Determination of the PM_{10} emission rate from an aerial grain conveyor belt by a set of SDS011 sensors by the Upwind-downwind method

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Summary

- SDS011 Low-Cost-Sensor for $PM_{10;}$
- Upwind-Downwind methodology;
- Experiment arrangement;
- Measurement and data processing;
- Emission factors as function of mass transport and wind speed;
- Conclusions.

Introduction

- **Conveyor belts of bulk** products in port terminals contribute significantly to PM air emissions;
- Due to the extension of the conveyor belts **emission control** is difficult;
- **Little information** is available about fugitive emissions of grain conveyor belts;
- AP-42 **emission factors are not available for conveyer belts separately**, only overall handling emission factors that relate emissions to processed mass, including other operations like elevators and cleaning.
- Therefore:

  ➢ Specific emissions have to be measured!

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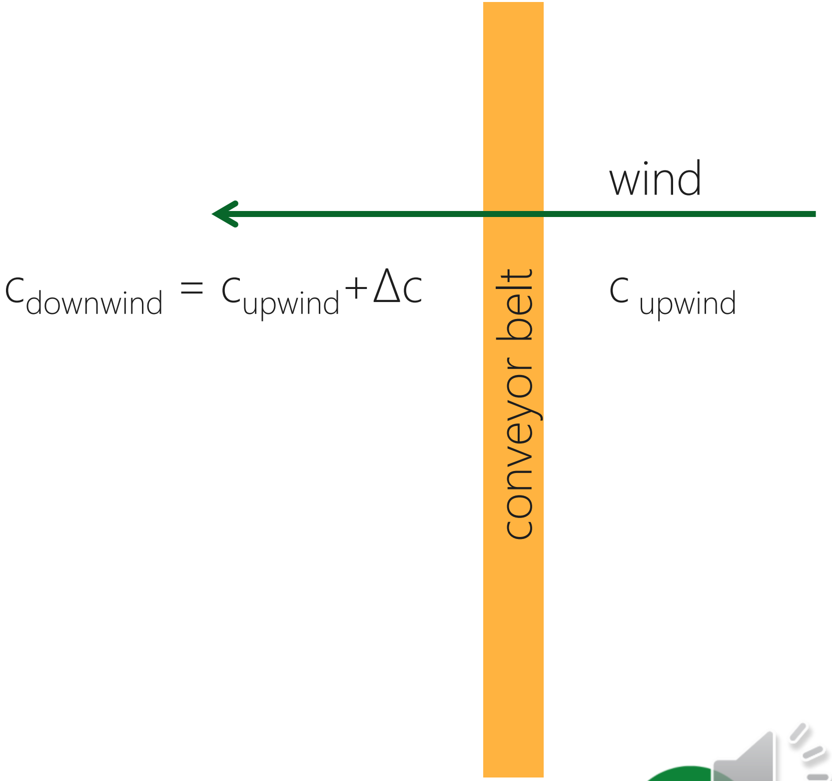
Measuring fugitive PM_{10} Emissions

- Quasi-stack method
- Roof monitor method
- Upwind-downwind method
- Exposure profiling method
- Portable wind tunnel method
- Scale model wind tunnel method
- Tracer method
- Balloon method



Gaussian Dispersion Model

Input

- Δc
- wind speed
- wind direction
- atmospheric stability

Dispersion Model

$$c\,(x,y,z) = \frac{Q}{2\pi v \sigma_y \sigma_z}$$

$$\sigma_y = \frac{W}{2{,}15} \qquad \sigma_z = a x^b$$

wind

$c_{downwind} = c_{upwind} + \Delta c$

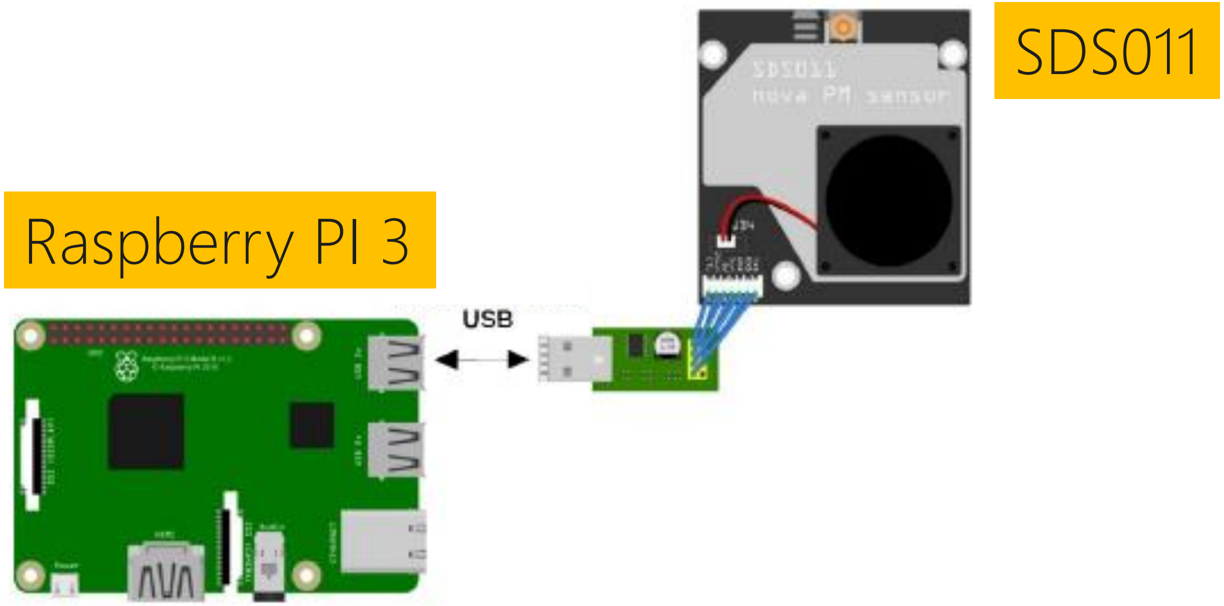
conveyor belt

c_{upwind}

Output: emission rate mg/(ms)

Equations based on the advection-diffusion equation and simplifications: EPA (1995) & TURNER (1994).

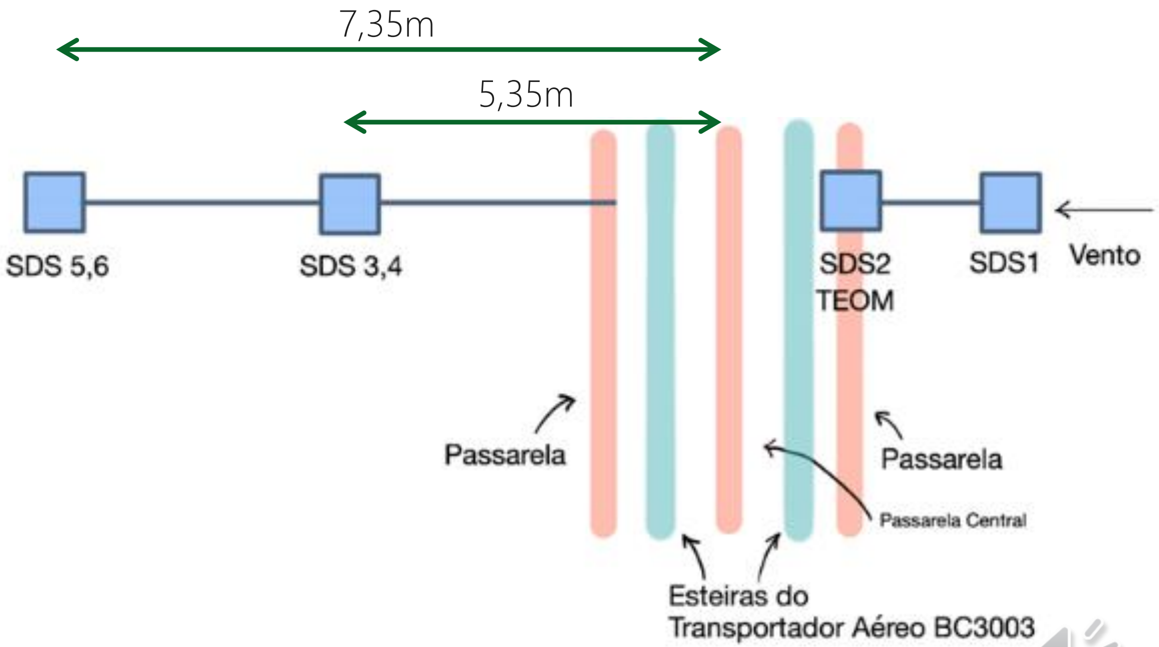
SDS011 optical PM_{10} sensor



source: Chaves, 2021

Experimental arrangement

- 1 upwind SDS sensor;
- 1 reference sensor TEOM 1405D with 1 SDS sensor;
- 4 downwind SDS sensors (5,35 and 7,35m from center);
- Meteorological station – wind speed/direction at 1-min intervals;
- 5 days of continuous monitoring.



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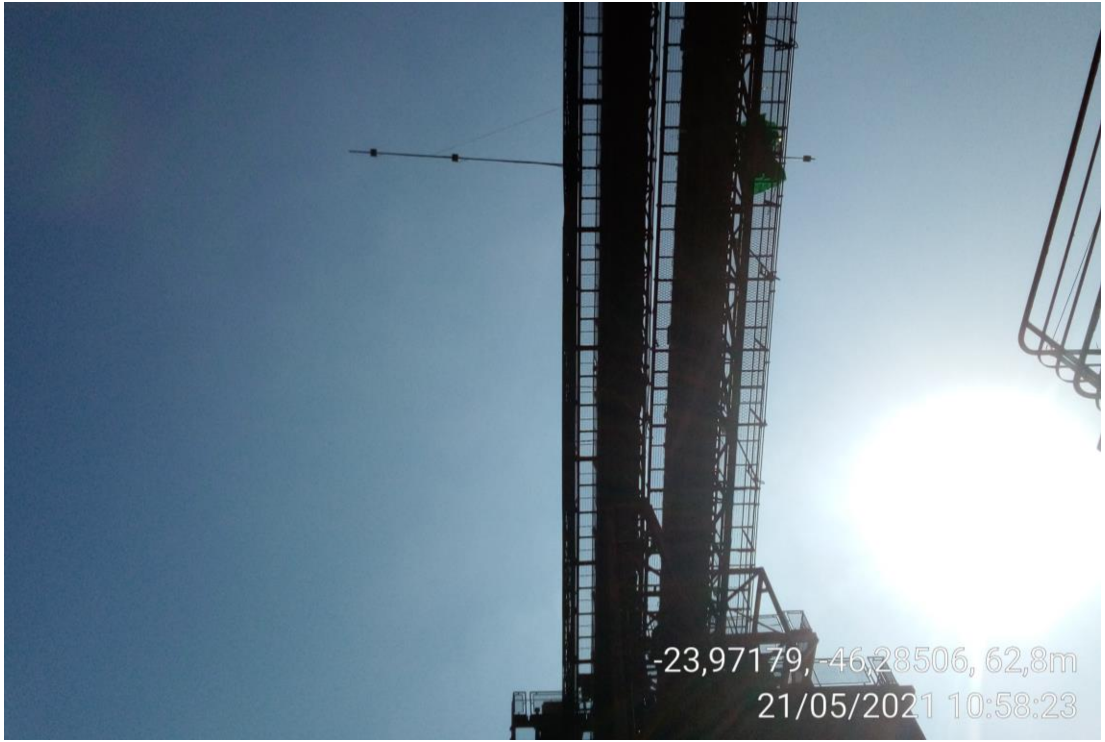
Downwind pole (SDS3,4 and 5,6)

Upwind pole with sensor SDS011 (SDS1) and reference method TEOM e SDS2

Experimental arrangement



View from the ground

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Data acquisition, sampling period

7056 registers, 1 minute intervals

- 6 SDS011 –PM_{10};
- 1 TEOM – PM_{10};
- wind speed
- wind direction
- mg/(m.s)

234 registers, 30 min intervals

- mass of grain transported:
- t/30 min

mg/(t.m)

Data processing

- **Calibration of SDS011** according to reference sensor;
- Filtration of registers **only with wind direction aligned** to pole (±45°), with 2493 registers remaining;
- Calculation of mean emission rate of 4 downwind sensors;
- Elimination of **outliers** (2%), with 2471 registers remaining;
- Data **classified** in:
  - 6 classes of grain mass transported (t/h);
  - 5 classes of wind speed (m/s); → Pivot-Table

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Pivot-table

Emission rate mg/(ms)	Transport- class (t grain/30 min)							Mass transported (t/h)	Emission factor mg/(tm)
Wind-class (m/s)	A 0-50	B 50-100	C 100-150	D 150-200	E 200-250	F 250-300	Total		
A 0-0,4	10,923	12,675	82,921	4,836	5,761	10,020	11,636	85,84	488
B 0,4-0,8	10,990	55,944	48,691	23,754	17,441	40,385	15,622	83,72	672
C 0,8-1,2	10,436	47,562	45,148	53,245	41,272	91,688	18,945	66,66	1023
D 1,2-1,6	11,019	53,510	54,377	98,267			24,560	66,03	1339
E 1,6-2,0	13,504	69,051	29,045	110,134	109,642		20,095	36,38	1988
Total	11,116	53,553	48,529	63,962	23,380	45,601	19,177	**68,34**	**1010**
Mass transported (t/h)	1,97	177,05	263,43	363,12	435,93	518,05	**68,34**		
Emission factor (mg/tm)	20322	1089	663	634	193	317	**1010**		

General increase

General reduction

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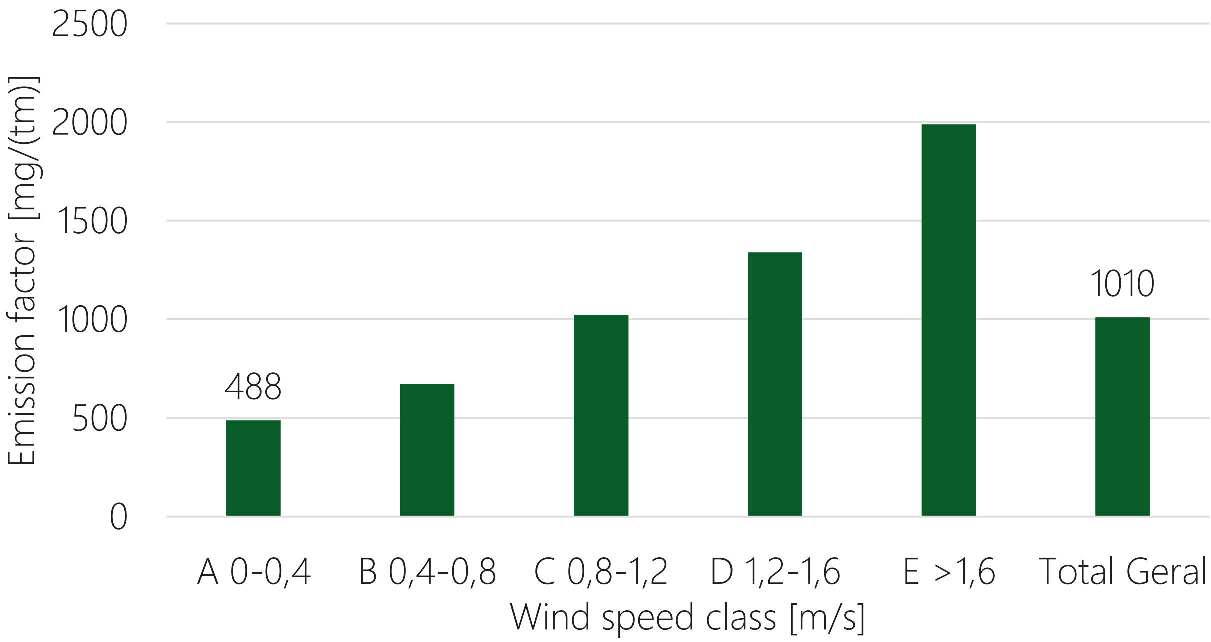
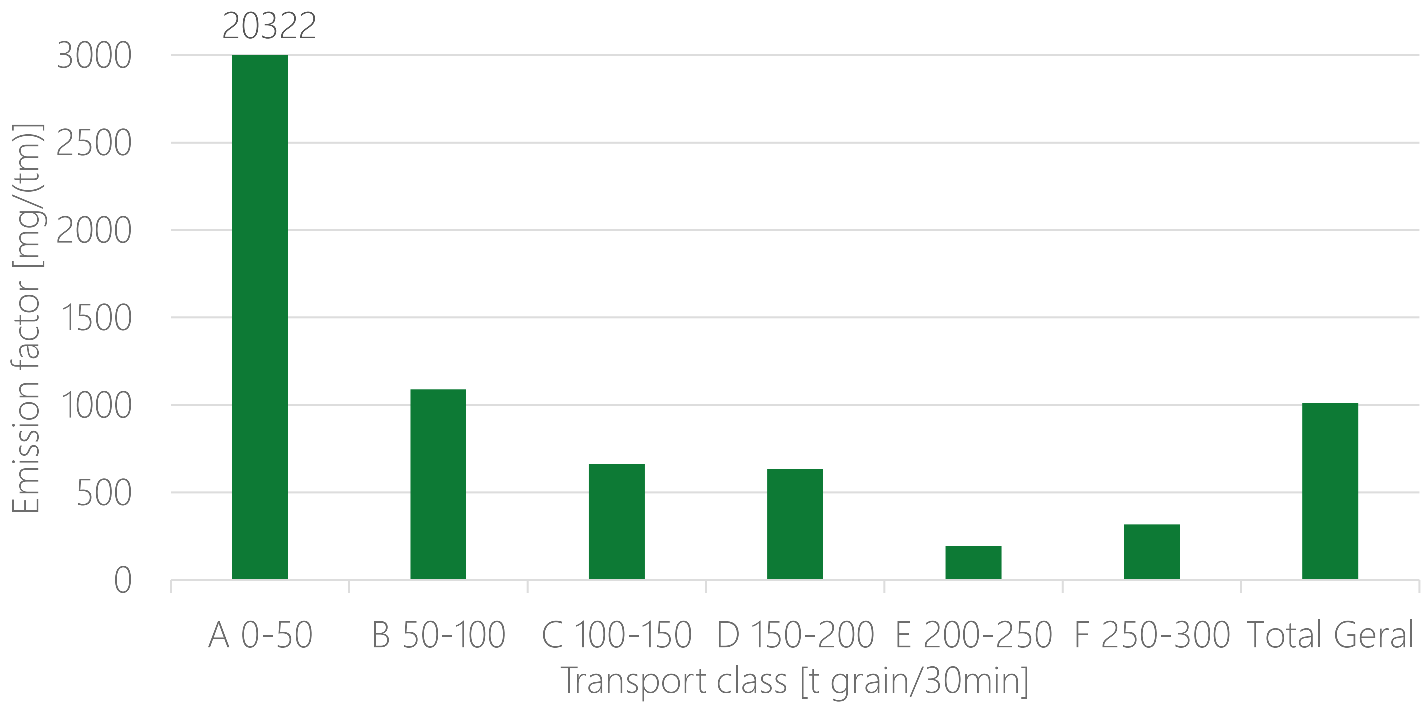
Emission factor vs wind speed



Emission factor vs grain transport



Comparison with EPA Emission factor[1]

- Tunnel belt factor: 0,7 kg/t (Total Particle Mass)
- This study PM_{10}: 1,01 g/(tm) and Total PM: 3,82 g/(tm)

0,7 kg/t divided by 3,82 g/(tm) = 183 meter of belt length

(1): Gorman, P.G., "Potential Dust Emission From a Grain Elevator in Kansas City, Missouri", Final Report, prepared for Environmental Protection Agency, May 1974

Conclusions

- **Calculation of emission factor was possible** with the use of six SDS011 sensors in combination com PM_{10} reference method and meteorological station;
- Calculated emission factor is in **good agreement** with EPA;
- **Strong dependence** between emission factor and **wind speed**;
- Wind protection of belt will significantly reduce emissions;
- **Best performance** (lower emission factor) near **full load** of conveyor belt.

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