

VERT Iran Workshop

Emission Control Technology for Clean Air

January 23rd 2018

Iran, Tehran
Volker Hensel

Emission Control Technology for Clean Air

Agenda

- Introduction
- Air Pollution effects from Road Traffic
- Technologies to reduce Gases and solid Particles from Diesel Engines
- Particle Reduction Efficiency of Emission Control Systems
- Summary



The challenge of Clean Air in Mega Cities

- Population is growing
- Need for mobility is increasing
- Total emissions are increasing
- Congested cities
- **No alternative for Best Available Filtration Technologies**

Introduction | City of Tehran on unhealthy Days

۹۴/۰۹/۰۳

Hazardous >301
Very Unhealthy 201-300
Unhealthy 151-200
Unhealthy for Sensitive Groups 101-150
Healthy 51-100
Good 0-50

December 2015						
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

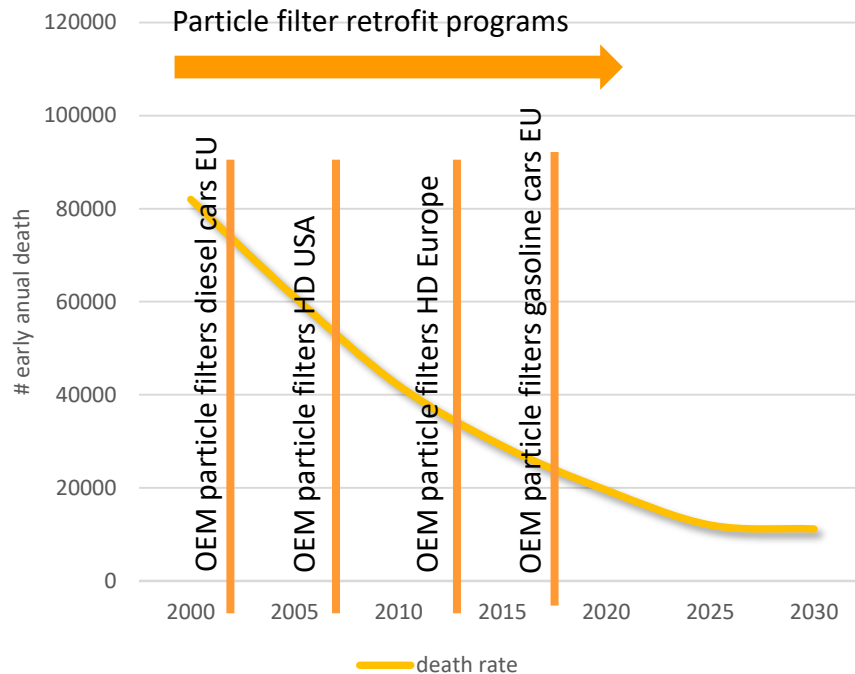
○ Introduction | The challenge for Clean Air



Air pollution Effects from Road Traffic

Annual early deaths by region under baseline and accelerated policies

Countries: EU-28; USA, CA; JP; AU; KR



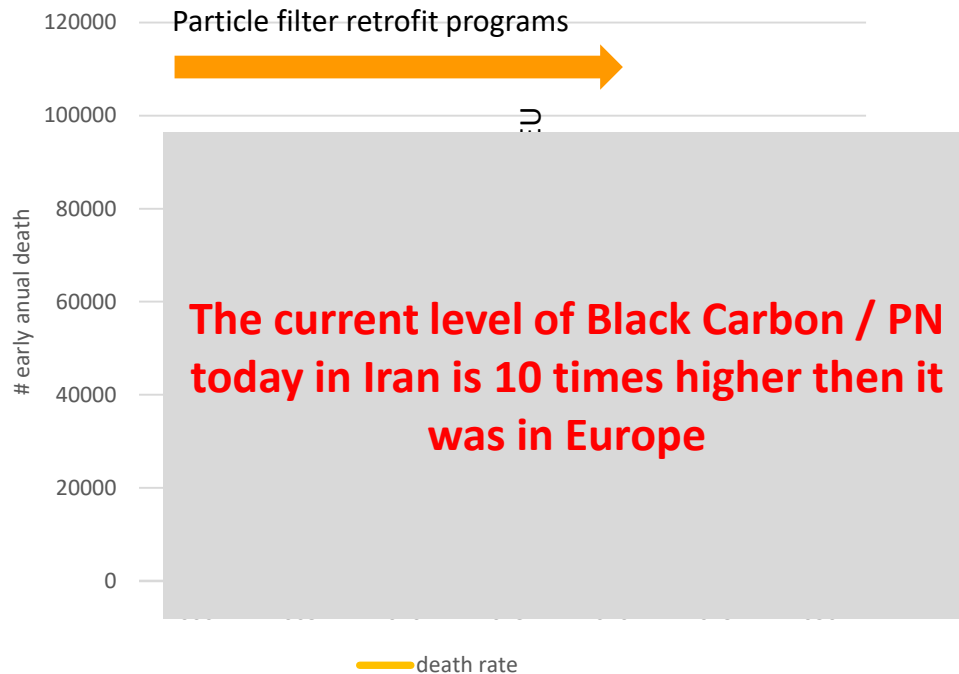
Lessons learned:

- European commission force the use of the best available technology (filter) to address UFP
- EURO I ... V without particle filters was not successful**
- Broad retrofit activities started early 2000 in Europa, USA, Korea and Japan
- USA introduced EPA '07 -> Particle Filters

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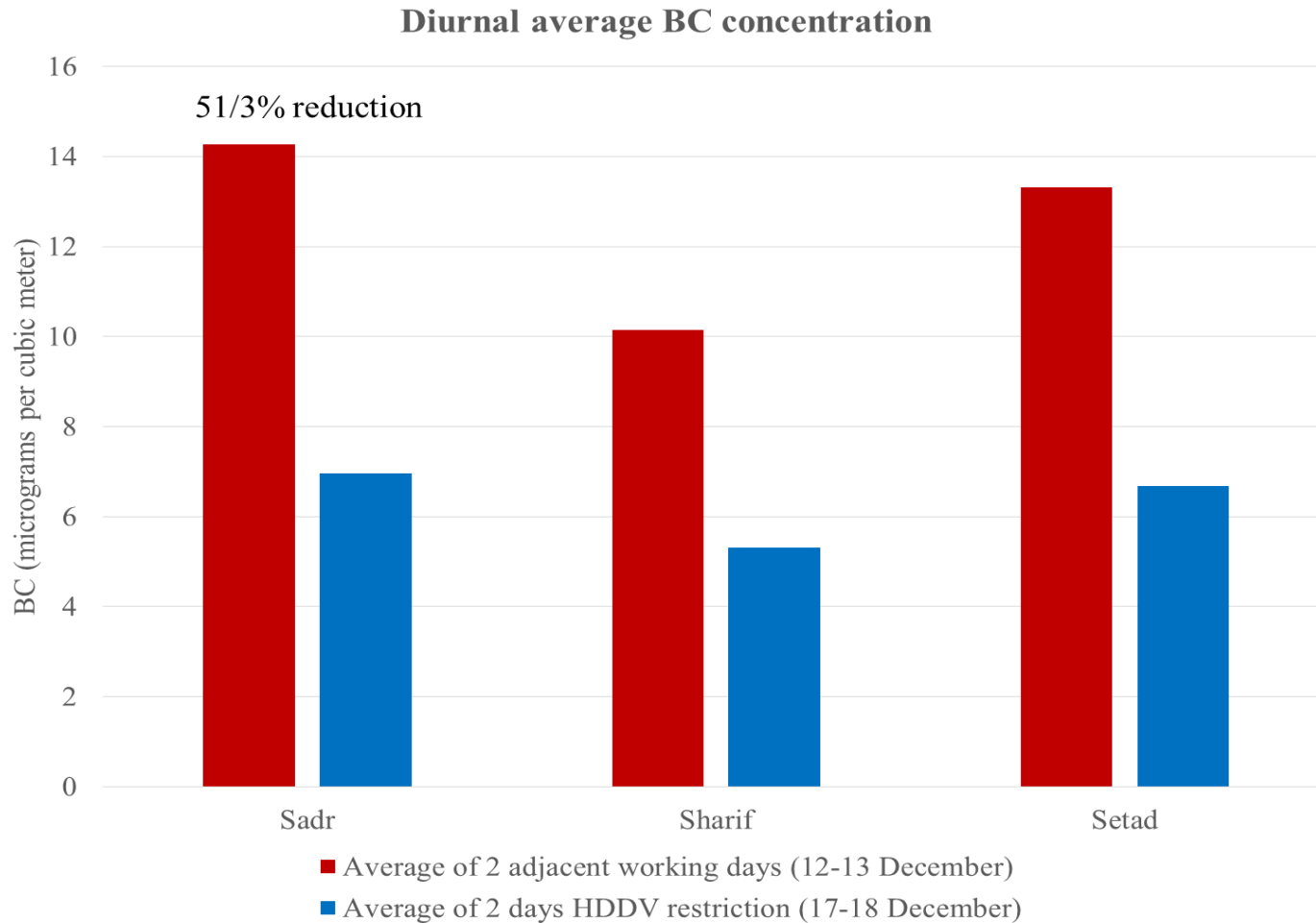
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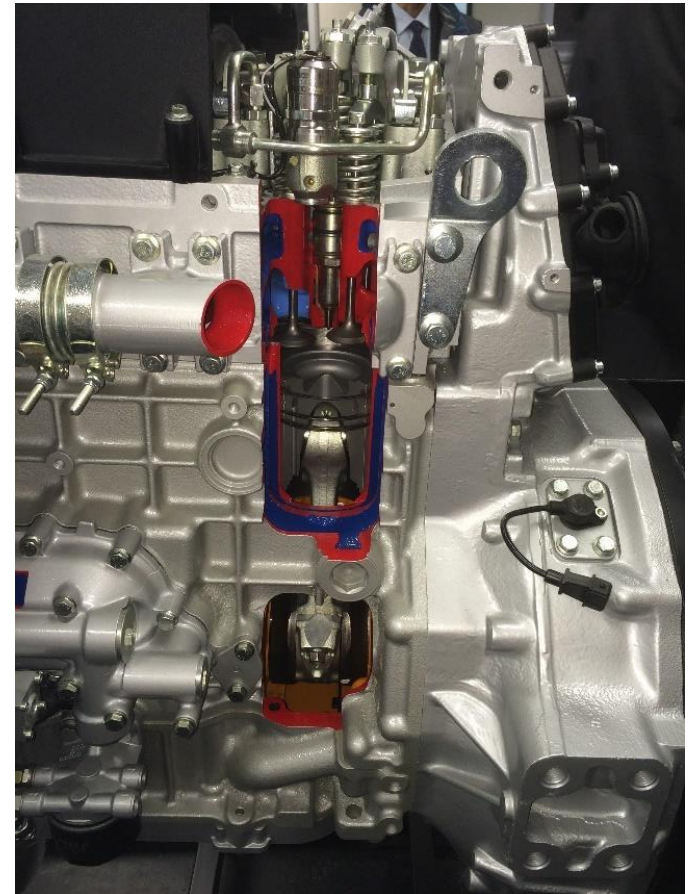
Air pollution Effects from Road Traffic



○ Substances of Diesel Exhaust

Substances of Diesel Exhaust

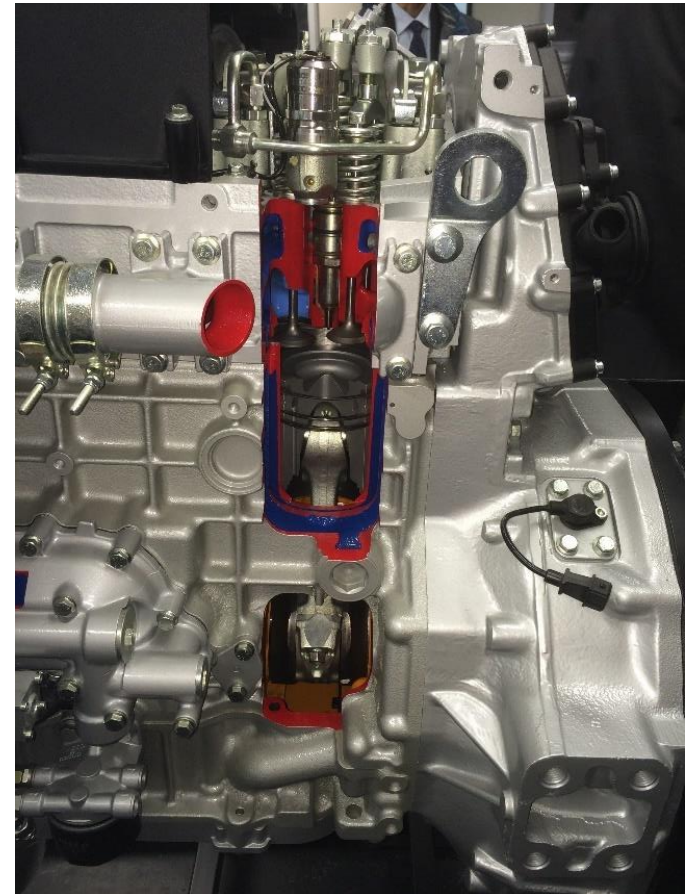
- Gases:
 - CO, CO₂,
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- Solid particles:
 - Soot particles
 - Ash particles
- Liquid droplets



○ Substances of Diesel Exhaust

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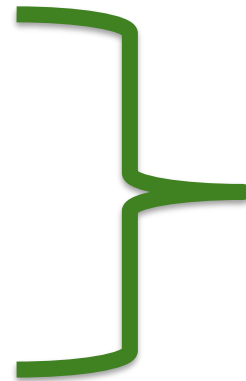
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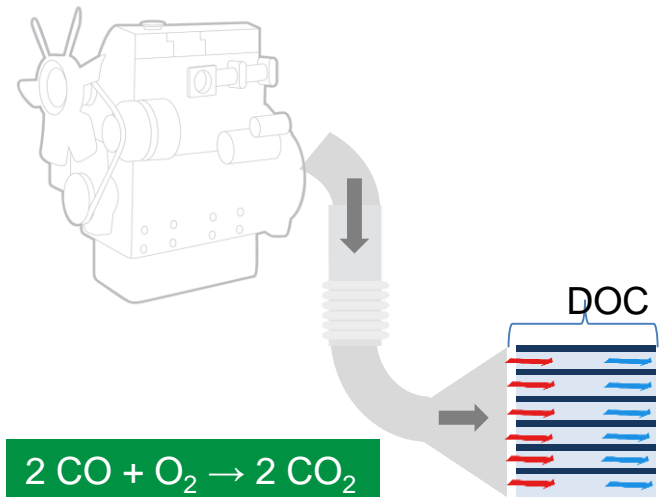
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Diesel Oxidation Catalyst (DOC)

Catalytic converter

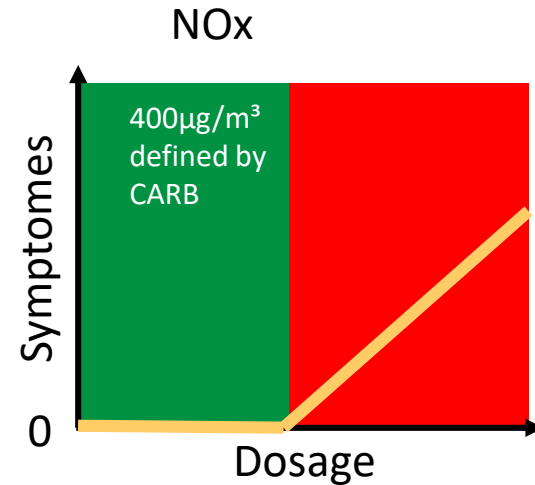
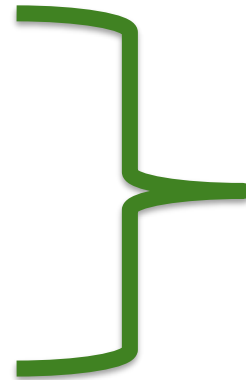


- Designed to oxidize carbon monoxide, gas phase hydrocarbons to CO₂ and H₂O
- **No reduction of Ultra Fine Particles**

Substances of Diesel Exhaust

Substances of Diesel Exhaust

- Gases:
 - CO, CO₂,
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- Toxic above 400 µg/m³
- Current value in cities 200 µg/m³
- Current Situation in most cities not critical to human health

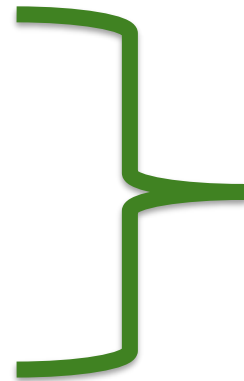
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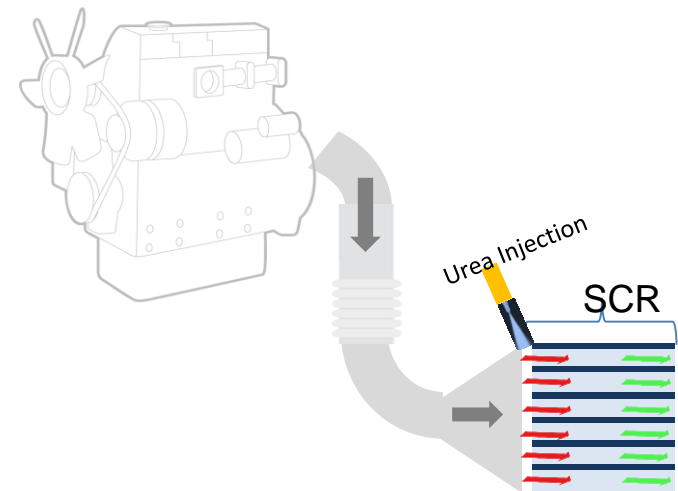
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Selectiv Catalystr Reduction (SCR)

Catalytic converter

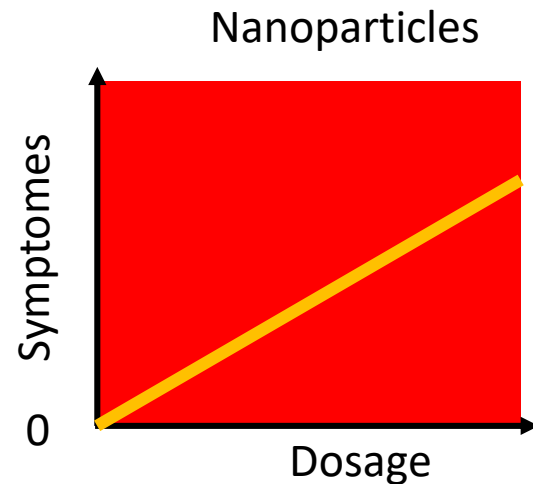
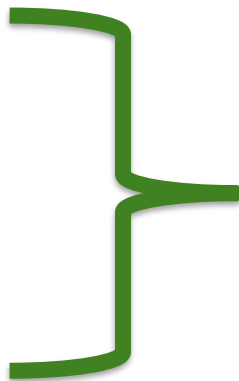


- Designed for selective catalytic reduction (SCR) of NOx
- **No reduction of Ultra Fine Particles**

Substances of Diesel Exhaust

Substances of Diesel Exhaust

- Gases:
 - CO, CO₂,
O₂,
HC,
NO, NO₂
- Solid particles:
 - **Soot particles**
 - **Ash particles**
- Liquid droplets



- Carcinogenic, no limit
- Has to be reduced as far as possible with Best Available Technology
- Current situation in cities highly critical – premature death

○ Substances of Diesel Exhaust

Substances of Diesel Exhaust

- Gases:
 - CO, CO₂,
O₂,
HC,
NO, NO₂

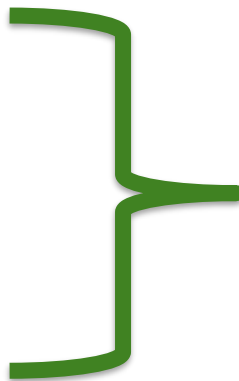
- Solid particles:
 - **Soot particles**
 - **Ash particles**

- Liquid droplets

- Very small 20 ... 500 nm
- High surface > 100 m²/g
- Transporting toxics persistent in organism
- Carcinogenic

Long life toxic aerosol (weeks to month)

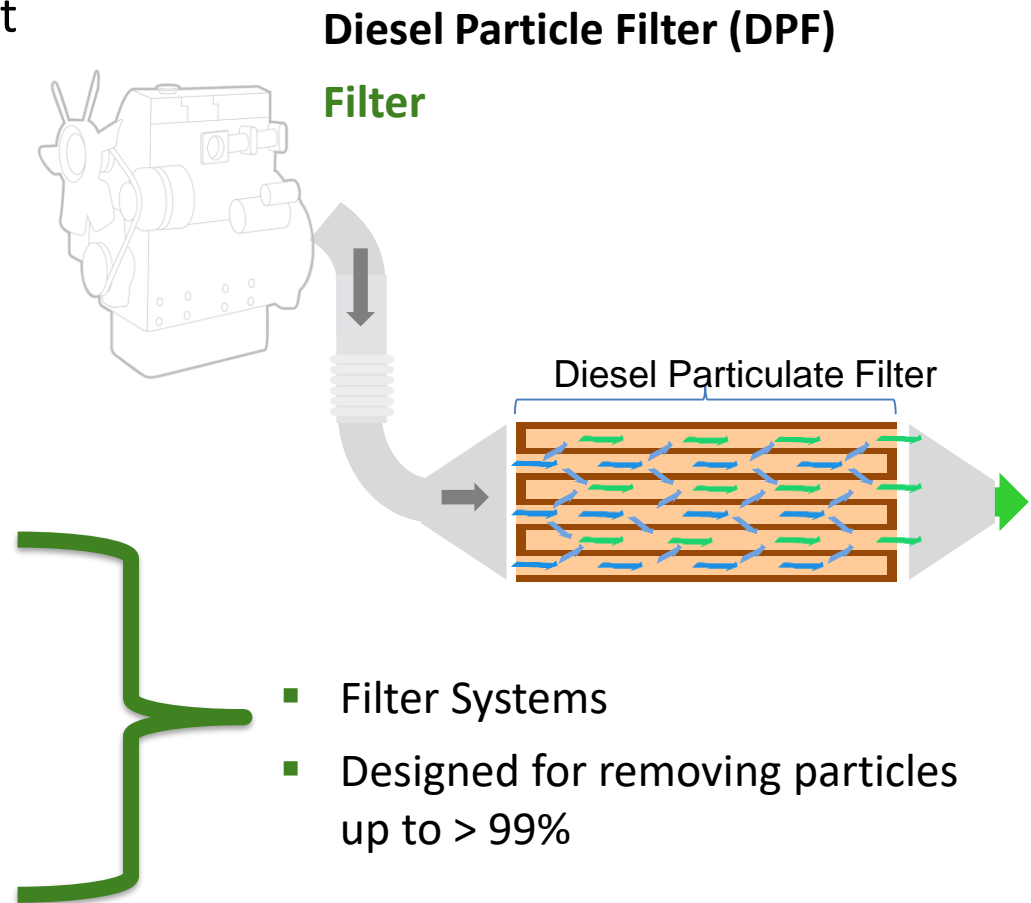
Defined by WHO since 2012 as evidenced carcinogenic (class 1 like asbestos)



Substances of Diesel Exhaust

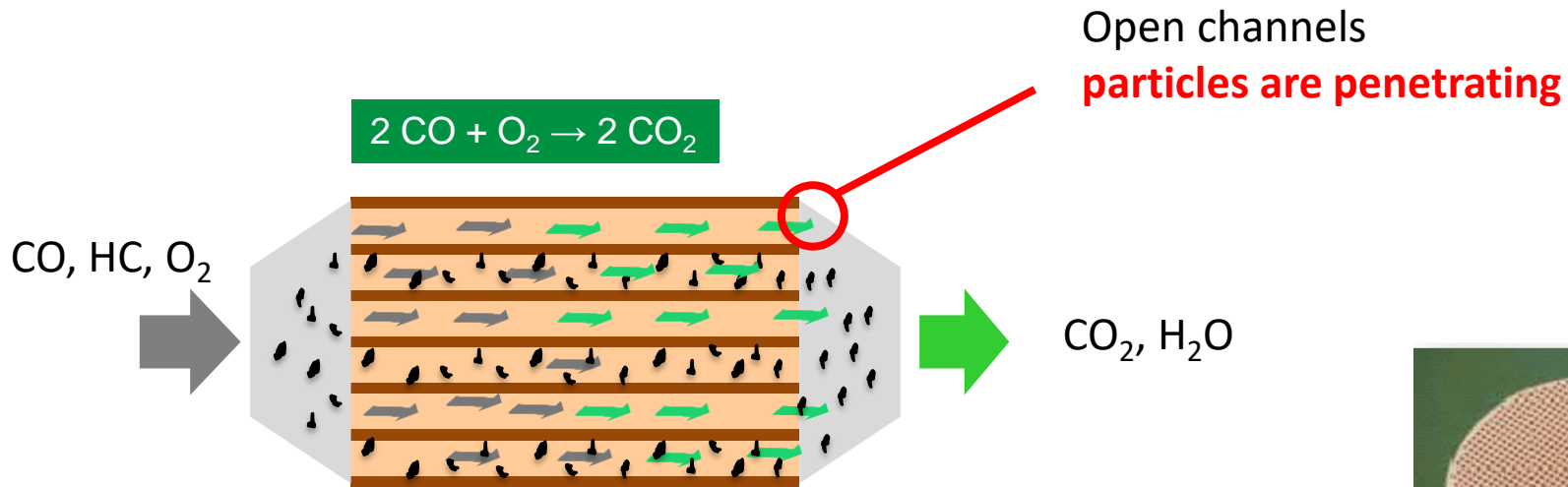
Substances of Diesel Exhaust

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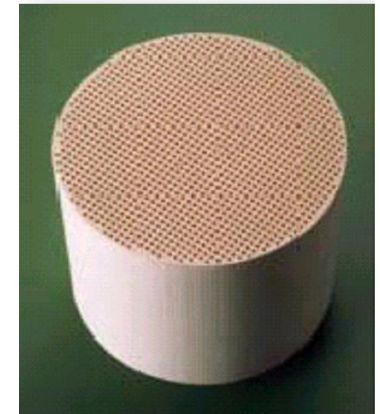


Substrates of Catalytic Converters and Filters

Diesel oxidation Catalyst

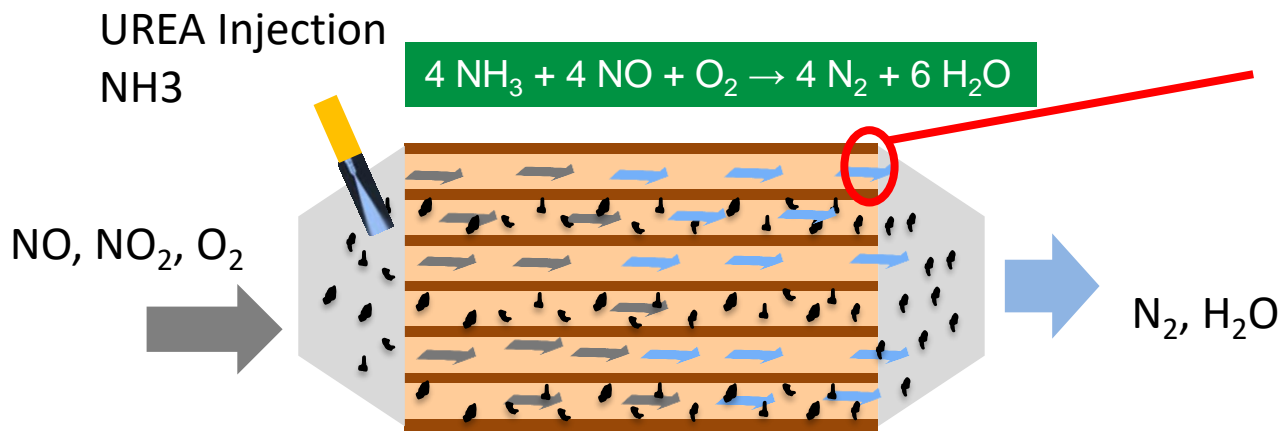


- Channels are open
- Substrate is coated
- Catalytic oxidation of CO to CO₂ and HC to H₂O and CO₂



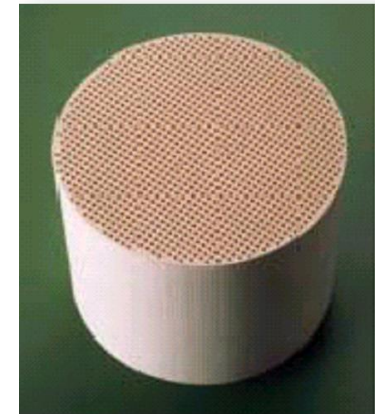
Substrates of Catalytic Converters and Filters

Selective Catalytic Reduction (SCR)



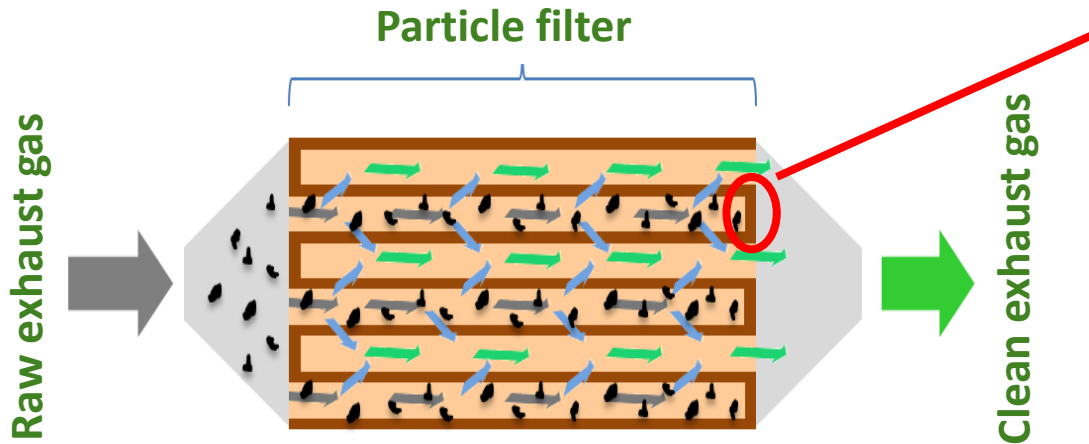
Open channels
**particles are
penetrating**

- Channels are open
- Substrate is coated
- Designed for selective catalytic reduction (SCR) of Nox by nitrogen compounds, such as ammonia or urea

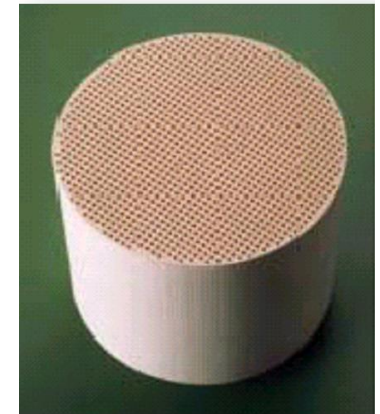


Substrates of Catalytic Converters and Filters

Filter Systems are holding > 99% of the particles back



Closed channels
particles **must pass**
the porous wall
(filtering)



- Channels are reciprocally closed
- Exhaust gas is forced to penetrate permeable walls
- Soot particles are hold back and collected on the walls of the filter material

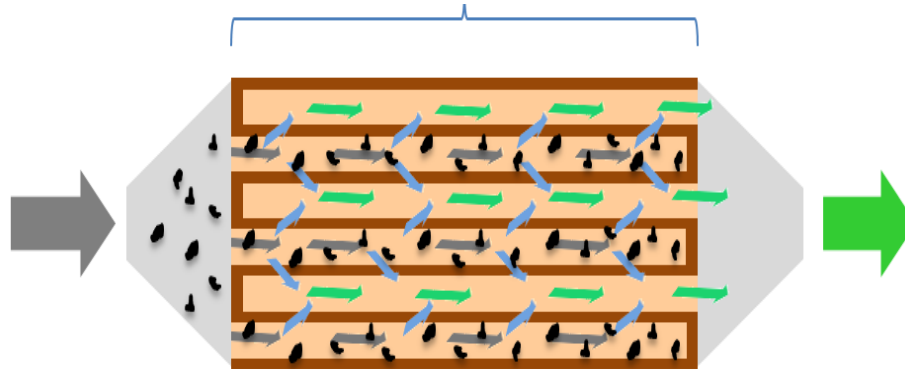
○ Introduction | Technical Concept of a Diesel Particulate Filter

Filter Systems are holding > 99% of the particles back

Inlet side of filter



Particle filter



Outlet side of filter



- Real results from a vehicle > 1,200 hours in operation
- Coach bus | age at retrofit 20 years
- Engine: DD Series 60; 470hp @ 2100 rpm

○ Technology Comparison

Substance	DOC	SCR	Particle Filter
HC, CO	90% reduction	No reduction	No reduction
NO _x	No reduction	90% reduction	No reduction
Particles	No reduction	No reduction	> 99% reduction

- Emission Control Systems are designed for specific substances
- Pollution / Ultra Fine Particles can only be removed with filters

○ Vehicles offered in the Iranian market

- **EURO III plus Filter** | Retrofit or Option Fit
 - DOC | **No SCR** | Diesel Particle Filter
 - -> **No NO_x reduction** ¹⁾ | Particle reduction > 99%

- **EURO IV plus Filter** | OEM (First Fit)
 - DOC | SCR | Diesel Particle Filter
 - -> NO_x reduction | Particle reduction > 99%

- **EEV (Enhanced Environmental Friendly Vehicles)** | OEM (First Fit)
Sold in Europe from 1999 to 2013
 - DOC | SCR | **No Diesel Particle Filter**
 - -> NO_x reduction | **no reduction of Particles**

¹⁾ Means on a conversion rate of 90%, EGR is supporting lower NO_x conversion rates

EEV in Comparison to EURO IV and EURO VI Vehicles offered in the Iranian market

EURO IV	CO	HC g/kWh	NOx	PM	PN 1/kWh
EURO IV	1.5	0,46	3,5	0,02	---
EEV	1.5	0,25	2,0	0,02	---
EURO VI	1.5	0,13	0,4	0,01	8x10 ¹¹

- Iranian EURO III + Filter and EURO IV + Filter are on EURO VI level with respect to particles
- The EEV Standard does not support particle reduction

The effect of SCR and Filter Technology

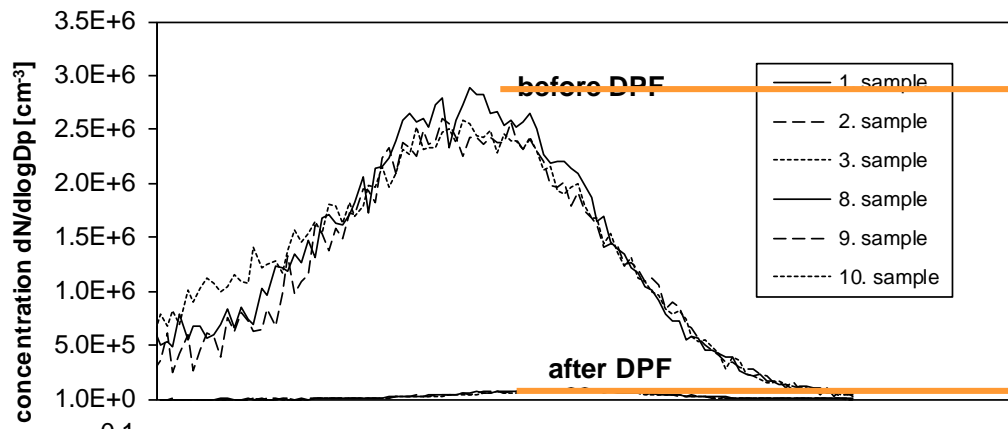


Vehicle

- MAN TGS
- 397 kW

Aftertreatment system

- OEM SCR
- DPF retrofitted



Particle reduction 99.7 % by Filter

- Full flow filter
- Retrofit is as efficient as first fit
- SCR only is not removing particles

○ Take Home Message

- Catalytic Converters are efficient to reduce toxic diesel emission gases
- Catalytic converters don't reduce carcinogenic Ultra Fine Particle
- Focus in Air Control shall be Ultrafine Particle reduction with respect to health effects
- Filters are reducing > 99% of these carcinogenic Ultra Fine Particles
- Iranian solution EURO III + filter and EURO IV + filter are suitable solutions to reduce carcinogenic Ultra Fine Particles
- EEV (Enhanced Environmental Friendly Vehicles) reduce NOx but not Ultra Fine Particles