XBEE

Natural Fuel Additive

How can Xbee Fuel Treatment reduce the NOx emissions?

1) Origin of NOx emissions:

NOx is caused almost entirely by the heat of flame oxidizing nitrogen supplied in the air/fuel mixture which is diffused (distributed) throughout the combustion charge as the fuel combusts and the gases expand. The amount of NOx produced is exponentially increased by and tied directly to the flame temperature. Increase flame temperature and increase NOx, but decrease HC, CO and soot. Decrease flame temperature, decrease NOx and increase HC, CO and soot. Flame temperature is controlled by two factors: air (oxygen) and chemical composition of the fuel.

2) Impact of Xbee on the NOx emissions:

Xbee does break that cycle in most cases. HC and soot are reduced by increasing the oxygenation, which would be similar to leaning out the fuel/air mixture by adding more makeup air. However, since it's done by catalytic use of the existing oxygen rather than by increasing the makeup air, no more atmospheric nitrogen is added to the combustion chamber. Therefore, any improvement in combustion is at worst, NOx neutral, and in most cases NOx reduced.

By improving flame speed, **Xbee** cuts down on flame quenching and waste heat that could impact NOx. Moreover, by interrupting carbon deposition in the combustion chamber and removing piston crown deposits, **Xbee** reduces both red-hot sources for NOx and pre-detonation, which in itself causes less thermal loss.
As carbon particulate transfer heat, **Xbee** also reduces radiant heat loss simply by having burned more of the carbon quicker, thus preventing it from participating in secondary combustion reactions, and thus reducing NOx formation.

3) Empirical NOx emissions measurements:

3.1 _ **Bay Area Air Quality Management District**, California (USA). Laboratory **University of Berkeley's Combustion Analysis**.

Run	Reference Fuels-Run in 5.9L, 6 Cylinder, Cummins	Blend	Fuel Filter	Xbee	Xbee Dosage	Speed (RPM)	Load (%)	Nox (ppm)	Nox (%)
1	CARB ULS Diesel	N/A	No	No	N/A	1800	80	636	0.0%
2	Biodiesel Produced from Aggregate Used Vegetable Oil	B20	No	No	N/A	1800	80	646	1.6%
3	Biodiesel Produced from Virgin Soy Oil	B100	No	No	N/A	1800	80	720	13.2%
4	Biodiesel Produced from Virgin Soy Oil	B20	No	No	N/A	1800	80	645	1.4%
5	Biodiesel Produced from Aggregate Used Vegetable Oil	B100	No	No	N/A	1800	80	656	3.1%
6	Biodiesel Produced from Virgin Soy Oil	B20	No	Yes	1:2000	1800	80	576	-9.4%
7	Biodiesel Produced from Aggregate Used Vegetable Oil	B20	No	Yes	1:2000	1800	80	559	-12.1%
8	CARB ULS Diesel	N/A	No	Yes	1:2000	1800	80	632	-0.6%
9	CARB ULS Diesel	N/A	Yes	No	N/A	1800	80	510	-19.8%
10	Biodiesel Produced from Aggregate Used Vegetable Oil	B20	Yes	No	N/A	1800	80	530	-16.7%
11	Biodiesel Produced from Virgin Soy Oil	B20	Yes	No	N/A	1800	80	528	-17.0%
12	Biodiesel Produced from Virgin Soy Oil	B100	Yes	No	N/A	1800	80	591	-7.1%
13	Biodiesel Produced from Aggregate Used Vegetable Oil	B100	Yes	No	N/A	1800	80	601	-5.5%
14	Biodiesel Produced from Aggregate Used Vegetable Oil	B20	Yes	Yes	1:2000	1800	80	515	-19.0%
15	Biodiesel Produced from Virgin Soy Oil	B20	Yes	Yes	1:2000	1800	80	505	-20.6%
16	Biodiesel Produced from Aggregate Used Vegetable Oil	B100	No	Yes	1:2000	1800	80	560	-11.9%
17	Biodiesel Produced from Virgin Soy Oil	B100	No	Yes	1:2000	1800	80	563	-11.5%
18	Biodiesel Produced from Virgin Soy Oil	B100	No	Yes	1:1000	1800	80	610	-4.1%
19	Biodiesel Produced from Aggregate Used Vegetable Oil	B100	No	Yes	1:1000	1800	80	550	-13.5%
20	Biodiesel Produced from Aggregate Used Vegetable Oil	B100	No	Yes	1:4000	1800	80	554	-12.9%
21	Biodiesel Produced from Virgin Soy Oil	B100	No	Yes	1:4000	1800	80	559	-12.1%

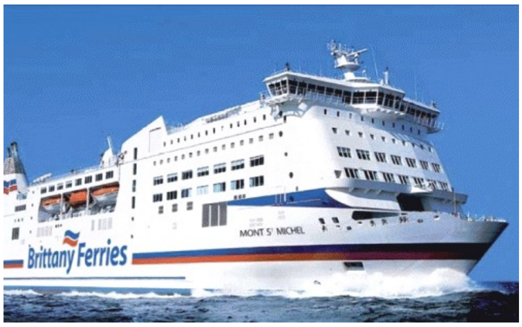
These measurements perfectly illustrates what is explained in the second article. Lines 2 to 5 show that biodiesels _ either B20 or B100, which increase the temperature during combustion _ increase the volume of NOx emissions. Lines 6, 7, and 16 to 21 (the last two being done with the correct advised dosage) show the same fuels enhanced with **Xbee**, which helps to hyper-oxygenate the fuels and reduces the flame temperature: 12.5% reduction of the NOx emissions in average.

XBEE Natural Fuel Additive

3.2 _ **Brittany Ferries**, France. Laboratory **Ascal – Air Liquide**.

	Without Xbee	With Xbee	Difference (%)
Flow (Nm^3/h)	22 536.00	22 521.00	***-0.07***
CO_2 – Carbon Dioxide (%)	6.10	4.70	***-22.95***
CO – Carbon Monoxide (mg/Nm^3)	98.40	56.20	***-42.89***
NO – Nitrogen Oxide (ppmv)	1 094.00	826.00	***-24.50***
NO_x – Nitrogen Dioxide (ppmv)	1 125.00	851.00	***-24.36***
O_2 – Oxygene (%)	12.60	14.70	***+16.70***
Particulates (mg/Nm^3)	99.30	59.65	***-39.93***
SO_2 – Sulfur dioxide (mg/Nm^3)	1 222.00	1 002.00	***-18.00***
VOC – Volatile Organic Compounds (mg/Nm^3)	76.90	45.60	***-40.70***

The *Mont Saint-Michel* used **Xbee** HFO 380 during this evaluation. At a stable flow rate, we can easily observe the capacity of the Enzyme Fuel Treatment to improve the combustion parameters and reduce the NOx emissions by more than 24%.



Mont Saint-Michel, Mak engines

3.3 _ **Mak/Caterpillar**, Germany. Research & Development Department.

MAK/Caterpillar 6M25 engine
Performance from driven Propellers

Performance levels (%)	**100%**	**75%**	**50%**	**35%**	**25%**	**10%**	
KiloWatt (kW)	**1980**	**1481**	**990**	**698**	**495**	**198**	
Number of revolutions	**750**	**681**	**595**	**529**	**476**	**357**	
Without Xbee / **With Xbee**							**Average**
Specific consumption (be) – Without Xbee	184.50	183.50	189.90	196.90	205.50	210.70	195.17
With Xbee	184.30	183.10	188.90	196.70	200.00	207.80	193.47
Difference	-0.11%	-0.22%	-0.53%	-0.10%	-2.68%	-1.38%	**-0.87%**
Specific air volume (le) – Without Xbee	7.20	7.03	6.46	6.26	6.07	8.69	6.95
With Xbee	7.31	7.04	6.50	6.30	6.44	9.28	7.15
Difference	1.53%	0.14%	0.62%	0.64%	6.10%	6.79%	**2.78%**
Nitrogen oxide (Nox ppm) – Without Xbee	1,060.00	1,155.00	1,250.00	1,210.00	1,320.00	1,610.00	1,267.50
With Xbee	900.00	995.00	1,050.00	1,075.00	1,175.00	1,315.00	1,085.00
Difference	-15.09%	-13.85%	-16.00%	-11.16%	-10.98%	-18.32%	**-14.40%**
Nitrogen oxide in the exhaust (Nox gKW/h) – Without Xbee	12.45	13.43	13.13	12.29	13.00	20.66	14.16
With Xbee	10.84	12.08	11.65	11.33	12.03	16.89	12.47
Difference	-12.93%	-10.05%	-11.27%	-7.81%	-7.46%	-18.25%	**-11.94%**
Density number of soot particles (FSN) – Without Xbee	0.18	0.13	0.15	0.20	0.21	0.30	0.20
With Xbee	0.11	0.09	0.12	0.12	0.14	0.23	0.14
Difference	-38.89%	-30.77%	-20.00%	-40.00%	-33.33%	-23.33%	**-30.77%**

The measurements have been done using a 6M25 engine powered with Marine Diesel Oil, and done in compliance with the norm ISO 3046. The gas emissions have been measured with equipments and methods in compliance with the norm ISO 8178 after only 15 hours of work.

This table also well illustrates what has been explained here above. The use of **Xbee** in the fuel improved the combustion by optimizing the use of oxygen, hence slight but steady increase of the air volume although Nitrogen

Oxide ppm and gkW/h both reduced respectively by 14.40% and 11.94%.

3.4 _ **Frinsa del Noroeste**, Spain. Laboratory **Dekra**.

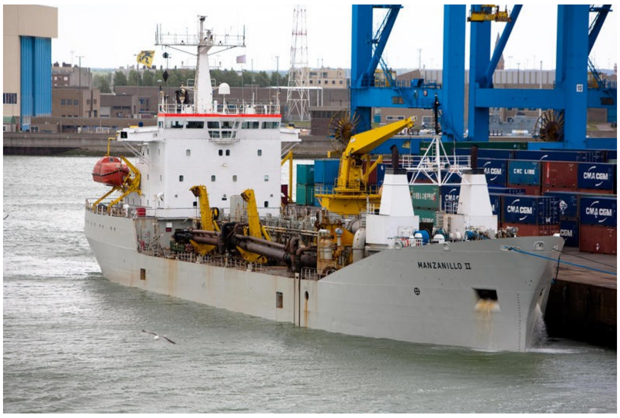
	Without Xbee	With Xbee	Difference (%)
Flow (Nm^3/h)	73 525.00	68 197.00	***-7.25***
CO_2 – Carbon Dioxide (%)	7.40	5.43	***-26.62***
CO – Carbon Monoxide (ppm)	70.33	40.00	***-43.12***
NO_x – Nitrogen Dioxide (mg/Nm^3)	2 340.67	2 023.67	***-13.54***
O_2 – Oxygen (%)	13.03	11.77	***-9.67***
Particulates (mg/Nm^3)	50.27	40.90	***-18.64***
SO_2 – Sulfur dioxide (mg/Nm^3)	486.47	500.17	***+2.82***
VOC – Volatile Organic Compounds (mg/Nm^3)	18.03	14.27	***-20.85***

The generators of this power plant have used an **Xbee** HFO 380 during six months to observe a reduction of the NOx emissions by 13.54%. The result is less remarkable than previously onboard the ferry, because inland power plants must answer more restrictive security and environmental norms _ including more advanced filtering technologies (the same difference is observed in the article 3.1 when we compare measure with or without filters). Yet, even with high standards, fuel can be improved and emissions can be reduced.

3.5 _ **Jan de Nul**, Belgium. Fleet Management Department.

	Without Xbee	With Xbee	Difference (%)
Flow (Nm^3/h)	392.00	385.75	***-1.59***
Temperature (°C)	367.50	361.75	***-1.56***
Excess of air (%)	132.45	146.15	***+10.34***
CO_2 – Carbon Dioxide (%)	6.70	6.30	***-5.97***
CO – Carbon Monoxide (mg/Nm^3)	79.50	66.50	***-16.35***
NO – Nitrogen Oxide (mg/Nm^3)	735.50	633.25	***-13.90***
NO_x – Nitrogen Dioxide (mg/Nm^3)	772.00	665.25	***-13.83***
O_2 – Oxygen (%)	11.90	12.40	***+4.20***

The measurements done by this company onboard a dredger powered by two Pielstick Diesel engines also illustrate clearly the impact of the **Xbee** Enzyme Fuel Treatment on the combustion. It is interesting indeed to compare the excess of air to the reductions of Nitrogen Oxide and Dioxides.



Manzanillo II

Coastway

3.6 _ **Royal Boskalis**, the Netherlands. Laboratory **Envirotech**.

Power	Without Xbee			With Xbee			Difference %	
%	kW	Nox (g/kWh)	Nox (kg/MT)	kW	Nox (g/kWh)	Nox (kg/MT)	Nox (g/kWh)	Nox (kg/MT)
100%	2610	9.68	40.66	3029	8.30	36.17	-14.26	-11.04
75%	2005	8.90	37.55	2034	7.79	33.33	-12.47	-11.24
50%	1375	9.82	38.14	1695	7.65	33.45	-22.10	-12.30
25%	838	12.52	46.27	1195	6.80	30.02	-45.69	-35.12
E2 average		10.20			7.60		-25.49	

These measurements were performed in compliance with the E2 norm as described by the IMO. It must be said also that measurements were done in two different seasons in Bahrein with a difference close to 15°C ambient temperature, that might impact the figures.
Yet, having said that, it is clear that **Xbee** improved the combustion parameters of this engine as we can observe the increase of power at the same load when NOx emissions are all reduced.

The E2 weighted average weighs the results for each power levels according IMO standards. This is the following:

Power	Weighing factor
100%	0.20
75%	0.50
50%	0.15
25%	0.15

3.7 _ **Veolia Transport**, France. Laboratory **Ascal – Air Liquide**.

	Without Xbee	With Xbee	Difference (%)
Flow (Nm^3/h)	151.60	104.80	***-30.87***
CO_2 – Carbon Dioxide (%)	1.52	1.36	***-10.53***
CO – Carbon Monoxide (mg/Nm^3)	342.20	262.60	***-23.26***
NO – Nitrogen Oxide (mg/Nm^3)	415.60	380.60	***-8.42***
NO_x – Nitrogen Dioxide (mg/Nm^3)	821.20	719.40	***-12.40***
VOC – Volatile Organic Compounds (mg/Nm^3)	113.00	105.40	***-6.73***

The laboratory measured five different buses at the idle to observe the above displayed results, gas emissions per Nm^3.

4) Conclusions:
It is quite easy to observe that the **Xbee** Enzyme Fuel Treatment helps to steadily reduce the emissions of Nitrogen Oxide and Dioxide, this matter possible due to the improved combustion of a hyper-oxygenated and clean fuel.

Diesel/MDO:

- Berkeley University at -12.50;
- Caterpillar at -11.94%;
- Jan de Nul at -13.83%;
- Royal Boskalis at -12.47% (based on the most regular load at 75%);
- Veolia Transport at -12.40%.

NOx emissions in engines powered by Diesel and MDO are reduced by 12.63% in average.

HFO 380:

- Brittany Ferries at -24.36%;
- Frinsa del Noroeste at -13.54%.

NOx emissions in engines powered by HFO 380 are reduced by 18.95% in average. Although this fuel deserves more emissions studies to flatten the figures.

Sources:

3.1 _ **Bay Area Air Quality Management District**, California (USA). Laboratory **University of Berkeley's Combustion Analysis**.
Testing was done under the direction of Professor Robert Dibble at the Combustion Analysis Laboratory at the University of California at Berkeley. Professor Dibble ran the testing protocols on a Cummins 5.9 liter diesel installed at the Combustion Analysis Laboratory in September 2005.

The reference diesel fuel used for the tests was CARB ultra low sulfur diesel (ULSD) procured from the British Petroleum distributor in San Jose, Western States Oil. The biodiesel used was made using the Mini Modular Production Unit from feedstocks acquired in the Bay Area consisting of virgin refined soybean oil and used fryer oil. These two types of biodiesel were selected because research published by the USEPA suggests tha NOx emissions would be highest with soy based biodiesel and lowest with used fryer oil based biodiesel. Various blends of biodiesel and ULSD were tested, including 100% ULSD, 20% biodiesel with 80% ULSD, and 100% biodiesel. Additional tests were run to test the effects of Xbee and a fuel/lubricating oil filtration system.

The emission testing equipment was obtained from Clean Air Instruments, and was a CARB and USEPA approved device, a Testo 350 M/XL. The device was calibrated before the tests were begun and was purged between tests on each vehicle. Protocols establised for the device were followed to allow for readings to stabilize before they were recorded.

3.2 _ **Brittany Ferries**, France. Laboratory **Ascal – Air Liquide**.
Testing was done under the direction of Emmanuel Moulin, Technical Air Engineering Manager at Ascal Bâtiment, on the stack of the **MaK** main engine number 4 of the *M/F Mont Saint-Michel*, operated by the **Brittany Ferries**. The ship is equipped with four engines with a power of 5,400 kW each, 6 cylinders, powered by HFO 380.

The first measures were done on October 8, 2006, prior to using the Xbee biotechnology. From 13 October, during each bunkering operation, the Enzyme Fuel Treatment was added at a rate of 4,000:1 (1 liter of Xbee for 4,000 liters of fuel). The second displayed measures were done on December 13, 2006, after two months of using Xbee fuel.

Measuring NO and NOx was done in compliance with the norms NF X 43-300 and NF X 43-018. Sampling: Made by pumping with a stainless steel sounding rob. The sampled gas is conveyed via a heated line with PTFE core at 180°C. The sampling device is also equipped with a filter and a cold group to filter the sampling and dry it before being put into the device.
Analysis: Continuous measure analyzer, mark COSMA model TOPAZE 3000, equipped with luminescent chemical sensor for determining NO and NOx. Numeric data recording is automatic with agil acquisition or SAM by Environnement SA.

3.3 **_ Mak/Caterpillar**, Germany. Research & Development Department.
Testing was done under the direction of Malte Rautenstrauch, R&D Engineer at Caterpillar Motoren GmbH & Co., on a bench engine Mak 6M25 as an ISO 3046 ship engine _ running at constant speed and as fixed propeller law. The fuel used during the 15 hours running work was standard MDO.

The emission data were mearsured in April 2003 with equipment and methods as described in ISO 8178.

3.4 _ **Frinsa del Noroeste**, Spain. Laboratory **Dekra**.
Testing was done under the direction of Emilio Aldao, Director of Dekra Ambio, on the stack of the generators: two Wärtsilä 8SWR80 of 9.5 mW each. The plant is powered by HFO 380.

The first measures were done on November 19, 2008. The plant started to treat all its fuel November 25. The second measures were done on May 15, 2009 after six months of treatment.

Measuring NOx emissions was done in compliance with the norm UNE EN 14792:2006, using a gaz analyzer model PG-250 by Horiba.

3.5 _ **Jan de Nul**, Belgium. Fleet Management Department.
Testing was done under the direction of Freddy Devolder, Fleet Manager at Jan de Nul B.V., on the stack of the main engines of the *M/V Manzanillo II*. The dredger is equipped with two SEMT Pielstick 8PA6 L280 engines with a total power of 12,140 kW, powered by Diesel oil.

The first measures were done on April 29, 2009. The second measures were done on October 3rd, 2009. Both using the same gas analyzer KM900+ by Kane-May.

3.6 _ **Royal Boskalis**, the Netherlands. Laboratory **Envirotech**.
Testing was done under the direction of Coen Smits at the Royal Boskalis Westminster nv, when gas measurement was done by Mr. Ponnuchamy at Envirotech Consultancy WLL, on the stack of the starboard engine of the *M/V Coastway*. The ship is equipped with Wärtsilä W6L32B engines of 2,760 kW each, powered with MDO.

The first measures were done on July 19, 2008 and the second measures on December 15, 2008, after almost four months of fuel treatment.

Measuring NOx emissions was done in compliance with the US EPA CTM 034 reference method, using a gaz analyzer model Landcom Series III by Land Combustion.

3.7 _ **Veolia Transport**, France. Laboratory **Ascal – Air Liquide**.
Testing was done under the direction of Emmanuel Moulin, Technical Air Engineering Manager at Ascal Bâtiment, on the exhaust pipes of five buses operated by Veolia Transport. Three buses were built by Renault in 1985, 1988 and 1990 respectively, and two buses were built by Heuliez in 2001 and comply to norm Euro 2.

The first measures were done on April 27, 2005 at the idle. The whole fleet used Xbee Diesel oil from the main storage tank afterwards. The second measures were done on July 5th, 2005.
Measuring NO and NOx emissions was done in compliance with the norms NF X 43-300 and NF X 43-018 respectively, using an analyzer Topaze 3000 by Cosma.

ALL THIS INFORMATION IS AVAILABLE IN ORIGINAL VERSIONS BY THE COMPANIES AND LABORATORIES IMPLIED IN THESE CASE STUDIES.