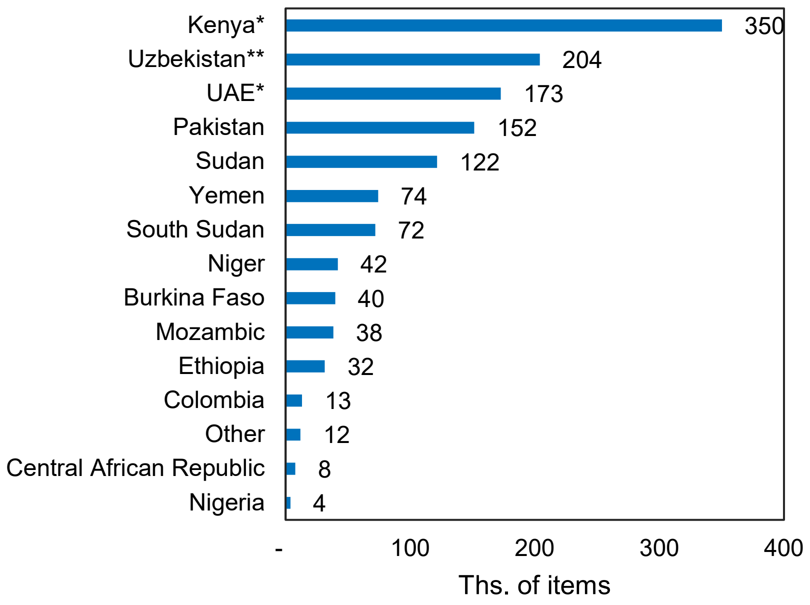
[35] https://www.sumivector.com/news/olyset-net-production-starts-in-ethiopia
[36] https://www.sumivector.com/news/sumitomo-chemical-expands-anti-malaria-olyset-net-production-in-tanzania#:~:text=Location%3A%20Arusha%2C%20United%20Republic%20of,Incorporation%3A%20September%2C%202005
[37] https://vestergaard.com/impact/sustainability/

ANNEX 2

Fig. A1. UNHCR supply of LLINs by country, number of items are in thousands (Ths): (a) in 2018; (b) in 2019; (c) in 2020; (d) in 2021; (e) 2022 (*Global Stockpiles that support other countries; ** LLINs from Uzbekistan were directed to Iran)



(e)


Kenya*
Uzbekistan**
UAE*
Pakistan
Sudan
Yemen
South Sudan
Niger
Burkina Faso
Mozambic
Ethiopia
Colombia
Other
Central African Republic
Nigeria
350
204
173
152
122
74
72
42
40
38
32
13
12
8
4
-
100
200
300
400
Ths. of items

ANNEX 3

Definition of oxi-biodegradation

It is necessary to distinguish between “bio-based”, “compostable”, “oxi-degradable plastics” and “oxi-biodegradable” plastics (Table A3). All these categories of plastics are considered environmentally friendly alternatives to ordinary plastics. However, all of them have different origins and different behaviors in the environment after disposal, and consequently different environmental impacts.

- *Bio-based plastic*s originate from renewable bio-based sources but do not necessarily bio-degrade in the natural environment.
- *Biodegradable or compostable plastics* might originate from both non-renewable fossil resources as well as renewable natural resources. The distinct feature of bio-degradable or compostable plastics is that they can degrade and be eaten by microorganisms. However, special conditions (elevated temperature, specific humidity, etc.), not commonly found in the natural environment, are needed to make this happen. Therefore, to properly bio-degrade, they should be collected and sent to the composting facility. If these plastics are not sent to a composting facility, they will behave as ordinary petroleum-based plastic and not bio-degrade in landfill or natural environment.
- *Oxi-degradable and oxi-biodegradable plastics* degrade under the influence of oxygen, but they degrade down to varied sizes. Thus, oxi-degradable plastics degrade down to microplastic particles, which still cannot be eaten by bacteria, while oxi-biodegradable plastics degrade down to pieces small enough to be eaten by bacteria that live in the natural environment.

Therefore, out of all these categories of plastics, oxi-biodegradable plastics represent the best alternative for LLINs.

Table A3. Definitions of “bio-based”, “compostable”, “oxi-degradable plastics” and “oxi-biodegradable” plastics

Type of plastic	Definition
Bio-based plastics	Plastics produced from renewable biomass sources, such as vegetable fats and oils, corn starch, straw, wood chips, sawdust, recycled food waste, etc. Bio-based plastics are not necessarily biodegradable or compostable.
Biodegradable and compostable plastics	Plastics produced from renewable biomass or non-renewable fossils. The main feature of these plastics is that they can be broken down by microorganisms into water, carbon dioxide, mineral salts and new biomass within a defined period. The rate of biodegradation or composting strongly depends on the conditions of exposition to during disposal. These include temperature, duration, the presence of microorganisms, nutrients, oxygen and moisture.
Oxi-degradable plastics	Ordinary plastics that include additive(s), which degrade through oxidation in the open and quickly create fragments, but do not necessarily become biodegradable except over a very long time
Oxi-biodegradable plastics	Ordinary plastics that include additive(s), which degrade through oxidation in the open environment until their molecular weight is low enough to be accessible to bacteria and fungi, who then recycle them back into nature.

DESK REVIEW: GREENING OPPORTUNITIES FOR MOSQUITO NETS (LONG-LASTING INSECTICIDAL NETS) PROCURED BY UNHCR

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