New-fit sulfur tolerant DPF solution to meet Iran's new emission legislation: a case study

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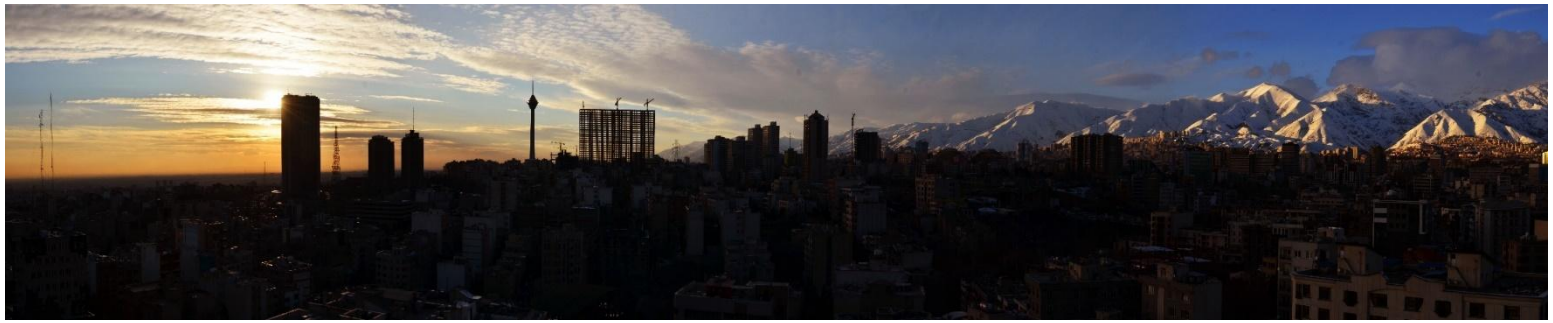
Background

Pictures from Tehran



- Population: 8.5 million
- 4 million LDVs and motorcycles all gasoline and CNG
- 130,000 HDVs, all diesel

History of legislations

- DPF subject was started in Iran in 2014
- Since then, there is a national legislation for Euro IV+DPF for new diesel vehicles starting Sep 2016
- Later on European OEMs lobbied for Euro V EEV to be added to legislation.
- There is a legislation for all public vehicles in 8 large Iranian cities (30+ million inhabitants) to be retrofitted to DPF
- There is a city council legislation in Tehran for soot purchasing scheme (paying more to contractors if they have filters on their diesel vehicles)

Tehran DPF retrofit project

- Pilot tests are running since 2014 (10 buses, 6 technologies)
- 50 buses now retrofitted to filters
- The project move forward despite of technical obstacles and resistance of operators

awareness and outreach

Pilot tests, local conditions

new products are coming

International events

A novel OEM approach for sulfur tolerant filters for Iran

General Specification

Fuso Canter	
Engine model	4P10-8AT4
Engine volume	3 Liter
Engine output	110 kW
Max torque	370 N.m
Emission level	EURO V
Emission reduction technology	EGR+DPF

DPF System and regeneration strategy

- Full flow silicon carbide DPF.
- The regeneration process is a quasi passive.
- Passive regeneration mechanism is DOC-CRT
- The active regeneration is a combination of early post injection, temporary EGR deactivation, and idle speed increase
- automatic and manual active regeneration

Regeneration strategy

- DPF regeneration mechanism consists of 3 main sequential steps:

1- CRT is working when the fuel sulfur level is low

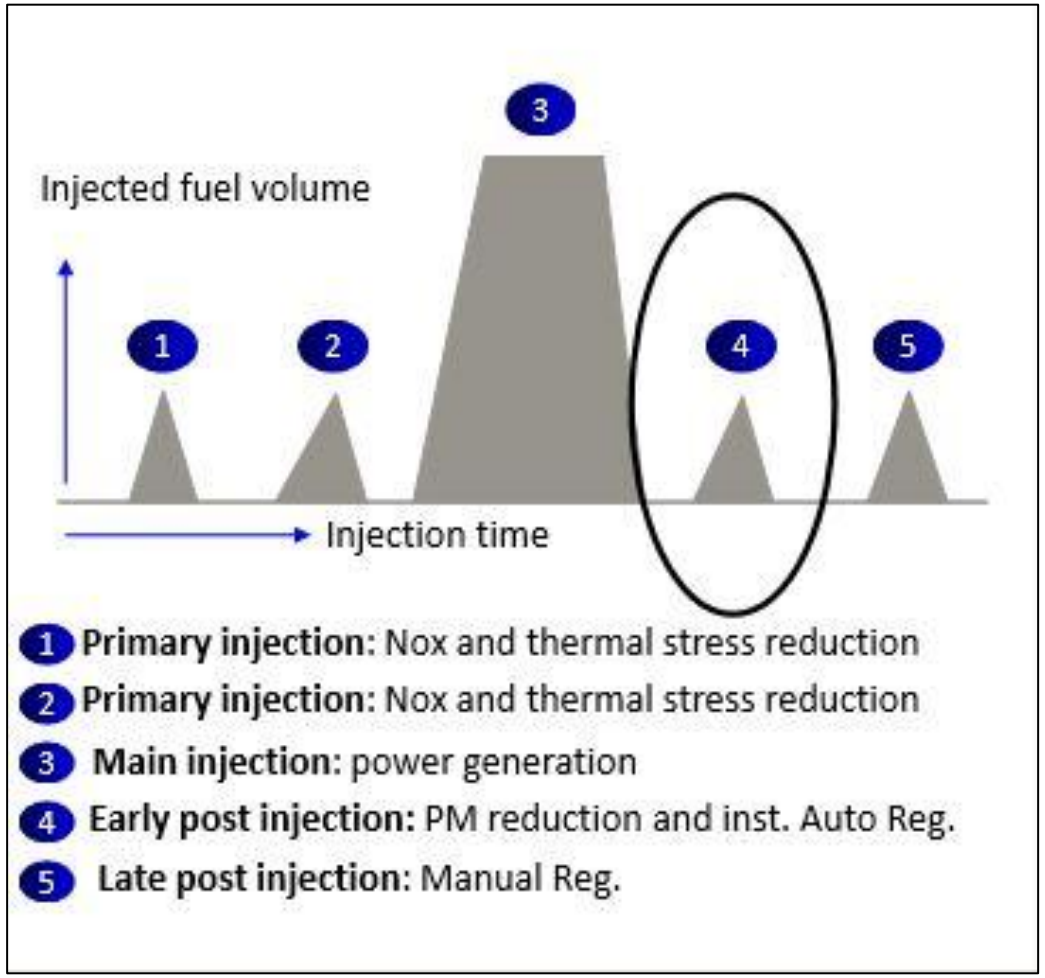
2- Instantaneous automatic regeneration when CRT is not fully working,

- o Early post injection
- o Temporary EGR deactivation
- o Temporary increase of idle speed from 600 rpm to 800 rpm

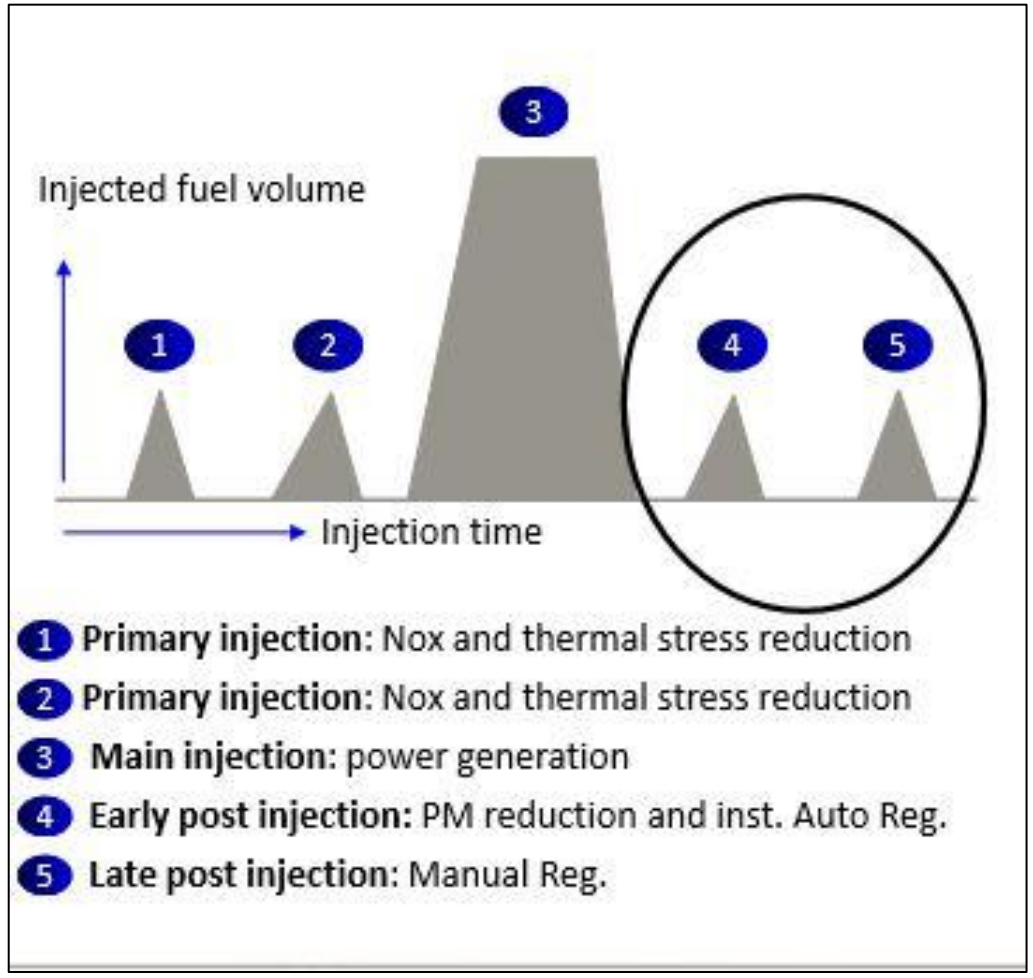
3- Manual Regeneration by the operator if there is still back pressure problem

- o Late post fuel injection

Regeneration strategy



Automatic regeneration



Manual regeneration

RDE evaluation of the system with PEMS

Instrumentation

matter aerosol
a testo company

Test procedures

- Besides Iranian normal driving cycle, some steady- speed tests and half load points also were added to the test procedure.

Steady-speed points

Stage	1	2	3	4	5	6	7	8
Gear	4th	4th	4th	5th	5th	5th	5th	4th
Vehicle speed	40	60	80	40	60	80	Max	40

Half loads points

Stage	Time (s)	RPM	Load
9	30	2000	50%
10	30	2500	50%
11	30	3000	50%
12 Average	90	2000-3000	50%

Iranian driving cycle

Vehicle category	Urban (0-50km/h)	Rural (50-75km/h)	Motorway (75km/h-)
M1, N1	45%	25%	30%
M2, N3	45%	25%	30%
M2, N3 (Class I, II or Class A)	70%	30%	-
N2	45%	25%	30%
N3	20%	25%	55%

Stage 16	Stage 13	Stage 14	Stage 15

Sampling

- Sampling was done w and w/o DPF installed

DPF system

Replaced pipe instead DPF

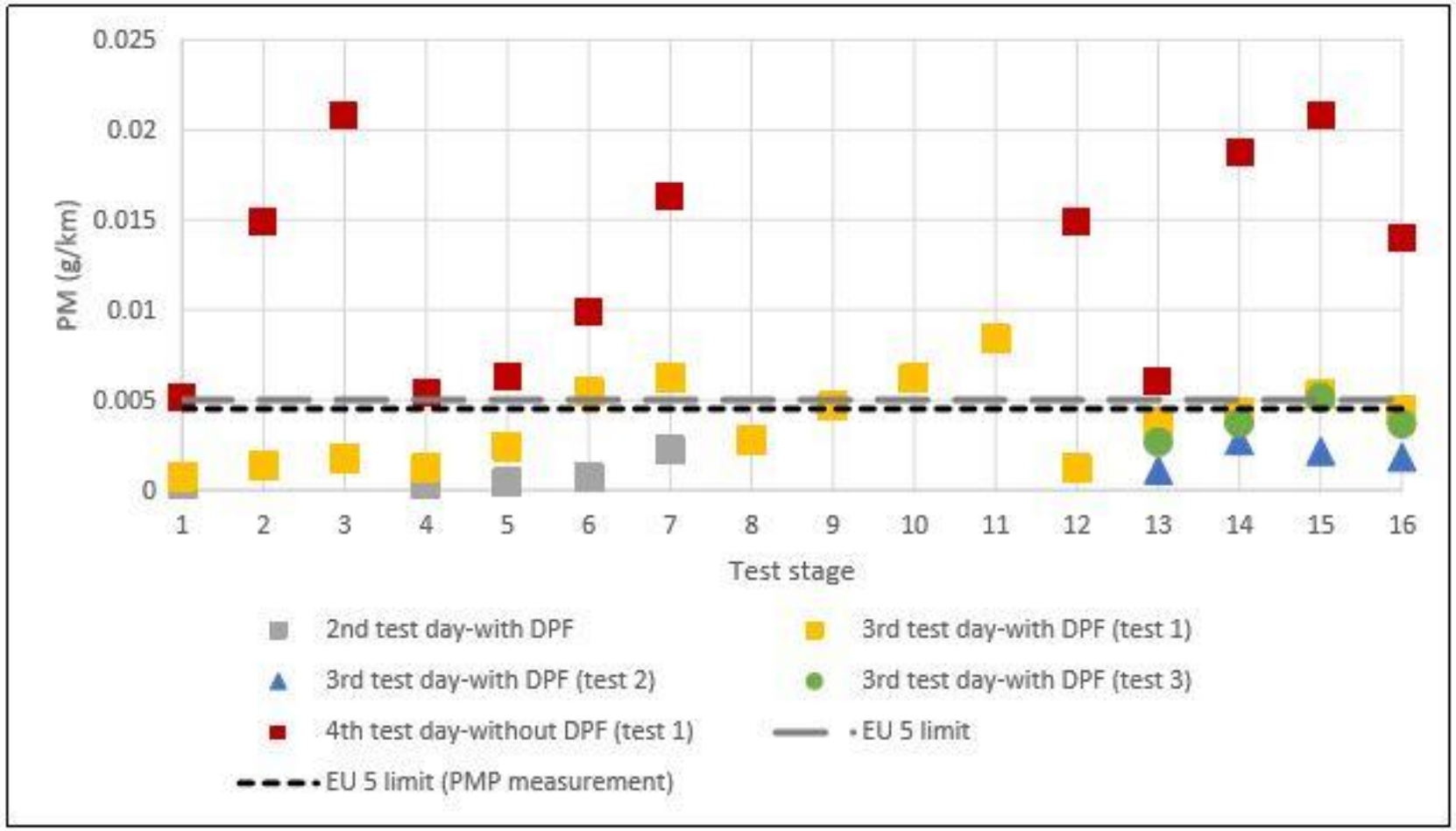
Test route

	Date, Time	Speed (mph)	Direction (Degree)	Altitude (ft)
Start:	29.08.2016 10:49	0	144	4259
Stop:	29.08.2016 12:36	0 ; 0	276	1383 ; 4537

Length = 100 km

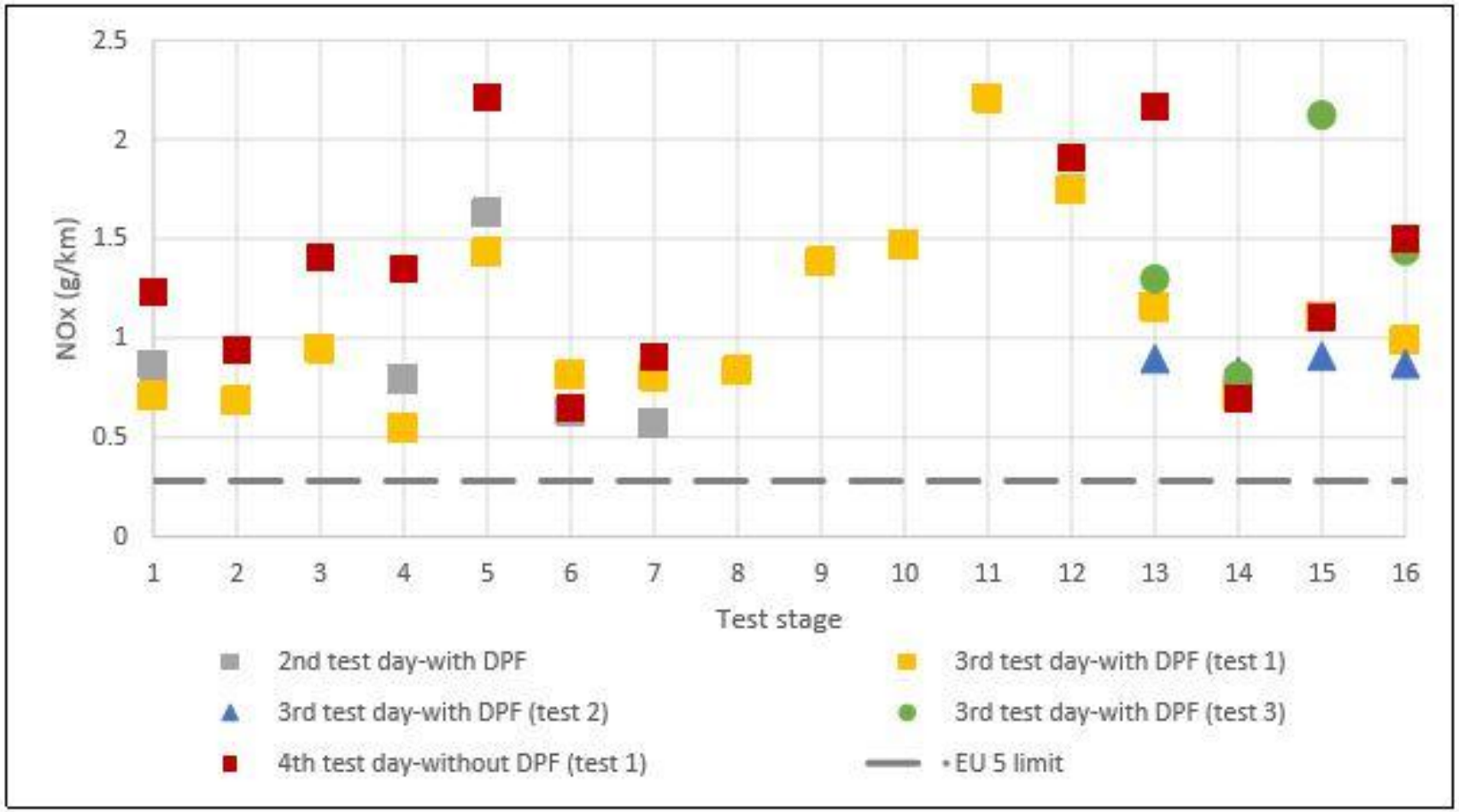
Elevation = 1200 meter above sea level

PM results (g/km)



Averaged values:
With DPF: 0.003 g/km
Without DPF: 0.0128 g/km

NOx (g/km)

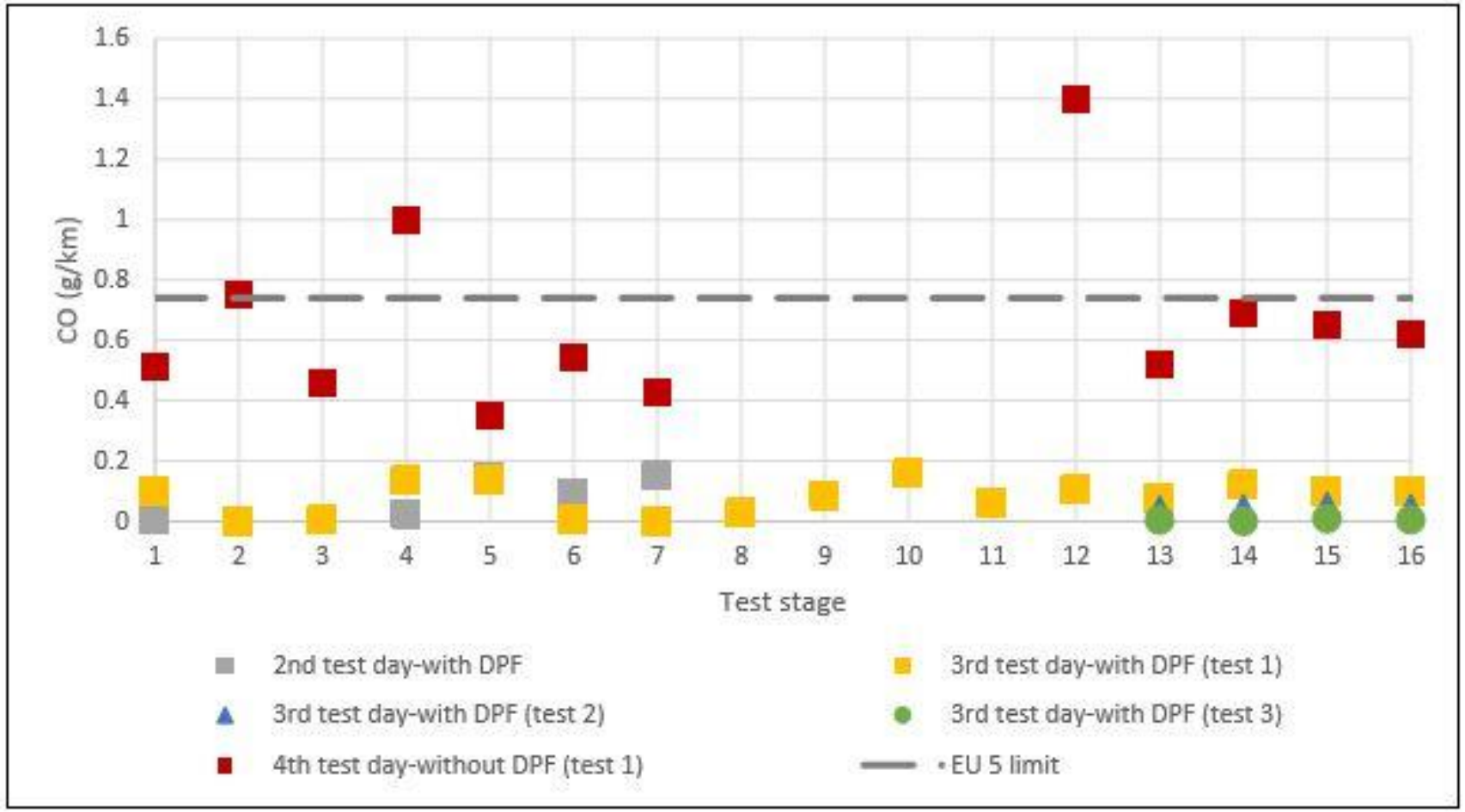


With DPF: 1.08 g/km

Without DPF: 1.34 g/km

Small reduction was observed in NOx values because of internal EGR which was caused by DPF back pressure

CO (g/km)



With DPF: 0.07 g/km
Without DPF: 0.66 g/km

PN measurement

- PN measurement was done at three different idle speeds

Engine speed (rpm)	600	2000	4000
PN concentration at DPF downstream (#/ccm)	4.25E+04	5.33E+04	3.20E+04
Average PN concentration at DPF upstream (#/ccm)		**7.4E+07**	

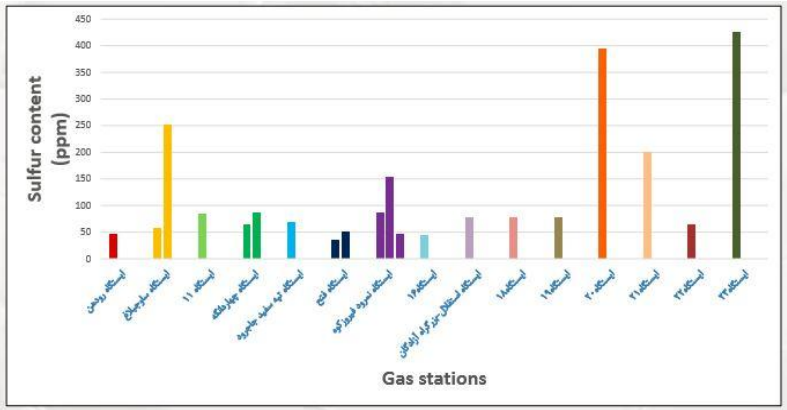
PN _ efficiency> 99%

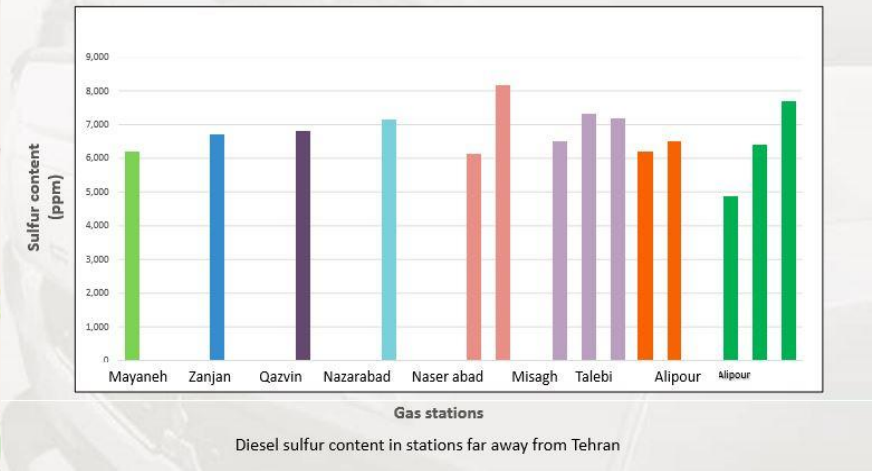
Durability runs

Durability test- basic information

- 50,000 km road test
- 2 trucks
- Duration of 4 months and 3 routes
- Various fuel sulfur content from 44 ppm to 8,180 ppm

Fuel Map (sulfur content)



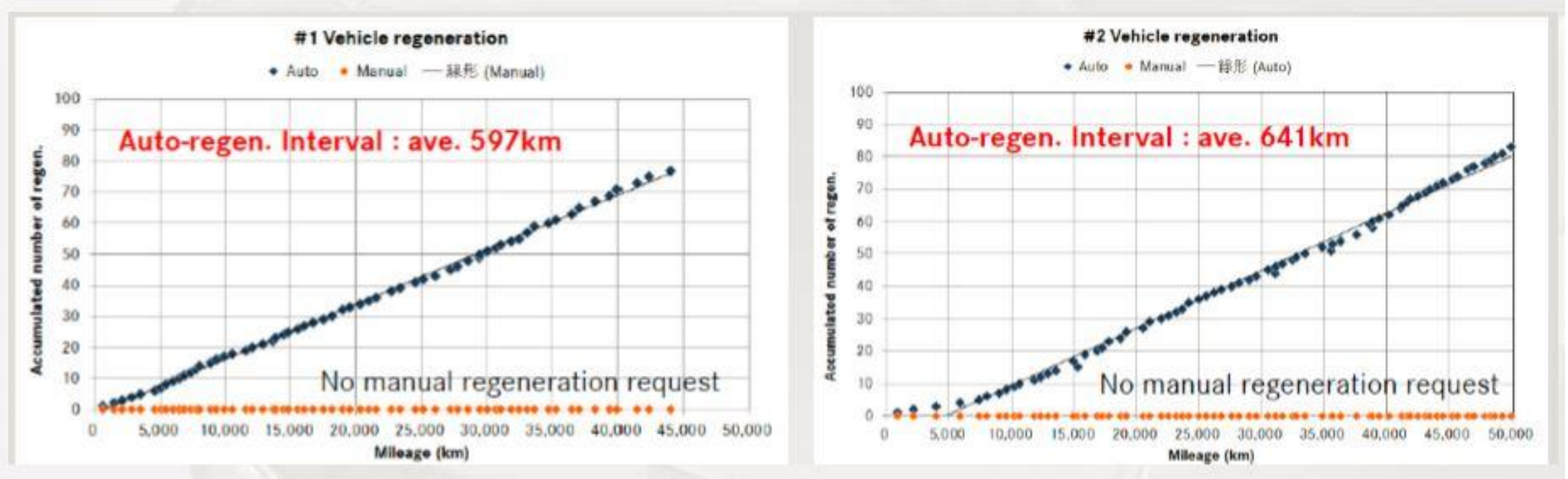


Sulfur content

- Large cities < 50 ppm
- Roads and remote areas up to ~8000 ppm

Durability results

- No manual regeneration was required within 50,000 km road test.
- As average, instantaneous automatic regeneration had been deployed every 600 km.
- This interval for instantaneous automatic regeneration is almost every 4,000 km, while operating with Euro IV diesel.



Challenges due to high sulfur diesel fuel

- In brief, in spite of using of highest oil quality level i.e. API CJ4 which is recommended for DPF equipped engines, oil had degraded considerably due to high sulfur content.

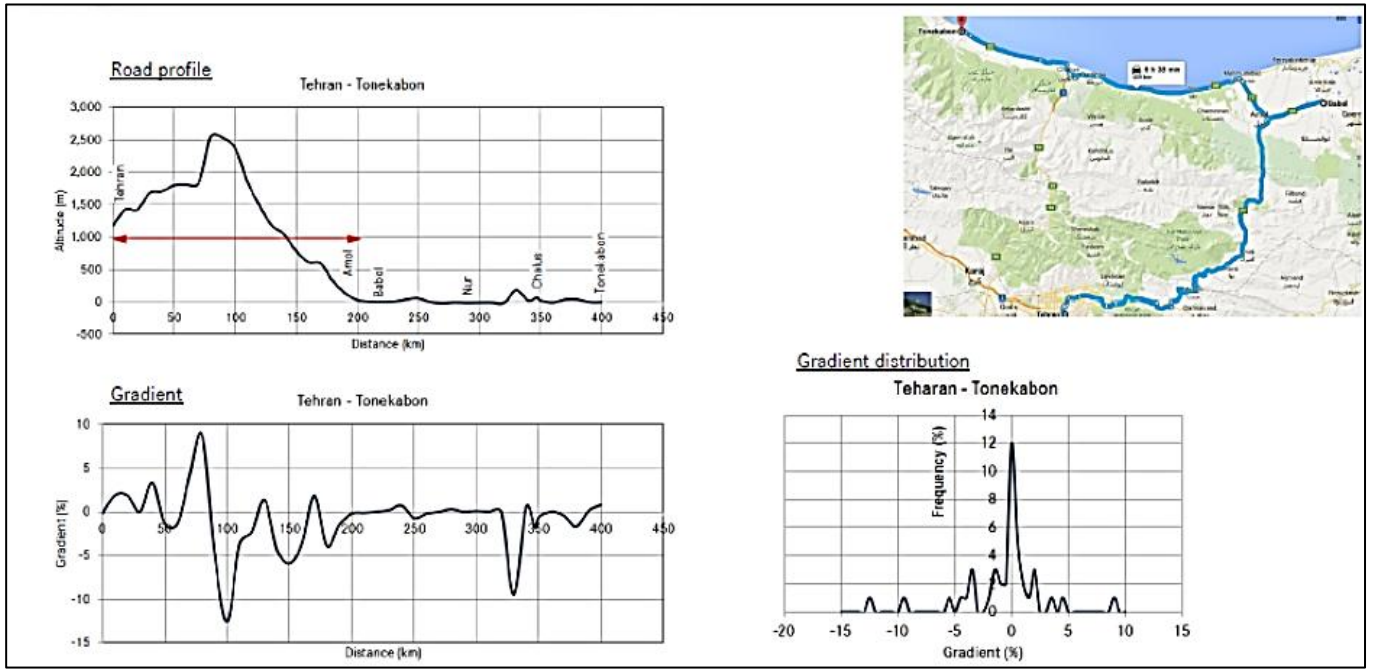
- Higher backpressure operation as the result of fuel sulfur content (DOC deterioration), turbocharger cooling oil penetration into engine intake

- Several post fuel injection leads to engine lube oil dilution by diesel fuel and rapid oil deterioration

- Based on effect of high sulfur content, level of metal elements increased considerably that is a clear sign of high corrosion and wear of engine components.

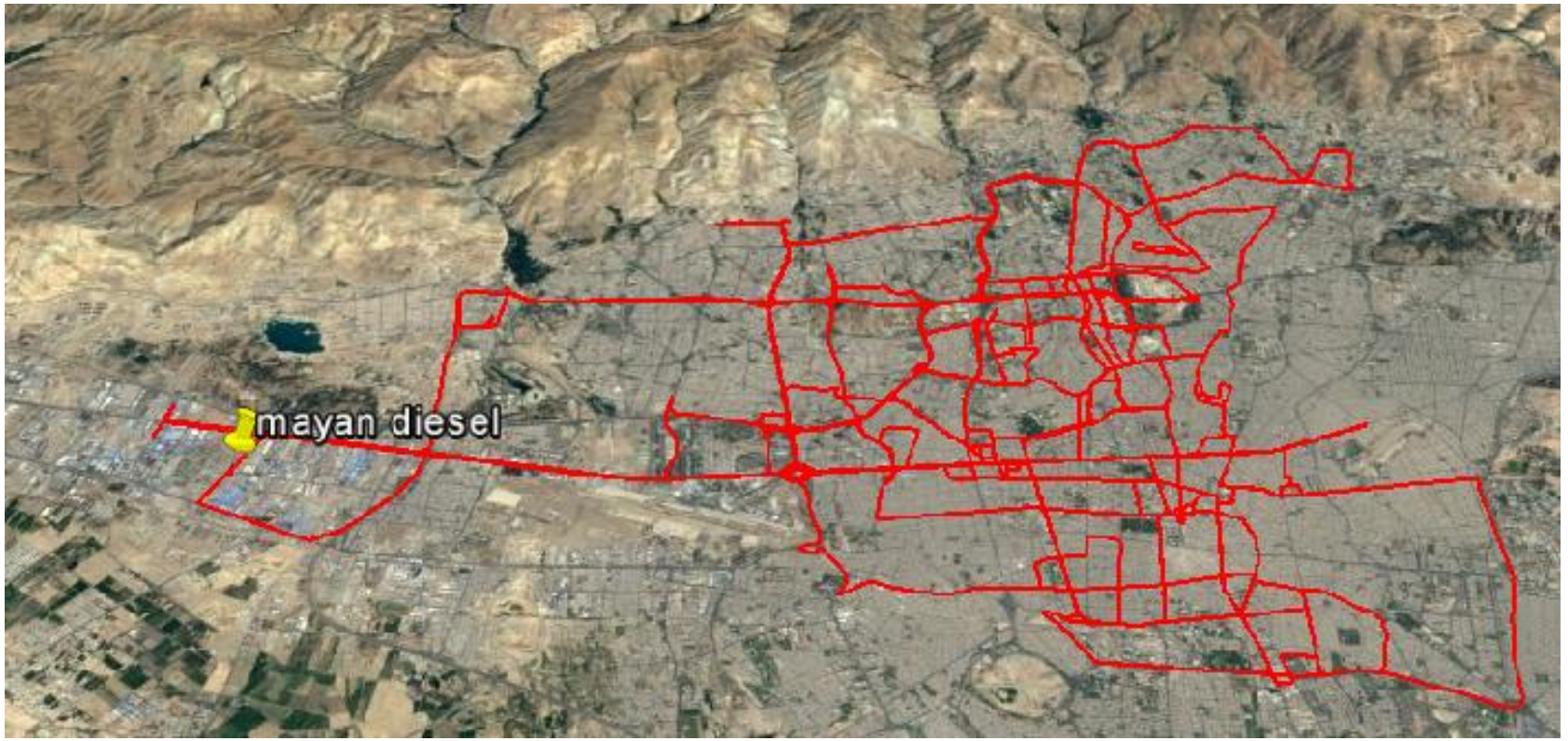
Worst case scenario – 2nd round of road test

- Driving in dense city traffic jam with frequent start and stop and low speed.
- -Drivers are instructed to drive in very low vehicle speed and high gears to cause minimum engine speeds.
- Whole test in EVM condition (3,980 kg).
- 6,000 L of very poor diesel with sulfur content of around 6,000 ppm was stocked in a tanker in origin point of daily hauling to guarantee running under highly poor fuel quality during the whole test.
- Engine is being switched off during night time for 8 hours every day.
- This testing condition is called 2nd round of the road test
- This round of the test was covered from 51,586 km till 54,405 km i.e. ~ 2,800 km



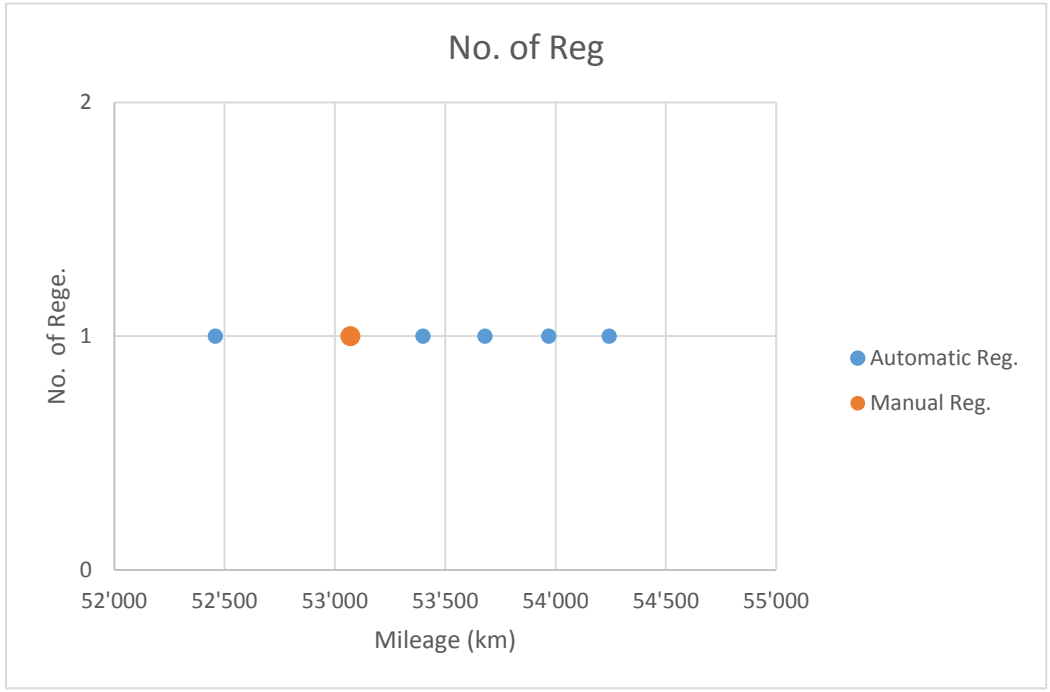
Routes

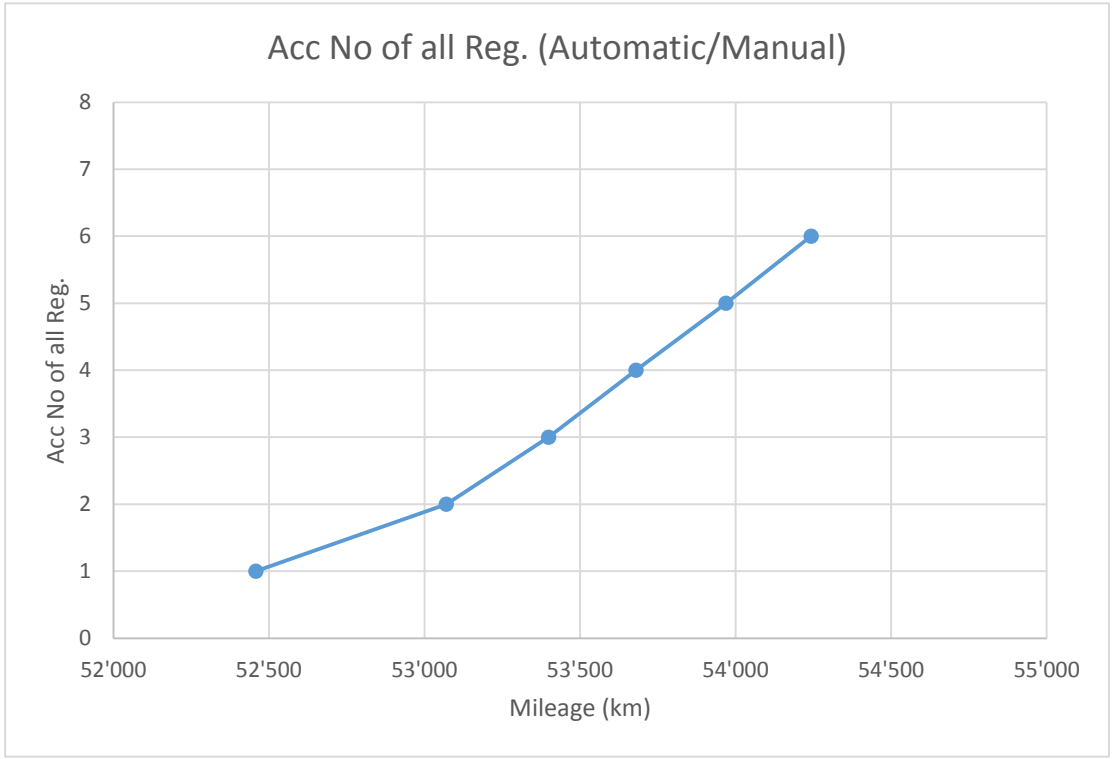
- Pure city driving, mostly in most dense and heaviest traffic jam.



DPF Regeneration

- 1 manual Reg. was requested by ECU in 1st week of this round of the test.
- 4 automatic regeneration and no manual regeneration have been deployed in 2nd week.
- Regeneration interval is reduced drastically in 2nd week of the test (from ~600 km to ~250 km)

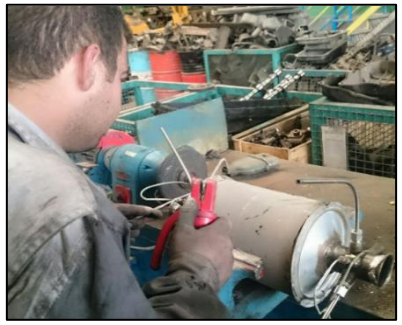




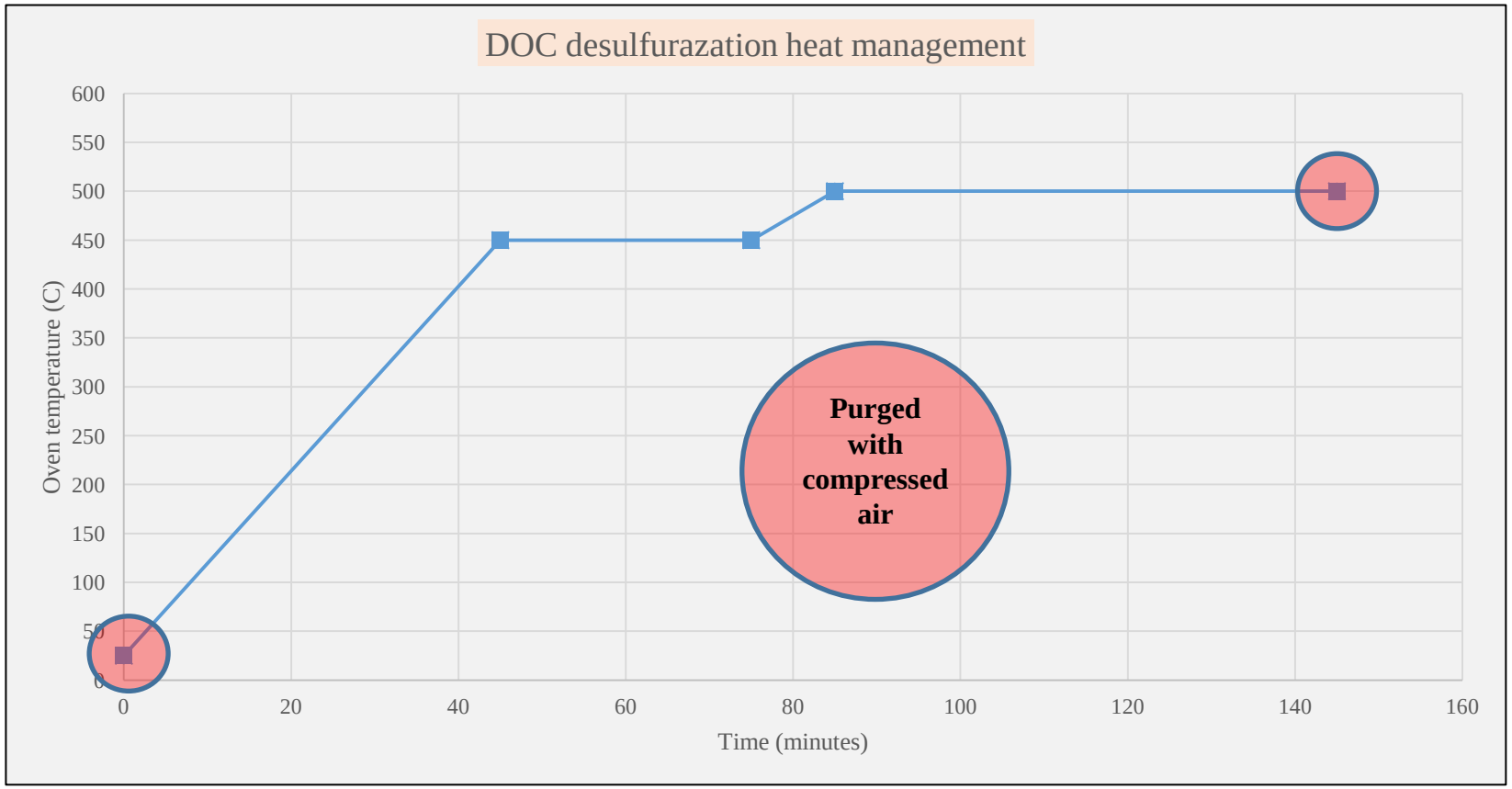
DPF and DOC cleanup procedure

7-steps for cleaning procedure

- Step 1: DPF evaluation before the cleaning.
- Step 2: Separating DPF and DOC.
- Step 3: DPF cleaning.
- Step 4: DOC poisoning evaluation.
- Step 5: DOC desulfurization.
- Step 6: Evaluation of DOC activity after desulfurization.
- Step 7: Cleaning efficiency measurement



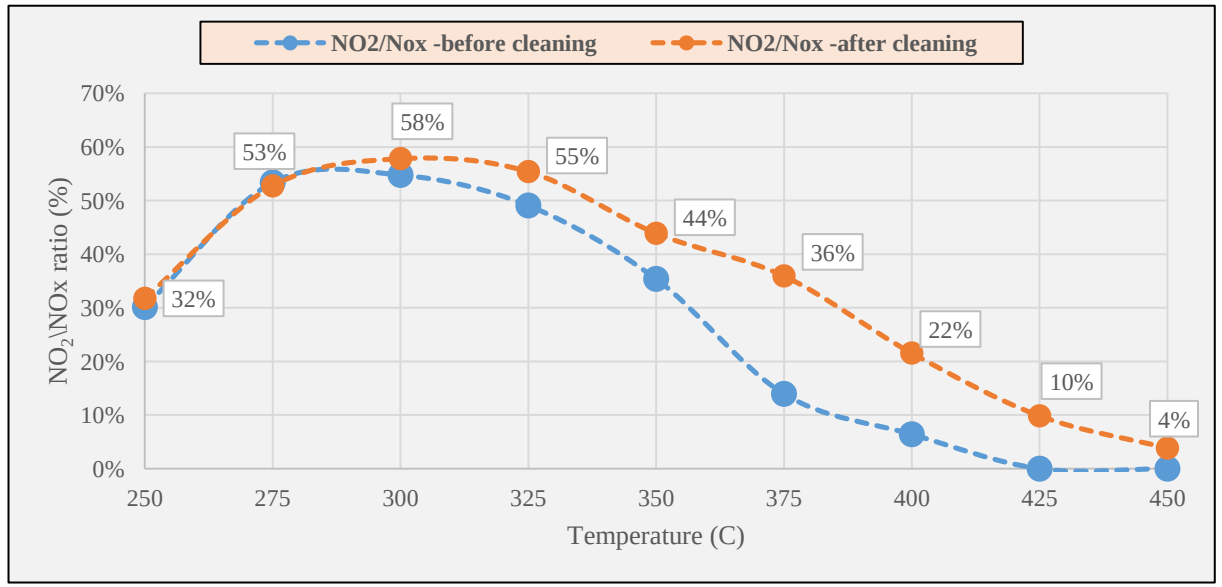
DOC desulfurization

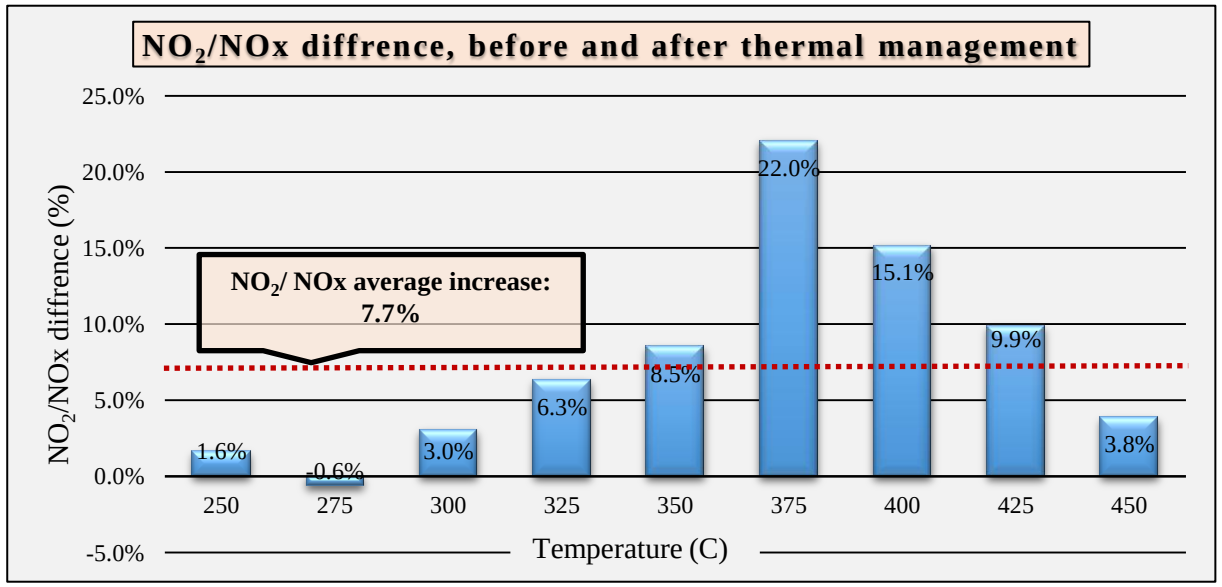


Before cleaning

After cleaning

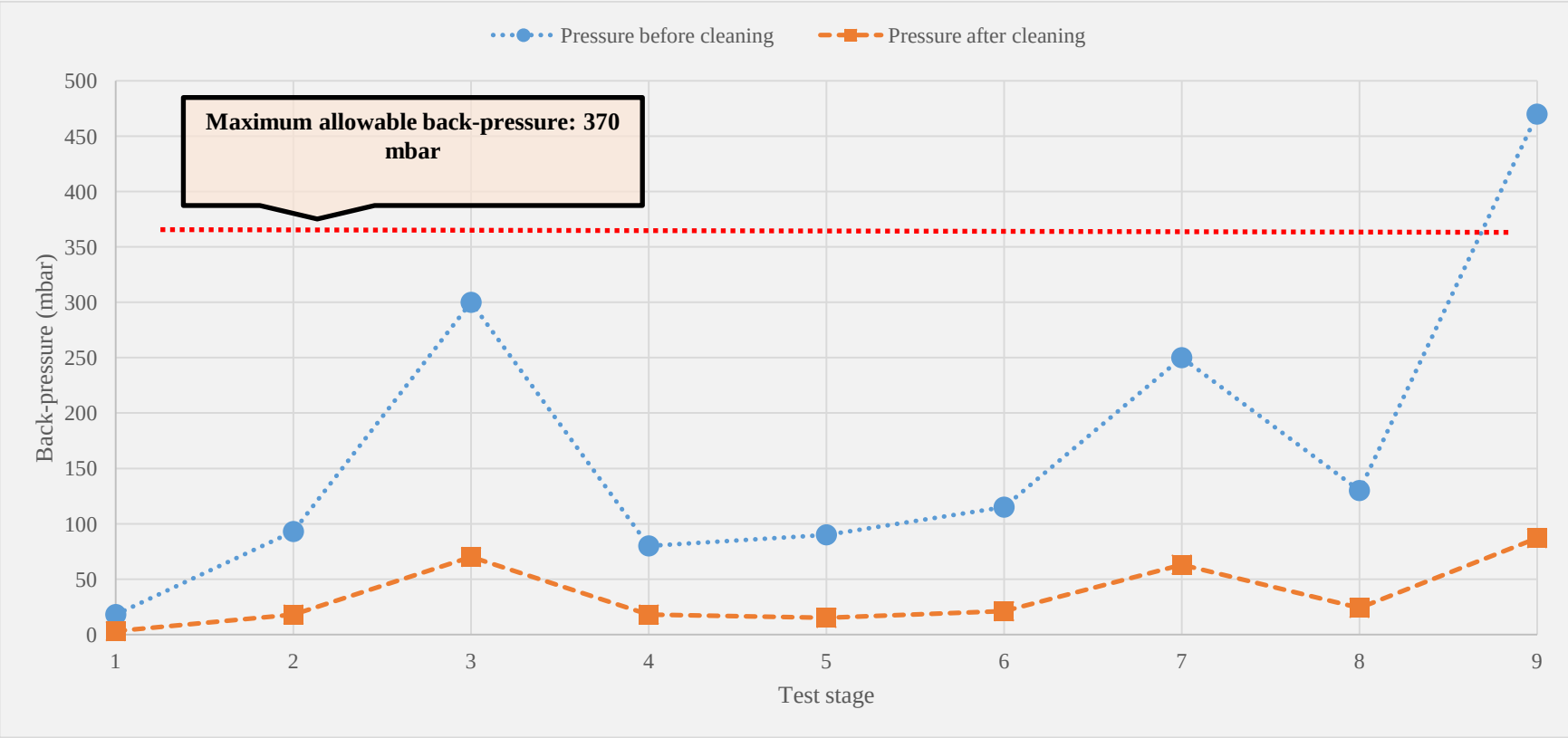
Evaluation of DOC activity after desulfurization





Considering DOC activity's average values for before and after desulfurization, average improvement was 29%.

Cleaning efficiency measurement

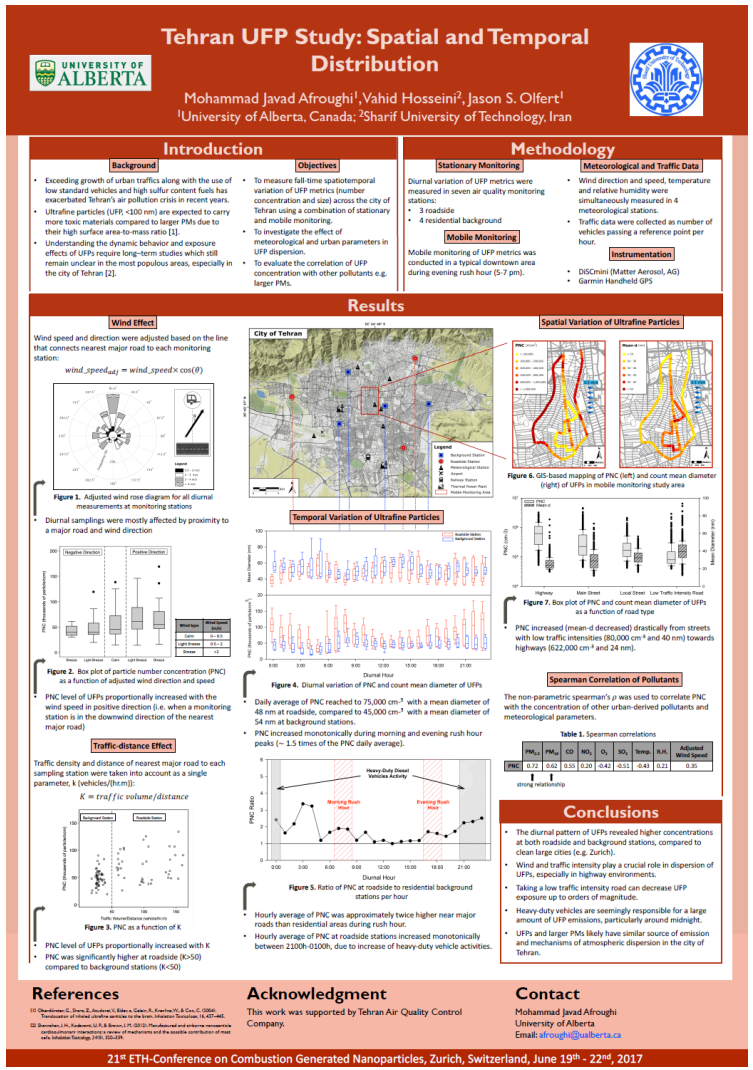


the proposed procedure for cleaning DPF was successful. Maximum 87 mbar and average 35.4 mbar showed the DPF was in very good condition after retrieval procedure.

Concluding remarks

- Dire situation in Iranian mage-cities air with respect to PM10, PM2.5 and BC requires immediate actions
- We cannot wait for nation-wide ULSD, we need DPF now
- Novel approaches based on old European experiences are needed (there are experiences of DPF with 1200 ppm sulfur diesel in Switzerland)
- Until full implementation of Euro VI level standard (fuel, oil, AdBlue infrastructure,…) Euro IV+DPF legislation must be supported at all levels

Please visit our posters in UFP measurement in Tehran air and source apportionment of Tehran PM2.5



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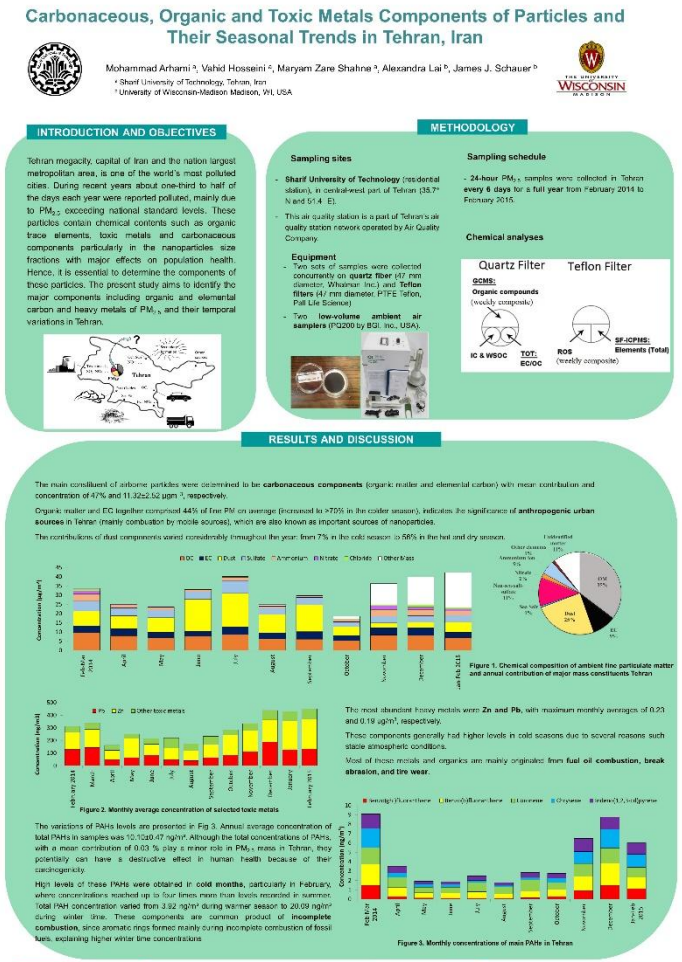

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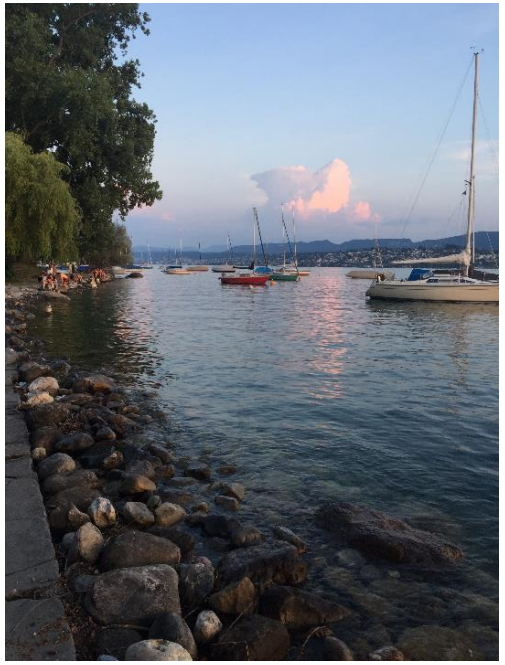
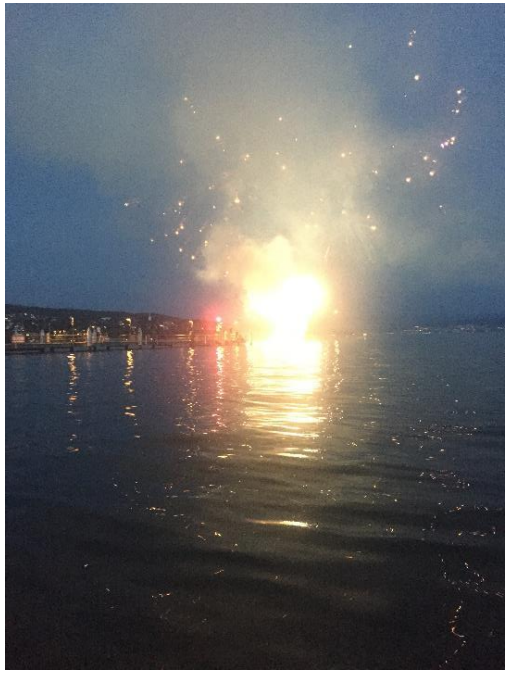


Zurich
June 20, 2017



it is all about health effects

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Thanks for your attention

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