Santiago de Chile experience with respect to inspection and maintenance using particle number measurement

INTRODUCTION

As a part of a comprehensive program aiming towards the implementation of DPF on public transport buses in Santiago, conducting by a partnership between Ministry of Transport of Chile and Swiss Agency for Cooperation and Developing (COSUDE), one randomly measurement campaign with Solid Particle Number metric (SPN), was done over a fleet of 3,200 buses with DPF, aged between 150,000 to 750,000 km. 124 buses with DPF and 104 buses without DPF were sampled. These measurements were useful to do an on road evaluation of real conditions of aged filters and to evaluate portable instruments for a future Inspection and Maintenance program for retrofitted Euro III and Euro VI buses.

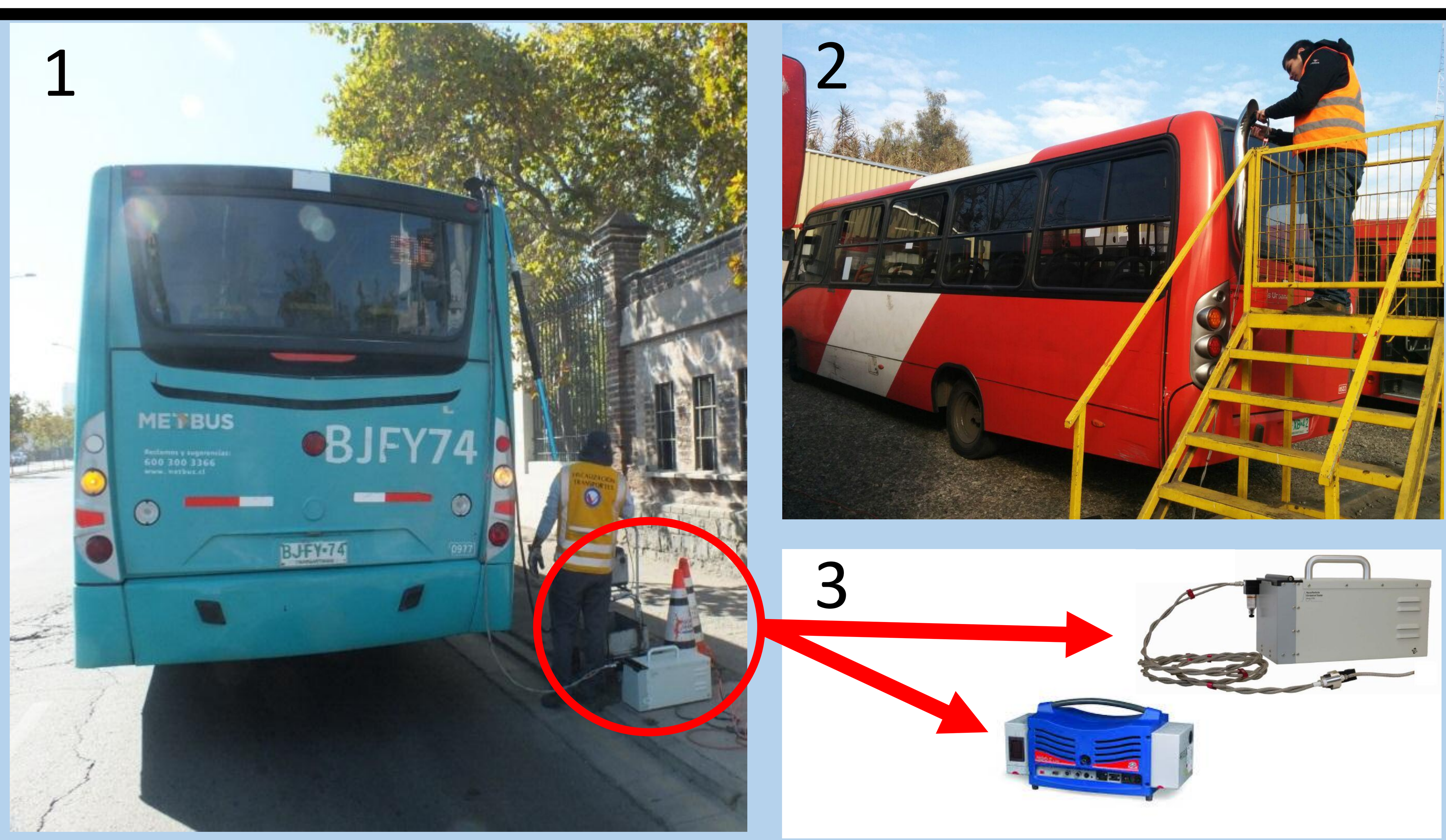
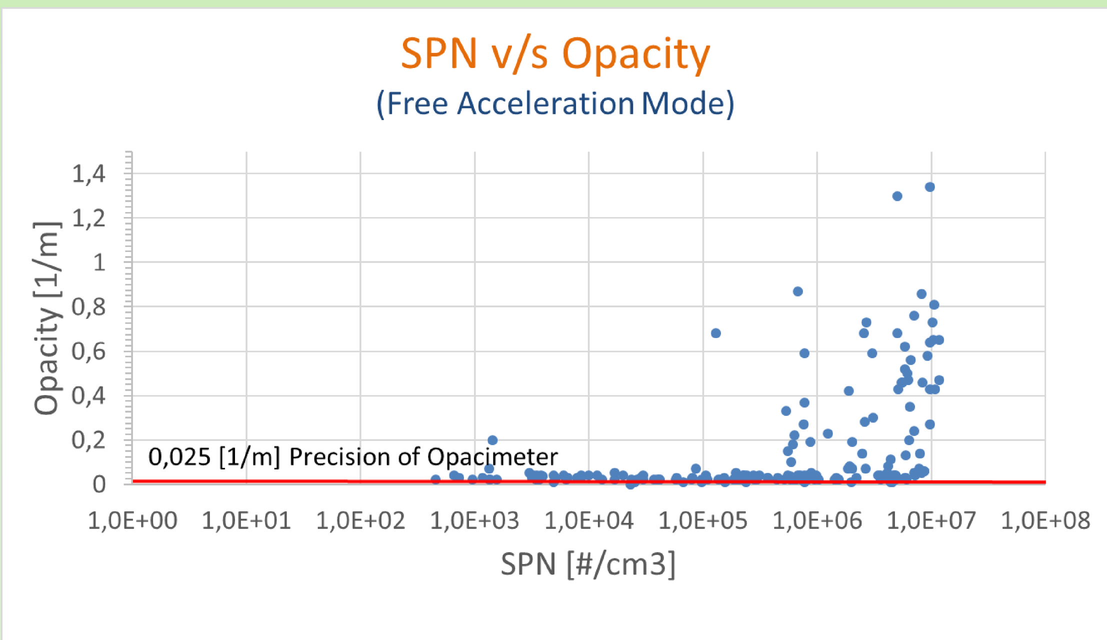


Fig. 1: Road side SPN measurement during an usual opacity control of Ministry of Transport (picture 1). Efficiency DPF measurement in the bus fleet depot (picture 2). NPET-TSI certified portable Solid Particle Number (SPN) instrument [1] and conventional opacimeter (picture 3)

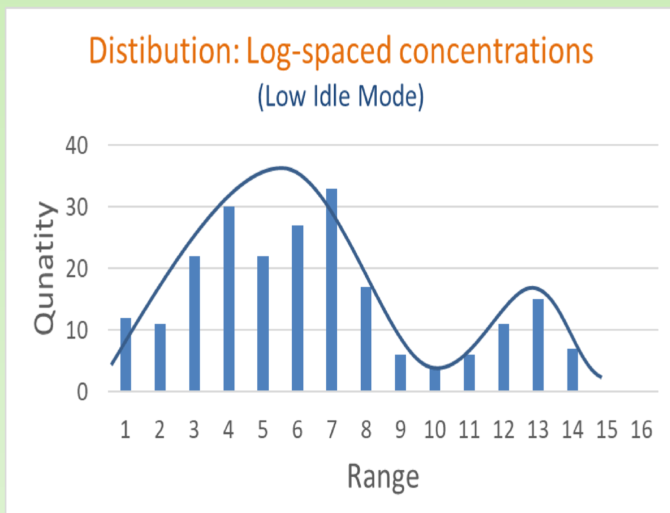
RESULTS



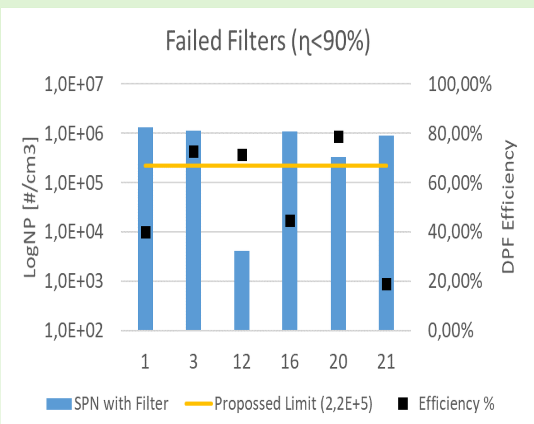
End of pipe road side measurements

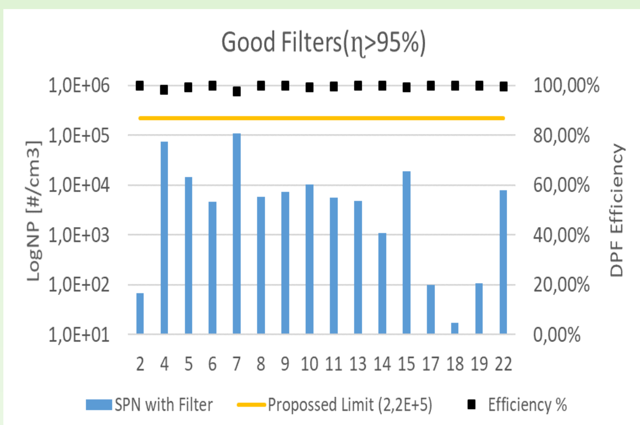
Left: 30% of opacity results in free acceleration were inside undetectable range of instrument (below 0.025 [1/m]), but with results between 10E+2 to 10E+7 [#/cm3] in SPN.

Right: Binned bus measurements at low idle into log-spaced concentration ranges, shows a separation in bimodal structure (low and high emitters). Bimodal structure suggests limit of 2.2x10E+5 [#/cm^3] as threshold.



Range	≥	<	N	Condition
1	1,0E+02	2,2E+02	12	Normal
2	2,2E+02	4,7E+02	11	Normal
3	4,7E+02	1,0E+03	22	Normal
4	1,0E+03	2,2E+03	30	Normal
5	2,2E+03	4,7E+03	22	Normal
6	4,7E+03	1,0E+04	27	Normal
7	1,0E+04	2,2E+04	33	Normal
8	2,2E+04	4,7E+04	17	Normal
9	4,7E+04	1,0E+05	6	Normal
10	1,0E+05	2,2E+05	4	Indifferent
11	2,2E+05	4,7E+05	6	Abnormal
12	4,7E+05	1,0E+06	11	Abnormal
13	1,0E+06	2,2E+06	15	Abnormal
14	2,2E+06	4,7E+06	7	Abnormal
15	4,7E+06	1,0E+07	0	Abnormal
16	1,0E+07	2,2E+07	0	Abnormal
		TOTAL	223	

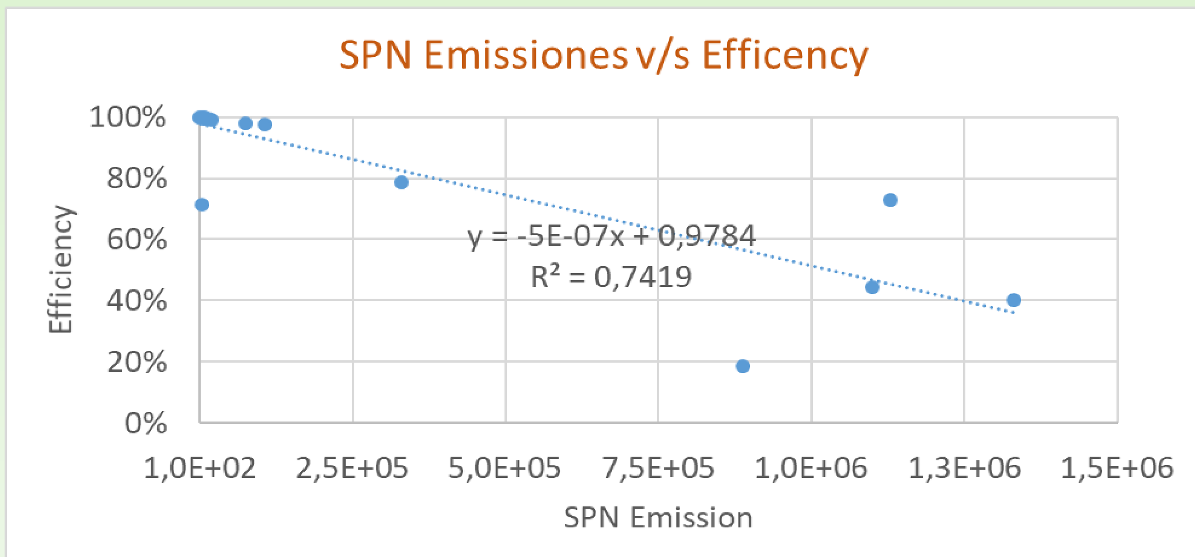




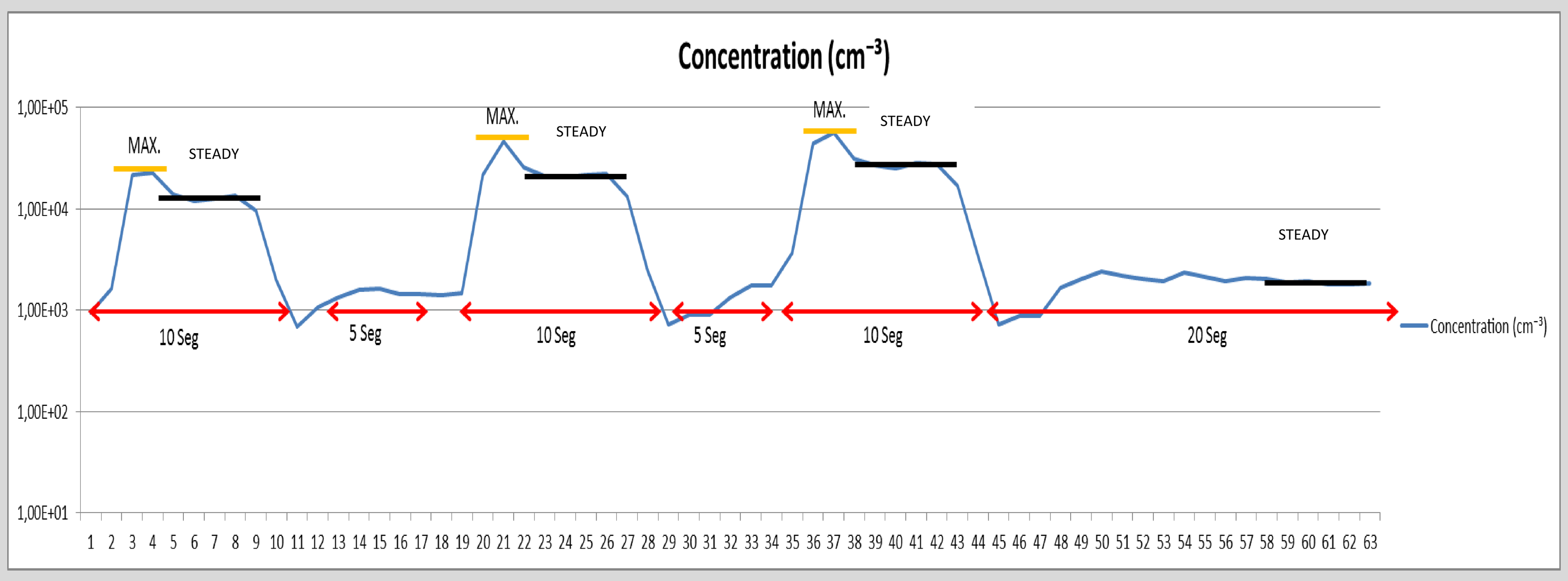
Low idle DPF efficiency measurements

Left: 22 buses, measured at low idle downstream/upstream of DPF. All buses with η>95% pass suggested limit ($\eta_{Average}$ = 99.5%). All but one bus with η<90% failed limit ($\eta_{Average}$ = 50%).

Right: A well adjusted linear function explains DPF efficiency like a function of end of pipe SPN concentration.



METHOD DETAILS



Above: An integrated cycle, composed by free acceleration, steady state to max. RPM and low idle, was applied during road side control. Opacity and SPN were measured simultaneously. For efficiency, SPN were only measured at Low Idle engine speed at end of pipe and upstream to DPF, in depot.
All measurement consider normal engine temperature and preliminary free acceleration for cleaning exhaust pipe.

CONCLUSIONS

- Solid particle number concentration is a more sensitive metric than opacity for determining DPF condition.
- SPN limit of 2.2x10^5 #/cm^3 , at Low Idle speed, could be a good indicator for detecting filters with η<90%.
- Additional data are needed before to be conclusive for setting a final limit (end of pipe and efficiency tests).

Low Idle v/s High Idle

- Low Idle more reliable than High Idle because no interference of driver or electronic idle speed control as seen in some modern engines.
- Low Idle less noisy than High Idle.
- Low Idle and High Idle with enough SPN concentrations to discriminate good and bad DPF.
- Low Idle permits to measure engine raw emissions inside measurement range of instrument without additional dilution, different to High Idle.

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