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Spray drift variability alongside the field edge of a sprayed orchard

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Summary

For orchard spraying, the variation in spray drift at a certain distance is not only depending on the weather conditions during application but also on the variation in tree and leaf canopy structure alongside the downwind treated area. To quantify the variation in spray drift alongside a treated apple orchard in the full leaf situation, spray drift collectors were not only positioned in the regular way, in an array of collectors perpendicular to the tree rows (ISO22866), but also at two distances over the length of the orchard. Collectors in parallel with the tree rows were positioned at 5 m and 9 m distance from the centreline of the tree row in a continues line of collectors over 100 m length parallel to the outside tree row and over 50 m at the headland in front of the tree rows. A fluorescent tracer was sprayed (Brilliant Sulfo Flavine) using a crossflow fan orchard sprayer (Munckhof) using Very Fine spray quality Albuz ATR Lilac nozzles and Albuz TVI 80025 95% drift reducing venturi hollow-cone nozzles, applying resp. around 200 L ha^{-1} and 750 L ha^{-1}. Results show little difference between the different measuring methodologies in mean spray drift deposition alongside the field, but does so for the headland measurements. Variation in spray drift deposition over 100 m length was large at the side parallel to the tree rows, having peak values in spray drift deposition up to 28% and of 0.3%–15% in mean values between repetitions. Coefficient of variation values ranged therefore from 24% to 104%, meaning that peak values in spray drift deposition are 1.6–7.4 times higher than mean measured values at 5 m and 9 m distance.

Key words: Fruit crop spraying, spray drift, variability, headland, nozzle type

Introduction

In the authorisation procedures of Plant Protection Products (PPP) the exposure of surface water and non-target organisms is determined by the spray drift deposition at a specific distance from the field edge based on a single spray drift curve (Ctgb, 2023; Rautmann *et al*., 2001; Zande *et al*., 2014, 2019). This one value spray drift deposition is in the authorisation procedure of PPP assumed to be evenly distributed over a 100 m length field ditch. Due to variation in tree shape, leaf canopy density and structure, wind speed and direction during spray application of an orchard, a large variation of the spray drift deposition may occur over the length of the ditch. Also turning, starting and stopping effects of the sprayer at the headlands can cause variation in actual spray drift exposure. As limited information is available, additional spray drift measurements were performed to quantify the edge of field variation of spray drift deposition in more detail spraying an apple orchard in the Netherlands over a 100 m length field edge and 45 m headland at two distances. A comparison was made with the regular way measuring spray drift deposit, in an array of collectors perpendicular to the tree rows (ISO22866) up to 25 m from the last tree row. Experiments were done with a standard cross-flow fan orchard sprayer equipped with two nozzle types, a standard Very Fine and a 95% drift reducing hollow cone. This paper describes the results of these measurements.

Materials and Methods

Spray technique

Spray drift measurements were carried using a standard cross-flow fan orchard sprayer (Munckhof, Horst, The Netherlands). The sprayer was equipped with Very Fine hollow cone nozzles (Albuz ATR lilac) and 95% drift reducing (Zande *et al.*, 2008) venturi hollow-cone nozzles (Albuz TVI 80025), operated at 7 bar spray pressure, a forward speed of 6.5 km h^{-1} applying a spray volume of resp. 200 L ha^{-1} and 750 L ha^{-1}. Air setting during the experiments was in the high fan gear box setting of the sprayer and 540 rpm of the PTO producing an air outlet speed of 21 m s^{-1}. Spray liquid used was a water solution of the fluorescent tracer Brilliant Sulfo Flavine (BSF, Chroma 1F 561, CI 56205, 3–5 g L^{-1}) and a non-ionic surfactant (Agral 0.075 ml L^{-1}).

Spray drift measurements

The spray drift measurements were performed in an apple (cv. Elstar) orchard (Randwijk, The Netherlands) in the full leaf situation (June-October 2009 and 2010; BBCH 75-91), spraying from both sides of the 14 rows (3 m row distance) of an apple orchard over its full length (100 m). Tree distance in the row was 1.10 m and tree leaf canopy height was appr. 2.25 m. Around the orchard was a grass strip of at least 30 m wide (Fig. 1) at which the spray drift was measured. Wind direction requirement (<30º from perpendicular; ISO22866) was relaxed as we measured spray drift deposition both along the long edge of the tree rows as well as at the headland.

The standard spray drift deposit measurements (ISO22866) were made downwind of the orchard at distances up to 25 m from the last tree row. The collectors used consisted of filter material (Technofil TF-290) of 0.50 × 0.10 m arranged in a continuous line from 3 m up to 15 m and two single collectors of 1.00 × 0.10 m at 1.5 m, 20 m and 25 m. At 7.5 m distance from the last tree row a 10 m high measuring pole was placed with double lines of ball shaped collectors (Siebauer Abtrifftkollektoren) at 1 m intervals up to 10 m height. This ISO setup was positioned in the middle of the downwind row side and the downwind headland side. To measure the variability of the spray drift over the length of the downwind edge of the orchard; collectors (0.50 m length) were laid down in a continuous array at 5 m and 9 m distance from the last tree row along the downwind tree row (120 m length) and at 6 m and 9 m distance from the last tree at the downwind headland (60 m length) (Fig. 1).

Weather conditions during application were recorded with sensors at a measuring pole positioned 7.5 m downwind of the treated orchard. Average temperature during the experiments was 21.7ºC, mean wind angle was 27º from perpendicular to the tree row direction (varying between -56º and 22º degrees and 33º standard deviation), mean wind speed at 2 m height was 1.7 m/s and 2.5 m s^{-1} at 4 m height (about 1 m above the top of the trees), varying between 1.4 m s^{-1} and 3.7 m s^{-1} and 1.4 m s^{-1} standard deviation.

Tracer analysis

After spraying the collectors were picked up, bagged, coded and stored for analysis in the laboratory. In the laboratory the collectors were washed with deionised water and the solution measured with a fluorimeter (Perkin Elmer LS45; λ_{ex}=450 nm en λ_{em}=500 nm) to quantify BSF concentration. From the quantified BSF concentrations the deposition on collectors was calculated in µL cm^{-2} and as percentage of applied volume rate.

Fig. 1. Overview experimental orchard (top left) and lay-out of the collectors around the orchard; corner long edge and headland (top right), ISO22866 drift measurement at headland (bottom) and crossing length and ISO collector layout (bottom right) at headland.

Data analysis

The results of the spray deposition measurements on collectors were described by different parameters characterising the height of spray deposition (µL cm^{-2} and % of nominal spray volume) and its variability.

Results

Spray drift

Results of the standard spray drift measurements (ISO22866) are for the ground deposition and the airborne spray drift presented both for the long edge of the field and the headland shown in Fig. 2 and Table 1. Spray drift for the TVI 80025 nozzle is lower than for the ATR Lilac nozzle, both for ground deposition and for airborne spray drift. Spray drift at the headland is lower than measured at the same time alongside the tree row edge of the orchard, for both nozzle types. Spray drift deposition at 5 m from the last tree row for the ATR and the TVI nozzle was 8.8% and 8.0% and respectively 3.7% and 0.7% at 9 m distance from the last tree row. At the headland spray drift deposition at 6 m from the last tree at the end of the row for the ATR and

TVI nozzles was 4.1% and 0.4% and resp. 2.1% and 0.18% at 9 m distance. Airborne spray drift averaged over 0–10 m height at 7.5 m distance from the last tree row for the ATR and TVI nozzles was 12% and 1.0% and at the headland resp. 6.2% and 0.4%.

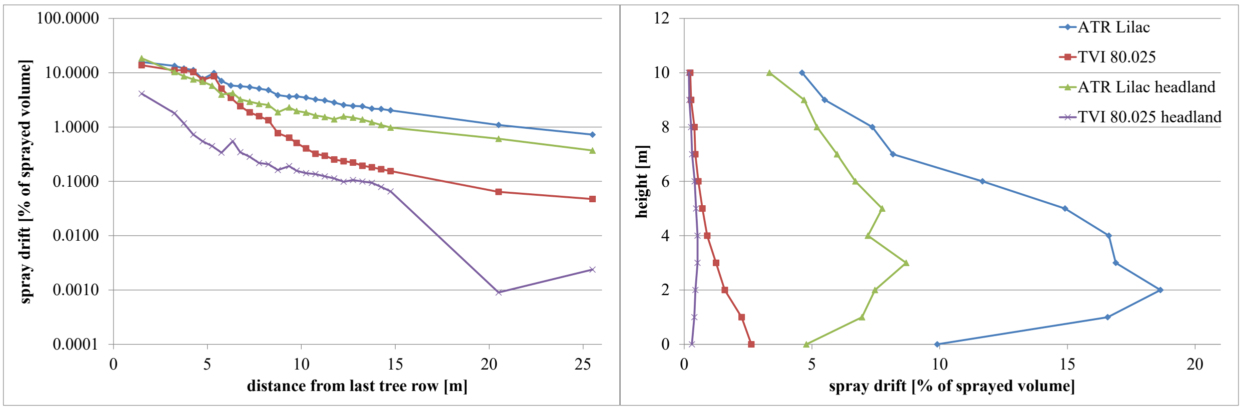

Fig. 2. Spray drift deposition (log % of sprayed volume) at different distances from the last tree row (left) and airborne spray drift at 7.5 m from last tree row (right) for a standard cross-flow fan sprayer equipped with Albuz ATR Lilac and TVI 80025 nozzles at the long side of the orchard and at the headland spraying an apple orchard.

Spray drift variability

Long edge

ATR nozzle

Spray drift along the long edge of the orchard, parallel to the tree rows, for the ATR nozzle at 5 m from the last tree row was 9.2% and shows a large variation 6.0%–14.6% between repetitions (Fig. 2, Table 1). Coefficient of variation of the different repetitions was 30%–40%. Maximum values of spray drift at 5 m distance are 1.6–2.6 higher than mean values and 1.3–1.9 times higher than 90-percentile values. At 9 m distance spray drift deposition of the ATR nozzle was lower, being 4.2%, varying 2.7%–6.4% between repetitions. Coefficient of variation of the different repetitions was 30%–44%. Maximum values of spray drift at 9 m distance are 1.6–3.4 higher than mean values and 1.2–2.3 times higher than 90-percentile values. Mean spray drift of the ISO setup at 5 m was 8.7% and coefficient of variation of the ISO drift measurements was much lower 5–15%. At 9 m distance spray drift measured with the ISO setup was 3.7% (CV 7%–21%).

TVI nozzle

Spray drift along the long edge of the orchard, parallel to the tree rows, for the TVI nozzle at 5 m from the last tree row was 8.3% and 2.8%–10.9% between repetitions (Fig. 2, Table 1). Coefficient of variation of the different repetitions was 43%–62%. Maximum values of spray drift at 5 m distance are 2.0–2.8 times higher than mean values and 1.4–1.8 times higher than 90–percentile values. At 9 m distance spray drift deposition of the TVI nozzle was lower, being 0.95%, varying 0.33%–2.4% between repetitions. Coefficient of variation of the different repetitions was 54%–104%. Maximum values of spray drift at 9 m distance are 2.8–7.4 times higher than mean values and 1.5–3.4 times higher than 90-percentile values. Mean spray drift of the ISO setup at 5 m was 8.0% and coefficient of variation of the ISO drift measurements was 5–45%. At 9 m distance spray drift measured with the ISO setup was 0.7% (CV 10%–41%).

Headland

ATR nozzle

Spray drift at the headland of the orchard, in front of the end of the tree rows, for the ATR nozzle at 6 m from the first tree in the tree row was 6.1% and shows a large variation 1.0%–

11.8% between repetitions (Fig. 3, Table 1). Coefficient of variation of the different repetitions was 40%–80%. Maximum values of spray drift at 6 m distance are 1.5–6.7 higher than mean values and 1.1–4.5 times higher than 90-percentile values. At 9 m distance spray drift deposition of the ATR nozzle was lower, being 3.2%, varying 0.24%–7.2% between repetitions. Coefficient of variation of the different repetitions was 45%–176%. Maximum values of spray drift at 9 m distance are 1.8–7.9 times higher than mean values and 1.1–3.9 times higher than 90-percentile values. Mean spray drift of the ISO setup at 6 m was 4.1%, varying 0.6%–8.8% between repetitions. At 9 m distance spray drift measured with the ISO setup was 2.1% (0.18%–4.0% between repetitions).

TVI nozzle

Spray drift at the headland of the orchard, in front of the end of the tree rows, for the TVI nozzle at 6 m from the last tree row was 0.35% and 0.06%–1.2% between repetitions (Fig. 2, Table 1). Coefficient of variation of the different repetitions was 65%–126%. Maximum values of spray drift at 6 m distance are 3.1–4.8 times higher than mean values and 1.5–2.2 times higher than 90-percentile values. At 9 m distance spray drift deposition of the TVI nozzle was lower, being 0.12%, varying 0.03%–0.42% between repetitions. Coefficient of variation of the different repetitions was 54%–98%. Maximum values of spray drift at 9 m distance are 1.8–4.4 times higher than mean values and 1.1–1.8 times higher than 90-percentile values. Mean spray drift of the ISO setup at 6 m was 0.44%, varying 0.11%–1.0% between repetitions. At 9 m distance spray drift measured with the ISO setup was 0.18% (0.03%–0.61% between repetitions).

Discussion

Spray drift deposition of the ATR nozzle at 5 m distance from the last tree row alongside 100 m row length of a treated apple orchard was 9.2% and 8.8% as measured in the standard setup (ISO22866) and resp. 6.2% and 4.1% at the headland. Spray drift deposition of the TVI nozzle at 5 m distance from the last tree row alongside 100 m row length of a treated apple orchard was 8.3% and 8.0% as measured in the standard setup (ISO22866) and resp. 0.35% and 0.44% at the headland. Drift reduction of the TVI nozzle is small (Heijne *et al*., 2002), why one-sided spraying of the last row was introduced. Measured spray drift deposition at the headland was in general lower than at the same distance alongside the long edge of the sprayed orchard. Especially at the headland, the position of the ISO setup is sensitive to the collector array layout; in between the tree rows or in line with the tree rows and the wind angle during application; more in line with the tree rows or more perpendicular to the tree row direction.

When measured in 50 cm steps over 100 m length alongside the long edge of the treated field mean spray drift deposition is higher than when measured with the standard ISO setup at the same distance. This indicates that the single value as used in the risk assessment in the authorisation of PPP (CTGB, 2023), which is based on measurements done with the ISO setup is not worst case. As maximum values of spray drift deposition can be up to 7.9 times higher than the mean of the measured values and even up to 4.5 times higher than the 90-percentile spray drift deposition values. It is suggested that measured distributions of spray drift deposition as presented, are incorporated in some way in the risk assessment. From the presented measurements, it can also be showed that e.g., at 5 m distance from the last tree row about 60% of the long edge length alongside the field has spray drift deposition values higher than the mean value with a mean value 25%–36% higher than mean, and at about 13% of the length the values are higher than the 90-percentile value with a mean value of 12%–15% higher than 90-percentile. This gives evidence that new ‘worst-case scenarios’ can be developed further. This can for example be done in using the presented data, or statistical information about the spray

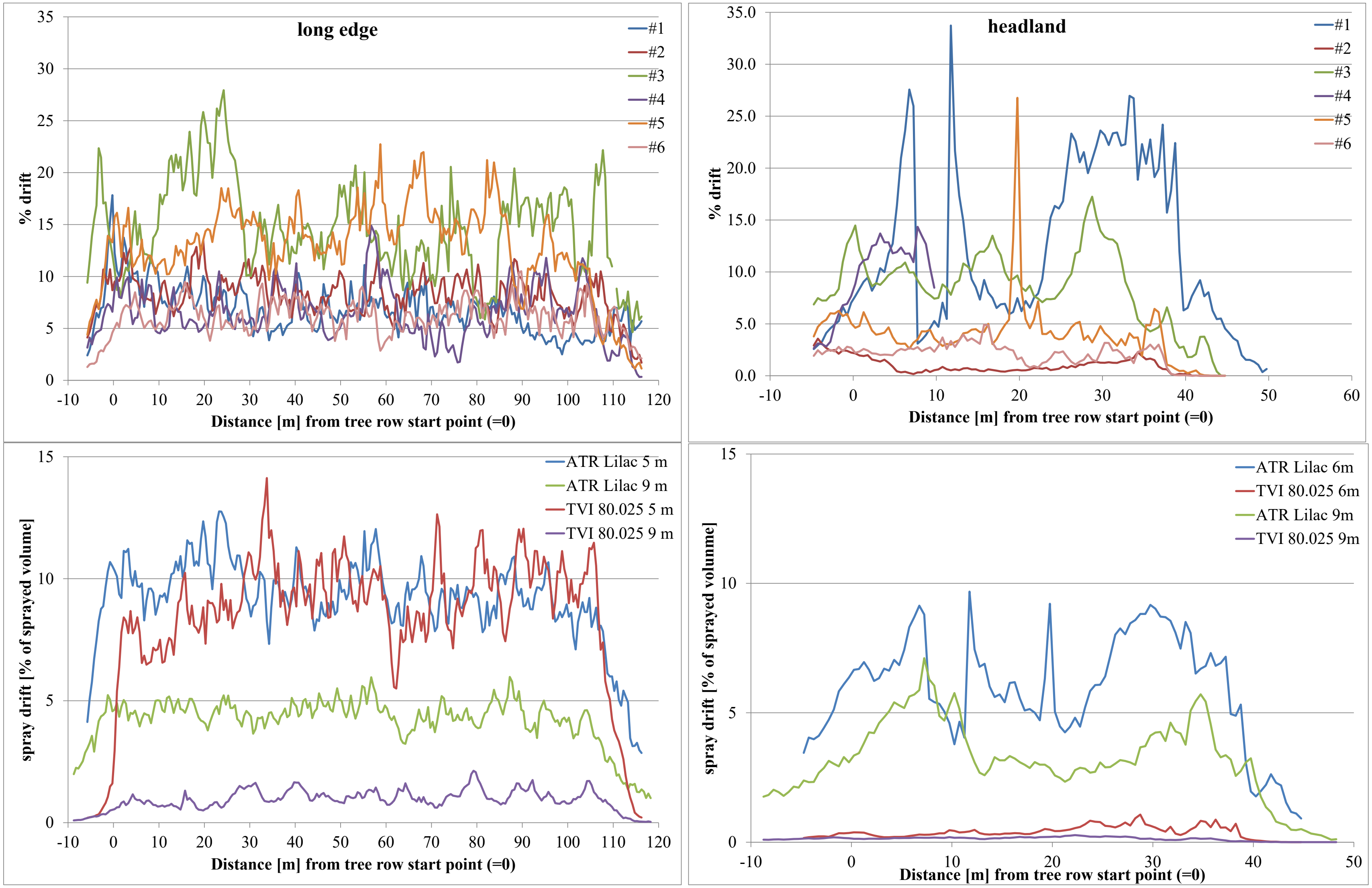

Fig. 3. Spray drift deposition (% of sprayed volume) at 5 m distance from the last tree at the long side (left) and at 6 m at the headland (right) of the apple orchard for a standard cross-flow fan sprayer equipped with Albuz ATR Lilac nozzles (top; 6 repetitions) and for the TVI 80025 nozzle type and at 9 m distance (bottom; long side (left), headland (right)).

Table 1. *Spray drift measured alongside the edge of the field and at the headland for ATR Lilac and TVI 80025 nozzle types at two distances from the last tree row at the field edge (5 m, 9 m) and at the headland (6 m, 9 m)*

	Field edge			ATR 5m					***Headland***			ATR 6m					***ISO***	
#	mean	stdev	CV	median	90 perc	max	max/ mean	max/ 90perc	mean	stdev	CV	median	90 perc	max	max/ mean	max/ 90perc	Edge mean	Head mean
1	6.83	2.28	33	6.74	9.57	17.83	2.6	1.9	11.83	7.94	67	8.48	23.20	33.7	2.9	1.5	9.00	5.37
2	8.25	2.01	24	8.20	10.62	13.46	1.6	1.3	0.98	0.78	80	0.69	2.17	3.6	3.7	1.6	6.20	0.56
3	14.60	4.57	31	14.21	21.05	27.94	1.9	1.3	8.57	3.63	42	8.72	13.12	17.2	2.0	1.3	9.97	8.78
4	6.43	2.54	40	6.25	9.93	14.89	2.3	1.5	9.45	3.77	40	11.03	12.92	14.3	1.5	1.1	6.19	
5	12.86	4.18	32	13.41	17.30	22.74	1.8	1.3	4.02	3.03	75	4.02	5.97	26.8	6.7	4.5	14.29	2.07
6	6.07	1.69	28	6.06	8.23	10.51	1.7	1.3	2.03	1.09	54	2.31	3.17	4.9	2.4	1.6	6.38	3.69
avg	***9.17***			ATR 9m					***6.15***			ATR 9m					***8.77***	***4.10***
1	3.41	1.51	44	3.07	5.20	11.73	3.4	2.3	7.23	6.43	89	4.76	17.62	25.77	3.6	1.5	3.74	3.74
2	3.70	1.27	34	3.45	5.39	8.05	2.2	1.5	0.24	0.42	176	0.09	0.49	1.91	7.9	3.9	2.75	0.18
3	5.61	1.69	30	5.59	7.81	9.17	1.6	1.2	4.47	2.01	45	4.86	6.55	8.11	1.8	1.2	3.80	3.99
4	2.74	1.09	40	2.80	3.97	5.20	1.9	1.3	3.98	2.58	65	3.63	7.35	8.19	2.1	1.1	1.88	
5	6.41	2.71	42	6.73	9.26	11.08	1.7	1.2	1.75	1.10	63	1.89	3.09	5.04	2.9	1.6	6.76	1.50
6	3.54	1.10	31	3.49	4.96	6.42	1.8	1.3	1.74	1.31	75	1.70	3.23	5.15	3.0	1.6	3.06	1.02
avg	***4.23***			TVI 5 m					***3.23***			TVI 6 m					***3.74***	***2.08***
1	10.23	4.44	43	10.69	15.30	21.11	2.1	1.4	0.17	0.22	126	0.07	0.53	0.82	4.8	1.5	7.93	0.11
2	8.74	5.40	62	9.64	14.86	21.62	2.5	1.5	0.11	0.10	91	0.08	0.25	0.46	4.3	1.8	12.89	0.39
3	10.92	4.68	43	11.57	16.28	22.27	2.0	1.4	1.18	0.78	66	1.06	2.40	3.62	3.1	1.5	14.95	0.99
4	10.03	4.78	48	10.08	15.34	23.04	2.3	1.5	0.26	0.23	90	0.22	0.57	1.16	4.5	2.0	9.02	0.16
5	2.80	1.22	44	2.68	4.37	7.83	2.8	1.8	0.32	0.27	85	0.26	0.66	1.41	4.4	2.1	2.76	0.56
6	7.34	3.85	52	8.00	11.59	16.05	2.2	1.4	0.06	0.04	65	0.05	0.10	0.22	3.7	2.2	6.27	
avg	***8.34***			TVI 9 m					***0.35***			TVI 9 m					***7.99***	***0.44***
1	1.03	0.78	76	0.81	1.88	5.29	5.2	2.8	0.03	0.03	97	0.02	0.06	0.11	4.4	1.8	0.57	0.03
2	0.37	0.39	104	0.29	0.80	2.75	7.4	3.4	0.03	0.02	70	0.04	0.06	0.08	2.5	1.3	0.12	0.04
3	2.43	1.71	70	2.04	5.01	7.49	3.1	1.5	0.42	0.23	54	0.49	0.67	0.75	1.8	1.1	3.53	0.61
4	1.19	0.68	57	1.11	1.98	3.88	3.3	2.0	0.10	0.09	90	0.08	0.25	0.33	3.3	1.3	0.51	0.61
5	0.35	0.19	54	0.32	0.61	0.97	2.8	1.6	0.14	0.13	98	0.11	0.35	0.54	3.9	1.5	0.37	0.14
6	0.33	0.32	96	0.26	0.68	2.18	6.6	3.2	0.03	0.02	62	0.03	0.05	0.09	2.8	1.6	0.18	
avg	***0.95***								***0.12***								***0.70***	***0.18***

drift deposition distribution obtained from it, in probabilistic modelling (Holterman et al., 2020) of the spray drift deposition at relevant evaluation distances for surface water and non-target organisms and develop procedures for probabilistic risk assessment further (Holterman *et al*., 2022). Spray drift deposition is not a single value and the more information on spray drift variability in practice is available, like presented data in this study, the more realistic the risk evaluation can be performed, when used.

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