BRITISH STANDARD

BS ISO 22856:2008

Equipment for crop protection — Methods for the laboratory measurement of spray drift — Wind tunnels

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British Standards

National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Foreword

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ISO 22856 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 6, *Equipment for crop protection*.

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Equipment for crop protection — Methods for the laboratory measurement of spray drift — Wind tunnels

1 Scope

This International Standard establishes general principles for the measurement of spray drift potential in wind tunnels under controlled laboratory conditions.

This International Standard is applicable where comparative assessment or classification of the relative spray drift potential from spray generators (e.g. nozzles) or spray liquids is needed.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5682-1, *Equipment for crop protection — Spraying equipment — Part 1: Test methods for sprayer nozzles*

ISO 25358, *Crop protection equipment — Droplet-size spectra from atomizers — Measurement and classification*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
spray drift
quantity of spray liquid that is carried out of the sprayed (treated) area by the action of air currents during the application process

3.2
spray drift potential
fraction of the spray, as a percentage of the output of a spray generator, that is displaced downwind as airborne spray

3.3
boundary layer
layer of air in the immediate vicinity of the wind tunnel floor where the local mean horizontal air velocity is retarded to less than 95 % of the nominal air speed

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3.4
nominal air speed
v
average velocity of the wind tunnel horizontal air flow (in the main direction of the air flow) outside the boundary layer

NOTE 1 The nominal air speed is expressed in meters per second ($m \cdot s^{-1}$).

NOTE 2 See A.3.

3.5
degree of turbulence
T
variation of the horizontal air velocity related to the nominal air speed

NOTE 1 The degree of turbulence is expressed in percentage.

NOTE 2 See A.4.

3.6
local variability of air velocity
S
local variation of horizontal air velocity (in the main direction of the air flow) related to the nominal air speed

NOTE 1 The local variability of air velocity is expressed in percentage.

NOTE 2 See A.5.

3.7
sprayed area
area to which the spray treatment is intended

3.8
virtual wind tunnel floor
virtual plane parallel to the wind tunnel floor situated at, or above, the edge of the boundary layer

4 Principles

The measurement of spray drift potential in a wind tunnel comprises the application of a material – generally being, or simulating, a plant protection product formulation – by a spray generator positioned within the wind tunnel. The spray generator can be static or moved, normally by traversing at right angles to the air flow.

Wind tunnels used for these tests shall be capable of generating and maintaining the nominal air speed with a low degree of turbulence. They shall be of a sufficient size to permit the spray generator to be used so that the air flow is not disturbed by the proximity of internal walls or the spray generator (or its mounting) and have enough height and downwind distance to contain sufficient arrays of sampling devices or collectors for assessment of spray drift potential (see Annex A).

Spray drift potential shall be measured by sampling or collecting spray displaced by the air flow in a defined downwind area which is commonly done by using traceable materials which are collected by defined passive sampling surfaces, normally standard line collectors. If results are to be used to classify relative spray drift potential of spray generators then the sampler or collector used shall provide comparable results to the standard sampling line collectors (see Annex B).

Spray drift potential is calculated using a computational algorithm or formula to translate the measurements made in the wind tunnel into the likely spray drift from the spray generator in field use. The results should only be used to classify relative spray drift potential when compared to a reference spray generator and only results from individual statically mounted spray generators should be used for spray drift potential classification purposes. Multi-nozzle spray drift potential can be calculated to represent a typical field spraying application from field crop sprayers and the result may be used to calculate distances required for safe application away from sensitive areas such as water courses.

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5 Test methods

5.1 Wind tunnel design and layout

Wind tunnels shall be large enough to generate and maintain the nominal air velocity at which the measurements are to be made with a uniform velocity profile, with a maximum local variability of air velocity of 5 %, whilst not exceeding a maximum degree of turbulence of 8 % along the whole length of the wind tunnel where drift measurements are being made (see Annex A). A commonly used layout is shown in Annex C, with 2 $m \cdot s^{-1}$ being the airspeed commonly used for measurements for classification of relative spray drift potential. Different wind tunnel designs and layouts may be acceptable for measurement with different airflows and speeds but to measure relative spray drift potential for spray generators that would be mounted on field crop sprayers travelling at forward speeds $\leqslant$20 $km \cdot h^{-1}$, then the wind tunnel shall have a minimum height of 1 m and a minimum width of 2 m and be capable of generating nominal air speeds in excess of 2 $m.s^{-1}$.

The length of the wind tunnel working section should be at least 2 m longer (at least 1 m at both ends) than the distance over which spray generators and samplers or collectors are mounted (see Annex C).

The floor of the wind tunnel shall be designed to minimise any spray liquid splashes or spray droplet bounce by, for example, using an artificial turf surface or grid.

The spray generator mounting, control and supply lines shall be arranged so as to minimise disturbance to the air flow.

5.2 Preparation of test equipment

For measurement of the airborne spray profile downwind of spray generators, spray generators shall be mounted in the centre of the wind tunnel and at a height recommended by the manufacturer above the virtual floor of the wind tunnel; the virtual floor being at least at the upper edge of the boundary layer (see A.6).

NOTE Some modification of these measuring technique(s) can be required to accommodate some spray generator designs, arrays, or uses. For example, it is sometimes required to test arrays of spray generators, such as part of a complete short boom section. Any modifications to the measuring technique(s) used will give consideration to any effect this can have on air speed and turbulence around the spray generator and downwind as well as any disturbance to the movement, and distribution, of the airborne spray drift that can affect the sampling or collecting technique.

The spray liquid supply to the spray generator shall be via solenoid valve(s) or similar control devices with a rapid switch-on and cut-off. A minimum spray time of 5 s should be used but appropriate spray times should be verified prior to measurement to avoid saturation of samplers or collectors, particularly regarding liquid retention capacity of sampling lines (see Clause 4 and Annex B). Supplies of atomising air (where applicable) and any power inputs to the spray generator (e.g. electrical supply to a motor) shall be controlled and measured via a pre-set controlled supply system.

5.3 Sampling and collection techniques

A variety of sampling or collecting devices can be used in the defined downwind sampling area, but these shall be appropriate for sampling from the entire spray plume emitted, i.e. the whole cloud of airborne spray. Since spray drift is principally of smaller spray droplets, any samplers or collectors used shall be appropriate in having a high collection efficiency (see Annex B). Airborne spray shall be sampled or collected on horizontal and vertical samplers or collectors arranged across the wind tunnel (ensuring that they can sample or collect from the entire spray plume).

Spray droplets are commonly captured on a defined passive sampling surface, normally polythene polyethylene (PE) [or polytetrafluoroethylene (PTFE)] sampling lines of 1,98 mm [or 2,00 mm] in diameter arranged across the tunnel in both vertical and horizontal arrays at various downwind distances from the spray generator.

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If the spray liquid is collected on sampling lines, then it shall be quantified by recovering the tracer captured on the lines by a known quantity of solvent such as de-ionised water and then using appropriate analytical techniques calibrated against samples of the original spray liquid taken from the spray generator (see Annex B).

Sampling times used shall not allow any overloading, and therefore loss, of spray liquid retained on collectors.

NOTE If using sampling lines, this applies at any location along their length.

Saturation levels can generally be simply assessed by correlating detected quantities against exposure times – the relationship will be linear up until the overloading point. However, the spray time used shall ensure sampling of the airborne spray for an adequate length of time to be representative of the airborne spray intensity and to be measurable with accuracy and repeatability.

Positioning of any horizontal and vertical samplers or collectors will need preliminary supportive research to consider the profiles of the spray plumes to be sampled such that the values later measured are representative. Consideration needs to be given to the length of spray time for static spray generators and the movement/number of traverses for moving spray generators. Controlled no-spray runs may also need to be made in some wind tunnel designs, before and after the test measurements, to ensure that there is no cross-contamination of samples or collectors between one run and another.

5.4 Measuring procedure

Humidity levels and air and spray liquid temperature shall be measured. When reproducibility of measurement is necessary – for example when the desire is to classify the relative spray drift potential of spray generators - then high levels of humidity of (80 ± 5) % are required and the maximum difference of the spray liquid temperature from the air temperature shall be ± 10 %. An air temperature of (20 ± 1) °C is commonly used for measurements for classification of relative spray drift potential.

If necessary, in wind tunnels with recirculating air systems, humidity levels can be increased by using misting nozzles positioned in the downwind end of the working section of the wind tunnel (see Annex C).

Instrumentation shall be fitted in the wind tunnel to measure:

— air speeds, at a position representing nominal air speed (typically the height of the spray generator in the centre of the wind tunnel) with a maximum error of 0,1 $m \cdot s^{-1}$;

— temperatures (wet and dry bulb) with a maximum error of 1 °C;

— relative humidity levels with a maximum error of 5 %.

Typical instrumentation positions are shown in Annex C.

The relevant spray liquid physical properties of dynamic surface tension (at a surface lifetime age of 20 ms) and shear viscosity shall be measured and reported, and the spray liquid temperature at the time of measurement. To simulate a plant protection product formulation it has been common practice to use water with a non-ionic surfactant added (generally at between 0,1 % and 0,5 %). Any tracer used shall be capable of being safely applied, collected and analysed without any risk to human or environmental safety.

NOTE 1 Some tracers can include a surfactant.

Results shall be expressed in terms of:

a) vertical airborne spray profile (as microlitres of spray collected); and

b) horizontal sedimenting spray profile (as microlitres of spray collected).

The vertical airborne spray profile shall be measured by sampling the entire spray plume produced by the spray generator, using a minimum of five samplers or collectors positioned between the spray generator height and the virtual floor (except if measurement shows spray on the highest sampler or collector in which

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case the samplers or collectors shall be repositioned until there is no spray drift measured on the highest sampler or collector).

Samplers or collectors shall be spaced at maximum vertical height increments of 0,1 m and shall be positioned horizontally across the wind tunnel.

The horizontal sedimenting spray profile shall be measured using a minimum of five samplers or collectors situated at the level of the virtual floor of the wind tunnel spaced at maximum horizontal increments of 1 m positioned across the wind tunnel. Samplers or collectors shall be arranged to measure at least at distances between 2 m and 5 m downwind of the spray generator.

Downwind distances from the spray generator shall be calculated from the downwind edge of the sprayed area, i.e. the downwind edge of the spray pattern generated in still air – with different spray generators having different spray patterns. The downwind edge of the spray pattern is commonly taken to be that distance furthest from the centreline of the spray generator where the spray volume collected in a patternator trough (as specified in ISO 5682-1) is 10 % of the maximum collected volume. This distance shall be verified before the measurements are taken. Spray generators with larger spray patterns may require use of a larger patternator or alternative means of assessing the level of 10 % of the maximum collected volume.

NOTE 2 In the case of measurements using flat fan hydraulic spray nozzles, measurements of spray drift potential are commonly made with the spray pattern at right angles to the direction of the air flow (to give a realistic worst case scenario).

Measurements for classification of the relative spray drift potential of spray generators shall be made with the candidate spray generator and an appropriately defined reference spray generator. In the case of individual hydraulic spray nozzles, this would commonly be a reference spray nozzle in accordance with ISO 25358 (commonly the reference spray nozzle and pressure defining the border of fine and medium spray quality).

Spray times will need consideration before measurement since not only is there the need to ensure adequate sampling or collection (see Clause 4 and Annex B) but, when switching on, to ensure proper establishment of the intended spray characteristics and pattern and, when switching off, to avoid any anomalous effects associated with the collapse of the spray pattern. Whereas minimum spray times in the order of 5 s may be appropriate for individual hydraulic spray nozzles some other spray generators, such as twin fluid nozzles, have been shown to require far longer (30 s) to establish the intended spray characteristics and pattern.

At least three replicates of every measurement shall be undertaken, of which at least two shall be reported and used for calculation of results.

6 Test report

The results of the measurements shall be presented in a test report.

The content of the test report shall be as given in Annex D.

7 Calculation of results

The measurements (in microlitres, sampled or collected) shall be normalised into percentage of nozzle output and recorded (see Annex E).

Vertical profiles of airborne spray and horizontal profiles of sedimenting spray can then be calculated.

NOTE These can be shown, if desired, in the form of a chart showing the percentage of the spray generator output collected at different heights or distances downwind.

The measurements can be used to calculate the spray drift potential of the spray generator, and can also be used for comparative classification of spray generators or spray liquids in terms of relative spray drift potential.

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Annex A
(normative)

Characterisation of the wind tunnel air flow

A.1 General

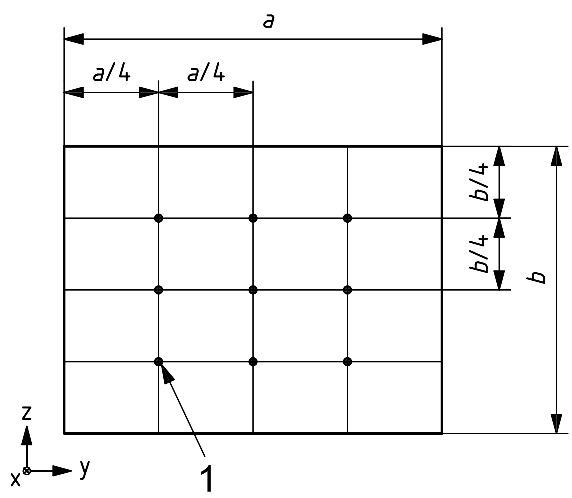
The characterisation of the wind tunnel air flow shall be done in a section located 2 m downwind from the spray generator at an approximate nominal air velocity of 2 m·s^{-1}.

The wind tunnel shall be free from any additional test equipment such as spray generators, samplers or collectors or their supporting devices. The only equipment in the wind tunnel shall be an anemometer and its support. The anemometer to be used shall allow local measurements, as possible for instance with a hot wire device, with a maximum error of ± 0,1 m·s^{-1} and a sample rate of at least 20 s^{-1}.

A.2 Measurement of air flow parameters

These measurements shall be done at least at the positions described in Figure A.1. Finer grids are possible.

Measure and register the instantaneous air velocity values in the main direction of the air flow, x, as well as in upward direction, z, at each location. The duration of the measurement at each position and direction shall be at least 10 s.



Key

1 measuring positions

a wind tunnel width

b wind tunnel height

Figure A.1 — Position of measuring locations in the measuring plane

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A.3 Nominal air speed

Calculate the nominal air speed, $\overline{v}_x$, as the mean value of all measuring values taken in the main direction of the air flow, x:

$$\overline{v_x} = \frac{\sum v_{x,ij}}{n}$$

where

v_x is the mean value of air velocity in the main (horizontal) direction of the air flow, x, at the position (i, j);

$i = 1...m$ is the vertical measuring position;

$j = 1...p$ is the horizontal measuring position;

$n = mpk$ is the total number of measuring values;

k is the number of measuring values per measuring position.

A.4 Degree of turbulence

Calculate the degree of turbulence, T, as the variation of the air velocity measured in the main direction of the air flow, x, and in the upward (vertical) direction, z, related to the local mean air velocity, $\overline{v}_{x,ij}$, at each position (i, j):

$$T_{ij} = \frac{\sqrt{\frac{1}{3}\left(\overline{v'^2_{x,ij}} + \overline{v'^2_{y,ij}} + \overline{v'^2_{z,ij}}\right)}}{\overline{v}_{x,ij}}$$

where

$$\overline{v'^2_{x,ij}} = \frac{1}{k}\sum\left(\overline{v}_{x,ij} - v_{x,ij}\right)^2$$

is the variance of air velocity in the main (horizontal) direction of the air flow, x, at the position (i, j);

$$\overline{v'^2_{y,ij}} = \frac{1}{k}\sum\left(v_{y,ij} - \overline{v}_{y,ij}\right)^2$$

is the variance of air velocity in the horizontal direction (across the wind tunnel, i.e. not in the main direction of the air flow) y at the position (i, j);

$$\overline{v'^2_{z,ij}} = \frac{1}{k}\sum\left(\overline{v}_{z,ij} - v_{z,ij}\right)^2$$

is the variance of air velocity in the vertical direction, z, at the position (i, j).

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A.5 Local variability of air velocity

Calculate the degree of local air velocity variability, S, as the variation of the air velocity mean values, $\bar{v}_{x,ij}$, measured in the main direction of the air flow, x, at all positions related to the nominal air speed:

$$S = \frac{\sqrt{\frac{1}{mp-1}\sum\left(\bar{v}_x - \bar{v}_{x,ij}\right)^2}}{\bar{v}_{x,ij}} 100\ \%$$

A.6 Edge of the boundary layer

Measure the mean air velocity values in the main horizontal direction of the air flow, x, at positions along a vertical line in the centre of the measuring plane with increments of $(5 \pm 0,2)$ cm starting at a height of $(5 \pm 0,2)$ cm above the wind tunnel floor.

The edge of the boundary layer is at the height at which the local mean air velocity becomes greater than 95 % of the nominal air speed.

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Annex B
(normative)

Selection and handling of spray drift samplers and collectors

Many samplers and collectors have been used for measurement, and new ones are continually being developed. However, measurements of spray drift potential using 1,98 mm diameter polyethylene (PE), or 2,00 mm diameter polytetrafluoroethylene (PTFE) lines in wind tunnels have been shown to correlate closely with field measurements of spray drift. These lines have therefore become the standard (preferred) option for use, and other spray drift samplers and collectors should be checked to ensure that they give comparable results and a similar level of resolution of 0,1 µl of spray liquid (or 0,001 µl of spray liquid per square centimetre of collecting area). This check should ensure that when the proposed sampler or collector is compared with the standard sampling line collectors

a) they produce the relative same drift potential ranking for the reference spray nozzles (in accordance with ISO 25358),

b) they show similar differences in relative spray drift potential between the reference spray nozzles (in accordance with ISO 25358), and

c) results are reproducible.

Any valid comparison of results (including any attempt to classify spray generators by relative spray drift potential) should ensure all measurements use the same samplers or collectors.

Examples of spray drift samplers and collectors that have been used are listed in Table B.1.

Table B.1 — Examples of spray drift samplers and collectors

Collection surface	Characteristics	Comments
— standard 1,98 mm diameter PE line — standard 2,00 mm diameter PTFE line	High collection efficiency, known sampling area	Verify tracer retention and recovery characteristics. Used to sample airborne spray
— Pipe cleaners — Cotton line — Woollen line — “Pan cleaners” — Filter cloth	Very high collection efficiency, variable and unknown collection area	Determine mean sampling dimension from photographs. Used to sample airborne spray
— Filter papers — Paper surface — Microscope slides — Petri dishes	Low collector efficiency when sampling airborne spray	Used to measure spray sedimenting on the ground only: — mounted horizontally
— Patternators	[a]	[a]
— Active collectors such as suction samplers and “rotorods”	High collection efficiency	Used to sample airborne spray only. Collection area difficult to define unless sampling is isokinetic

[a] Data not available.

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NOTE 1 Collection efficiency, particularly on vertical samplers and collectors, depends on both spray droplet size and air speed (with data/test results available on collection efficiency of different spray samplers and collectors).

Procedures for handling samplers or collectors prior and post exposure to airborne spray shall be established that minimise any risk of cross-contamination. The potential for cross-contamination (and/or tracer degradation) shall be monitored during a trial using clean samplers or collectors (and, if using tracers, those loaded with a measured volume of the tracer solution).

After use, samplers or collectors should be stored for the minimum period possible. Where storage is necessary, this should be in appropriate conditions, typically, for a tracer, dry, in darkness, and at a temperature of less than 4 °C, with any risk of condensation minimised (since this may result in inaccuracy).

The recovery and stability of any tracer used on the target sampler or collector shall be verified prior to the start of any measurement. Such preliminary work shall define the level of resolution of the techniques to be employed. Details of all analytical procedures shall be documented. Deposits on samplers or collectors should be calculated based on the calibration of the tracing technique with samples of the spray liquid taken internally from the spray generator at the time of the spraying.

When using a fluorescent dye as a tracer it is important to optimise the excitation and emission wavelength of the fluorimeter/photometer to the tracer to maximise discrimination of the tracer over the background. Background can come from the collector, the dilution liquid (for example fluorescence of tap water or demineralised water can change over time) and pollution of the capillary (measuring) cell in the fluorimeter. Collectors are soaked with dilution liquid to get the tracer into solution. The volume of the dilution liquid should be minimised to maximise tracer recovery, but this is dependent on the collection area and the volume of spray liquid collected. The dilution volume and the amount of tracer on the collector also determine recovery from the collector surface. The optimal dilution volume should be investigated in advance by putting a known quantity of spray liquid on the sampler or collector and then testing how much of it can be detected (the aim is to give dye concentration in the middle of the practical working range for fluorometry or photometry when the collectors are washed with the amount of dilution liquid to be used). Results should be comparable between different fluorimeters/photometers with equivalent resolution to the standard sampling line collectors. The reading of the fluorimeter is related to the amount of tracer in solution through a calibration curve. This curve is determined through sampling known concentrations of the tracer.

NOTE 2 Within limits of the scale this curve is a straight line (for example $10 < x < 950$ of ‘0-1000’).

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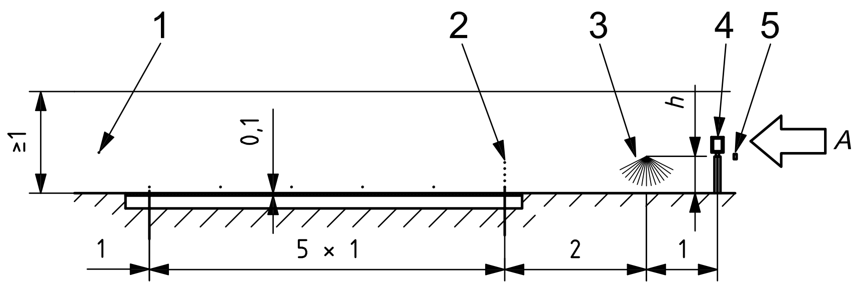
Annex C
(informative)

Typical design and layout of wind tunnel

See Figure C.1, showing typical design and layout of sampling lines, spray generator and monitoring instrumentation.

Dimensions in metres



Key

1 misting nozzles

2 collecting lines (at 0,1 m vertical spacing)

3 spray generator

4 anemometer

5 relative humidity and temperature sensor

h spray generator height above the virtual floor of the wind tunnel (to be specified by the spray generator manufacturer)

A air flow

Figure C.1 — Diagram of wind tunnel working section

Annex D
(normative)

Required content of the test report

- Wind tunnel working section dimensions (m)
- Spray (type/size/angle/orientation/material) generator(s) used
- Air speed ($m \cdot s^{-1}$)
- Maximum turbulence level (–)
- Sampler/collector used
- Air temperature (°C)
- Relative humidity (%)
- Spray liquid type
- Liquid dynamic surface tension ($dyn \cdot cm^{-2}$)
- Liquid shear viscosity
- Liquid temperature (°C)
- Spray generator height (m)
- Liquid flow rate ($ml \cdot s^{-1}$)
- Spray generator traverse distance/velocity ($m/m \cdot s^{-1}$)
- Spraying pressure (kPa)
- Spray time (s)
- Maximum deviation of measurements from any individual samples or collector used compared with the mean value (%)

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Annex E
(informative)

Example of calculation of results

When using 1,98 mm line collectors, for example, to assess a horizontal profile of sedimenting spray drift, the deposit shall be measured, then scaled up and normalised as a percentage of spray generator output.

Spray generator, X, with a flow rate of 850 ml·min^{-1}, has spray drift from a 10 s spray run measured in the wind tunnel. If the total deposit of spray on collector line Y is measured as 2,5 µl then scaling the 1,98 mm diameter line to be representative of a strip 1 m wide (representing the distance between the midpoints of downwind collectors spaced at horizontal increments of 1 m) then:

Deposit in microlitres over 1 m in 10 s

$$= 2{,}5 \times \frac{1\,000}{1{,}98} = 1\,262\ \mu\text{l}$$

In 1 min therefore, deposit in millilitres

$$= 2{,}5 \times \frac{1\,000}{1{,}98} \times \frac{60}{10} \times \frac{1}{1\,000}\ \text{ml} \cdot \text{m}^{-1} \cdot \text{min}^{-1}$$

$$= 7{,}57\ \text{ml} \cdot \text{m}^{-1} \cdot \text{min}^{-1}$$

Flow rate from the nozzle was measured at 850 ml·min^{-1}, therefore:

Spray drift potential

$$= \frac{7{,}57}{850} \times 100\ \%\ \text{ of nozzle output}$$

$$= 0{,}89\ \%$$

Tables need to be compiled for all the different collectors for at least two of the three replicates undertaken before combining or averaging measurements. The results are often shown in the form of a chart showing the percentage of spray output that has been sampled or collected as spray drift to give a graphical representation of the vertical airborne spray drift profile, or horizontal sedimenting spray drift profile.

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