Parker Hannifin Corporation
Racor Division

Nonwoven Filter Media : Fuel Filtration a Case Study

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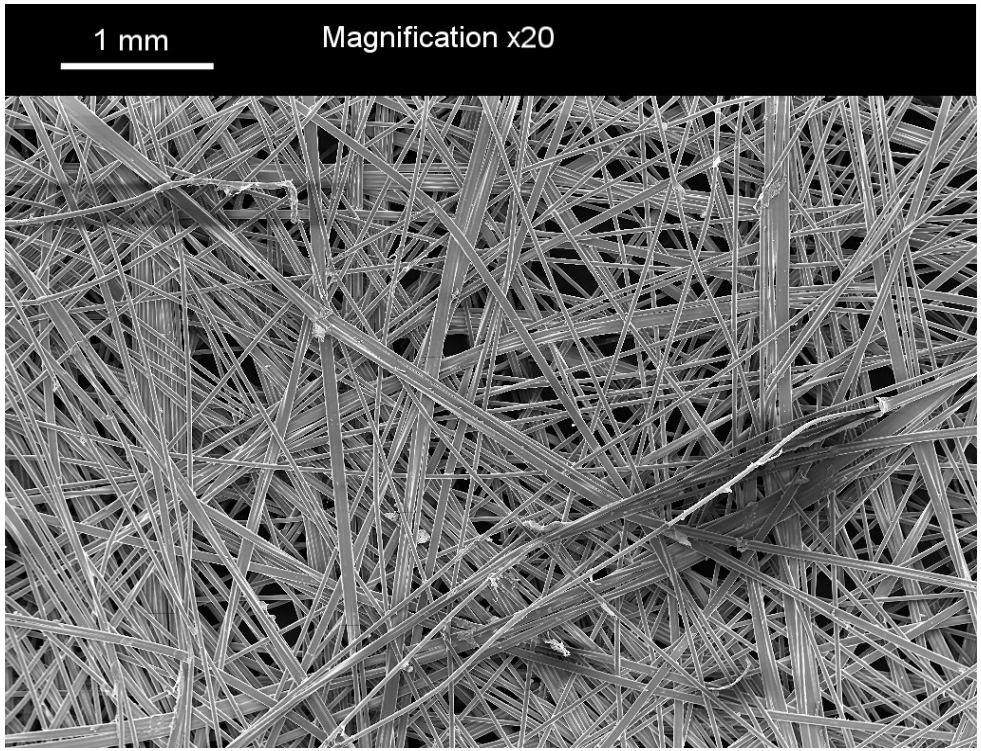
ENGINEERING YOUR SUCCESS.

Overview

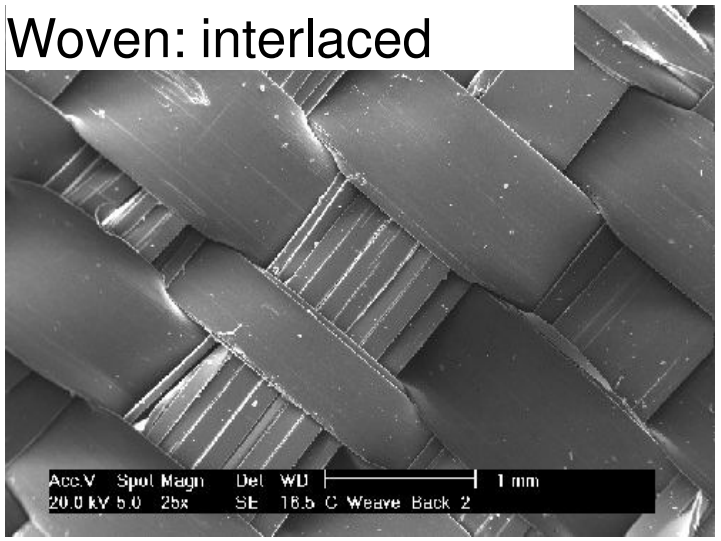
- What is a nonwoven ?
- Applications and uses.
- Filtration Terminology.
- Fuel Filtration – a case study

What is a nonwoven fabric?

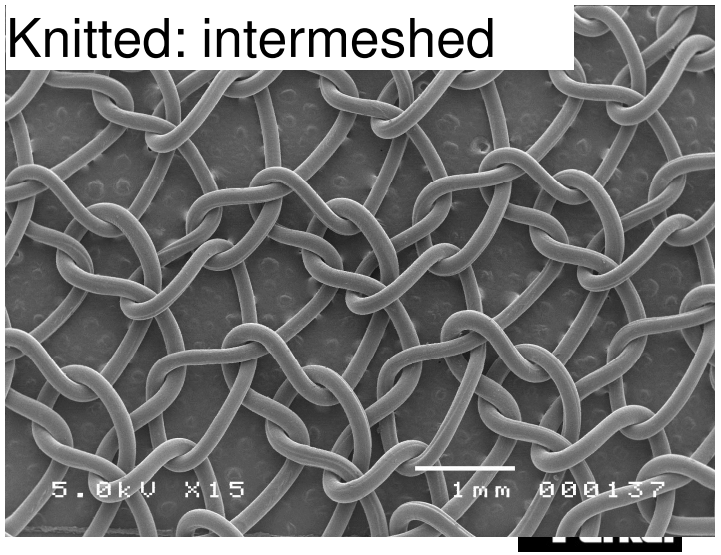
"A fabric made directly from a web of fibre (or filaments), without the yarn preparation necessary for weaving and knitting".



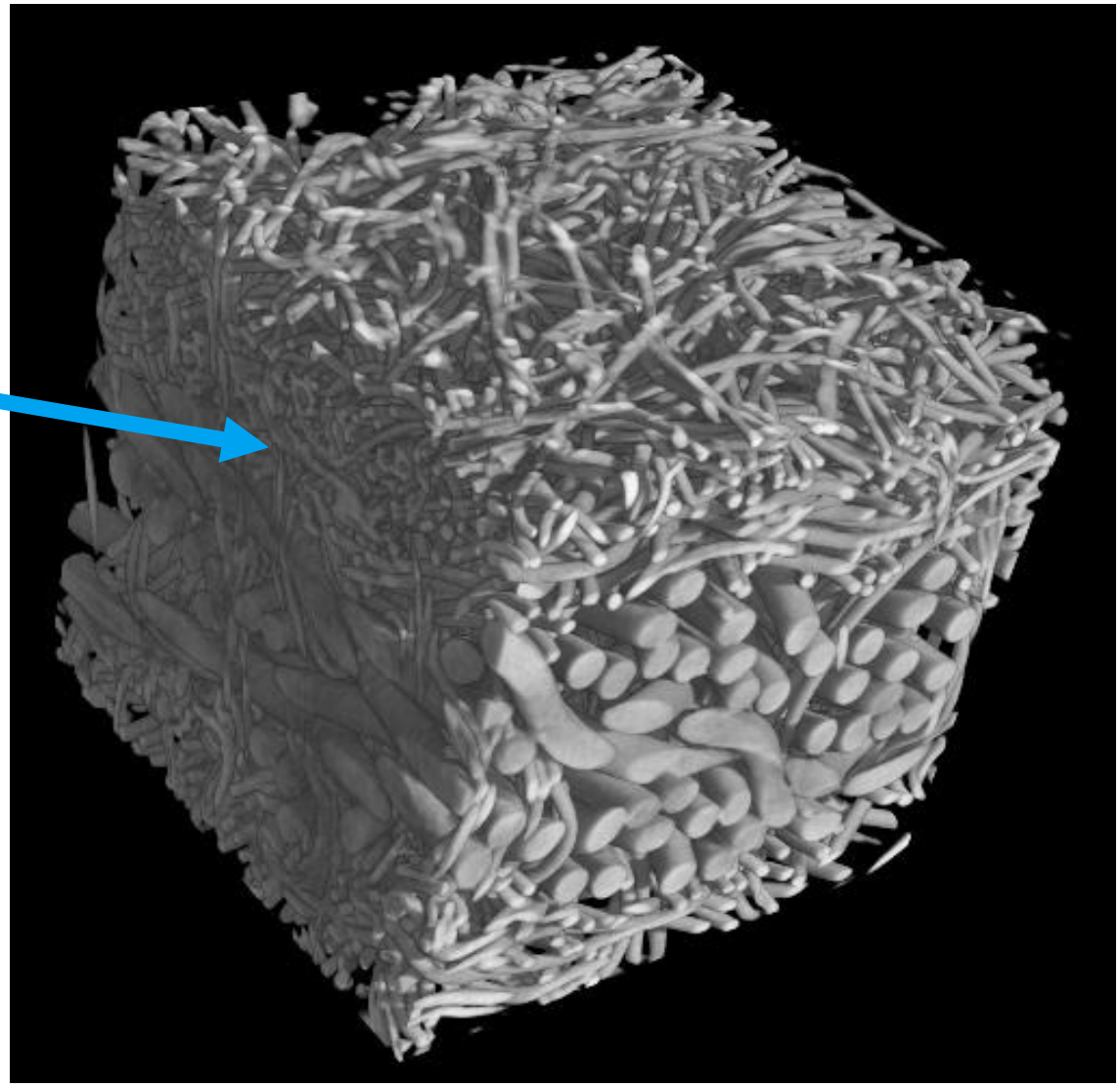
Woven: interlaced



Knitted: intermeshed



What is a nonwoven?



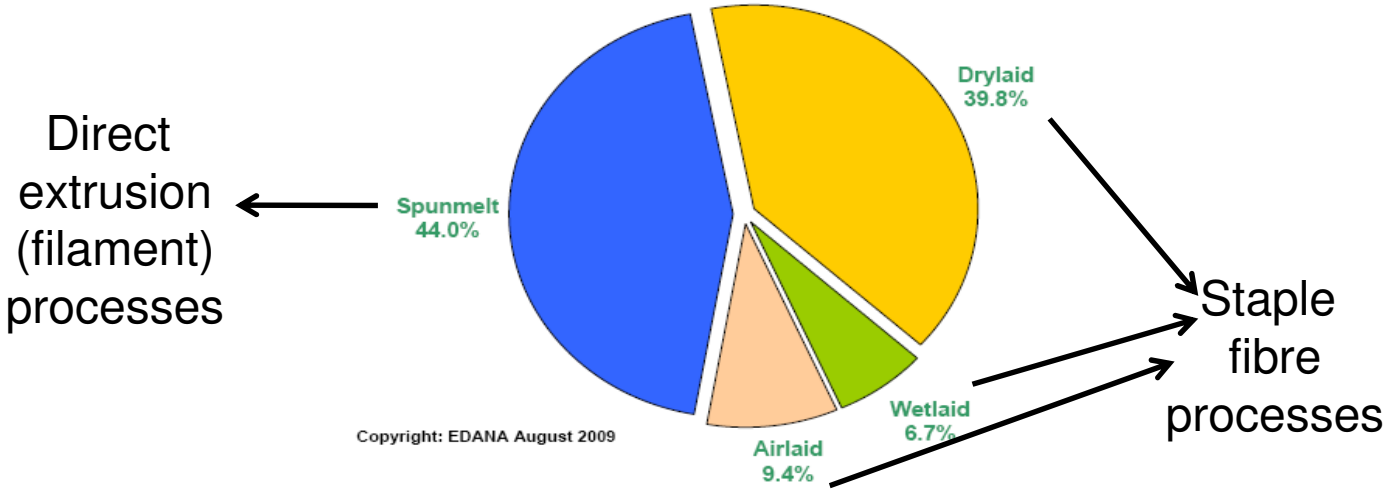
A bonded fibrous assembly made of fibres or filaments with a complex architecture

- Bonded Fibre Webs

Web Forming

- Drylaid – carding, carding & lapping (cross or vertical), airlaying
- Wetlaid – derived from papermaking
- Spunmelt (polymer-laid) – filament extrusion, e.g. Spunlaid; Meltblown; Electrospun

Web Forming Production Methods (Europe: % tonnes)



Process	2006		2007		2008	
	,000 T	Δ %	,000 T	Δ %	,000 T	Δ %
Spunmelt *(1)*	710.6	*9.4*	776.5	*9.3*	758.7	*-2.3*
Drylaid *(2)*	623.8	*5.8*	659.6	*5.7*	685.7	*4.0*
Wetlaid	106.8	*8.8*	107.8	*0.9*	115.7	*7.4*
Airlaid	140.2	*5.7*	154.8	*10.4*	162.3	*4.8*
Total	**1,581.4**	*7.6*	**1,698.7**	*7.4*	**1,722.4**	*1.4*

(1) Includes spunlaid and other polymer-based processes e.g. meltblown, flashspun by extension as well as composites of these fabrics (e.g. SMS...)

(2) Basically groups thermal and chemical bonding, plus needling or stitching only and hydroentangled webs. Does not include any airlaid products. The weight of adhesives, additives and similar chemicals has been taken into account in addition to binders.

Nonwovens are “Bonded” Webs

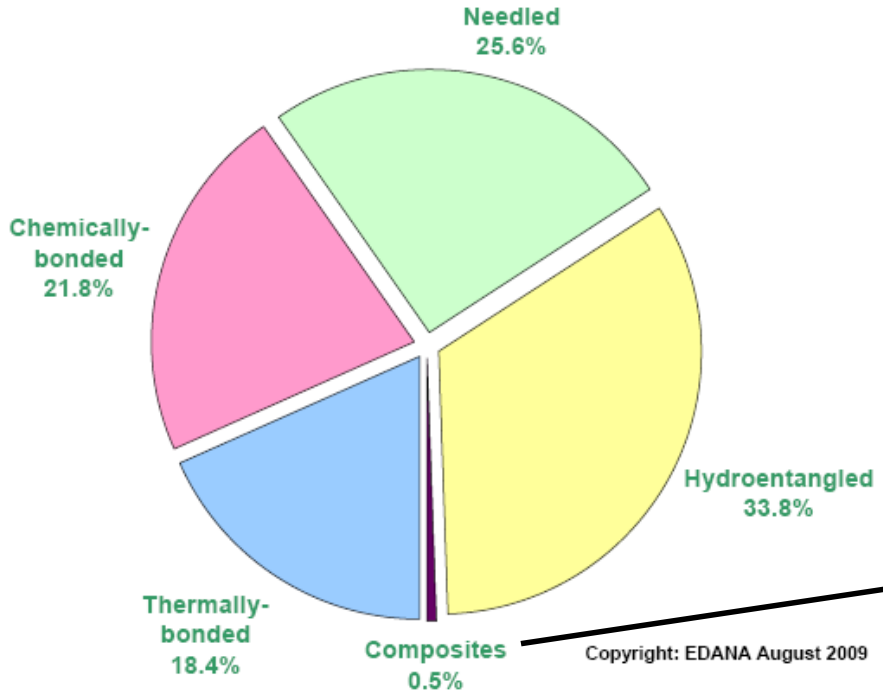
- In a nonwoven, the assembly of textile fibres is held together:

- 1. by mechanical interlocking in a random web or batt, → Mechanical bonding

- 2. by melt-fusing the fibres in the case of thermoplastic fibres, → Thermal bonding

- 3. by bonding with a cementing medium (natural or synthetic adhesive). → Chemical bonding

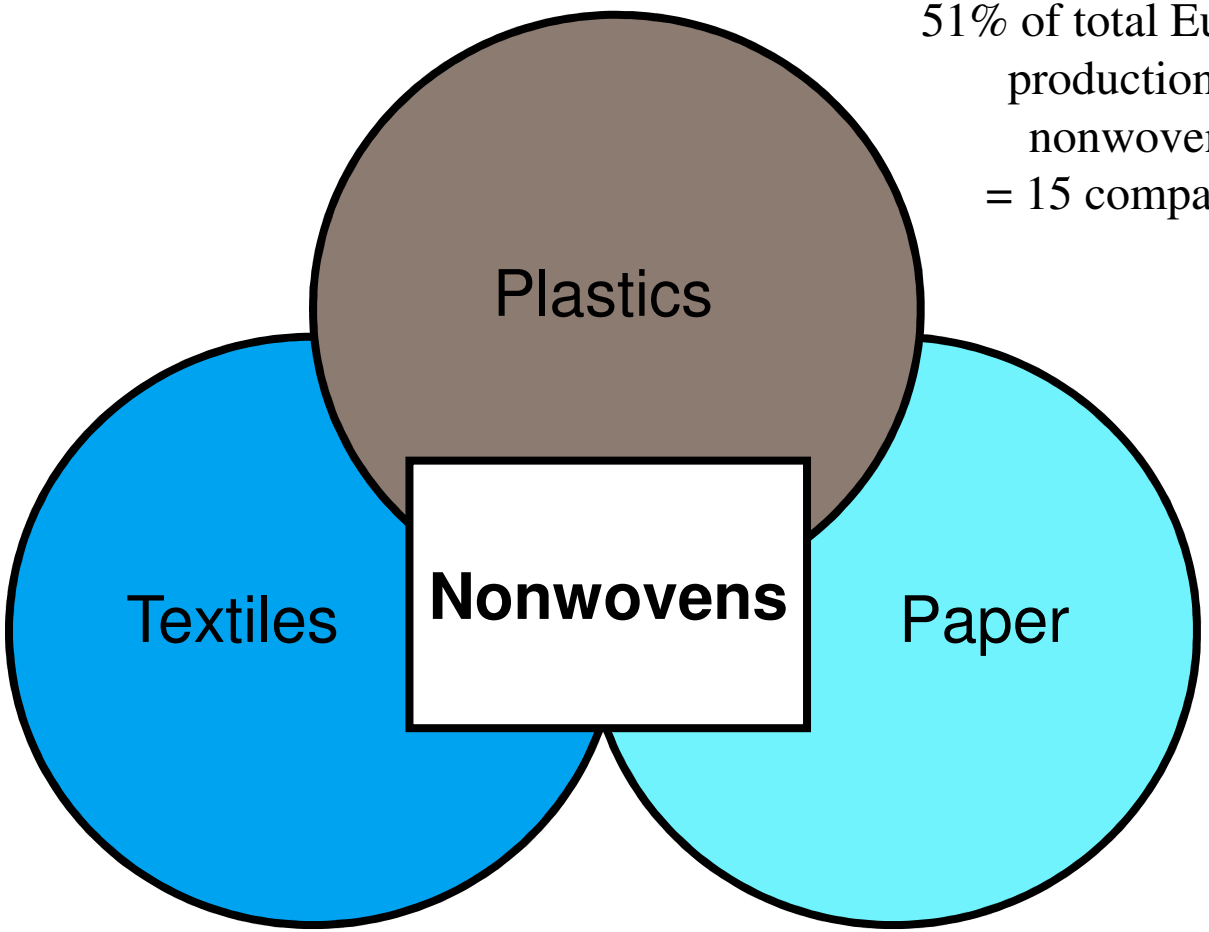
Web Bonding Production Methods (Europe: % tonnes)



Combination of technologies

Process	2006		2007		2008	
	,000 T	Δ %	,000 T	Δ %	,000 T	Δ %
Thermally-bonded	123.7	*-4.5*	127.5	*3.1*	126.2	*-1.0*
Chemically-bonded	150.9	*5.1*	157.8	*4.6*	149.5	*-5.3*
Needled	147.1	*16.8*	160.9	*9.4*	175.4	*9.0*
Hydroentangled	194.3	*9.1*	208.3	*7.2*	231.5	*11.1*
Composites	7.8	*-35.8*	5.1	*-35.0*	3.2	*-37.9*
Total Drylaid	**623.8**	*5.8*	**659.6**	*5.7*	**685.7**	*4.0*

Convergence of 3 industries

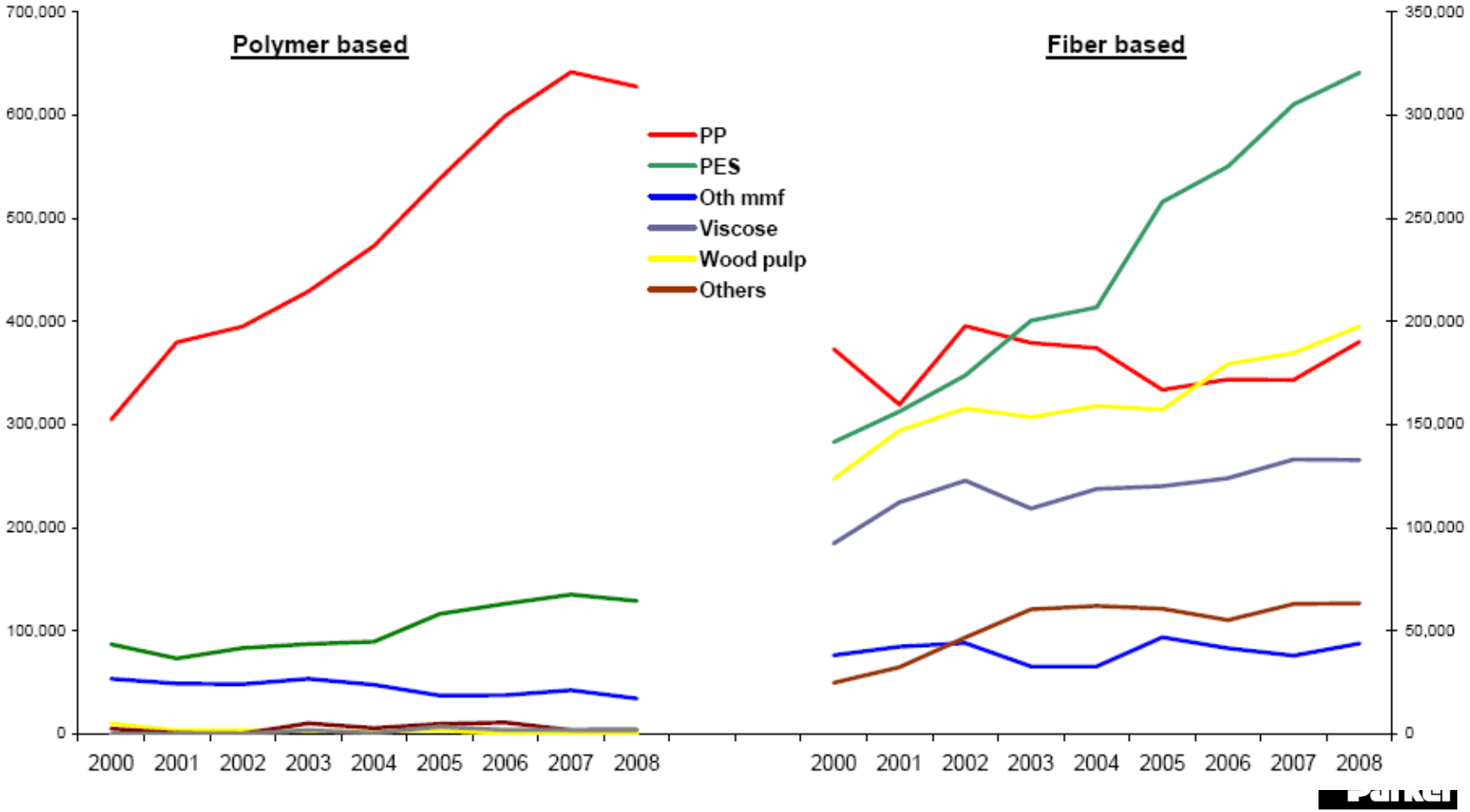


51% of total European production of nonwovens = 15 companies →

Ahlstrom,
Albis,
Buckeye,
Concert,
DuPont,
Fibertex,
Fiberweb,
Freudenberg,
Glatfelter Schoeller,
Johns Manville,
PEGAS,
Rex-Cell,
Sandler,
Tesalca/Texnovo,
Union.

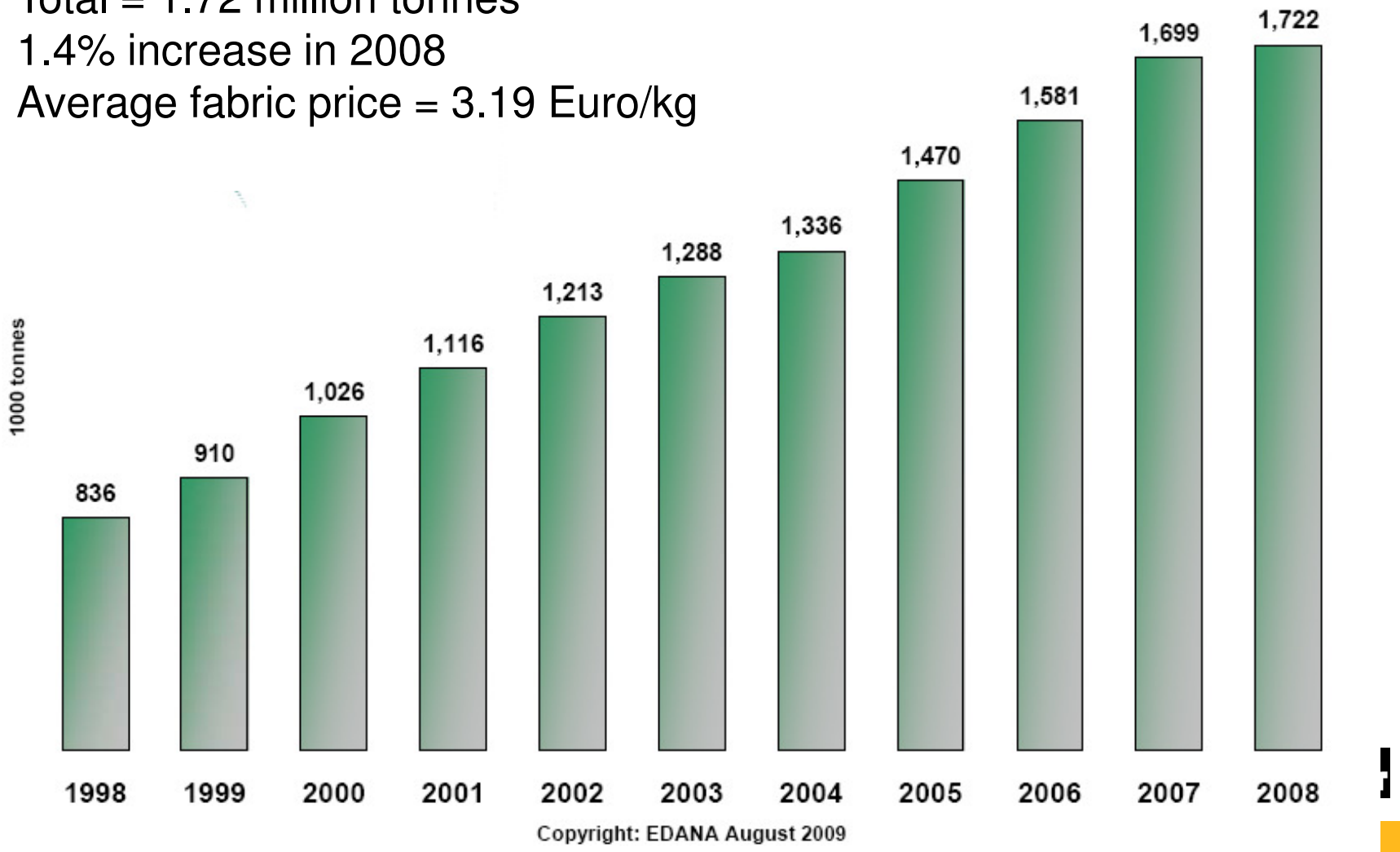
Polymer utilisation in nonwoven fabrics

Filament form (left) and Fibre form (right) - Tonnes



European Production of Nonwovens (10^3 tonnes)

Total = 1.72 million tonnes
1.4% increase in 2008
Average fabric price = 3.19 Euro/kg



Overview

- What is a nonwoven ?
- Applications and uses.
- Filtration Terminology
- Fuel Filtration – a case study

Product Lifespan

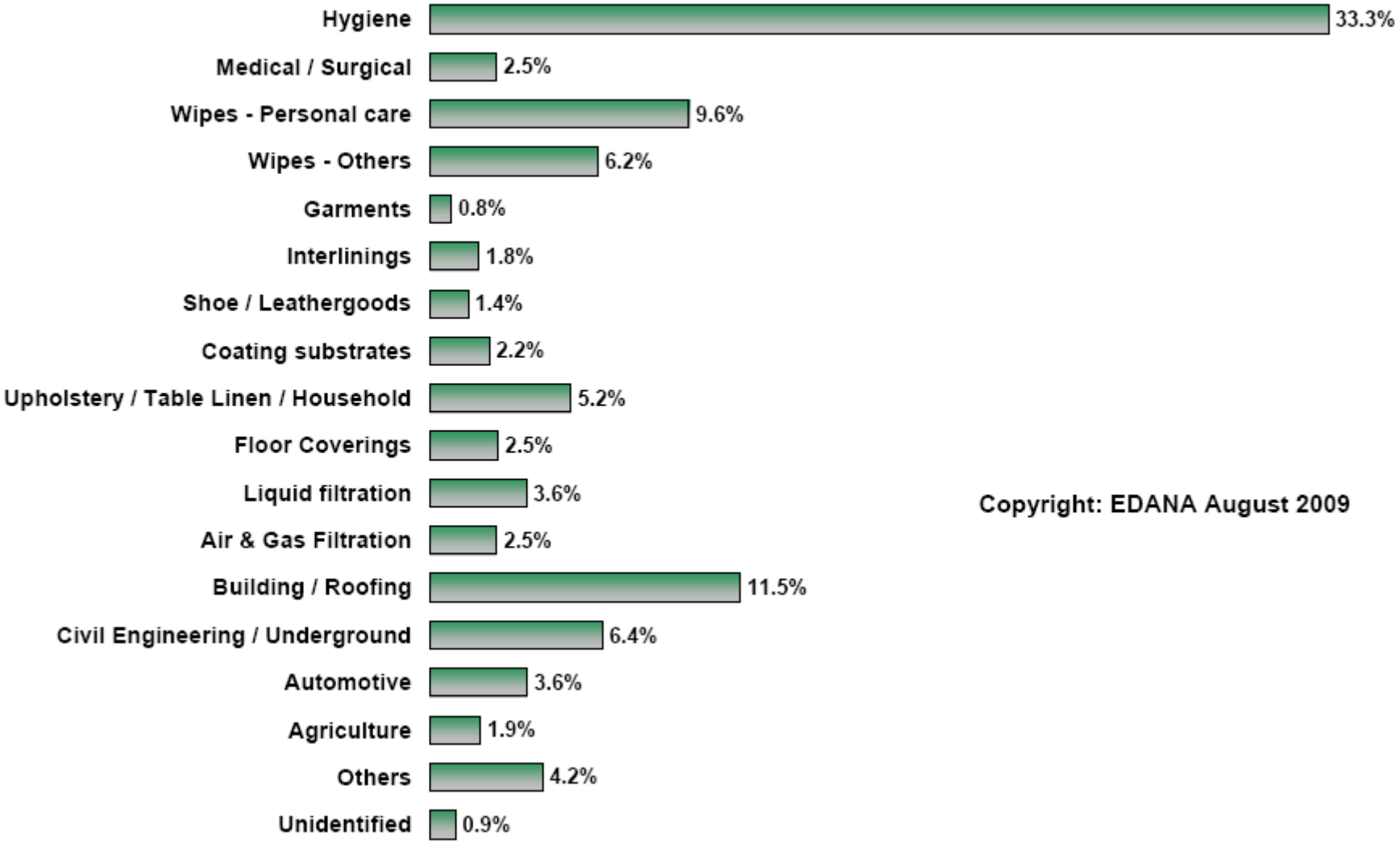
Product Life:
Disposable vs Durable

USE: Wipes, Tea bags, Protective Clothing, Fuel Filters, Linings for clothing, Upholstery

LIFE: Seconds, Minutes, Hours, Months, Years

DISPOSABLE (short life) → DURABLE (long life)

Major applications (tonnes)



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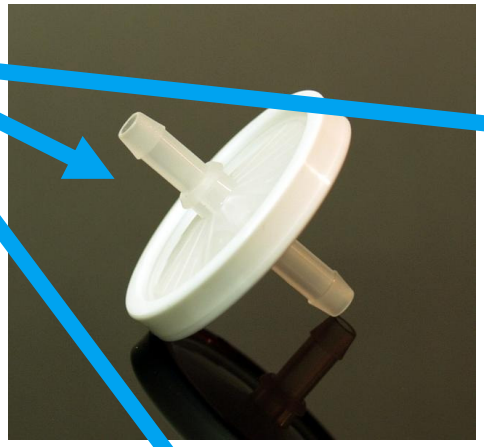
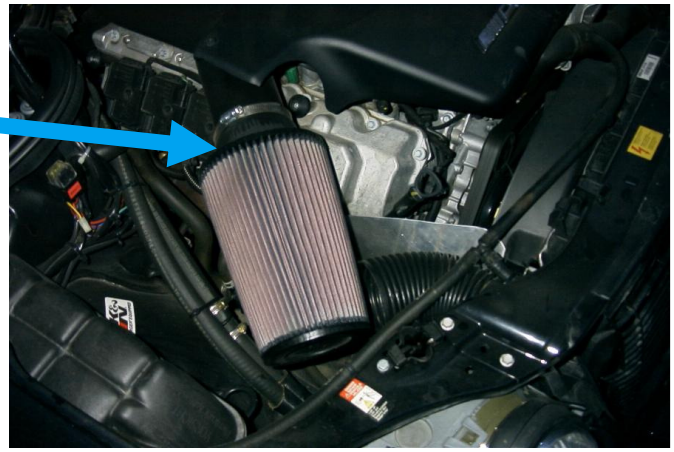
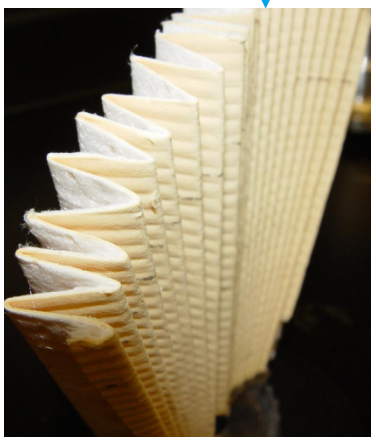
Filtration (of liquid, air, gas)

Air & gas filters (HEPA - 99.97%; ULPA-99.999%)

Liquid – oil / fuel, water, food and beverages….



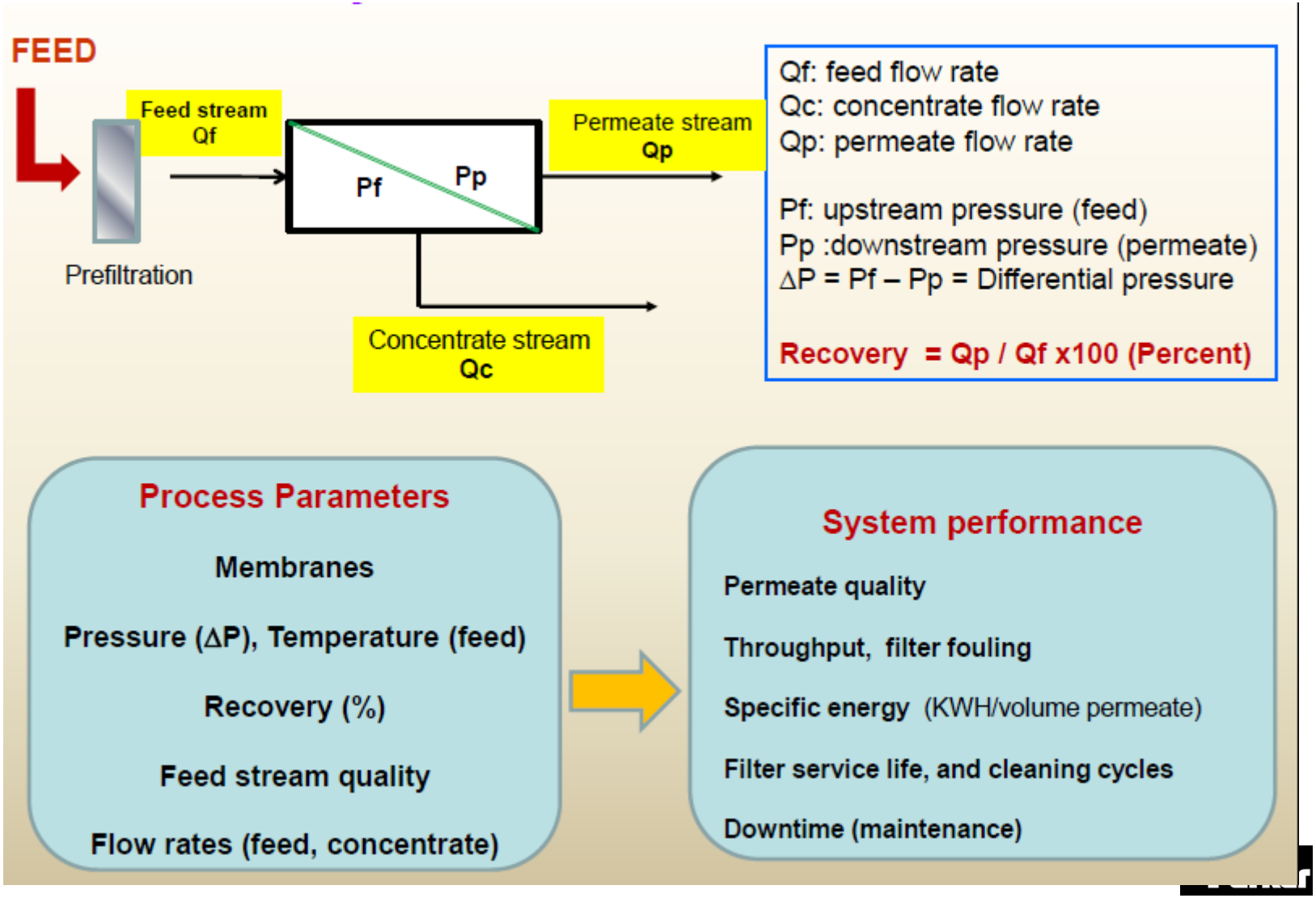




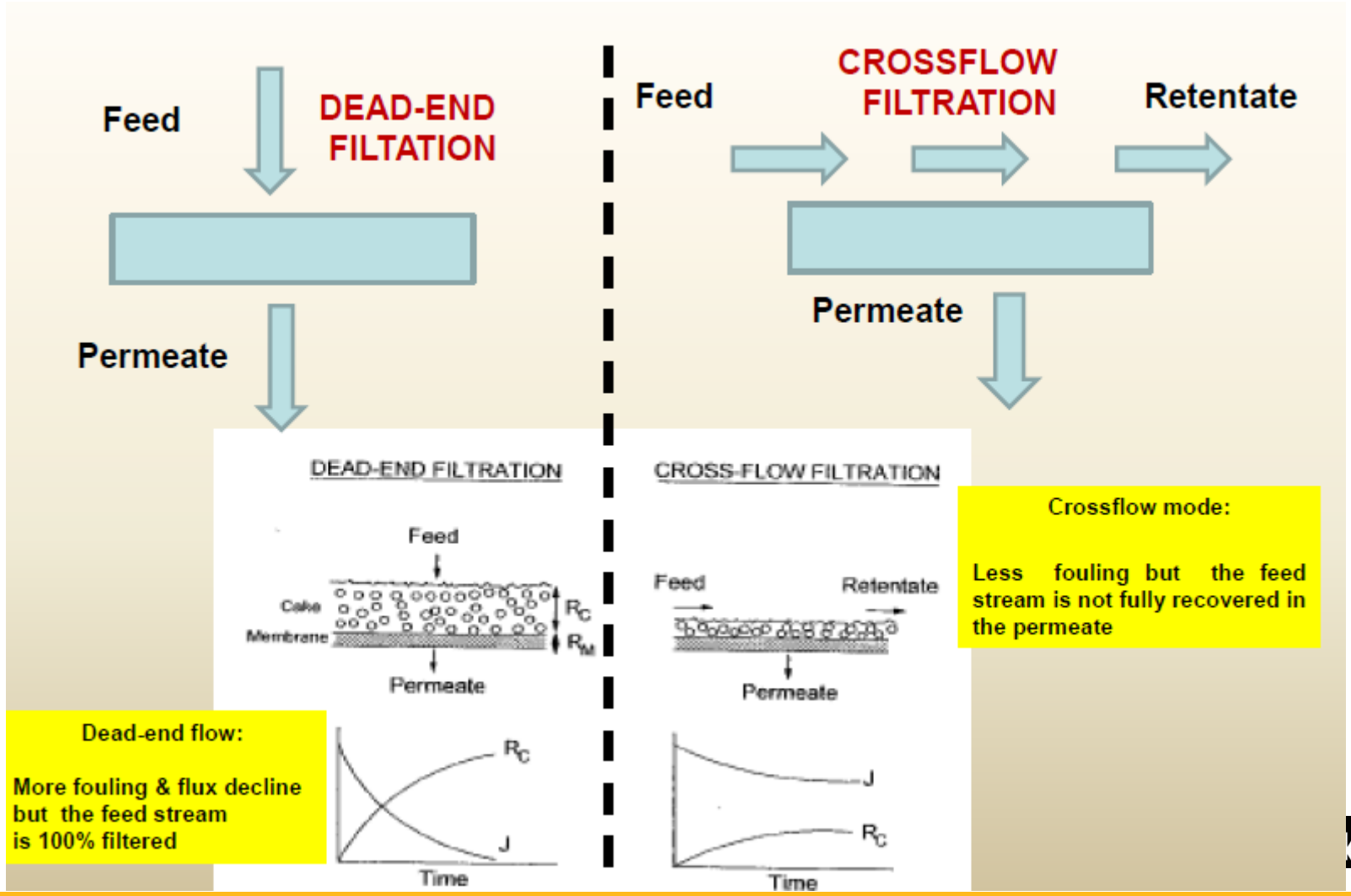
Key Terms Defined…

- Filtration refers to the act of separating one or more distinct phases from another in a process which uses physical differences in the phases – such as particle size or density or electric charge.
- A *filter medium (or media)* is any material, that under the operating conditions of the filter, is permeable to one or more components of a mixture, solution or suspension and is impermeable to the remaining components.
- The operation of a filter usually needs a pressure differential across the filter medium, and this can be effected by means of fluid pressure upstream of the medium (pressure filters) or suction downstream (vacuum filters).

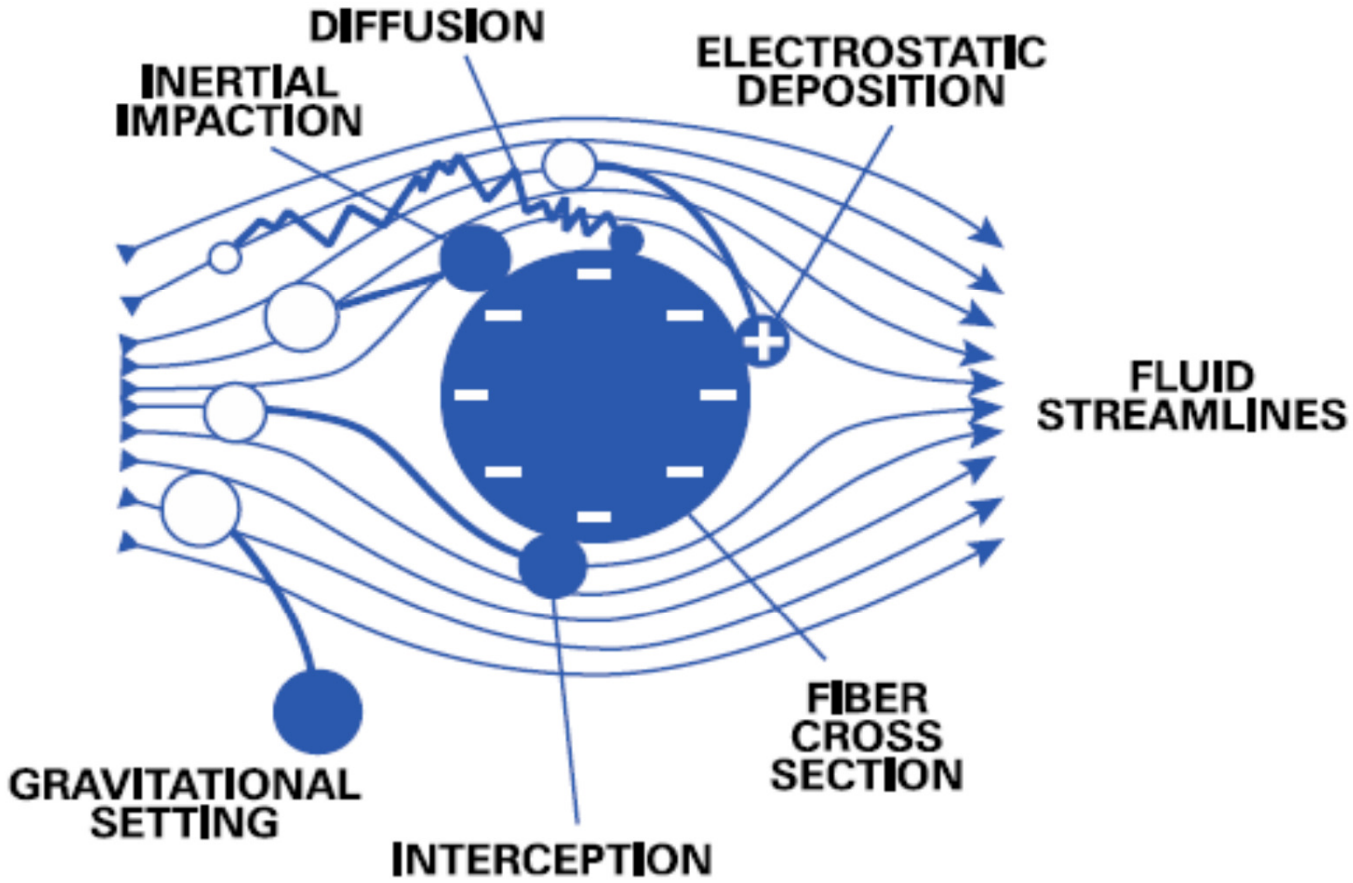
Filtration System and Process Parameters



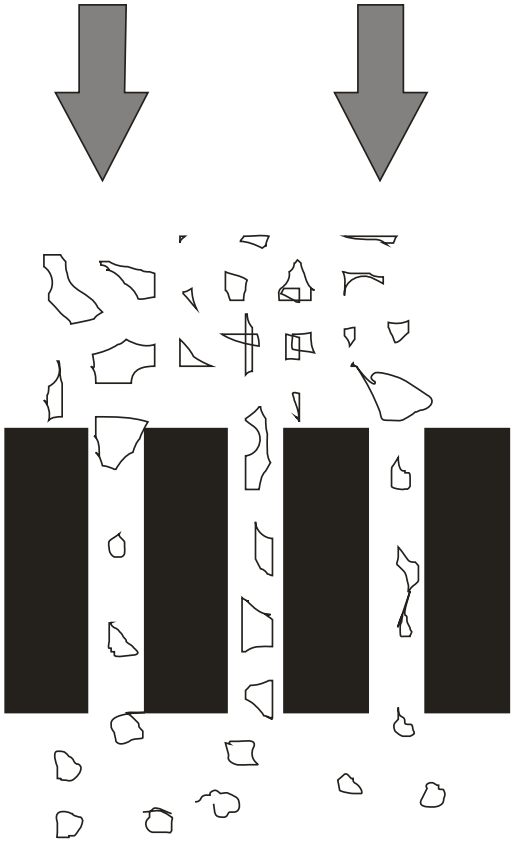
2 Modes of Filtration



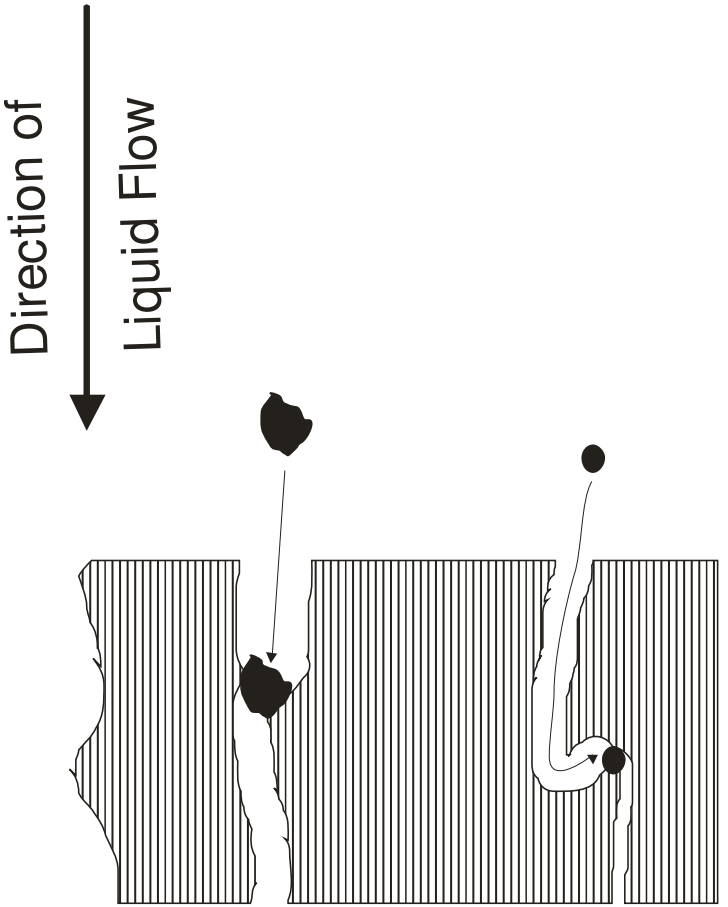
Basic filtration mechanisms – Micro Level



Filtration Mechanism – Macro Level

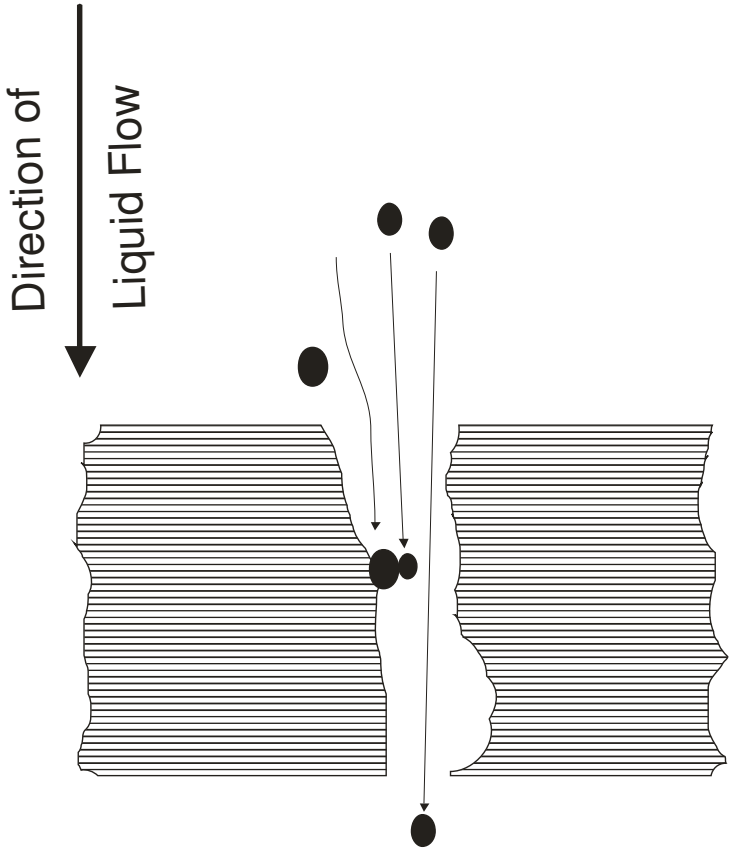


Surface Straining

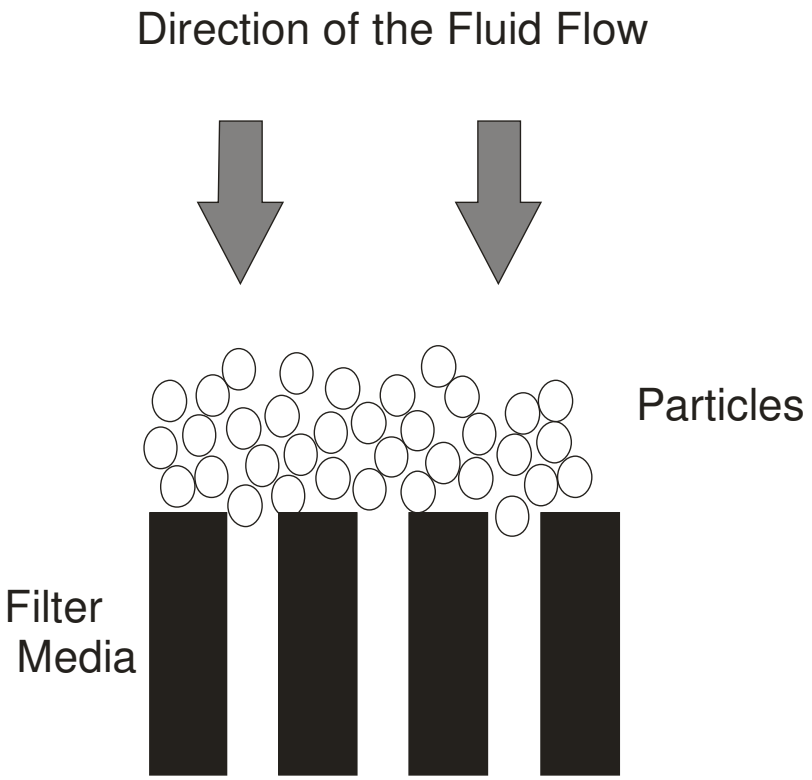


Depth Straining

Filtration Mechanism – Macro Level



Depth
Filtration

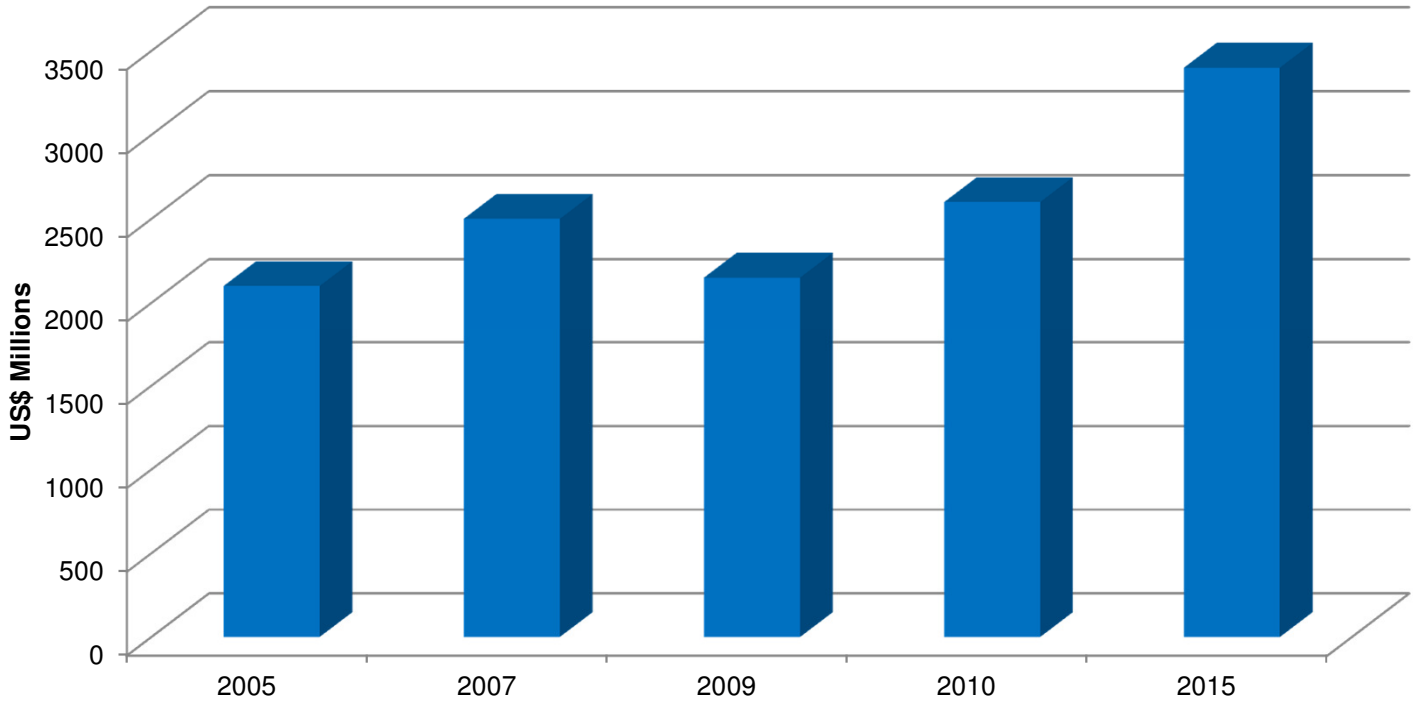


Cake
Filtration

Overview of Markets for Basic Type of Non-woven Media

Market Segment	Type of non-woven media				
		Bonded Media			
				Spun Media	
	Needle felt	Dry laid	Wet laid	Spunbonded	Meltblown
Air Filters		x		x	x
Fabric Dust Filters	x				
Tea Bags			x		
Coffee Bags		x			
Milk		x			x
Vacuum Cleaner Bags	x		x		x
Edible Oil			x		x
Face Masks	x	x			
Food & Beverages			x	x	
Fuel & oil	x		x	x	x

Global Market for Non-woven Filter Media 2005 – 2015 (Projected) US $ Millions



From, BCCResearch.com
"Nonwoven Filter Media: Technologies and Global Markets" 2011

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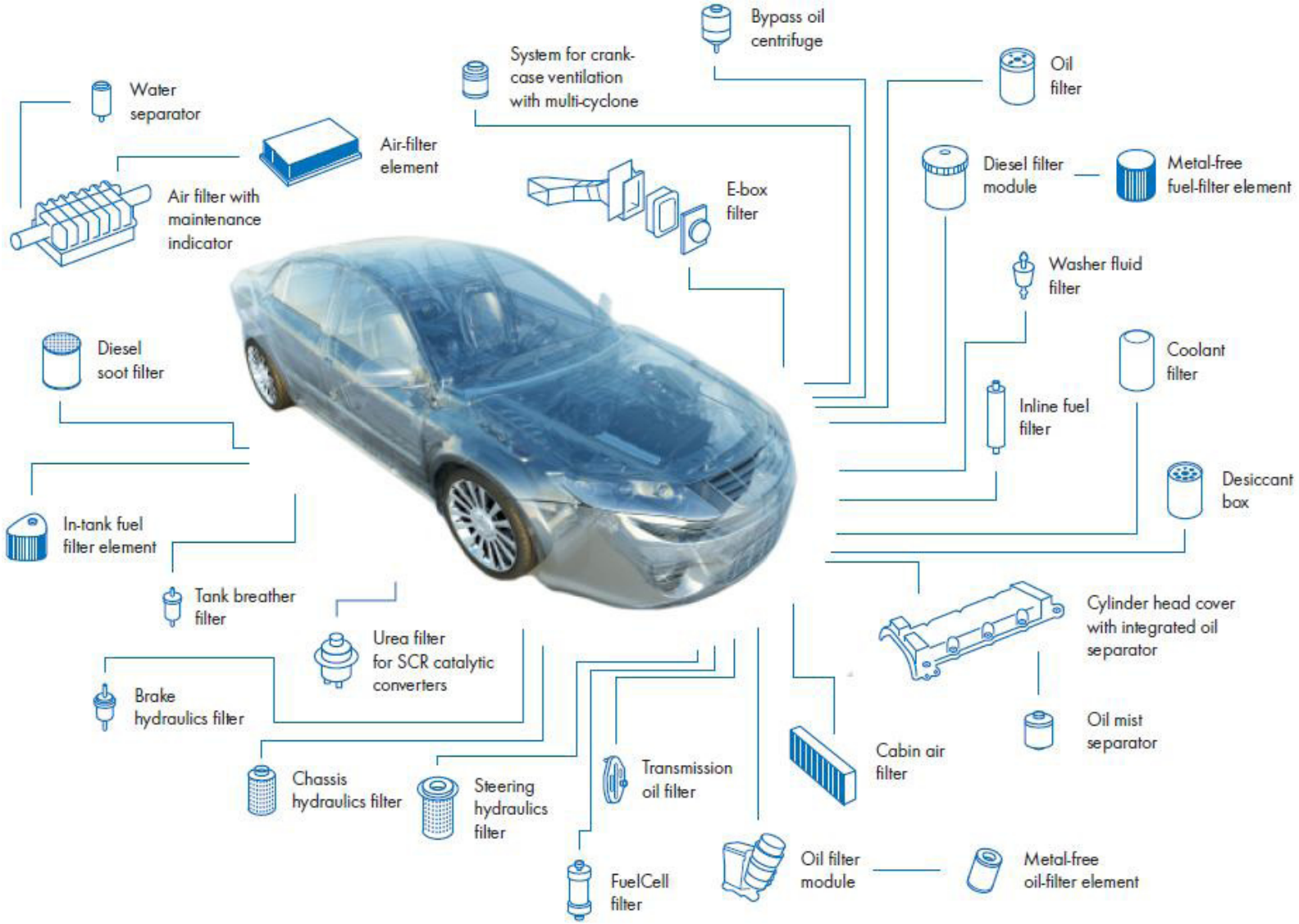
Filters in Automotive Applications – A Case Study on *Fuel Filters and Water Separators in Diesel Engines*

Filters in Automotive Applications – Light Vehicle



BACKGROUND

- Ever tightening emission requirements - high pressure modern fuel systems with precise injection equipment
  - Injection volumes – microlitres;
  - Injection cycle timings – milliseconds;
  - Injection pressures in the order of 30,000 psi
- ... Precision injection systems require contamination free fuel
- WATER is a FUEL CONTAMINANT and can affect:

- Physical properties of the fuel by altering its filterability
- Accelerates fatigue wear in highly stressed parts of engine injectors, by:
  - promoting corrosion of steel components,
  - encouraging microbiological growth
  - reduces lubricity causing nozzle and pump plunger scoring

  .... FATAL FOR HIGH PRECISION DEISEL ENGINE INJECTORS – ENGINE MANUFACTURERS ARE NOW DEMANDING 100% WATER FREE FUEL
- Fuel filters and water separators are used to remove the contaminants before diesel enters the injectors

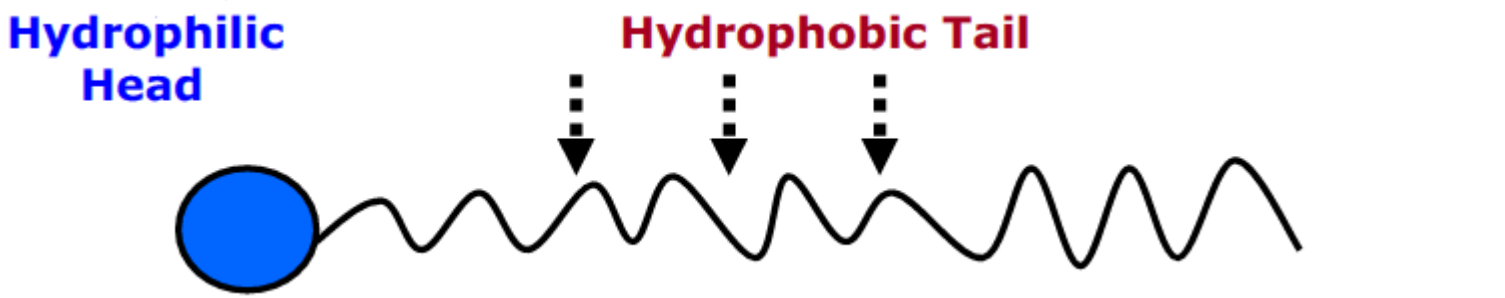
PROBLEM AT HAND

- The efficiency of existing water separating media has recently been adversely affected by radical changes in the composition of the diesel fuel; namely:
  - Introduction of Ultra Low Sulphur Diesel (ULSD) – which requires additives e.g. lubricity enhancers, rust inhibitors, and anti-wear agents
  - Advent of Bio-diesels - European Legislation targets aim to increase content of the bio-fuels in EN590 (standard diesel) up to 20% by 2020!

All these additives belongs to the chemical category of SURFACTANTS ...

Surfactants ...

- Surfactants are *amphiphlic* organic compounds i.e. they contain both hydrophobic groups (their *tails*) and hydrophilic groups (their *heads*) – soluble in both organic solvents and water.



Assists Solubility in water

Assists Solubility in diesel

Surfactants …

1. **Surfactants change the nature of water in fuel.**

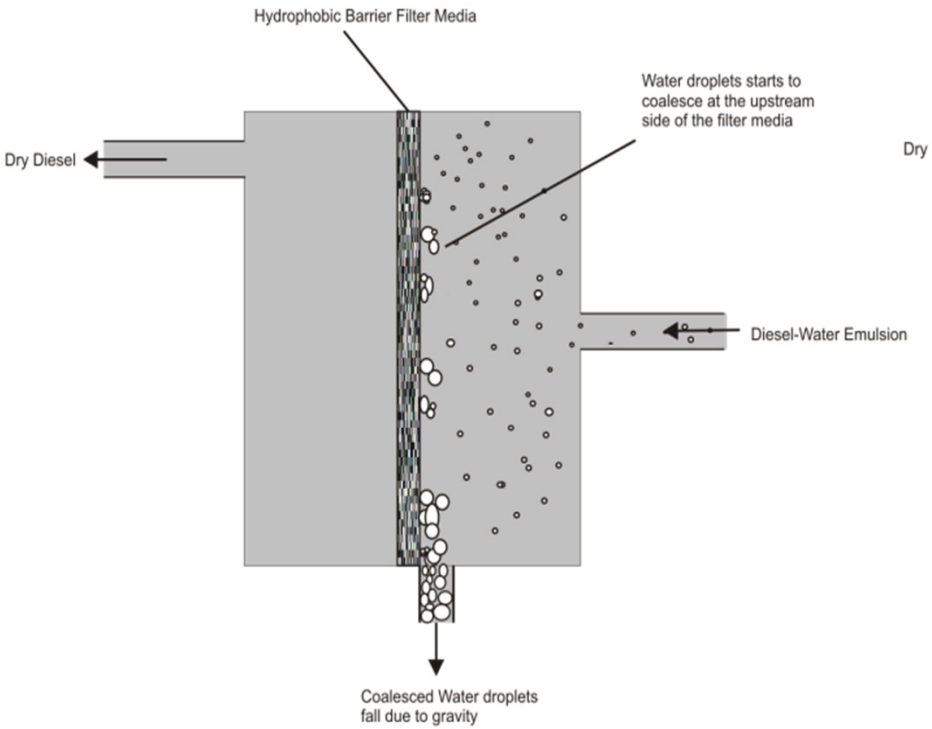
- Water drops in ULSD and biodiesel blends are smaller.
  - Surfactants lower interfacial tension between fuel and water, and enable smaller droplets to form.

- Water drops in ULSD and biodiesel blends are more resistant to coalescence.
  - Surfactants associate with water drop surfaces, and create a barrier to drop coalescence. Coalescence is required for successful water separation.

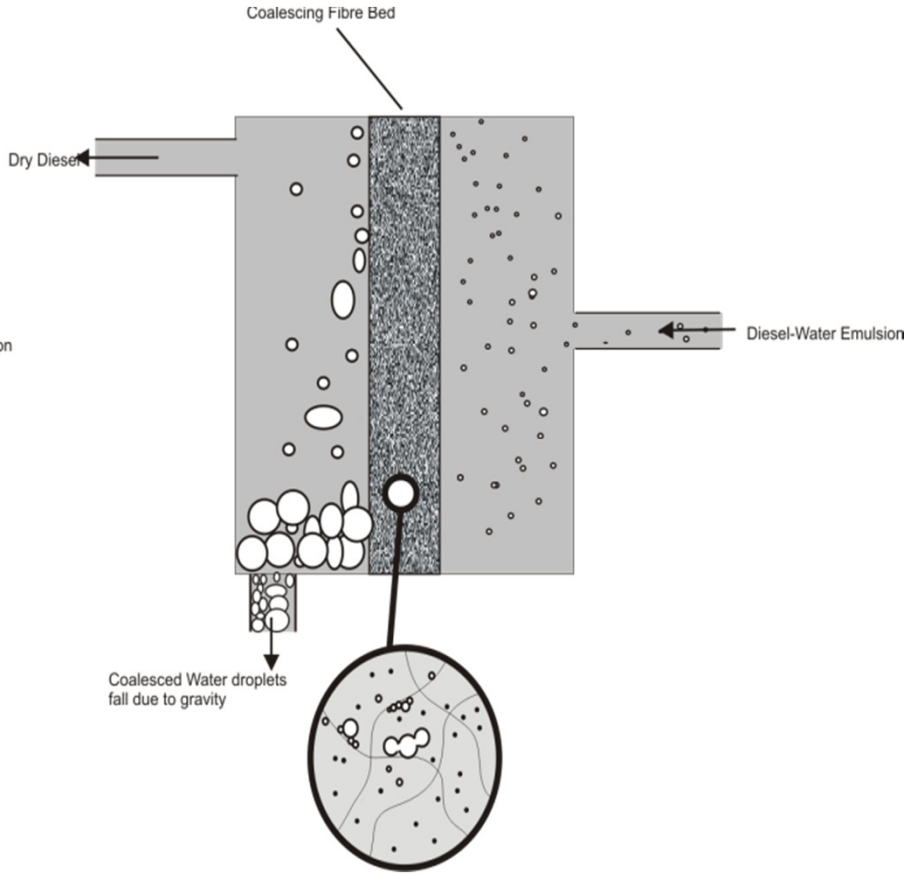
2. **Surfactants change the surface chemistry of water separation media.**

- Surfactants associate with media surfaces, and alter surface energies that are fundamental to successful separation.

Current Fuel Filters and Water Separators



The Hydrophobic Barrier Media



The Fibre-bed Coalescing Media

The Hydrophobic Barrier Type

Barrier type coalescers function through the use of hydrophobic (non-wettable) barrier to stop water droplets at the Upstream side.

Droplets smaller than the filter pore size may not be captured

Enhanced Water Separation Through Surface Modifications

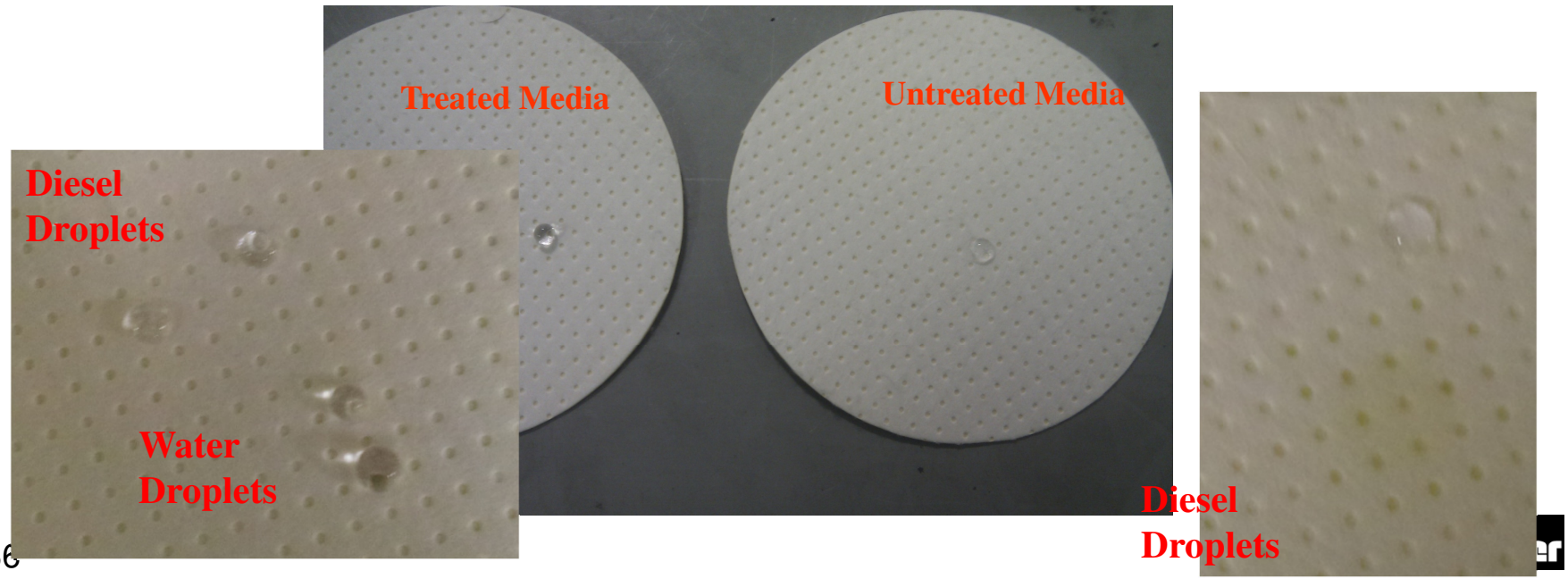
Existing Parker melt-blown hydrophobic cellulose composite media was used.

Alter the surface characteristics of the media by:

- **Super hydrophobic treatments**
- **Hydrophilic treatments**
- **Deposition of electro-spun nano-fibres**
- **Hydrophobic / Oleophilic Treatments**

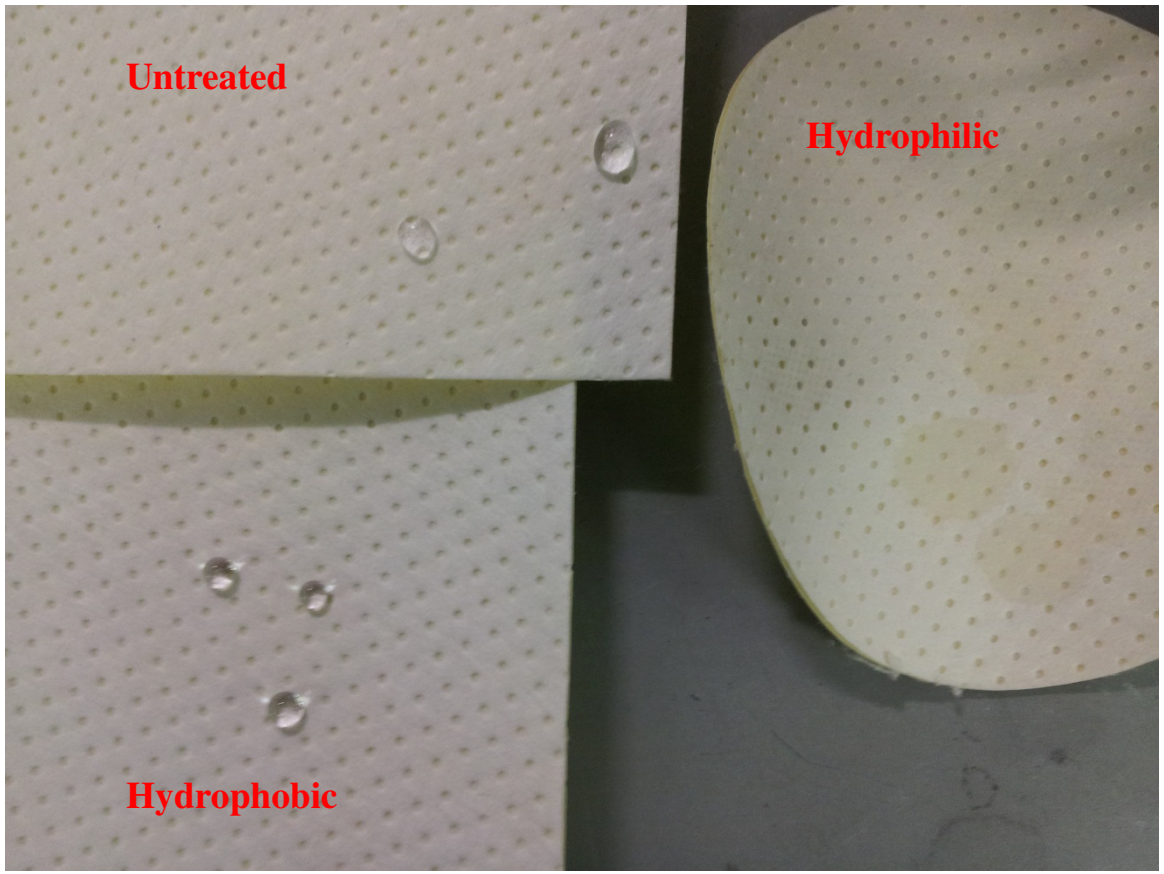
Super Hydrophobic Treatments

- A combination of plasma and electro-spraying techniques were used to successfully create super-hydrophobic surfaces:



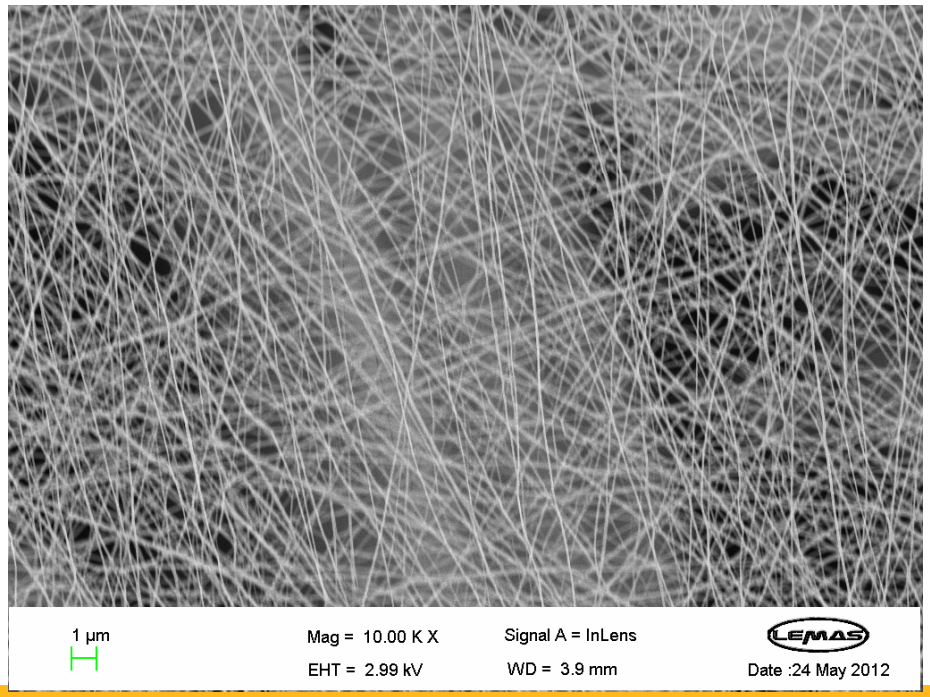
Hydrophilic Treatment

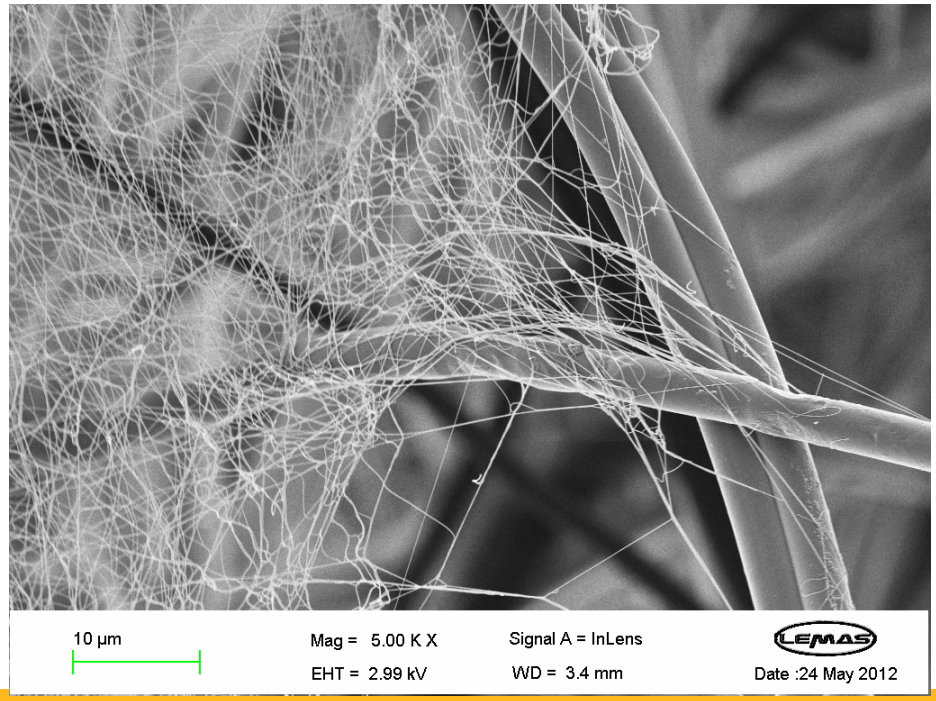
Electro-spraying technique was used to create Hydrophilic surfaces



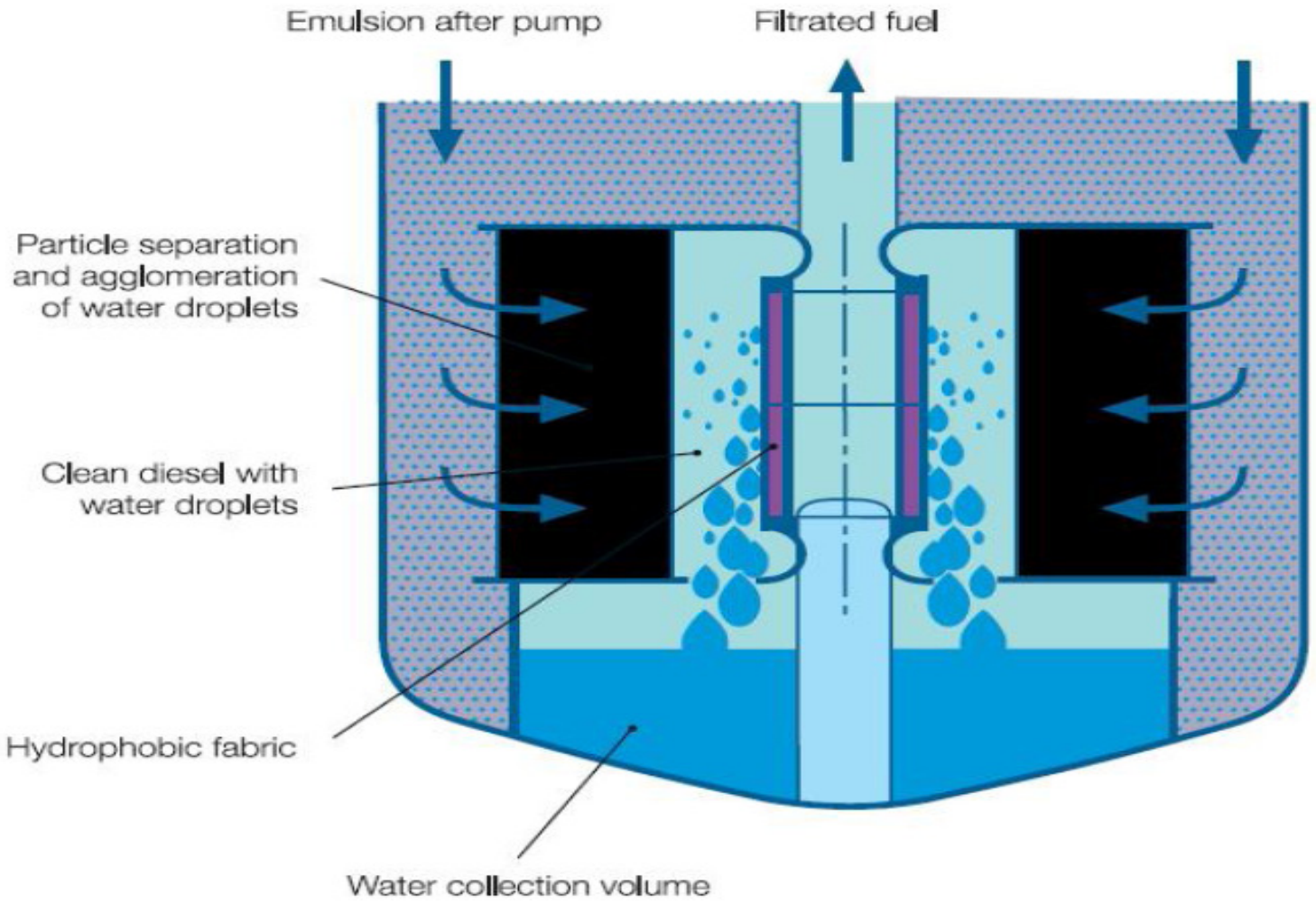
Nano-fibre coatings

- Nano-fibres (*Dia ≈ 100 – 300 nm)* were sprayed on our existing barrier media using state-of-the-art electro spinning technique:

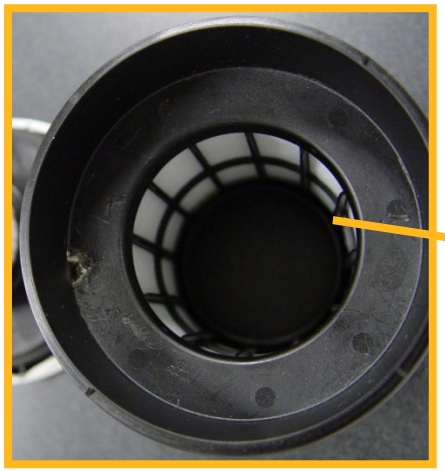




A typical coalescence bed filter

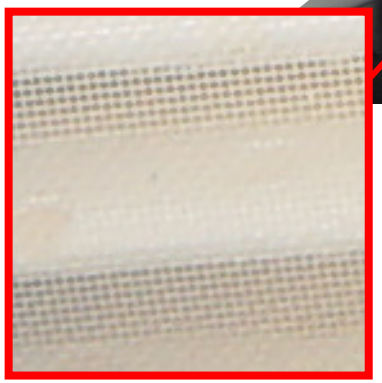


Development of samples



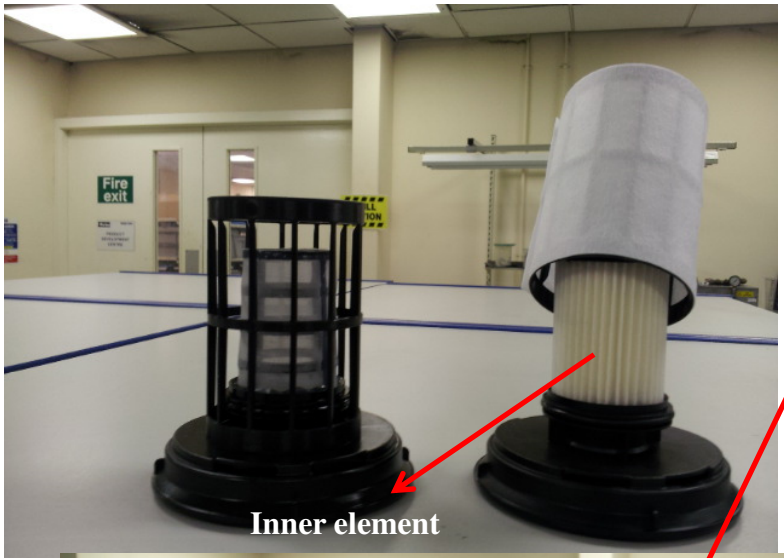
Interior – Drainage Layer

Outer Element : DCM I

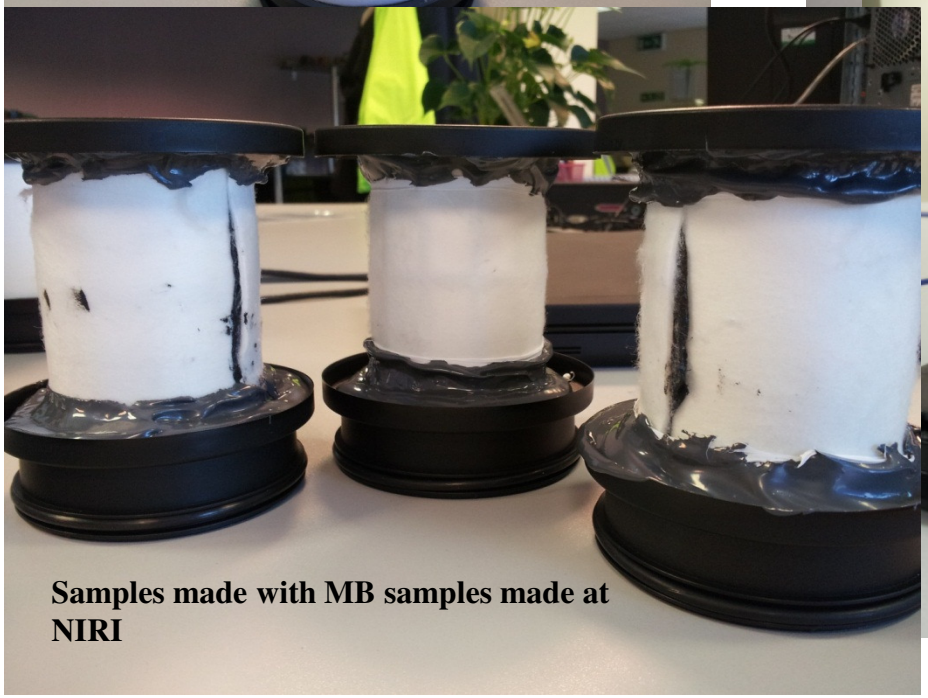


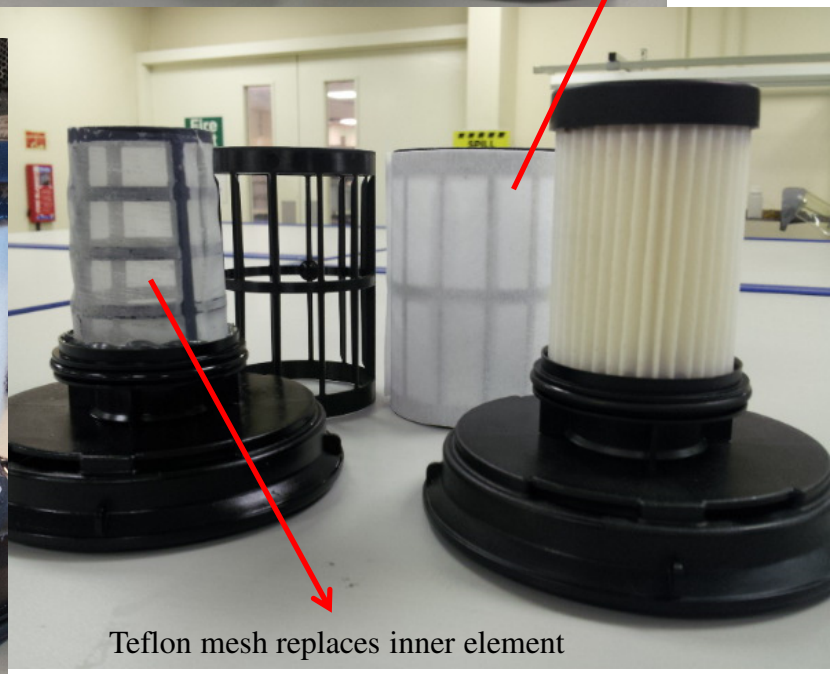
Inner Element : Exterior -- Hydrophobic screen, Interior – pleated high efficiency meltblown-hydrophobic cellulose composite.

Development of Samples



Drainage layer on inner core





Thank you … questions, comments?