

## BlueTEC technology for vehicle emissions control

Devaryan Gupta

Delhi Public School, Delhi, India

### Abstract

BlueTEC is a name for engines equipped with advanced NO<sub>x</sub> reducing technology for vehicle emissions control in diesel-powered vehicles. In this paper, the working of emission system is discussed. The main aim of the paper is to describe various technologies of Blue-TEC. Different application areas and advantages of Blue-TEC are mentioned significantly. Emissions defeat device allegations is studied. There is a focus on services offered by blue-TEC technologies. Issues in Blue-Tec technology are also taken into account.

**Keywords:** BlueTEC technology, vehicle emissions

### Introduction

Bluewater's Tidal Energy Converter (Blue-TEC) is a floating platform for tidal turbines. Blue-TEC is a name for engines equipped with advanced NO<sub>x</sub> reducing technology for vehicle emissions control in diesel-powered vehicles. The technology in Blue-TEC vehicles includes a selective catalytic reduction (SCR) system that uses diesel exhaust fluid, and a system of NO<sub>x</sub> adsorbers the automaker calls *DeNO<sub>x</sub>*, which uses an oxidizing catalytic converter and diesel particulate filter combined with other NO<sub>x</sub> reducing systems. Unlike conventional bottom founded designs, Blue TEC offers significant advantages by accommodating most of the critical equipment above the waterline, where it is dry and protected, allowing for easy access for inspection and repair. The most energy is at the top of the water column, near the surface, where the turbine is situated.

This technology is based on cutting-edge diesel engines with common rail direct injection and features all the strengths and advantages of this drive principle. Blue-TEC is a modular concept for the effective reduction of fuel consumption and emissions in diesel vehicles. It comprises various coordinated technical measures combining technologies inside the engine aimed at reducing untreated emissions with the effective after treatment of exhaust gases. All the relevant constituents of emissions are minimized. The employed technology includes an oxidation catalytic converter and a particle filter. The most important objective, however, is to drastically reduce nitrous oxide emissions – the only component of exhaust gases today whose level is higher for diesel engines than the corresponding value for petrol engines. Usable water, renewable energy, and recovery of raw materials are world-wide emerging topics due to the lack of clean water, the need of regenerative energy, and the depletion of raw materials. BLUE-TEC offers sustainable technologies as a solution for these emerging problems.

### Literature Review

Daimler introduced Blue TEC in the Mercedes E-Class (using the *DeNO<sub>x</sub>* system) and GL-Class (using SCR) at the 2006 North American International Auto Show. At

that time, these BlueTEC vehicles were 45- and 50-state legal, respectively, in the United States.

Daimler AG has entered into an agreement with Volkswagen and Audi to share BlueTEC technology with them in order to increase the Diesel passenger-vehicle market in the United States. VW introduced the Jetta Clean TDI, the Tiguan concept, and the Touareg Blue TDI as part of the Blue Tec licensing program. The Jetta and the Tiguan use NO<sub>x</sub> adsorbers, while the Touareg uses a Selective Catalytic Reduction catalytic converter.

In August 2007 VW Group announced that cooperation on Blue TEC with Daimler AG would end. The reasoning for this change is due to the recognition of the VW TDI branding. VW did not want to use a competitor's branding for a product they would introduce into the market. VW developed their own system, but it failed and they re-programmed the engine control to show false values during pollution tests.

By 2010 a Blue TEC version of the Mercedes Sprinter was released. The Blue TEC systems allowed the elimination of much of the EGR in that vehicle's engine, which as a result gives 188 horsepower (140 kilowatts) compared to the non-Blue Tec engine's 154 horsepower (115 kilowatts).

Daimler Trucks uses Blue TEC on all its Freightliner and Western Star Trucks destined for highway use, as these vehicles are only available with diesel engines.

### Working Process

The emissions system works in a series of steps:

1. A diesel oxidation catalyst reduces the amounts of carbon monoxide (CO) and hydrocarbons (HC) released from the exhaust.
2. A *DeNO<sub>x</sub>* catalytic converter begins a preliminary removal of oxides of nitrogen.
3. A particulate filter traps and stores soot particles, burning them off when the filter gets full.
4. If the above are not sufficient to meet the prevailing emissions regulations, a Selective Catalytic Reduction (SCR) catalytic converter will convert the remaining nitrogen oxides to nitrogen and water; so-called diesel

exhaust fluid (solution of urea and water) is injected into the exhaust gas stream to enable the conversion. To prevent vehicles from breaking emissions regulations, the engine may go into a limp-home-mode if the DEF tank is depleted; drivers are instructed to keep the tank refilled as necessary. Some commercial vehicles are equipped with a request or inhibit switch which allows the DEF injection to be "postponed" as it can reduce power output and increase temperatures temporarily; if the vehicle is climbing a grade, for example, it may be necessary to delay the cycle.

**Technologies**

There are a number of technologies of Blue-Tec. These are:

1. Forward Osmosis
2. Membrane ammonia stripping
3. Membrane Distillation
4. Pressure driven membrane process
5. Membrane bio-reactors
6. VUNA technology

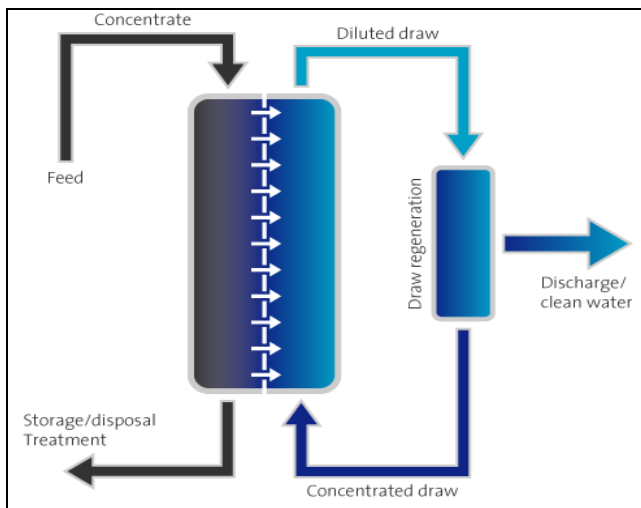
**Forward Osmosis Technology**

Forward Osmosis (FO) is based on the principle that water separated by a semi-permeable membrane goes from a liquid with a low osmotic pressure to a liquid with a high osmotic pressure until equilibrium is reached. This mechanism takes place in all living cells.

This process doesn't require energy or pressure to occur. FO membranes reject organics, minerals and other solids, similar to RO, but don't have the typical fouling problems.

In FO, technology the role of the solution with low osmotic pressure is played by the feed stream and the solution with the high osmotic pressure is called draw solution. Normally FO is operated with a second system to re-concentrate the draw solution. This can be Reverse Osmosis (RO), Membrane Distillation (MD), or the use of specialized systems, like switchable solvents.

In some cases FO can operate without a draw solution recovery system, this is called osmotic dilution, for example, the dilution of seawater before desalination by treated wastewater over a FO membrane.



**FO can be used in many processes, such as**

- Concentration in the food and beverage industry
- Concentration of high fouling wastewater (oil & gas, landfill leachate, chemical wastewater)

- Zero Liquid Discharge (ZLD)
- Direct concentration with wastewater with recovery of water, biogas and nutrients
- Cooling water make-up
- Osmotic-MBR

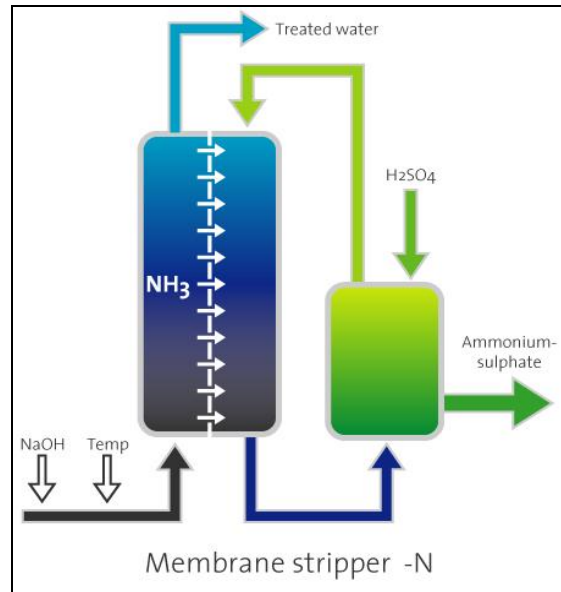
**Membrane Ammonia Stripping**

BLUE-TEC has developed an innovative process for recovery of ammonia from nitrogen rich streams by means of stripping through a gas-permeable membrane.

Current technologies for ammonia removal are mostly biological processes, which are energy intensive and also produce the strong greenhouse gas nitrous oxide (N<sub>2</sub>O). Furthermore at fertilizer production sites the Haber-Bosch process is used for the production of ammonium out of nitrogen gas using a lot of energy.

By means of membrane stripping ammonia is recovered at low energy consumption, without the production of N<sub>2</sub>O, with a small footprint and avoiding Haber-Bosch process.

In this process the pH and temperature of the feed stream are raised and in order to shift the equilibrium from NH<sub>4</sub> to NH<sub>3</sub>. In the membrane stripping process free ammonia gas diffuses across the pores of the hydrophobic membranes. On the other side of the membrane concentrated sulphuric acid captures the ammonia, ensuring a high driving force all the time.



**Applications**

- Centrate water from anaerobic sludge digestion
- Landfill leachate
- Industrial ammonia rich streams
- Manure treatment

**Membrane Distillation**

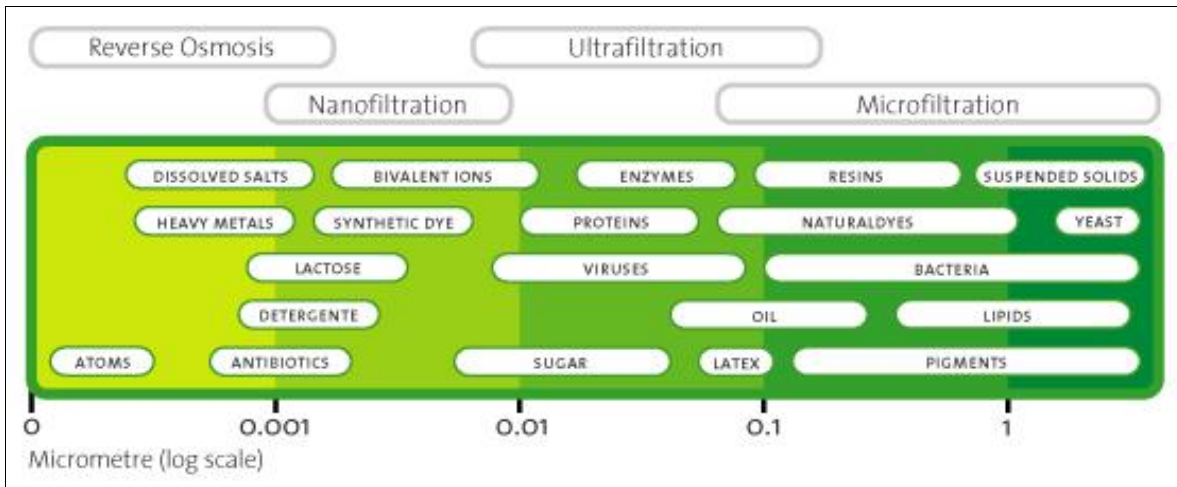
In membrane distillation water is transferred through a hydrophobic membrane by difference in vapour pressure. The driving force of this process is temperature difference. The difference in vapour pressure allows water in gas form to pass the membrane pores while water molecules are rejected by the hydrophobic membranes.

There are several configurations of MD. BLUE-tec uses mostly Air Gap MD (AGMD) for a high energy recovery. MD can run on low grade (waste) heat of 80°C, and

therefore very suitable for industrial applications, or of grid applications where waste heat from CHP units can be used. In a FO-MD setup MD is used for draw solution recovery. In the FO-MD combination high concentration factors can be achieved or feed solutions with an already high osmotic pressure can be treated. Salt concentrations above 180 g/l can be reached.

**Pressure driven membrane processes**

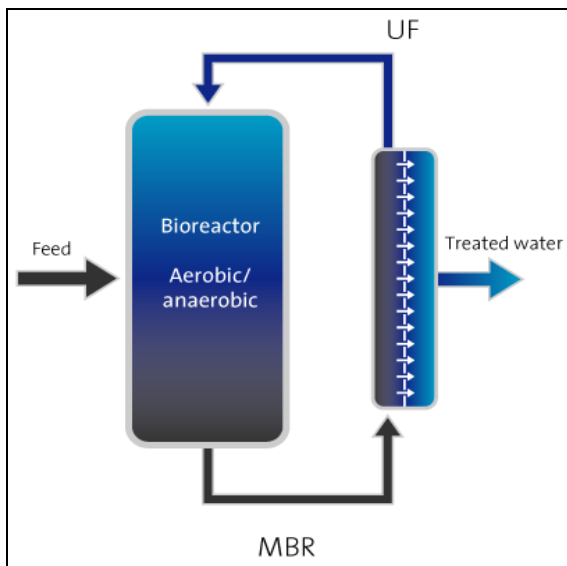
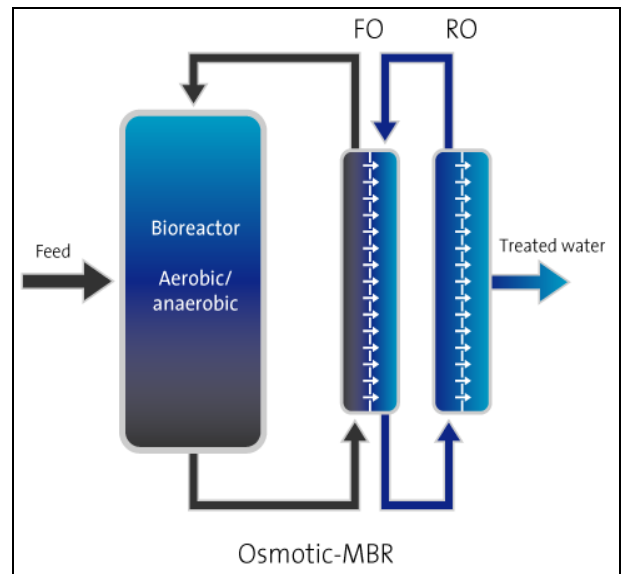
Microfiltration, ultrafiltration, nanofiltration and reversed osmosis are pressure driven processes. By applying pressure the water flows through the membrane and components with a certain size are retained. The figure shows the size of components passing each type of membrane.



The pressure driven membrane processes are used in Forward Osmosis applications, where they are used for Draw Solution Recovery. The picture shows a pilot of BLUE-tec, in which RO and MD can be applied after FO.

**Membrane bioreactors**

In membrane bioreactors membrane (MBR) filtration is combined with a biological process. The membrane filtration process can be a pressure driven membrane like UF, but also FO, the Osmotic Membrane Bioreactor (OMBR). The biological process can be either aerobic or anaerobic. Advantage of the O-MBR is the low fouling tendency of the FO membrane and the excellent treated water quality after the RO-process ready for reuse.



**(O)MBR's can be applied for the treatment of:**

- Industrial wastewater
- Wastewater from the waste processing industry
- Domestic wastewater
- Wastewater on board of ships and off shore locations

**VUNA technology**

The VUNA technology was developed at Eawag in Switzerland. It consists of a wastewater treatment system for nutrient recovery from urine. In order to treat the urine, it is required to collect this specific wastewater stream separately from other streams. Urine diversion toilets and waterless urinals are examples of how this can be made possible.

One of the VUNA pilot plants is installed in the main building of Eawag. It is able to treat 50 litres of urine per day. Urine is collected through waterless urinals and urine-diversion toilets. The pilot consists of two nitrification columns filled with biofilm carriers and urine. By applying

**Advantages of (O)MBR processes are:**

- Small foot print due to high biomass concentrations
- Excellent treated water quality
- Low sludge production

aeration, bacteria stabilize the urine during nitrification. In batches the distiller hygienises and concentrates the nitrified

urine, by removing 97% of the water content.



As an end product, the concentrated urine can be used as a liquid fertilizer. Research at Eawag has shown that it can be used as an alternative to commercialized plant fertilizers. Distilled water is a valuable by-product, as it contains hardly any nitrogen or organic compounds.

### Applications

The major challenge of Blue-TEC is to apply technology and make it valuable part of increasing environmental and economic sustainability, whether it is for industrial process streams or domestic waste water. The sustainable technologies of BLUE-tec are applied in several segments.

- **Process water:** BLUE-tec has a lot of experience in applying membrane filtration processes in the industry, especially in the food and beverage industry. Examples are the use of FO for whey concentration, fruit juice concentration, concentration of specific compounds, etc.
- **Industrial waste water:** Several types of industrial wastewater can be treated by BLUE-TEC technologies, like FO, O-MBR, etc. Examples are:
  1. Oil & gas industry
  2. Land fill leachate
  3. Heavy polluted industrial streams, including Zero Liquid Discharge (ZLD)
  4. Cooling tower water make up
- **Agro-industry:** BLUE-TEC offers solutions for the treatment of manure and digestate in the agro-industry. By the use of smart membrane filtration will nutrients can be recovered as a concentrate.
- **Domestic wastewater:** Domestic wastewater is a resource for biogas and nutrients. Through concentration of domestic wastewater by FO clean water is produced, next to a concentrate. From the concentrate biogas and nutrients can be recovered and micro pollutants can be removed.

### Emissions Defeat Device Allegations

The Netherland's official automobile inspector TNO, on behalf on the Dutch Minister of the Environment, conducted on-road tests of a C-Class Mercedes C220 TDi BlueTec diesel and determined it emitted more than 40 times the amount of cancer-causing NOx than in the lab test. The tests were done at temperatures below 10 degrees Celsius (50 F). Mercedes says it is permissible for the BlueTec engine to emit 40 times more NOx when the temperature is less than 10C (50 F)

As of 2016 April 22, Mercedes-Benz USA disclosed it is under investigation by the Department of Justice for potential discrepancies over its diesel emissions certifications, according to a Daimler statement. The DOJ effectively told MBUSA to begin an internal investigation "to review its certification and admissions process related to exhaust emissions in the United States," Daimler said. Emissions controls on the BlueTec vehicles include a diesel particulate filter and a selective catalytic reduction system, which plaintiffs say turns off below 50 degrees to help the cars maintain their high-performance driving characteristics.

### Services Offered by Blue-Tec technology

BLUE-tec works as a one-stop-shop company, realizing technology from laboratory scale up to turn-key delivers. It offers solutions in combination with Forward Osmosis and other membrane filtration technologies. BLUE-Tec can offer:

- Feasibility studies
- Laboratory research
- Pilot testing
- Full scale design
- Turn-key delivery



**Advantages of Blue-TEC Technology**

**National incentives**

In connection with the European Union's increasingly drastic reductions in the limits for emissions many European cities have implemented driving bans for vehicles not designated as being low on emissions.

Consideration is also being given to the possibility of extending emissions-linked Autobahn charges to smaller motorways.

Blue-Tec achieves significant reductions in emissions which can thus result in toll savings and exemption from driving bans. There are other financial benefits for Blue-Tec customers too: in many European countries the investor can expect tax breaks, and in various European municipalities Blue-Tec counts in the favour when tendering for a public contract.

**Everyday Use**

In the long-distance haulage sector, fuel consumption makes up the lion's share of the lifecycle costs. Here, too, Blue-Tec offers outstanding benefits. Further developed engines make such efficient use of the fuel that they not only have a higher output but also consume significantly less fuel. Blue-Tec also gets top marks when it comes to service intervals: the technology is robust and requires only low maintenance. The impressive engines fitted in the Actros deliver greater pulling power and efficiency – while offering potential fuel savings of up to 3% in the case of straight-six engines and 5% in V8 engines.

**Resale advantages**

Europe's legislation is becoming increasingly standardised. The demand for commercial vehicles meeting the new Euro emissions standards is set to increase accordingly. When someone invests in Blue-Tec, the investment is in a technology that pays for itself, even if the investor decides to resell several years down the line.

**Issues/Problems in Blue-TEC technology**

- Government regulations for fuel economy & emission controls are at the heart of the problem. The regulations are so complicated that it is quite hard to know what's going on.

- What oil should go in the Blue-Tec diesel engines? Emission problems in cold weather are considered while these forget the cars in hot climates.
- Who claims modern engine oil doesn't need to be changed very often?
- Blue-Tec engines run stupid hot. Heat destroys oil. That means oil with a high viscosity index.

**Conclusion**

The Blue-Tec technology is based on cutting-edge diesel engines with common rail direct injection and features all the strengths and advantages of this drive principle. Usable water, renewable energy, and recovery of raw materials are worldwide emerging topics due to the lack of clean water, the need of regenerative energy, and the depletion of raw materials. BLUE-Tec off eredvarious technologies as a solution for these emerging problems. The major issue came out that Blue-Tec engines run very hot due to which oil is destroyed.

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