SOP Title 3A: Calibration for Backpack and Truck-Mounted Sprayers

SAFETY NOTICE: All persons involved with the transfer of the chemical must wear overalls, protective gloves and goggles as a minimum. Those persons involved with the operation of the machinery should also wear a suitable respirator and ear protection. Operators must follow national regulations on pesticide use and the recommendations of the manufacturer, paying attention to the PPE section.

All spray equipment must be properly calibrated to ensure accurate application of the compound. There is a large range of equipment available with many different designs: refer to the manufacturer's user manual for specific details on calibration procedures and operation.

Backpack Sprayers

Introduction

Each sprayer must be calibrated to ensure that the correct amount of insecticide is delivered with the prescribed droplet size distribution. The output rate depends on the walking speed of the operator and the effective track spacing. Track spacing is the distance between each spray line and is the measure required for calibration. Swath width is the effective application distance downwind. For backpack sprayers, it is often easier to find the natural pace of the operator and adjust the flow rate to achieve the required application rate per unit area (ml/ha or l/ha). Flow can be controlled manually by a valve or fixed restrictor orifices. Most backpack aerosol generators have an integrated flow meter & flow control valve, and the calibration is accomplished by means of viscosity charts to identify the appropriate settings. It is recommended, however, that the flow rate is still tested with the method below. Note that different chemicals have different viscosities at different temperatures. Calibrate flow rate at a temperature relevant to the conditions during operation.

The following flowrate equation can be used:

Flowrate (mL/min) = (WS * TS * AR) / 10, where

WS (m/min) = Applicator normal walking speed with sprayer

TS (m) = Track spacing or distance between walking tracks

AR (L/ha) = Target application rate

10 is used for unit conversion

Example: If an operator walks at a speed of 60 meters per minute with a track spacing of 10 m (600 m^2 in one min) for an application rate of 0.5 l/ha, the flow rate should be 30 ml/min.

Measuring flow rate

Equipment

- Personal Protective Equipment
- Graduated cylinder
- Stopwatch
- Collection jug or large container

Method 1

1. Put on gloves, overalls, respirator and protective goggles.
2. Run the equipment for a suitable time to ensure the lines are primed with insecticide solution.
3. Operate the equipment under the same conditions as during actual spray operations. Most equipment is operated at full throttle during spray operations; therefore, the sprayer should be operated similarly during the calibration measurements.
4. Disconnect the discharge tube from the spray nozzle and hold the tube in the graduated cylinder. Turn the sprayer on and let it flow for one minute. If the nozzle head must remain attached, a larger measuring vessel will be required, one that will cause minimal loss due to the velocity of the spray. After one minute of discharge into the measuring container, measure the liquid volume
5. Measure flow rate as ml/min.
6. Repeat this a minimum of three times and calculate the average value, aiming to have a coefficient of variation of less than 10% between replicates.
7. Return insecticide collected to the main tank and wash all measuring containers following an appropriate protocol according to the insecticide used. The graduated cylinder and additional tubing should be dedicated to this task and not used for anything else.

Method 2

An alternative technique is to measure the time to discharge of a known volume.

1. Put on gloves and protective glasses and overalls.
2. Run the equipment for a suitable time to ensure the lines are primed with insecticide solution.
3. Mark the tank and spray for one minute, then using a graduated cylinder to refill to the original mark and measure the volume needed to fill the tank. Or, add a known quantity to the tank and time how long it takes to fully discharge the liquid.
4. Measure flow rate as ml/min.
8. Repeat this a minimum of three times and take the average value, aiming to have a coefficient of variation of less than 10% between replicates.

Sprayer Calibration Truck Sprayer

Introduction

Each sprayer must be calibrated to ensure that the correct amount of insecticide is delivered with the prescribed droplet size distribution. The output rate depends on the driving speed and the effective track spacing (or swath width, if practically feasible). Track spacing is the distance between each spray line and is the measure required for calibration: this should conform to street spacing distance in each country. Swath width is the effective application distance downwind. Once this is known, the required flow rate from the vehicle can be calculated. The flow from the sprayer (l/min) equals the coverage (ha/min) multiplied by the application rate (l/ha). Flow can be controlled manually by either a valve or fixed restrictor orifices, or electronically by means of a variable speed pump. See the manufacturer's instructions for the appropriate method of controlling flowrates.

The following flowrate equation can be used:

Flowrate (mL/min) = VS * TS * AR * 1.67, where

VS (km/hr) = Vehicle speed during normal spray operations

TS (m) = Track spacing or distance between walking tracks

AR (L/ha) = Target application rate

1.67 is used for unit conversion

Example: If a vehicle's speed is 12 km/hour and track spacing is 50 m with a target application rate of 0.5 l/ha, the flow rate would be 500ml/min.

Spray emanating from a cold fogging nozzle cannot be captured into a container. Most truck mounted cold foggers come with a method to either insert a calibration tube into the nozzle head or detach the feeder tube from the nozzle assembly for flow rate measurement.

All persons involved with the transfer of the chemical must wear overalls, protective gloves and goggles. Those persons involved with the operation of the machinery should also wear a suitable respirator and ear protection (when standing within 2 m of the sprayer). Operators must follow national regulations on pesticide use and the recommendations of the manufacturer, paying attention to the PPE section.

Measuring flow rate

Equipment

- Personal Protective Equipment
- Stopwatch
- Graduated cylinder

Method

1. Put on gloves, overalls, a face mask and protective glasses.
2. Run the equipment for a suitable time, until all of the lines are primed with insecticide solution.
3. Disconnect the discharge tube or the calibration tube inserted and hold in the graduated cylinder. Turn the spray on and let it flow for one minute. At the end of the minute measure the liquid volume in the graduated cylinder.
4. Measure and record flow rate as ml/min.
5. Repeat this a minimum of three times and calculate the average value, aiming to have a coefficient of variation of less than 10% between replicates.
6. Return insecticide collected to the main tank and wash all measuring containers following an appropriate protocol according to active ingredient. The graduated cylinder and additional tubing should be dedicated to this role and not used for anything else.

Droplet Sizing

It is essential that the droplet size distribution is known and adjusted if necessary. The required droplet size distribution could range between $Dv_{0.5}$ 10-40 µm (WHO 2018; Equipment for Vector Control Specification Guidelines, second edition, Geneva) depending of the machinery, the chemical formulation or other application parameters. Follow the label and instructions by the equipment manufacturer. The statistics requested from droplet sizing analysis are the $Dv_{0.1}$, $Dv_{0.5}$ and $Dv_{0.9}$, where 10%, 50% and 90% of the spray volume is in droplets of a smaller diameter. For backpack sprayers, the two most relevant techniques are hotwire anemometry and a slide wave technique for microscopic analysis. Laser based techniques are also available but highly specialized and cost prohibitive. However, droplet size data for several backpacks are available using the Vector Sprays app for iPhones (this data was collected by the USDA-ARS).

Hot wire anemometry

The most common instrument for these measurements are the DC-III an DC-IV systems available from Adapco, Inc. (https://www.myadapco.com/product/dc-iv/). This is an electronic technique where a fine (5 µm) wire, typically platinum, is electrically heated to a uniform temperature. As a droplet impinges on the surface of the wire the temperature drops proportionally to the size of the droplet and is measured by a change in resistance. This technique requires that the operator be close to the nozzle as the sensor is velocity dependent, droplets must be traveling at 5-7 m/s for the measurement to be accurate. Hotwire anemometers are not suitable for calibrating thermal foggers.

Equipment

- Personal Protective Equipment
- Hot Wire Anemometer
- Computer

Procedure for using the DC-III (KLDlabs.com)

1. Ensure hot wire equipment is set-up to the spray solution type according to the manufacturer's instructions
2. Wear gloves, overalls, respirator and protective goggles
3. Turn on the sprayer and let it run to ensure that it is primed with insecticide solution
4. Place the sensor away from the nozzle where air velocity is estimated to be <5 m/s until a reading is provided and measure the air velocity
5. Move probe closer to the nozzle in short steps, each time measuring the air velocity until it is within the range of 5-7 m/s. Then mark that distance.
6. Measure the droplet size at that distance.
7. Take five separate samples
8. Turn off the sprayer
9. Carefully clean the anemometer with a solvent by dipping the probe in 50% acetone and 50% xylene. Gently shake the container for 10 second to ensure the probe is cleaned, and then repeat with distilled water. Do this after every measurement test.

Slide Wave Technique

The slide wave technique is simple and effective. As the name suggests, a coated microscope slide is waved through the spray plume at a high speed. The slide is coated with Teflon for oil-based formulations or magnesium oxide (MgO) for water based. MgO slides can be used for both water and oil-based formulations, but it is not effective for droplets <10 um so should be avoided where possible. To collect the droplets, the operator tapes a slide to a stick and swings it through the plume via a rapid arm movement (the slide should take ~1 sec to pass through the spray plume). Alternatively, the slides can be attached to a rotary device placed in the path of the machine at the height of the spray discharge. This method is preferred when spraying active ingredients to limit personnel exposure.

Equipment

- Personal Protective Equipment
- Microscope slides

- Stick and tape
- Rotating impactor
- Stand for rotating impactor
- Microscope

Procedure

1. Wear gloves, overalls, respirator and protective goggles.
2. Turn on the sprayer, let it run to ensure its primed with insecticide solution.
3. For the human powered swing, allow the sprayer to remain stationary. Once primed the operator approaches and rapidly swings the slide through the plume. For the rotating slide, turn the device on and have the sprayer move past the device once it is primed.
4. Take five separate samples.
5. Turn the sprayer off.
6. Remove the slide and return it to the laboratory for microscopic analysis.

Data Analysis

The hotwire anemometer connects to a computer and provides all the required statistics.

The slide wave technique requires visual examination of droplets using a compound microscope. As a droplet impacts on a slide it spreads larger than the original spherical drop. Droplet diameter is then determined by multiplying a spread factor that corrects for this anomaly. A common spread factor for many oil-based sprays is 0.62, which means that the droplet measured on the slide was created by a droplet that is 62% smaller. As a droplet impacts on a slide it spreads, and is larger than the original spherical drop, the original size is calculated by applying a spread factor to the data[1]. The diameter of the droplet is multiplied by the spread factor to provide the size of the original droplet. Image analysis software can rapidly compute the required statistics. The manual technique uses an eye piece graticule to measure the diameter of a minimum of 200 droplets per slide. To account for the varying collection efficiencies of different aerosol droplet sizes on waved or spinning slides, the calculation methods developed by A. H. Yeomans (1949) are used. In this method the volume contributions of each droplet size class are calculated by multiplying the number of droplets (N) by the droplet class diameter (D) rather than the diameter cubed.

Then from the cumulative volume fraction calculate the $Dv_{0.1}$, $Dv_{0.5}$ and $Dv_{0.9}$. With both image analysis and manual assessment, ensure that the operator traverses the slide widthwise because smaller droplets will preferentially collect to the outer edge of the slide[2]. Image analysis software is also available that can rapidly compute the required Dv statistics (http://www.remspc.com/SlideAnalysis/).

[1] Oil based formulations have differing spread factors for droplet size analysis, typically between 0.6 – 0.8. Magnesium Oxide slides have a spread factor of 0.8 For 15 -20 µm droplets and 0.75 for 10 – 15 µm droplets.

[2] As the air flows around an object (the slide) suspended particles will continue in their original direction due to their inertia. Smaller particles have less inertia, streamlining with the air, so the impact probability will increase closer to outer the edge.

SOP Title 3B: Calibration for Aerial Application Equipment

Introduction

There is a wide range of different aerial systems used in public health sprays with many custom-built systems in use. The following guidelines can be used to calibrate aerial application equipment. However, it is highly recommended that the user consult with personnel that have extensive experience with aerial application systems to ensure proper calibration and droplet size analyses. Weekly calibration is recommended. The spray system should be designed using information from nozzle manufacturers to provide an appropriate droplet size distribution and flowrate. Each machine must be then be calibrated to ensure that the correct amount of insecticide is delivered in the desired droplet size distribution. First the coverage needs to be calculated and this depends on the aircraft speed and the effective track spacing (commonly referred to as swath width), which is the distance between each spray line. Once the desired spray rate is known or specified by the chemical manufacturer on the product label, the required flow rate can be calculated from the following equation:

Flowrate (L/min) = (VS * TS * AR) / 600, where

VS (km/hr) = Aircraft speed during normal spray operations

TS (m) = Track spacing or swath width

AR (L/ha) = Target application rate

600 is used for unit conversion

Example: If an aircraft's speed is 120 km/hour and the track spacing or swath width is 300 m with an application rate of 0.5 l/ha, the flow rate would be 30 l/min.

Measuring Flow rate

Equipment

- Personal Protective Equipment
- Graduated Cylinder
- Stopwatch

Procedure

1. Wear gloves, overalls, a suitable respirator, ear protection and protective goggles as a minimum for protective equipment. Spill Containment Kit, MSDS and Labels, and Emergency Contact should be readily available in the aircraft.
2. Load the chemical to be calibrated to the chemical tank.
3. Start the spray pump system from ground-based source.
4. Place a graduated measuring device under each of the chemical spray nozzles.
5. Run the spray system until primed and then empty and reset all collection devices.
6. Turn the spray system back on for 60 seconds.
7. Measure and record the volume collected from each nozzle and total the amount sprayed.
8. The flow rate can be adjusted by increasing or decreasing spray pressure, changing the nozzle orifice size, changing the number of nozzles, or making slight adjustments to aircraft speed.

9. Repeat until a minimum of three replicates are achieved within ± 10% of that specified on the label.
10. Return insecticide collected to the main tank and wash all measuring containers following an appropriate protocol. The graduated cylinder and additional tubing should be dedicated to this role and not used for anything else.

Droplet size distribution of rotary and fixed winged aircraft

It is essential that the droplet size distribution is known and adjusted if necessary. The droplet size should be checked at the beginning of the study, or between different application rates. The droplet size distribution required should range between a $Dv_{0.5}$ of 25 to 45 µm depending on formulations, operational parameters, and environmental conditions. Follow the label and instructions provided by the equipment manufacturer. The statistics requested from droplet sizing analysis are the $Dv_{0.1}$, $Dv_{0.5}$ and $Dv_{0.9}$; where 10%, 50% and 90% of the spray volume is in droplets of a smaller diameter. For aerial application, rotating impactors are the only practical droplet collection devices that can be used in the field, with the aircraft being flown as low as safely possible over the devices at normal operating speeds

Equipment

- Personal Protective Equipment
- Stands for the rotary impactor
- Rotary impactors
- Slides
- Microscope
- Aircraft
- Radios

Procedure

1. Ensure that there is a place for workers to take cover when the aircraft flies over (e.g. truck or car).
2. Wear gloves and goggles.
3. Place a minimum of 3 rotating impactors, with Teflon coated slides, in a straight line 15m apart, in an open field perpendicular to the direction of flight. The aircraft should fly into the wind and the wind speed should be less than 15 km/h).
4. Mark the flight line for the pilot.
5. The first pass over the sampling line should be made with the spray system turned off so the pilot can practice the approach safely as they will be flying low and fast.
6. Turn on the rotating impactors.
7. Call the aircraft in wet, the spray should be turned on 500m prior to reaching the sample line and be left on for 500m past the sample line.
8. The spray altitude should be as low as safely possible, but no more than 15m, with the forward speed, and spray system configured to follow operational settings.
9. Wait for 5 minutes after spray to be sure that the whole droplet size distribution is sampled.
10. Collect the slides, place in sealed containers with the position annotated,
11. Repeat a minimum of three times.
12. Return to the laboratory for microscopic analysis.

Data Analysis

Image analysis software can rapidly compute the required statistics. For manual assessment use an eye piece graticule, measure the diameter of a minimum of 200 droplets per slide. Cube the diameter[3] and calculate the volume fraction in each size class and from the cumulative volume fraction calculate the $Dv_{0.1}$, $Dv_{0.5}$ and $Dv_{0.9}$. With both image analysis and manual assessment ensure that the operator traverse the slide widthwise because smaller droplets will preferentially collect to the outer edge of the slide[4]. If droplets are not within the desired range for the application, various adjustments must be made, depending upon the method being used to atomize the pesticide into droplets. Generally, the higher the airspeed, the smaller will be the droplets.

---

[3]Note on accuracy of spinning slide method for calculating droplet size statistics of larger (>30 microns $Dv_{0.5}$) droplets used in aerial space spray applications:

The spinning slide method, coupled with "Yeomans' correction", produces a reasonable estimation of droplet sizes from truck-based equipment (typically having a $Dv_{0.5}$ <20 microns). However, when used to measure/calculate the droplet size from aircraft which typically have a $Dv_{0.5}$ of 30-60 microns, it will estimate an erroneously low number due to "Yeomans' correction" no longer being appropriate for these larger droplets. It is suggested that these droplet size measurements are supplemented by information from equipment and chemical manufacturers whereby previous laser-based measurements conducted in wind tunnels under similar operating conditions (nozzle type/formulation type/aircraft speed for wind, etc) can provide more realistic estimates.

[4] As the air flows around an object (the slide) suspended particles will continue in their original direction due to their inertia. Smaller particles have less inertia, streamlining with the air, so the impact probability will increase closer to outer the edge