USAID NetMark
End-of-Line LLIN Production Process Technology Transfer Documentation

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USAID NetMark End-of-Line LLIN Production Process

Since the Fall of 2004, USAID's AED NetMark project has sponsored the development and optimization of a new end-of-line production process for the manufacture of long lasting insecticide treated nets (LLINs). Initially, NetMark partnered with Siamdutch Mosquito Netting Company, Bayer Environmental Science, and Anovotek, LLC. This work resulted in the concept, process development, facility design, construction, start-up and optimization of Tana Netting Company, Siamdutch's world class mosquito net manufacturing facility, whose DawaPlus 2.0 LLIN product recently received its interim WHOPES recommendation. A similar partnership was begun with Sunflag Nigeria in the Summer of 2008. Sunflag is now scaling up production and preparing to launch its new PowerNet Plus LLIN product in Nigeria and submit its registration dossier to WHOPES for certification as a WHO approved LLIN.

The purpose of this report is to provide companies interested in adopting this technology with a comprehensive set of documentation that can serve as a technology transfer guide for implementing the USAID NetMark End-of-Line LLIN Production Process. This documentation contains six important sections including:

1. An executive summary of the USAID NetMark End-of-the-Line LLIN Production Process,
2. Detailed technical and engineering specifications,
3. Capital equipment requirements and productivity benchmarks,
4. Product cost analysis,
5. Standard operating procedures (SOPs) that can be used as a guidance document for start-up and optimization of any new end-of-the-line production facility, and
6. A process trouble-shooting guide.

Executive Summary

The technology to impart long-lasting insecticide treatment to mosquito nets is evolving rapidly, and there are currently three technologies for producing LLINs being used in the commercial market.

- Inclusion of the insecticide in the yarn during fiber extrusion,
- Application of the insecticide to open-width fabric, and
- Application of the insecticide to sewn nets after stitching, also known as the USAID NetMark End-of-Line LLIN Production Process.

Because the USAID NetMark production process is an end-of-line treatment process it eliminates many of the costs and complexities associated with producing treated yarn or treated fabric while also minimizing many of the health, safety and environmental concerns associated with the manufacturing of insecticide treated products.

In its simplest form, an end-of-line LLIN production facility can be set-up where untreated nets are sourced from a 3rd party supplier, treated with LLIN chemistry in an

industrial washer, dried in an industrial dryer, and then inspected, folded and packaged. This means that the barrier to entry is relatively low compared to other LLIN technologies, thus providing an approach that allows both entrepreneurial start-ups and existing fabric and net suppliers to easily forward integrate into producing higher value, highly demanded LLIN products.

The end-of-line LLIN production process is a batch process, meaning that a finite number of nets (limited by the cylinder size of the washer/extractor) can be processed each production cycle. However, with good planning and proper execution, high levels of productivity (exceeding 85% run time) can be achieved.

The end-of-line LLIN production process is relatively straight forward. A production lot of sewn, untreated mosquito nets is loaded into an industrial end-loading open-pocket washer/extractor, such as the Washex DPM 5000 apparel processing machine shown in Figure 1, and a predetermined volume of LLIN treatment liquor is injected into the machine through a custom engineered mist spray system. The LLIN chemistry is applied to the nets while they rotate and tumble within the machine's cylinder. This results in the uniform distribution of LLIN chemistry across all surfaces of the net. The cycle time for LLIN treatment is typically around 40 minutes per production batch.

Figure 1. Washex DPM 5000 end-loading washer/extractor.

After the chemical application process is complete, the treated nets are transported from the washer/extractor to an industrial gas fired or steam heated dryer such as the Washex Challenge CPG 600 shown in Figure 2. Net transportation options range from manual carts and overhead sling systems to fully automated conveyor handling systems.

Figure 2. Washex Challenge CPG 600 industrial dryer.

The production capacity and cycle time of the drying process is essentially the same as for the LLIN chemical application process, so one dryer supports the output from one washer/extractor. As a result, the process is very modular, and production capacity needs can be satisfied through the selection of machine size and the quantity of installed production modules.

After the drying process, the treated nets must be transported to a finished goods area where they can be inspected, folded, and packaged. Inspection must include both a physical assessment of the finished product as well as periodic random sampling and analytical testing (HPLC or GC) to verify active ingredient (AI) content and AI content uniformity (with-in and between nets).

Technology Advantages

There are a number of advantages associated with adopting this LLIN treatment technology when compared to other LLIN production options. These include:

- The process was developed around readily available, off-the-shelf, industrial grade equipment that only requires a special adaptation for the insecticide treatment chemical mixing and feed system.
- The equipment can be scaled to match the desired LLIN output capacity because it is available in a range of sizes (i.e. from 8 ft^3 to 178 ft^3 of cylinder capacity).
- The process is designed to have zero effluent and low environmental impact.
- Chemical treatment is done at the end of the net production process, in a closed vessel, resulting in minimal worker exposure to insecticide and/or insecticide treated fabric.
- The technology is easily installed at the end of the net production process and provides rapid and high quality mass treatment of finished nets.

- Specifications for implementing the technology are available to all companies.
- Relatively low barrier to entry in terms of investment capital required as compared to other LLIN technology options.

Health Safety and Environmental – Zero Effluent and Minimum Work Exposure

The end-of-line LLIN production process was designed to minimize worker exposure to insecticide and to be a "zero waste" production process. This approach utilizes commercially available garment processing machinery equipped with a precision control air atomizing spray system. Once the nets are loaded into the treatment machine (garment washer/extractor) the door is closed creating a totally enclosed vessel where the LLIN treatment liquor (insecticide and binder) is applied to the nets as they tumble in the machine. Once treated with LLIN chemistry the nets are transferred from the washer/applicator into the dryer. This process requires little direct exposure of the operators to the insecticide.

The treatment process is designed to produce "zero waste" of LLIN chemistry. Only enough LLIN chemistry is sprayed onto the nets so that the nets are uniformly wet. No excess LLIN chemistry remains in the application machine. The only residual liquid is the water that is used to rinse the machine at the end of each production shift. Standard operating procedures dictate that this rinse water be captured, filtered, and reused for making additional LLIN treatment mixes. If managed and run properly, the process should have zero effluent.

The end-of-line LLIN production process creates less worker exposure to insecticide than any other method of producing LLIN products. Using this process, LLINs can be made using the following process steps:

1. Receiving and storing chemicals
2. Mixing and weighing chemicals
3. Transferring chemicals to the Day Tank
4. Loading nets into the applicator (washer/extractor)
5. LLIN treatment (within the enclosed vessel)
6. Unloading LLIN treated nets from the washer/extractor
7. Loading LLIN treated nets into the dryer
8. Unloading LLIN treated nets from the dryer
9. Folding and packing LLIN treated nets

Personal Protective Equipment

As with all manufacturing processes, certain types of personal protective equipment (PPE) are recommended for those individuals operating the end-of-line LLIN production process. These include chemical resistant gloves, splash proof goggles and chemical resistant aprons. As shown in Table I, these PPE are specifically prescribed by work activity. Note that the specification and use of PPE should always follow the recommendation from the insecticide supplier.

Table I. Recommended Personal Protective Equipment (PPE) When Operating the End-of-Line LLIN Production Process				
	Goggles	**Gloves**	**Apron**	**Respiratory Protection**
Receiving and Storing Chemicals	X			As Needed
Mixing and Weighing Chemicals	X	X	X	As Needed
Transferring chemicals to Add Tank	X	X	X	As Needed
Loading Nets	X			As Needed
LLIN Treatment Area	X			As Needed
Unloading Treated Nets from Washer	X	X	X	As Needed
Loading Dryer with Treated Nets	X	X	X	As Needed
Unloading Treated Nets from Dryer		X		As Needed
Folding and Packing Treated Nets		X		As Needed

Machinery Requirements

The following three pieces of industrial scale processing equipment are necessary to establish a manufacturing module for LLIN production:

1. End-loading open-pocket garment washer/extractor
2. End-loading open-pocket garment dryer with auxiliary wet type lint collector (air scrubber)
3. Custom engineered chemical feed system

This type of garment processing equipment is readily available worldwide from companies such as Washex, GA Braun, Pellerin Milnor and others. The chemical feed system must be custom engineered, built and integrated separately. Specific details are provided in the next section of this report

Industrial grade washer/extractors and dryers are available in a wide range of sizes, with the smallest scale equipment having cylinder sizes in the 8 to 12 ft^3 range, and the largest machines in the industry offering up to 178 ft^3 of cylinder volume. Table II shows a range of possible machinery options and the manufacturer's suggested list price for each.

Table II. Examples of LLIN Production Process Machinery Options and Manufacturer's Suggested List Price

Washer/Extractor			Dryer			Chemical Feed		
Make and Model[1]	Cylinder Volume[4] (ft^3)	List Price[1] ($)	Make and Model[1]	Cylinder Volume[4] (ft^3)	List Price[1,2] ($)	Make and Model	List Price ($)	Estimated Capacity[3] (nets/hr)
Washex RVS550	21	$22,610	Washex FL623G	35	$27,980	Custom	TBD	15
Washex FLPS-1200	42	$83,140	Washex FL633G	49	$35,630	Custom	TBD	30
Washex FLPS-2250	80	$124,370	Washex CPG200	100	$75,040	Custom	TBD	57
Washex DPM4000	141	$143,550	Washex CPG400	155	$94,030	Custom	TBD	100
Washex DPM5000	178	$152,100	Washex CPG600	210	$105,100	Custom	TBD	126
GA Braun 145ST	144	149,855	GA Braun 440P-NG	165	$96,215	Custom	TBD	102
Milnor 64046-J6N	86	$158,105	Milnor SL-65058	108	$79,515	Custom	TBD	61
Milnor 72058-J2N	137	$134,945	Milnor SL-72072	170	$93,530	Custom	TBD	97
Milnor 72075-J2N	178	$144,340	Milnor SL-M670	256	$103,615	Custom	TBD	126
Milnor 72058-J5N	137	$190,895	Milnor SL-M460	175	$98,425	Custom	TBD	97

Note[1]: Machinery list prices are for base model equipment. Numerous options are available, some of which may be required for operation in locations outside the U.S. Other costs that must also be taken into consideration when planning for this type of investment include: 1) Freight, 2) Installation and 3) Start-up by Factory Certified Technicians. Note that the cost of these services will vary by carrier, machinery vendor, size and quantity of production modules purchased and location of installation. Please consult your machinery vendor for firm quotations.
Note[2]: Price includes estimated cost of auxiliary wet type lint collector (air scrubber).
Note[3]: Estimated capacity based on lot sizes equal to one (1) X-Family net (190 x 180 x 150 cm) per 1.8 ft^3 of washer/extractor cylinder volume, 40 minute total cycle time, and 85% production efficiency.
Note[4]: Washer/extractor and dryer cylinders should be specified for use with delicate fabrics – they must be extremely smooth and free of any protruding defects (burrs, picks, rough edges, etc.)

As shown in Table II, cylinder volume is an important metric, because this machine parameter limits the production capacity of the washer/extractor for treating mosquito nets with LLIN chemistry. Research and development has determined that a ratio of 1 net (X-Family, 190 x 180 x 150 cm) per 1.8 ft^3 of cylinder volume yields excellent LLIN treatment results (when using a 40 minute production cycle). This means that a small machine with an 8.0 ft^3 cylinder can only process 4 nets (X-Family, 190 x 180 x 150 cm) per production cycle, while the largest machines with 178 ft^3 cylinders can process 100 nets (X-Family, 190 x 180 x 150 cm) per production cycle.

Note that attempting to over fill the machine with too many nets in one production batch will result in poor distribution of LLIN chemistry because the nets will not tumble and move properly within the cylinder. *Regardless of net size, the machine loading rate should not exceed 1.0 m^2 of netting material per 0.125 ft^3 of cylinder volume.*

In addition to optimizing the batch size for both productivity and quality, it is also very important that the washer/extractor cylinder speed be adjusted so that the nets tumble from the 11:00 o'clock position to the 5:00 o'clock position when the machine cylinder is rotating clockwise, and from the 1:00 o'clock position to the 7:00 o'clock position when the machine cylinder is turning counterclockwise. Too high or too slow of cylinder speed will result in the nets not tumbling and mixing properly in the machine and less than optimal AI content uniformity (within and between nets).

Chemical Mix and Feed System

A properly engineered chemical mixing and air atomized mist spray system is critical to the overall performance of the end-of-line LLIN production process. Key technical specifications include the following:

- Adequately sized plastic or stainless steel mix tank capable of holding enough treatment liquor to run the production process for 8 to 12 hours,
- Variable low-speed propeller type mixer for constant low shear mixing of the treatment liquor (agitation without foaming)
- Chemical resistance piping, valves and fittings
- A precision type metering pump, such as a Prominent Sigma/2 diaphragm metering pump shown in Figure 3, is necessary to accurately control treatment liquor dosage (see www.prominent.com)

Figure 3. Prominent Sigma/2 diaphragm metering pump.

- Internal mix air atomizing spray nozzle(s), such as those shown in Figures 4 and 5, available from Spraying Systems Company (see www.spray.com)
  - ✓ Proper flow rate and spray pattern (single or tandem installation depending on size of machine)
  - ✓ Stainless steel construction
  - ✓ Through wall mounting
  - ✓ Target wet pick-up of 90% (i.e. 50 kg of nets treated with 45 kg of treatment liquor) sprayed onto the nets over a 33-35 minutes spray cycle (the longer the spray cycle the more uniform the chemical application)

Figure 4. Spraying Systems Company internal mix air atomizing spray nozzles with thru-wall mounting device.

Figure 5. Tandem air atomizing mist spray nozzle configuration on end-of-line LLIN treatment machine.

- In-line 500 micron canister type filter, as shown in Figure 6, to remove contaminates from treatment liquor prior to entering spray nozzles

Figure 6. In-line 500 micron canister type filter.

- In-line treatment liquor pressure gauge, as shown in Figure 7, located between chemical feed pump and spray nozzles to allow monitoring of treatment liquor pressure and nozzle blockage

Figure 7. In-line treatment liquor pressure gauge.

- Reliable supply of good quality (clean and dry) 80 PSI compressed air delivered to the nozzle through a high quality pressure regulator and air filter, as shown in Figure 8

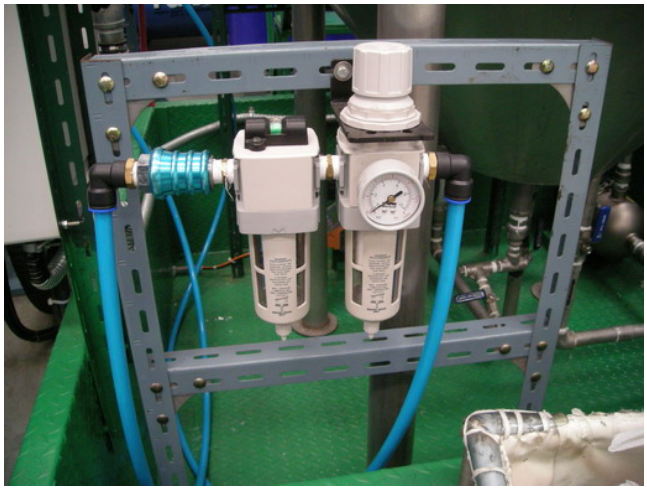

Figure 8. Air pressure regulator and filter supplying clean dry compressed air to the air atomizing spray nozzles.

- Maintaining system air pressure at a minimum set point of 65 PSI is critical to good atomization of the LLIN treatment liquor.

Typical Auxiliary Equipment and Utility Requirements

The following type of auxiliary support equipment and utility hookups are typically required to operate a large size end-of-line LLIN production system:

- **Electrical:**

Washer:	60 amp breaker,	261. KW
Dryer:	50 amp breaker,	18.6 KW
Chemical system:	15 amp breaker for controls	

- **Compressed Air:**

Washer:	3 to 5 SCFM
Dryer:	0.33 SCFM (control air)
Chemical Feed System:	15 to 20 SCFM

- **Steam:**

Dryer:	775 lbs of steam per hour
Recommended boiler size:	45 boiler horse power (BHP)

Optionally, a natural gas or propane fired dryer could be used in place of steam heat, which would then require the appropriate gas utility hook-ups.

Example of Facility Requirements

Figure 9 illustrates an example of the space required to install and operate a single large capacity end-of-line LLIN production module. Note that an optional automated conveyor system is shown between the washer/extractor and the dryer.

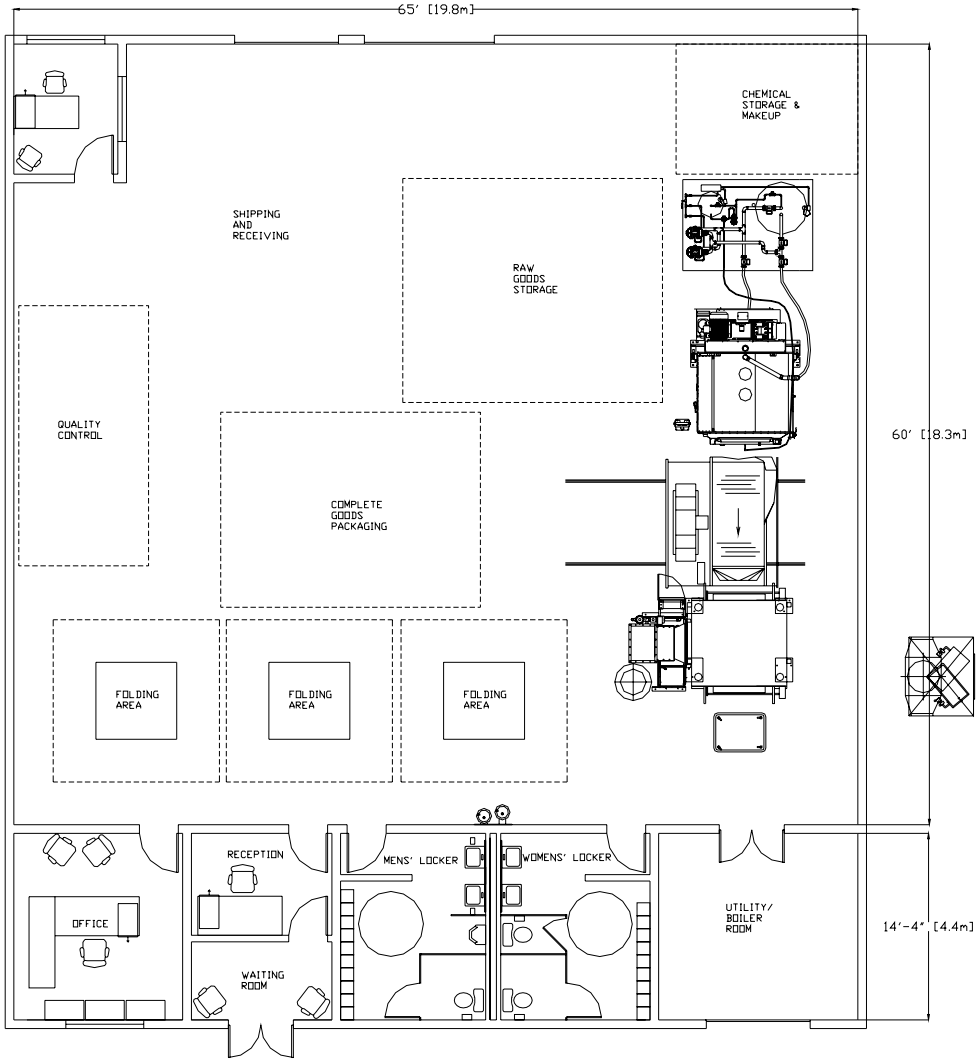

Figure 9. Schematic diagram of end-of-line LLIN treatment facility housing a single large size production module.

Production Capacity and Ten Year Straight Line Machinery Depreciation Estimates (Largest Capacity System)

For purposes of making production capacity calculations, it is recommended that the following parameters be taken into consideration:

a. Machine loading capacity
    i. One (1) X-Family size net (190 x 180 x 150 cm) per 1.8 ft^3/cylinder volume (1.0 m^2 of netting material per 0.125 ft^3 of cylinder volume)
b. Treatment time (40 minutes per production batch)
c. Production efficiency 85%

Based on these processing parameters and the estimated required investment for the largest capacity Washex brand machinery (as detailed above in Table I) production capacity and ten year straight line machinery depreciation estimates ($ per net) were calculated. This data is shown in Table III for both 8 and 24 hour per day manufacturing operations.

Table III. Estimated LLIN Production Capacity and Ten Year Straight Line Machinery Depreciation Using 8 and 24 Hour Per Day / 6 Day Per Week / 50 Week Per Year Production Schedules (largest capacity system)[1]

Application Process	DPM 5000 Volume (cubic/ft)	# of Nets Processed per Cycle	Target Total Cycle Time (min)	Target Production Efficiency (%)	Max Net Production Per Day	Max Net Production Per Week (6 days/wk)	Max Net Production Per Year (50 wks/yr, 6 days/wk)	Cost Per Net Using a 10 Year Payback Period[2]
8 Hrs/Day	178	100	40	0.85	1,020	6,120	306,000	$0.097
24 Hrs/Day	178	100	40	0.85	3,060	18,360	918,000	$0.033

Note[1]: Note that Table II only includes the per net, ten year machinery straight line depreciation cost of producing LLIN products.
Note[2]: Based on total estimated machinery cost of $299,146 USD for the Washex DPM5000/CPG600 turnkey system (including estimated freight, installation, and start-up).

Conversion Cost for End-of-Line LLIN Production

Developing an accurate product cost model is a difficult task, as it requires a substantial amount of input data that often times can only be estimated. However, numerous feasibility studies have been conducted related to the conversion cost (cost of labor, machinery, facilities and utilities) of LLIN treatment using the end-of-line production process and the results, regardless of the proposed African location, normally fall within a relatively narrow range ($\pm$ 7%). Table IV provides an accurate example of the product cost breakdown for an end-of-line produced LLIN product by both resource consumption category (materials, labor, machinery, facilities, and utilities) and production process (sewing, LLIN treatment, drying, fold and pack).

Table IV. Cost Concentration Table ($USD/net) for 190 x 180 x 150 cm Size 75 Denier White LLINs Produced in Africa using USAID NetMark End-of-Line LLIN Production Process									
	Sew	**LLIN Treatment**	**Drying**	**Fold & Pack**	**Quality Control**	**Total**	**% of Total**	**Grand Total**	**% of Grand Total**
Material								3.3916	88.97%
Untreated Pre-Cut	1.850	0.0000	0.0000	0.0000	0.0000	1.8500	48.53%		
Strategic Stock	0.011	0.0000	0.0000	0.0000	0.0000	0.0108	0.28%		
Consumables	0.110	0.0000	0.0000	0.0000	0.0582	0.1682	4.41%		
LLIN Chemistry	0.000	1.2626	0.0000	0.0000	0.0000	1.2626	33.12%		
Packaging and Baling	0.000	0.0000	0.0000	0.1000	0.0000	0.1000	2.62%		
Labor								0.1876	4.92%
Supervision/Technical	0.0201	0.0091	0.0091	0.0068	0.0000	0.0451	1.18%		
Hourly	0.0746	0.0085	0.0085	0.0412	0.0098	0.1425	3.74%		
Machinery								0.1016	2.67%
Depreciation	0.0023	0.0199	0.0116	0.0027	0.0124	0.0489	1.28%		
Interest	0.0020	0.0175	0.0102	0.0023	0.0109	0.0430	1.13%		
Parts/Supply	0.0005	0.0040	0.0023	0.0005	0.0025	0.0098	0.26%		
Facilities								0.0396	1.04%
Depreciation	0.0137	0.0021	0.0021	0.0021	0.0011	0.0211	0.55%		
Interest	0.0121	0.0019	0.0019	0.0019	0.0009	0.0185	0.49%		
Other	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00%		
Utility								0.0918	2.41%
Electricity	0.0275	0.0275	0.0251	0.0039	0.0000	0.0841	2.21%		
Natural Gas	0.0000	0.0000	0.0072	0.0000	0.0000	0.0072	0.19%		
Water	0.0000	0.0005	0.0000	0.0000	0.0000	0.0005	0.01%		
Total	**2.1234**	**1.3536**	**0.0780**	**0.1615**	**0.0958**	**3.8123**	**100.00%**	**3.8123**	**100.00%**

As shown in Table IV, 190 x 180 x 150 cm size 75 denier white rectangular LLINs can be produced at an estimated cost of $3.81 per net with an input cost of $2.12 per untreated sewn net. Based on this data, the conversion cost is $1.69 per net. Of this cost, $1.42 is for conversion materials (i.e. LLIN chemicals, packaging, QC supplies) and the remaining $0.27 cost is for labor, machinery, facilities and utilities. Note that this model only details the cost of goods (COG) and does not include any added cost allocation for fixed corporate overhead or desired profit margin. However, with market prices for this size and style of LLLN product currently equal to or greater than $4.50 per unit, enough margin exists to make end-of-line LLIN production an attractive business opportunity.

Checklist of Items to Facilitate Efficient Plant Operation

The following is a checklist of items necessary to facilitate efficient plant operations:

- Machinery
  - Determine the spare parts and supplies recommended by the machinery vendor and develop a plan to have critical parts either on-hand or available with fast delivery
    - Washer
    - Dryer
    - Chemical spraying system (air valves, nozzles, pumps, piping)
    - Air compressor
    - Etc.
  - Follow machinery vendor guidelines for preventive maintenance and ensure that the maintenance is done according to schedule

- Ensure that proper supplies are on site for plant operation - these include:
  - Adequate supply (8 or more) plastic transport buggies (or carts) large enough to hold a production batch of 125 nets
  - Supply of nets adequate enough to support LLIN production
  - Supply of insecticide and binder chemistry adequate enough to support LLIN production
  - Personal protective equipment
  - Electronic laboratory scale (for weighing of individual nets, liquid samples, etc.)
  - Laundry basket or similar type container for use when weighing nets on lab scale as necessary
  - Floor scales for weighing full size loads of nets (dry vs. wet weight)
  - Rotary sample cutters (see www.olfa.com/Products.asp?C=3&P=71
  - Templates for sample preparation (i.e. Plexiglas 25 x 25 cm or other)
  - Tables for sample cutting
  - Cutting boards for sample cutting
  - Sharpie brand or similar indelible marking pens for labeling nets, etc.
  - Small and medium size plastic bags for holding treated net samples
  - Lab notebooks, pencils, pens, etc.
  - Calculator
  - Basic tools (screw drivers, pliers, channel lock pliers, hammers, wrenches, etc.)

- Ensure that proper material handling is available for transferring nets from the net staging area to the treatment machine, from the treatment machine to the dryer, and from the dryer to the sampling/folding/storage area.
  - Overhead sling rail system
  - Industrial laundry carts
  - Etc.

- Ensure that adequate space and storage containers are available for the following:
  - Nets staged before treatment (nets should be segregated into production-size lots)
  - Treated nets after drying
  - Chemicals
  - Process wastewater (to be recycled)

- Production lot numbers should be assigned to each production run. A methodology and system for accomplishing this should be determined and in place prior to plant start-up.

- Training of the operators should be completed before full production begins
  - It would be helpful to provide some level of training before the machines arrive at the factory for installation … such as providing basic instructions with written materials, slides, etc.

- Ensure that adequate chemical handling, mixing, weighing, metering, and pumping is in place prior to plant start-up

- One or more maintenance technician should attend a factory certified training program prior to machinery installation (enrollment is typically included with the purchase of new equipment)

- Ensure that proper and reliable utilities are available including electricity, compressed air, natural gas, steam or other energy for drying of nets.

Standard Operating Procedures

A full set of general (non machine brand specific) standard operating procedures (SOPs) is provided in Appendix A. This step-by-step document suggests the recommended procedures for efficient operation of an end-of-line LLIN production module.

Note that the recommended machine cycle for end-of-line LLIN treatment is as follows:

1. Load machine (1 m^2 of netting material per 0.125 ft^3 of cylinder volume)
2. Close door and START
3. 1 minute (30 seconds clockwise/30 seconds counterclockwise) tumble with no LLIN chemical spray application (load balance step)
4. 33 to 35 minute air atomized spray cycle (clockwise/counterclockwise cylinder rotation at 30 second intervals) – Target wet pick-up of LLIN treatment liquor should be 90% (i.e. a 50 kg batch of nets should be treated with 45 kg of LLIN treatment liquor).
5. 4 to 6 minutes (clockwise/counterclockwise cylinder rotation at 30 second intervals) to help optimize insecticide distribution within and between nets.
6. AUTO STOP (with siren alarm to notify operators) and open door

7. Unload LLIN treated nets, weigh to determine actual wet pick-up and if in specification transfer to dryer

Note that drying time and temperature is LLIN chemistry dependent and should be determined through consultation with your chemical provider.

Process Troubleshooting

The following is a list of potential processing problems that could be encountered along with the key items to check when troubleshooting. With this process, quality and production efficiency results from properly controlling all process variables including the chemical formulation, batch size, net quality, dosage of LLIN treatment liquor, delivery of LLIN treatment liquor into the machine (air atomized spray time, flow rate, and pattern), cycle time, drying time and drying temperature.

Problem

- The LLIN application machine drum will not rotate.

Solutions

- ✓ Ensure that the machine power is turned on.
- ✓ Be sure that the proper application procedure has been selected and initiated.
- ✓ Ensure that adequate air supply is present at the machine panel.
- ✓ Check the program steps to ensure that the drum rotation step is included and has been properly activated.
- ✓ Ensure all safety and position switches (i.e. door close, machine tilt, etc.) are properly engaged.
- ✓ Check the machinery manual for additional solutions.

Problem

- The nets are not tumbling properly in the machine.

Solutions

- ✓ Check the number of nets loaded into the machine to ensure that it is the proper batch size for the size and type of nets being treated.
- ✓ Ensure that the rotation speed of the drum is correct. Too slow and the nets will ball up in the lower half of the machine. Too fast and the nets will not properly tumble and mix.

Problem

- The LLIN treatment liquor is not spraying from the nozzles, or is not spraying properly (as a very fine air atomized mist).

Solutions

- ✓ Check all valve positions in the chemical feed system (from the Day Tank to the nozzle) to ensure that a closed valve is not blocking the flow of treatment liquor.
- ✓ Ensure that the pump is operating properly and that there is sufficient head pressure.

- ✓ Check the air supply to the nozzles to ensure that the proper air pressure is being used (too high of air pressure will restrict treatment liquor flow, too low of air pressure will not produce and air atomized mist).
- ✓ Bleed the pressure from the LLIN treat liquor feed line(s), remove the nozzle(s), inspect them for obstructions, clean the nozzle(s) thoroughly and replace them properly.

Problem

- HPLC analysis shows that the LLIN treatment liquor does not meet specification (AI content is too high or too low).

Solutions

- ✓ Ensure that the LLIN treatment liquor in the Day Tank was properly stirred to prevent settling of chemicals.
- ✓ Recheck the LLIN mixture using the HPLC system. Sample from the bottom and the top of the LLIN treatment liquor mix tank.
- ✓ Ensure that the HPLC instrument is operating properly by checking a reference standard.
- ✓ Check the chemical weighing records to determine if an error was made in making the treatment liquor mixture.
- ✓ Ensure that all chemicals are mixed properly before being weighed and added to the mix tank. These chemicals are commonly suspension concentrates and the active ingredients will settle.
- ✓ Check the weighing scales to ensure that they are accurate and properly calibrated.
- ✓ Notify a supervisor to determine the best option for correcting the mixture.

Problem

- After LLIN treatment the treated batch weight is out of specification (i.e. target wet pick-up $\pm$ 5%).

Solutions

- ✓ Ensure that the nozzles are spraying properly.
- ✓ Ensure that the chemical feed pump is properly calibrated and operating correctly.
- ✓ Check the air supply to the nozzles to ensure that the correct volume and pressure of compressed air is being supplied to the nozzle(s).
- ✓ Check the nozzle(s) to ensure that they are not clogged. Clean as necessary.
- ✓ Check all treatment liquor filters in the system to ensure that no filters are clogged.
- ✓ Ensure that all automatic process control valves (if applicable) are opening properly during the LLIN chemical application cycle.
- ✓ Ensure that the correct nozzle(s) are being used and that they are installed properly.
- ✓ Open the drain valve to ensure that any liquid that has passed through the drum cylinder has been drained from the machine. Check the drain pipe to ensure that it is not clogged with lint, strings, fabric trim waste, etc.

Problem

- During unloading of LLIN treated nets excess treatment liquor is dripping from the nets.

Solutions

- ✓ Ensure that the proper volume of LLIN treatment liquor is being sprayed onto the batch of nets (correct % WPU is being used; correct net weights are being processed; the correct volume of treatment liquor is being sprayed during the application cycle)
- ✓ Ensure there is no excess treatment liquor in the machine sump. This can occur if the machine's drain valve is closed or clogged for an extended period of time.

Problem

- Nets are still damp or wet at the end of the drying cycle.

Solutions

- ✓ Check the dryer to ensure that the target drying temperature is being achieved and maintained during the drying cycle.
- ✓ Ensure that the target drying time is being used.
- ✓ Be sure that all filters are properly cleaned.
- ✓ Check the air flow through the dryer to be sure that adequate air flow is being achieved.
- ✓ Ensure that the dryer drum is rotating properly.

Problem

- Physical damage to the nets is observed after LLIN treatment or drying.

Solutions

- ✓ Inspect the nets as they are loaded into and unloaded from each machine to determine the source of the damage (incoming nets or from a particular machine).
- ✓ Ensure that all machine surfaces are free of all burrs, picks and rough edges. Use sandpaper or other tools to smooth and buff the machine and drum surfaces.

Assistance with Technology Transfer

For assistance with technology transfer inquires can be addressed to:

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Summary

The USAID NetMark End-of-Line LLIN Production Process was developed through partnership between USAID's AED NetMark Program, Siamdutch Mosquito Netting Co., Ltd., Bayer Environmental Science, and Anovotek, LLC. The process is now in commercial production at both Tana Netting (see www.tananetting.com) and Sunflag Nigeria. Tana Netting's DawaPlus 2.0 LLIN product received its interim WHOPES recommendation by WHO in July 2009. All processing specifications are in the public domain and individuals or companies interested in learning more should visit www.netmarkafrica.org or www.anovotek.com.

Appendix A

Anovotek, LLC
www.anovotek.com

Production and Quality Assurance Standard Operating Procedures for the USAID NetMark End-of-Line LLIN Production Process

Prepared for:
AED NetMark

Prepared by:
Don Alexander
Andy Butenhoff
Anovotek, LLC

September 11, 2009

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USAID NetMark End-of-Line LLIN Production Process

Background

Process and product development research has shown that application of long lasting insecticidal net (LLIN) chemistry can be done successfully to finished sewn mosquito nets in industrial garment washing machines using a metered addition mist spray approach.

The purpose of this document is to detail the production and quality assurance Standard Operating Procedures (SOPs) for this end-of-line LLIN production process. Implementing these SOPs will help to maximize production output, product quality, and worker safety.

USAID NetMark End-of-Line LLIN Process Control Plan

Process control of chemical application to mosquito nets in the USAID NetMark end-of-line LLIN production process requires checks of numerous items during the manufacturing process. Reliance on QC testing of active insecticide on the treated nets is not sufficient to achieve consistent and reliable quality nets.

Numerous items should be checked as specified in the specific standard operating and quality assurance procedures for the process. These checks are conducted to ensure that:

- Incoming chemicals are consistent
    - Review the COA of the incoming chemicals to ensure that they are within the expected concentration
    - Stability of incoming chemicals meets visual standard

- Chemical mixes are made properly
    - Ensure that acceptable quality water is used for making chemical mixes
    - Ensure that proper chemical weights are added
    - Ensure that the order of mixing is followed
    - Ensure stability of chemical mix meets visual standard (no coagulation, slow to settle, etc.)
    - Ensure that the AI content of chemical mix meets specification (requires on-site HPLC testing)

- The correct amount of the chemical mix is sprayed into the washer/extractor during the treatment cycle
    - Weigh the nets before and after LLIN treatment to ensure that the proper amount of LLIN chemistry has been applied to the nets

- The spray nozzles are not clogged
    - Visually inspect spray pattern
    - Remove, clean, and inspect the nozzles as necessary

- The proper amount of nets are processed during each production cycle
    - Each lot of nets should be weighed before processing to ensure that the load size is correct

- The nets are thoroughly dried
    - Visual inspection
    - Weigh the production batch after drying and compare to the weight of the batch before treatment
    - Periodic calibration of process control machinery sensors (i.e. exhaust air temperature and moisture sensor)

- The nets meet or exceed final quality control specifications
    - Visual inspection
    - Physical testing as required
    - Chemical testing of AI content as required
    - Wash fastness and bio efficacy testing as required

USAID NetMark End-of-Line LLIN Production Process –
Checklist of Items to Facilitate Efficient Plant Operation

- Machinery
  - Determine the spare parts and supplies recommended by the machinery vendor and develop a plan to have critical parts either on-hand or available with fast delivery
    - Washer
    - Dryer
    - Chemical spraying system (air valves, nozzles, pumps, piping)
    - Air compressor
    - Etc.
  - Follow machinery vendor guidelines for preventive maintenance and ensure that the maintenance is done according to schedule

- Ensure that proper supplies are on site for plant operation - these include:
  - Adequate supply (8 or more) plastic transport buggies (or carts) large enough to hold a production batch of 125 family size nets
  - Supply of nets adequate enough to support LLIN production
  - Supply of insecticide and binder chemistry adequate enough to support LLIN production
  - Electronic laboratory scale (for weighing of individual nets, liquid samples, etc.)
  - Laundry basket or similar type container for use when weighing nets on lab scale as necessary
  - Floor scales for weighing full size loads of nets (dry vs. wet weight)
  - Rotary sample cutters (see www.olfa.com/Products.asp?C=3&P=71
  - Templates for sample preparation (i.e. Plexiglas 25 x 25 cm or other)
  - Tables for sample cutting
  - Cutting boards for sample cutting
  - Sharpie brand or similar indelible marking pens for labeling nets, etc.
  - Small and medium size plastic bags for holding treated net samples
  - Lab notebooks, pencils, pens, etc.
  - Calculator
  - Basic tools (screw drivers, pliers, channel lock pliers, hammers, wrenches, etc.)

- Ensure that proper material handling is available for transferring nets from the net staging area to the treatment machine, from the treatment machine to the dryer, and from the dryer to the sampling/folding/storage area.
  - Overhead sling rail system
  - Industrial laundry carts
  - Etc.

- Ensure that adequate space and storage containers are available for the following:
    - Nets staged before treatment (nets should be segregated into production-size lots).
    - Treated nets after drying
    - Chemicals
    - Chemical wastewater

- Production lot numbers should be assigned to each production run. A methodology and system for accomplishing this should be determined and in place prior to plant start-up.

- Training of the operators should be completed before full production begins
    - It would be helpful to provide some level of training before the machines arrive at the factory for installaion … such as providing basic instructions with written materials, slides, etc.

- Ensure that adequate chemical handling, weighing, metering, mixing, and pumping is in place prior to plant start-up

- One or more maintenance technician should attend a factory certified training program prior to machinery installation (enrollment is typically included with the purchase of new equipment)

USAID NetMark End-of-Line LLIN Production Process
Glossary of Terms

Bill of Lading

A bill of lading is a document which is issued by the transportation carrier to the shipper acknowledging that they have received the shipment of goods and that they have been placed on board a particular vessel which is bound for a particular destination. Included in the document are the conditions, limitations of liability, shipping instructions, description of commodity, and applicable transportation charges.

Certificate of Analysis

Certificates of Analysis (COA) describe quality control data for a particular lot/batch of product. See www.ivstandards.com/tech/articles/consumer/coas.asp for additional details.

Day Tank

Day tank refers to the tank used to prepare and hold enough LLIN chemical mixture to run one production machine for one production shift.

Master Mix

Master Mix refers to a large volume of LLIN chemical mixture that will be used from the Day Tank.

Material Safety Data Sheet (MSDS)

A MSDS is provided by the chemical supplier and contains details of the properties and hazards associated with a chemical, and gives information on its safe use.

Personal Protective Equipment (PPE)

Personal Protective Equipment, or PPE, is designed to protect employees from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. Besides face shields, safety glasses, hard hats, and safety shoes, PPE include a variety of devices and garments such as goggles, coveralls, gloves, vests, earplugs, and respirators.

Recovery Water Tank

This is the tank used to store water that has been used to clean the add tank, chemical spray system and treatment vessel. Once filtered to remove solid particles such as yarn, thread and fabric waste, this water can be re-used to make another master mix of LLIN chemical mixture.

Standard Operating Procedure (SOP)

Quality Control of Incoming Insecticide

Scope: This Standard Operating Procedure provides details for establishing quality control procedures for incoming insecticide.

Purpose: The purpose of this SOP is to standardize procedures for documenting the quality of incoming chemicals used in the production of LLIN products.

Procedure:

1. Obtain the proper paperwork for the incoming chemical shipment including:
    a. Bill of lading
    b. Certificate of Analysis (COA) from the chemical supplier
2. Check the lot number on the chemical shipment documents and on each container of chemicals – all lot numbers should match (paperwork to actual containers of chemicals)
3. If any containers have lot numbers that do not match the lot numbers on the shipment documentation, flag these containers for further inspection and notify the supervisor
4. Check to ensure that the number of containers match the number of containers shown on the shipment documentation
5. Check each container to ensure that the weight on the container label matches the weight on the shipment documentation
6. Weigh each container of chemical to verify that the actual weight matches the weight on the documentation
7. Review the COA for each lot of chemicals – if any COA is found to be out of specification, flag the containers for further inspection and notify a supervisor
8. Record data from the shipment in the "Incoming Insecticide Quality Control Log"

Approved by: _____ **Effective Date: _____**

9. Sample the content from each container of active ingredient (AI) received by the plant
    a. Obtain a sample container
    b. Label the sample container to include
        i. Date
        ii. Chemical name
        iii. Lot number
        iv. Shipment number
    c. Read and follow the Personal Protective Equipment (PPE) guidelines on the Material Safety Data Sheet (MSDS) before opening any chemical containers
    d. Ensure that the active ingredient is properly stirred then remove the sample and place it in the sample container
10. Submit the sample to the laboratory for AI content testing
11. Record all sample test data in the "Incoming Insecticide Quality Control Log"
12. If the result from any test sample is not within the target specification, flag the container(s) and notify a supervisor for disposition

Approved by: _____ **Effective Date: _____**

Incoming Insecticide Quality Control Log

DATE	OPERATOR NUMBER	LOT NUMBER	SHIPMENT NUMBER	CONCENTRATION OF INSECTICIDE ON COA	STANDARD CONCENTRATION	PASS / FAIL

Approved by: _____ **Effective Date: _____**

Standard Operating Procedure (SOP)

Quality Control of Incoming Binder

Scope: This Standard Operating Procedure provides details for establishing quality control procedures for incoming binder.

Purpose: The purpose of this SOP is to standardize procedures for documenting the quality of incoming chemicals used in the production of LLIN products using a binder in combination with an active insecticide.

Procedure:

1. Obtain the proper paperwork for the incoming chemical shipment including:
    a. Bill of lading
    b. Certificate of Analysis (COA) from the chemical supplier
2. Check the lot number on the chemical shipment documents and on each container of chemicals – all lot numbers should match (paperwork to actual containers of chemicals)
3. If any containers have lot numbers that do not match the lot numbers on the shipment documentation, flag these containers for further inspection and notify the supervisor
4. Check to ensure that the number of containers match the number of containers shown on the shipment documentation
5. Check each container to ensure that the weight on the container label matches the weight on the shipment documentation
6. Weigh each container of chemical to verify that the actual weight matches the weight on the documentation
7. Review the COA for each lot of chemicals – if any COA is found to be out of specification, flag the containers for further inspection and notify a supervisor
8. Record data from the shipment in the "Incoming Binder Quality Control Log"

Approved by: _____ **Effective Date: _____**

Incoming Binder Quality Control Log

DATE	OPERATOR NUMBER	LOT NUMBER	SHIPMENT NUMBER	BINDER COA	STANDARD COA	PASS / FAIL

Approved by: _____ **Effective Date: _____**

Standard Operating Procedure (SOP)

Mist Spray Application of LLIN Chemistry –
Preparation of Master Mix in the Day Tank

Scope: This Standard Operating Procedure provides details for the preparation of binder and insecticide mixture (Master Mix) in the Day Tank. The Day Tank refers to the tank used to hold enough binder and insecticide mixture to run one production machine for one production shift. **Note: This SOP is specific to Bayer's Deltamethrin based LLIN formulation and may need to be adapted for use with other LLIN chemistries.**

Purpose: The purpose of this SOP is to standardize procedures for the preparation of chemicals for LLIN treatment of mosquito nets using the end-of-line mist spray application method.

Procedure:

1. Select the appropriate mix formulation for the nets that will be processed (i.e. based on target wet pick-up, desired AI dosage, etc.)
2. Read and follow the Personal Protective Equipment (PPE) guidelines on all applicable Material Safety Data Sheets (MSDS) before mixing chemicals
3. **Add approximately 80 % of the total required water for the mix into one mixing vessel (i.e. 55 gallon drum, etc.) and keep the remaining 20% of the required water in a separate container.** This 20% will be used to rinse the buckets and drum pumps after Deltamethrin has been mixed and pumped using the drum pump.
    a. Use fresh water or water from the Cleaning Water Recovery Tank.
    b. Use a maximum of 30% of the total water needed for the mix from the Cleaning Water Recovery Tank.
    c. Be sure to filter the recovered water before it is added to the mixing drum. The recommended filter media is a fine screen mesh of 200 microns. The purpose of filtering is to remove solid particles such as yarn, thread and fabric trim waste.
    d. Record the amount of "recovered water" used in the mix on the "Master Mix Production Log".
    e. Add fresh water as needed to complete the addition of water required.

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4. **Add the required amount of NWA-100** (stabilizer) to the mixing drum containing 80% of the water and rinse the NWA-100 container in the water. Stir the water and NWA-100 gently. **Add the required amount of binder** to the drum containing 80% of the water and rinse the binder container in the water. Stir the mixture.
5. Move the drum pump into the mixing drum containing 80% of the water.
6. **After mixing well with a drum pump, add the required amount of Deltamethrin SC** to the mixing drum containing 80% of the water. Stir the mixture well using a drum pump.**Add the remaining 20% of the water using the drum pump.** Clean the drum pump hoses while adding this water.
7. **Stir the entire mix thoroughly using a drum pump.**
8. Record all information on the "Master Mix Production Log".
9. Take a sample of the mixture and place in a properly labeled sample bottle for analysis by the laboratory.
    a. A proper label for the sample should include the mix number, date and time the mixture was made and other formulation identification as available.
    b. Visually inspect the sample to ensure that the mixture is stable. If any coagulation or rapid settling is observed notify the manager.
    c. Submit the sample to the HPLC lab for AI content testing.
    d. Wait for final authorization "Released for Production" from QC lab before using the mix.
10. Ensure that all valves on the Day Tank are in the proper position. All valves should be closed except the valve between the Day Tank and the metering pump (it should be open).
11. Transfer the mix into the Day Tank using a drum pump.
12. Turn on the mixer in the Day Tank.
13. Rinse the drum pump and return it to its designated storage area.

Approved by: _____ **Effective Date: _____**

Master Mix Production Log

OPERATOR NAME	DATE	# BATCHES TO PROCESS	MIX NUMBER	STEP 1 ADD RECOVERED WATER (KG)	STEP 2 ADD FRESH WATER (KG)	STEP 3 ADD NWA-100 (GRAMS)	STEP 4 ADD BINDER (KG)	STEP 5 ADD DELTAMETHRIN (KG)	STEP 6 QC SAMPLE TAKEN TO LAB	STEP 8 MIX RELEASED FOR PRODUCTION

Approved by: _____ **Effective Date: _____**

Standard Operating Procedures

Application of LLIN Chemistry

Scope: This Standard Operating Procedure applies to end-of-line mist spray application of LLIN chemistry (binder and active insecticide) to finished sewn nets.

Purpose: The purpose of this SOP is to standardize operating parameters and machine control settings in order to maximize production efficiency, product quality, and worker safety.

Procedure:

1. Properly prepare each batch of nets
    a. Count the appropriate number of nets to be treated (max load size depends on the size of LLIN treatment machine – target is 1.0 m^2 of netting material per 0.125 ft^3 of cylinder volume).
    b. Lay nets for each batch into a smooth plastic transport buggy in an open lengthwise manner. This will facilitate rapid and proper loading into the LLIN treatment machine.
    c. Weigh the batch of nets (the weight of each batch should be within a set specification (i.e. 50 kg $\pm$ 0.5 kg). Remember to subtract the tare weight of the transport buggy.
    d. Prepare a batch ticket for each load of nets including batch number, size of net, number of nets, dry weight, etc.
2. Determine the next production batch to be treated with LLIN chemistry by referring to the production schedule.
3. Verify and record the batch number on the "LLIN Treatment Production Log".
4. Verify and record the dry weight (Kg) of the production batch on the "LLIN Treatment Production Log".
5. Move the production batch from the LLIN Treatment Staging Area to the machine.
6. Open the machine door and load the nets into the machine -- ensure that the nets are not "balled or rolled" tightly when loaded into the machine.
7. Move the batch ticket from the transport buggy to the operator station/control panel on the LLIN treatment machine.
8. If necessary, rotate the washer cylinder using the jog button to evenly distribute the load of nets within the machine.
9. Close the washer door.

Approved by: _____ **Effective Date:** _____

10. Determine the correct LLIN treatment program for the batch to be processed and select the correct LLIN treatment program from the machine control panel.
11. Start the treatment program
12. Using a flashlight, visually check to make sure that:
    a. The application machine is rotating properly - (nets should be falling at approximately a 45-60 degree angle when viewed through the glass in the machine door.
    b. The nozzles are evenly spraying the LLIN chemistry onto the nets (there should be a "fog or mist" coming out of the spray nozzles inside the machine. If a solid stream of liquid is observed call a manager to inspect and clean the nozzles.
13. Periodically check the spray system air pressure gauge to ensure proper flow rate of treatment liquor through the spray nozzles during the treatment cycle.
14. While the LLIN chemistry is being sprayed onto the nets, check the production schedule to determine the next production batch to be processed.
15. Verify the location of the next production batch in the LLIN Treatment Staging Area and ensure that it is properly prepared for loading into the LLIN treatment machine.
16. After completion of the LLIN chemical application cycle, open the door on the LLIN treatment machine.
17. Tilt the treatment machine forward (if this option is available), and empty the wet treated nets into a transport buggy. *Note: Operators should be wearing full safety gear including goggles, apron and gloves. Try to minimize tangling of the nets during unloading.*
18. Move the batch ticket from the operator station/control panel to the transport buggy.
19. Immediately weigh the full load of wet LLIN treated nets on a floor scale.
20. Record the Wet Weight of the treated batch (minus the transport buggy tare weight) on the batch ticket.
21. Record the Wet Weight of the treated batch (minus the transport buggy tare weight) on the "LLIN Treatment Production Log".
22. Ensure that the weight of the LLIN treated batch is within specification (i.e. target wet weight +/- 5% tolerance).
    a. If weight of the treated batch is below or above the target specification notify supervisor immediately for corrective action.
23. If the LIIN treated batch weight is within specification immediately load the nets into the dryer and start the drying operation.
24. Move the batch ticket from the transport buggy to the operator station/control panel on the dryer.

Approved by: _____ **Effective Date: _____**

LLIN Treatment Production Log

Date: _____
Machine Number: _____

OPERATOR NUMBER	BATCH NUMBER	# OF NETS IN BATCH	WEIGHT OF DRY NETS (KG)	WEIGHT OF WET NETS (KG)	LLIN TREATMENT SPECIFICATION LCL = ____ (KG) UCL = ____ (KG) RELEASE Y/N

Approved by: _____ **Effective Date: _____**

Standard Operating Procedure (SOP)

Operation of LLIN Dryer

Scope: This Standard Operating Procedure applies to drying 100% polyester mosquito nets treated with LLIN chemistry (binder and active insecticide).

Purpose: The purpose of this SOP is to standardize operating parameters and dryer control settings in order to maximize production efficiency, product quality, and worker safety.

Procedure:

1. Determine the next production batch to be processed through the dryer.
2. Verify and record the batch number on the "LLIN Dryer Production Log".
3. Load the wet LLIN treated nets into the machine.
4. Select the appropriate drying cycle (time/temperature control).
5. Start the drying cycle.
6. Record the cycle start time on the "LLIN Dryer Production Log".
7. Ensure that the correct drying and cooling time is programmed into the controller.
8. After completion of the drying cycle, open the door and visually inspect the nets to ensure that they are dry. If there is concern that the nets have not properly dried, reweigh the entire batch and compare this weight to the original dry weight of nets in the batch.
9. Unload the dry LLIN treated nets into a transport buggy.
10. Attach the batch ticket to the transport buggy.
11. Move the dry load of LLIN treated nets to the net folding and packing area and ensure that the batch ticket remains with the treated nets.
12. Enter the cycle stop time on the "LLIN Dryer Production Log".

Approved by: _____ **Effective Date:** _____

LLIN Dryer Production Log

Date: _____
Machine Number: _____

OPERATOR NUMBER	BATCH NUMBER	CYCLE START TIME	SPECIFIED DRYING TIME (MIN)	CYCLE STOP TIME

Approved by: _____ **Effective Date: _____**

Standard Operating Procedure (SOP)

Cleaning of Day Tank, Chemical Spray System and LLIN Treatment Machine at the End of Each Shift

Scope: This Standard Operating Procedure provides details for cleaning of the Day Tank, Chemical Spray System and Washer at the end of each production shift.

Purpose: The purpose of this SOP is to standardize procedures for cleaning of the Day Tank, Chemical Spray System and Washer at the end of each production shift to ensure that excessive build up within the tank, spray system and machine is prevented. Water used for cleaning purposes should be captured in the Recovery Water Tank to prevent residual insecticide from entering the plant wastewater discharge.

Procedure:

1. Read and follow the Personal Protective Equipment (PPE) guidelines on all applicable Material Safety Data Sheets (MSDS) before cleaning the Day Tank, Chemical Spray System or Washer.
2. Ensure that the Day Tank is empty by visual inspection.
3. If any chemical mixture is remaining in the Day Tank, pump this chemical to a suitable storage container or into the recovery water tank.
4. Rinse the Day Tank with water using a hose with spray nozzle – all sides of the tank should be rinsed.
5. If necessary, use a scrub brush to remove residual build-up.
6. Pump the rinse water from the Day Tank to the Recovery Water Tank through a 500 micron filter to remove solid impurities (i.e. fiber fragments, polymer build-up, etc.).
7. Inspect and clean the filter cartridge as necessary.
8. Manually fill the Day Tank with 30-40 liters of clean water (spray the tank with clean water while filling to ensure that the sides of the tank are cleaned).
9. Start the LLIN treatment machine and chemical feed system to pump the clean water from the Day Tank through the chemical spray system into the machine.
10. Repeat steps 2 and 3 above.
11. Wipe the outside of the Day Tank clean using a damp rag.

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12. Remove and clean the 500 micron in-line filter between the chemical feed pump and the spray nozzles.
13. Remove and clean the spray nozzles in an ultrasonic cleaning bath using suitable cleaning solution as necessary.
14. Reinstall in-line filter cartridge and spray nozzles.
15. Open the door on the washer.
16. Using a hose, spray the inside of the machine cylinder to rinse away any residual insecticide and binder mixture.
17. Transfer the rinse water inside the machine into the Recovery Water Tank.
    a. Pump or drain the rinse water from the machine into the Recovery Water Tank through a 500 micron filter.
18. Inspect and clean the Recovery Water Tank filter cartridge as necessary.
19. Wipe the outside of the machine using damp cleaning rags.
20. Recovered and filtered rinse water should be used to make the chemical mix the following day.
21. Dispose of collected waste water that cannot be reused according to prescribed method in applicable Material Safety Data Sheets (MSDS) and/or local regulation.
22. Ensure that all hoses are properly stored after use.

Approved by: _____ **Effective Date: _____**