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## Use of a flexible drop counter for a better comparability of potential spray drift measurement protocols in wind tunnels

Jean-Paul Douzals<sup>1</sup>, Cyril Tinet<sup>1</sup> and Richard Goddard<sup>2</sup>

<sup>1</sup> IRSTEA, UMR ITAP, 361 Rue JF Breton, 34196 Montpellier, France

<sup>2</sup> Billericay Farm Services Ltd, Downham, Billericay, Essex, CM11 1QU, U.K.

[jean-paul.douzals@irstea.fr](mailto:jean-paul.douzals@irstea.fr)

### ABSTRACT

In Europe, three main low wind speed wind tunnels (cross-section 3m x 2m) are used for regulatory authorization of drift reducing nozzles to implement three different measurement protocols to assess the potential spray drift. Both German and UK protocols use short duration sprays including a dye tracer and implements the ISO 22856 standard protocol based either on a vertical array of horizontal nylon strings placed 2m downwind and every 0.1m vertically (Herbst, 2001) or on a horizontal array of nylon strings placed every meter at 0.1 m above ground cited by Taylor et al. (2004) respectively. Both protocols consider a wind speed of 2m s<sup>-1</sup>. The French protocol is based on a long duration process where sedimentation is collected on a 9m long distribution test bench with 3m x 0.05m grooves connected to 500 ml collecting tubes mounted on weight cells, under a wind speed of 7.5 m s<sup>-1</sup> (Douzals, 2014). The major differences highlighted in previous protocols offer a limited comparability of the drift reducing performance of nozzles. However a preliminary study conducted by Douzals et al. (2017) demonstrated the interest of an *in situ* droplet characterization in a wind tunnel by using a laser diffraction device although the experimental domain is limited by an insufficient amount of intercepted droplets to get a measurement. The context of the future revision of the ISO 22856 standard on the assessment of potential drift in a wind tunnel stresses the question of a better comparability of the previous protocols. The purpose of the present study aims at better defining the spatial qualitative distribution of droplets in a wind tunnel based on the reference sampling positions of each protocol. A portable Drop Counter (Billericay Farm Service, UK) was used to qualify the droplet distribution in a 3D sampling grid. Experimental parameters include different reference nozzles used in *ad hoc* countries (FF 03, 3bar and FF02 2.5bar) and air induction nozzles (BFS Air Bubble Jet, Albus CVI) at a pressure of 2 bar and under wind speeds of 2, 4, 6 and 7.5 m s<sup>-1</sup>. Results in terms of local droplet size distribution profiles are discussed for various wind speeds and nozzle types for a better comparability of the results between methodologies.

Key Words: Droplet size, wind tunnel, drop counter

### Introduction

In Europe, three main low wind speed wind tunnels (cross-section 3m x 2m) are used for regulatory authorization of drift reducing nozzles that implements three different measurement protocols to assess the potential spray drift. Both German and UK protocols use short duration sprays including a dye tracer and implements the ISO 22856 standard protocol based either on a vertical array of horizontal nylon strings placed 2m downwind and every 0.1m vertically cited by Herbst (2001) or on a horizontal array of nylon strings placed every meter at 0.1 m above ground described by Taylor et al. (2004) respectively. Both protocols consider a wind speed of 2m s<sup>-1</sup>. French protocol is based on a long duration process where sedimentation is collected on a 9m long distribution test bench with 3m x 0.05m grooves connected to 500 ml collecting tubes mounted on weight cells, with a wind speed of 7.5 m s<sup>-1</sup> (Douzals, 2014). The major differences highlighted in previous protocols offer a limited comparability of the drift reducing performance of nozzles.

However a preliminary study conducted by Douzals et al. (2017) demonstrated the interest of an *in situ* droplet characterization in a wind tunnel by using a laser diffraction device although the experimental domain is limited by an insufficient amount of intercepted droplets to get a measurement. The context of the future revision of the ISO 22856 standard on the assessment of potential drift in a wind tunnel stresses the question of a better comparability of the previous protocols. The purpose of the present study aims at better defining the spatial qualitative distribution of droplets in a wind tunnel based on the reference sampling positions of each protocol by using a flexible droplet counter.

## Materials and Methods

### Nozzles

Different nozzle types were tested according to Table 3. Reference nozzles used in UK/Germany and France respectively FF03/50/3 and FF02/70/2.5 were tested. Air Induction nozzles ABJ03/50/2 and CVI03/60/2 were selected as already authorized as DRT in various European countries.

**Table 1: Nozzles characteristics**

Nozzle #	Status	Type/size/height	Flowrate l.min <sup>-1</sup>	Pressure bar
1	Reference FR	Flat Fan (FF)/02/0.7	0.73 ± 0.1	2.5 ± 0.1
2	Reference UK, DE	Flat Fan (FF) /03/0.5	1.2 ± 0.1	3 ± 0.1
3	CVI, Albuz	Air Induction (AI)/03/0.6	0.98 ± 0.1	2 ± 0.1
4	Air Bubble Jet, BFS	Air Induction (AI)/03/0.5	1.00 ± 0.1	2 ± 0.1

Four identical nozzles were mounted on a short boom with 500 mm spacing and oriented perpendicularly to the wind direction. Nozzle height was manually adjusted to desired value ±5mm. Real-time measurements of the flowrate (SIKA, VMZ081, Germany) and the operating pressure (Keller, Type PR-33/80794-30, Germany) were operated with a precision of ± 0.1 l min<sup>-1</sup> and ±0.1 bar respectively.

### Wind tunnel settings

The IRSTEA wind tunnel has a cross section of 3000 x 2000 mm and the sedimentation drift can be evaluated along a distance of 9000mm. The wind is generated by 6 hydraulically driven fans with a load sensing control. Potential wind velocity is from 0 to 12 m s<sup>-1</sup>. In this study, the selected wind velocities were 2, 4, 6 and 7.5m/s. Controlled climatic conditions inside the wind tunnel were 20 °C (± 0.1 °C) and a relative humidity of min. 95 % (± 1 %) was applied as measured with a capacitive sensor (VAISALA, HMT337, Vanta, Finland). Wind speed was measured by using a 2D ultrasonic sensor (Windsonic M, Gill Instruments Limited, Lympington, Hampshire UK) with RS-232-output with an accuracy of ±0.2 m s<sup>-1</sup>.

### Wind tunnel floor

The lower floor of the wind tunnel is equipped with a distribution test bench consisting of 180 grooves of 3000 mm length, 50 mm width and 100 mm depth placed perpendicularly to the tunnel main dimension. These grooves are generally used to convey the deposition onto filing tubes placed on weight cells. In the present situation, the top of the grooves were used to drive the mobile device supporting the Drop Counter perpendicularly to the wind direction.

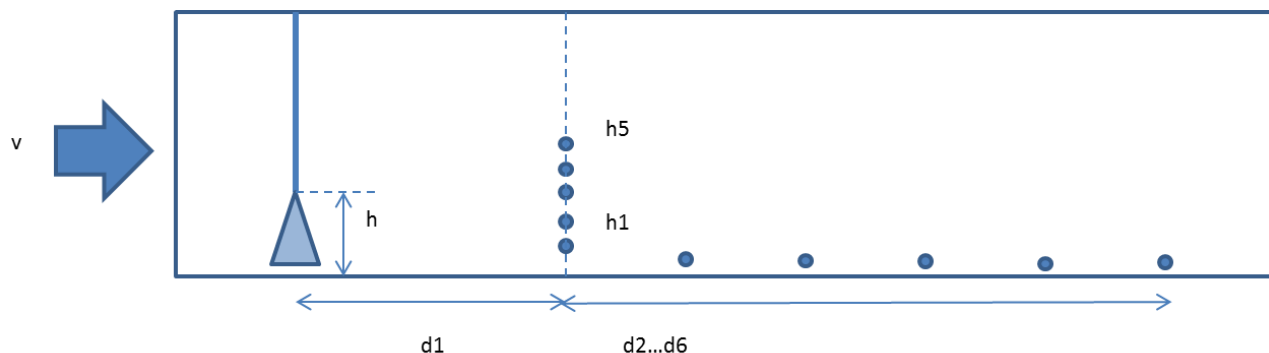
## Droplet size measurement

A DropCounter©, BFS, UK was mounted on a mobile device provided by BFS Company. The Dropcounter was already described elsewhere (Kateley et al., 2016). The beam created by an Infrared LED is reoriented through prisms to create a measuring chamber of 8mm x 10mm. there are 37 buckets corresponding to different drop size ranges from 15 to 2000 $\mu$ m. By using a mobile device remotely controlled, the Drop Counter was moved laterally in the wind tunnel at different distances (0 to 5m) downwind to assess droplet size for the UK and French protocols or at different heights (every 20cm) at 2m downwind to assess droplet size for the German protocol. Each measurement at 1 position corresponded to a return travel of the drops counter along the cross section with an average speed of about 70s. Sampling frequency was set up at 5Hz (0.2s) for the FF02 and FF03 nozzles but then reduced to 1Hz for both AI nozzles (CVI03 and ABJ03) assuming that the sampling frequency did not show significant impact on the results.



**Figure 1: horizontal sampling protocol (left) and vertical sampling (right) in the wind tunnel.**

Two return travels were operated for each situation for a sampling time of about 1 minute with a sampling frequency of 0.2s representing 300 lines of acquisition. Droplet size distribution values (Dv10, Dv50, Dv90) were calculated on the basis the total sampling time.



**Figure 2 : Sampling positions**

**Table 2: Reference and Protocol used**

Protocol Type/height/pressure	V (m/s)	h(m)	d1(m)	d2(m)	d3(m)	d4(m)	d5(m)
FF03/0.5/3	2	0.50	1	2	3	4	5
	4, 6, 7.5	0.50	1	2	3	4	5
FF02/0.7/2.5	7.5	0.70	1	2	3	4	5
	2, 4, 6	0.70	1	2	3	4	5
		h(m)	d1(m)	h1(m)	h2(m)	h3(m)	h4(m)
FF03/0.5/3	2	0.5	2	0	0.2	0.4	0.6
	4, 6, 7.5	0.5	2	0	0.2	0.4	0.6

Note: Grey cells illustrates the reference protocols for UK, France and Germany from top to bottom.

Horizontal and vertical sampling protocols were reproduced for 2 AI nozzles (size/height/pressure): CVI Albus 03/60/2 and Air Bubble Jet BFS 03/50/2.

## Results

### Horizontal sampling protocol

Dv50 values are given for nozzle at each distance and wind conditions in the following table.

**Table 3: Evolution of Dv50 values according to nozzle, distance and wind speed (horizontal sampling)**

Modality	Distance(m)	Wind (m s <sup>-1</sup> )			
		2	4	6	7.5
FF02/2.5/0.7	1	128.5	152.2	180.8	193
	2	54.1	109.8	138	153.7
	3	48.2	76.9	119.5	133.3
	4	45.9	67.4	99.5	113.8
	5	37.9	57.9	84.1	110
FF03/3/0.5	1	52.9	85.1	111.6	121.2
	2	44.6	62.2	79.1	90.4
	3	41.24	52	72.8	85.4
	4	39.14	49.5	63.9	79.4
	5	36.35	46.9	54.1	74.9
CVI03/2/0.6	1	107.7	179.2	255.7	313
	2	49.4	105.5	156.8	195.2
	3	45.7	75.8	131.4	173.1
	4	39.5	55.8	92.9	120.8
	5	33.3	35.8	64.3	76.2
ABJ03/2/0.5	1	94.2	153.1	220.2	270.5
	2	47.5	65.5	123.7	167.4
	3	47	69.1	90.7	106.8
	4	29.9	48.9	70.7	87.1
	5	18.3	28.7	39.2	56.4

Comments:

At a low wind velocity of  $2 \text{ m s}^{-1}$ , fine droplets of about  $35$  to  $50 \mu\text{m}$  are observed whatever the nozzle (FF or AI), the boom height and the sampling distances, the only exceptions were found at  $1\text{m}$  downwind, probably corresponding to direct spray interferences. Logically a higher wind velocity involves the sampling of coarser droplets.

For a given type of nozzle (FF or AI), a correspondence can be found taking into account the ration between the sampling distance divided by the wind velocity called Time of Flight (ToF). When plotting the data of each nozzle according to the ToF, a power law curve is obtained.

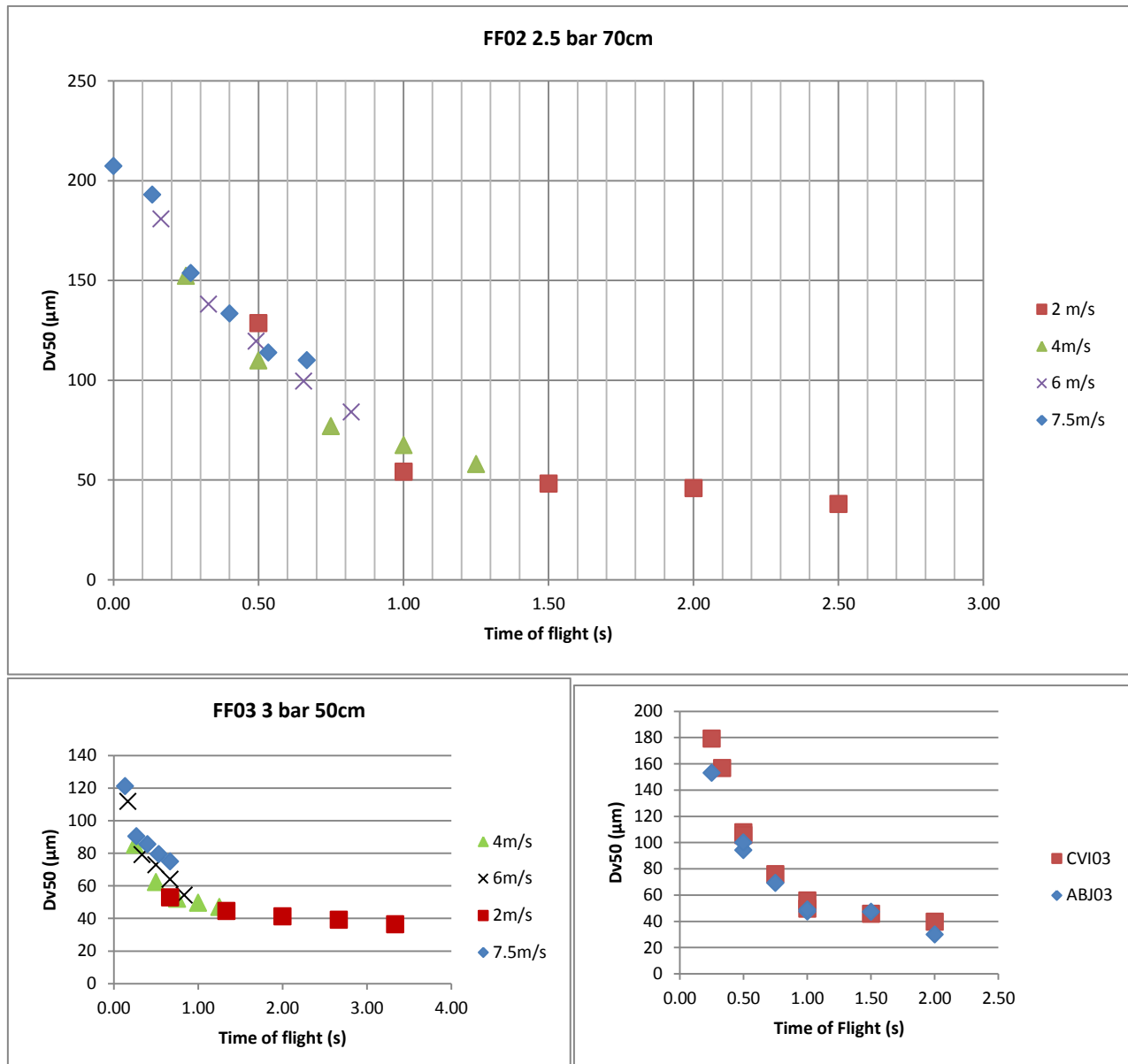


Figure 3: Evolution of the Dv50 for FF02 (top) or FF03 (bottom left) and AI nozzles (bottom right) according to the Time of Flight.

## Vertical sampling protocol

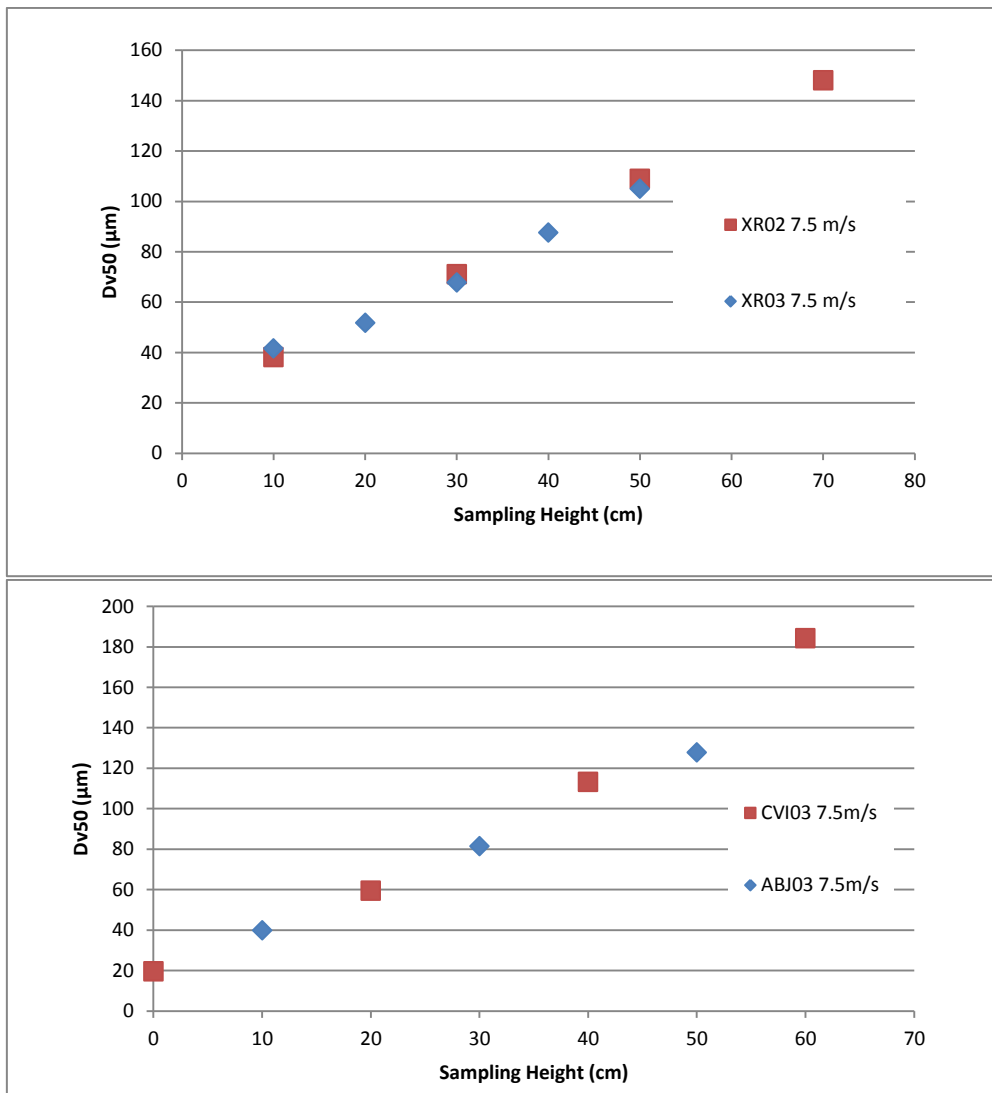
The Dv50 average values obtained 2m downwind, according to a vertical plane and at different heights are given by the following table.

**Table 4: Evolution of Dv50 values according to nozzle, distance and wind speed (vertical array of horizontal sampling lines)**

Modality	Height (m)	Wind (m s <sup>-1</sup> )			
		2	4	6	7.5
FF03/3/0.5	0	47.7	68.5	89.4	105
	0.1	44.6	58.7	78.9	87.6
	0.2	47.4	51.6	62.3	67.8
	0.3	50.3	47.3	50	51.7
	0.4	39.4	38.9	39.8	41.6
FF02/2.5/0.7	0	51.2	118.1	136.2	148
	0.2	48.6	75	94	109
	0.4	40.5	51.1	59	71.1
	0.6		32.8	37.3	38.1
CVI03/2/0.6	0	47.4	67.5	101.6	127.8
	0.2	34.6	51.8	72.5	81.4
	0.4	12.6	19.8	34.4	39.8
	0.6				
ABJ03/2/0.5	0	46.2	101.1	150.7	184.3
	0.2	46.2	71.2	91.8	113.3
	0.4	24	46.1	51.4	59.5
	0.6		13.3	17.8	19.6

### Comments:

Low wind velocity of 2 m s<sup>-1</sup> involves the measurement of fine droplets of about 45 to 50 µm whatever the nozzle and the setting considered. Higher wind speeds allow the sampling of coarser droplets with a logical decrease in the drop size according to the sampling height. In the case of a vertical plane composed of horizontal sampling lines, the main factor determining the drops size is the height between the nozzle and the sampler. Correspondences between similar types of nozzles were found considering the sampling height with reference to the boom location in the next figure.



**Figure 4: Evolution of the Dv50 of various nozzles as a function of the sampling height under the nozzle outlet (examples at 7.5 m/s).**

## Conclusion

This study aimed at better defining the droplet size distributions that are usually collected according to various sampling strategies in the main wind tunnels used in Europe. Results showed that a low wind speed of  $2 \text{ m s}^{-1}$  can only catch fine droplets between 35 to  $50 \mu\text{m}$  at distance greater than 1m or at any sampling heights whatever the nozzle considered. Increasing the wind speed allows the catch of coarser droplets with predictive effects of the time of flight in case of the horizontal sampling and the sampling height in the case of the vertical protocol. Further work in the analysis of the data is to be done in order to deeper investigate the potential for correspondences between the horizontal and vertical sampling protocols.



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