بسم الله الرحمن الرحيم

# The Reduction of Exhaust Emissions from Jordanian Diesel Vehicles

# تقليل الإنبعاثات الضارة من غازات العادم للسيارات ذات محركات الديزل في الأردن

**By**

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**الملخص العربي**

تهدف هذه الدراسة إلى بحث تأثير استخدام فلتر منقي للديزل يركب على دائرة الوقود بين خزان الوقود والفلتر الرئيسي. والذي يقوم بإزالة المياه والأوساخ والدقائق الصلبة العالقة في الوقود. وكذلك على تخفيض انبعاث السناج مع غازات العادم من محركات الديزل. حيث أن الفلتر يعمل على تحييد عامل الحموضة والقلويات وبنسبة ملحوظة. كذلك يحتوي فلتر التنقية على سخان مما يعمل على تقليل لزوجة الوقود وبالتالي تحسين اشتعال الوقود وأيضا سرعة بدء التشغيل في الظروف الجوية المختلفة وتحسين تزييت الأجزاء الداخلية لمضخة الوقود.

تم تركيب فلتر تنقية وقود الديزل على مجموعة من سيارات الديزل ، والسير بهذه السيارات لمسافات 3000كم ذهابا و3000كم ايابا مع وبدون فلتر التنقية على الترتيب.

أوضحت الدراسة أن استخدام فلتر تنقية وقود الديزل يعمل على خفض نسبة وجود السناج المنبعث مع غازات العادم بنسبه كبيرة وكذلك تغير نسبة مكونات غازات العادم وذلك من خلال تحسين عملية الاحتراق وليس تقليل كمية الغازات العادم بالمطلق.

كذلك أثبتت التحاليل المعملية التي أجريت على عينات الوقود ما يلي:

- اختفاء 75% من الدخان الأسود وانخفاض يصل إلى 10.4 ٪ من أول أكسيد الكربون و5.9 ٪ من أكسيد النيتروجين. وكذلك تم ملاحظة انخفاض صوت اشتعال المحرك .
- انخفاض في كمية الوقود المستهلك بنسبة 25%.

**Abstract**

The purpose of this study is to demonstrate appreciable reductions in the particulate exhaust emissions from diesel engines by using a certain type of diesel fuel purifying filter installed on the engine.

The used fuel purifier is a simple, one step unit that removes 99.9% of the water and 95% to 98% of the dust, dirt, and other normal and natural contaminates found in all diesel fuels. Even today's "clean" diesel fuel will easily become contaminated during transportation and storage.

Several test vehicles were driven under normal conditions for 6000 kms. The test vehicles were mounted by the test Diesel fuel purifier, and other 3000 km were driven to show the difference in performance. Mileage and driving type were recorded throughout this period. Different tests were carried out at several intervals of 50 kms.

Diesel fuel consumption was calculated and gas analyses of exhaust emissions were measured.

At the result of the tested 25% reduction of fuel consumption, 75% reduction of smoke; 10.4% reduction of carbon monoxide and 5.9% reduction of nitrogen oxide were observed.

**Key words**:- Diesel fuel purifier, diesel engine, fuel consumption, vehicles in Jordan, carbon monoxide, nitrogen oxide, particulates.

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## 1. Introduction:-

### 1.1 Air Pollution Problem in Jordan

Air in Jordan is considered relatively clean in most of the country except for some polluted areas such as the city of Zarqa and downtown Amman. Pollution sources are mainly: transportation, energy consumption industries, and waste dumping sites and natural dust (see Table 1) [1]. Main pollutants are SOx, NOx, CO, unburned fuels, and particulate matter (soot), see Refs [2-7]). Details of pollutants and their percentages are given in Table 2 [2].

**Table 1: Type of Pollutants by Source [1]**

| Sources | Percentage pollution |
|---|---|
| Industry | 16.8% |
| Power generation plants | 14.6% |
| Automobile engines | 60.6% |
| Damage waste | 5.6% |
| Other factors | 2.4% |

**Table 2: Air pollution from automobile engines [ 2]**

| Sources | Percentage pollution |
|---|---|
| carbon monoxide | 76.5% |
| nitrogen monoxide | 7.0% |
| hydrocarbons | 13.9% |
| lead compounds | 0.19% |
| postings emissions that have color such as soot | 2.41% |

The Jordanian government has set up many regulations to protect the environment. For example, see the regulations and bylaws given in reference [6].

As a result of the rapid population growth and the consequent increase in the number of vehicles (see Fig. 1), the associated increase in energy consumption has led to severe deterioration of air quality in many areas in the country.

Thereby carbon monoxide (CO) and hydrocarbons (HC) emissions have been growing significantly.

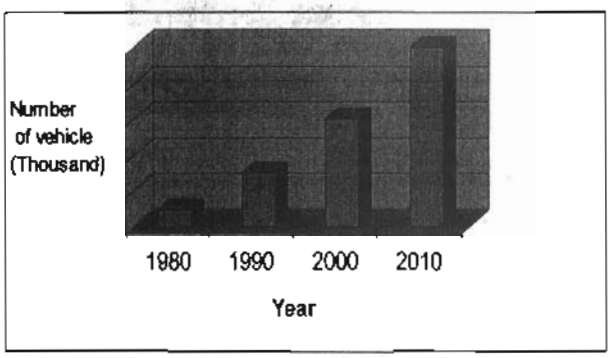


**Figure 1: Number of vehicle in Jordan (Thousands) [2]**

Figure 2 shows the year of manufacturing of cars as related to CO emissions. More than 40% of the vehicles currently on the roads were found to be non-compliant with regard to their carbon monoxide (CO) emissions. The older the car, the higher amount of carbon monoxide emission.

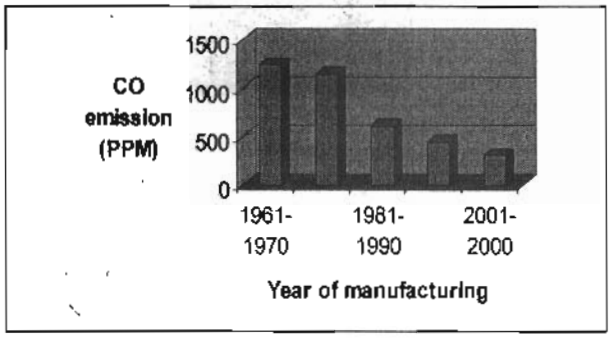


**Figure 2: Average carbon monoxide vehicles emissions versus year of manufacture [2]**

Figure 3 shows the cumulative carbon monoxide emission as related to the number of vehicles in Jordan. 80,000 cars in Jordan did not meet the standard CO emission limit allowed by traffic law.

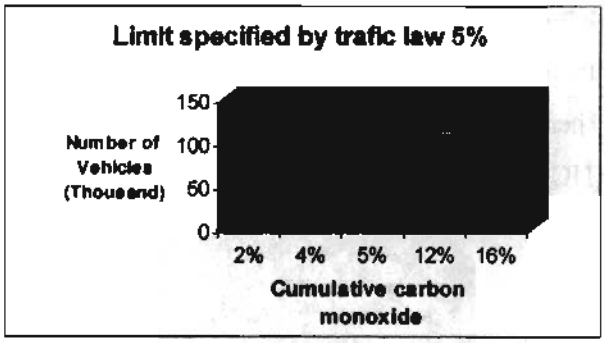


**Figure 3: Cumulative carbon monoxide (CO) emission versus umber of vehicles [2]**

Figure 4 shows the average concentration of hydrocarbon (HC) in vehicles emissions as related to the year of manufacture (in PPM). 25% of the cars emit more hydrocarbon (HC) than the acceptable limit (600 part per million) which is consisted with figure 2. [2-3]

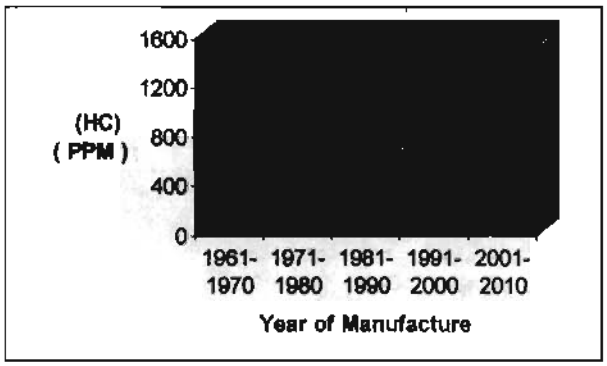


**Figure 4: Average hydrocarbon (HC) emissions versus year of manufacture [2]**

### 1.2 Importance of The Present Study

Refined oil products used in Jordan are highly dependent on imported oil. Moreover, the Jordan fleet of gasoline and diesel-powered vehicles consume about 38% of the total Jordanian oil and contribute about 67% of the total Jordan pollutants emissions. Therefore, improvements of the fuel quality and combustion process are of great importance [12-16].

The primary factors affecting vehicle exhaust emissions and fuel consumption can be classified into three categories; which are vehicle technology-related factors, fuel quality-related factors and engine-related factors.

In this study it is intended to address the second category related to the fuel quality. Hereby a diesel fuel purifying filter is mounted to a test-vehicle to assure purified diesel before being admitted to the engine cylinders. Some details of the used filter are given in subsequent sections [17-27].

## 2. The Diesel Fuel Purifier Technique

The diesel purifier produces a fuel of high purity that meets the full ignition requirements in the combustion chamber of the engine.

### 2.1 Element of Used Diesel Fuel Purifier Filter

The purifier comprises a purification chamber encapsulated by an external body of the unit wherein, the purification chamber has a barrier with conical and cylindrical parts surrounded by a filter. This enables the fuel to flow from the unit inlet through a pipe to the conical part. The upper part of the unit has a relief valve, while the lower part has a heating element, and a water sensor connectable to sound and light indicators at a cabin dash board. At the bottom there is a drain valve and a filter, which is secured at the outlet of the unit.

Figure 5 shows a photographing plate of the diesel fuel purifier filter. Also, a cross-sectional view of the body of the diesel fuel purifier is illustrated in figure 6.

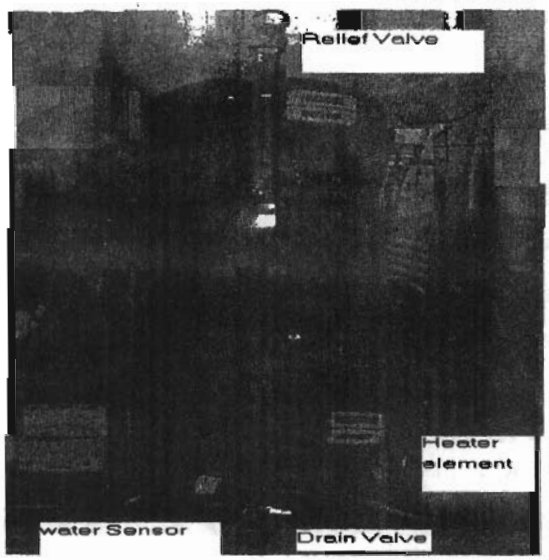


**Figure 5: Photographing plate of the Diesel fuel purifier**

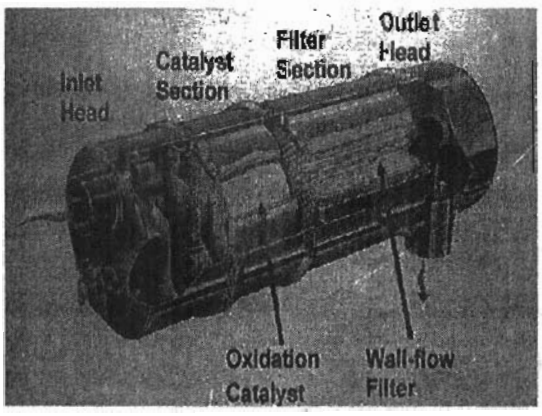


**Figure 6: Cross sectional view of the body of the Diesel fuel purifier**

The Diesel fuel purifier filter is a unique product utilizing a three-stage purification process using two well-known fuel separation principles, centrifugal and coalescence.

**2.2 Theory of Operation of Diesel Fuel Purifier**

As the fuel enters the purifier, it flows downward in a circular movement through an internal baffle system entering the lower chamber of the purifier.

In the first stage, the velocity of the fuel slows down considerably, allowing any free water droplets and other contaminates to maintain their mass and not emulsify with the fuel. These impurities accumulate and remain at the bottom of the purifier until purged.

In the second stage, the fuel migrates through three perforated baffle plates to stop any particulates and attract, by way of coalescence, any water droplets still remaining.

In the final stage, the fuel passes through the patented coalescence medium to assure that any small water droplets or particulates will be coalesced out of the fuel stream. Only the clean fuel rises to the top, providing a cleaner burning fuel for quicker ignition and better combustion.

## 3. Result and Discussion

### 3.1 Experimental Procedure and Measurement

Figure 7 shows the diesel fuel flow circuit.

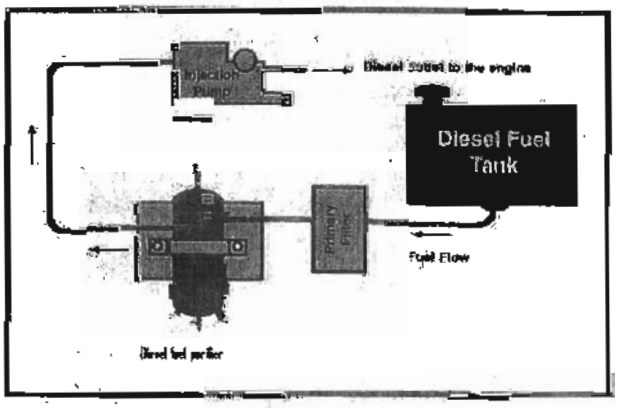


**Figure 7: The diesel fuel circuit**

The test-vehicles were driven under normal conditions for 3000km. The test vehicles were then fitted with the test Diesel fuel purifier. And then they were driven another 3000km.

Mileage and driving type (quickly, slowly) were recorded throughout this period. Smoke tests were carried out at intervals of approximately 1000km. Thus 6000km were driven in total.

At the completion of the second 3000km samples were taken, analysis and determination of the following items were carried out:

1. Smoke Particle Measurements
2. Total Acid Number
3. Determination of Sulfur:
4. Fuel consumption
5. Water percentage

Samples were taken for diesel fuel from three different points as shown in figure 8, and the samples were divided as follows:

1. Sample number (1) of diesel which coming from the diesel tank before entering the purified filter
2. Sample number (2) of the diesel was taken from the bottom of the purified filter,
3. Sample number (3) of diesel was taken from the outlet of purified filter. It should be mention that the quality of diesel at the filter exit at point 3 is better than the quality at the drainage at point 2

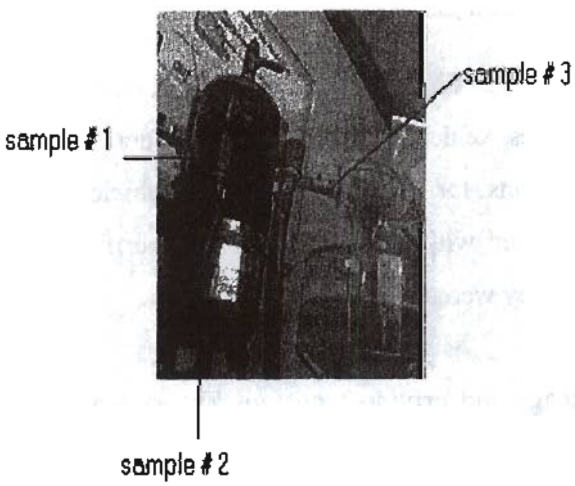


**Figure 8: Locations of Diesel fuel samples**

### 3.1.1 Smoke Particle Measurements

Sediment in diesel fuel can block filters and damage fuel injectors. Sediment extraction method IP440 was used to measure smoke particulates. Table 3 shows that smoke particulates in the exhaust emissions were reduced with 59% by the Diesel fuel purifier.

### 3.1.2 Total Acid Number Reduction

Acidity in diesel fuel results in corrosion of engine components. The "acid number" is measured by the amount of potassium hydroxide (KOH) required to neutralize the acidity in a sample (titration). Indicator vibration IP 177 was used to determine the total acid number in petroleum products.

The Purifier filter block 0.18mgKOH/g entering to engine fuel, thus the purifier filter neutralizes the acidity in the diesel fuel tank by 71% as shown in table 4, which could reduce the corrosive effect of the fuel on engine components.

### 3.1.3 Sulfur Reduction

Sulfur oxides can cause engine corrosion and are potentially hazardous to health and the environment when emitted in exhaust fumes.

With the Diesel purifier installed, sulfur at the filter output was reduced by 5.8% compared to diesel fuel in the fuel tank. This could reduce the sulfurous oxides released in exhaust gases by a corresponding amount as shown in table 5.

### 3.1.4 Particulate Matter Reduction

Sedimentation at the purifier output was 26% less than that found in the fuel tank. The sedimentation found in the residue compartment was very much higher than that in the tank because this section is where particles are filtered from the fuel tank collected. This could decrease sediment-related damage to fuel injectors. Large dark particles

found in the diesel fuel tank were not present in the filter output this shows that the Diesel fuel purifier removes the vast majority of large sedimentation from the fuel.

Table 6 shows results for two diesel samples labeled non purified and purified. Pure diesel was adulterated with particles (11 g , $\leq 105$ $\mu m$) and water (and 100 ml of water with 10 liters of diesel).. Water and particulate matter were determined using standard procedure.

**3.1.5 Fuel consumption:-**

As a result of fitting the purified filter in vehicle engine, the fuel become cleaner, thus only clean fuel rises to the top, which will provide a cleaner burning fuel for quicker ignition and better combustion. Consequently consistent clean fuel will help to increase the engine's dependability, power, fuel saving and efficiency.

The traditional method to determine the saving in fuel consumption is testing an engine in the lab and fix its operating conditions for some time and see how much fuel it consumes (with and without filter). There are several parameters that may affect vehicle engine fuel consumption during operation on the rod such as traffic jam or the driver changes style or speed, or acceleration. So the difference between the cases (with and without filter) might be attributed not only to the filter by the driving conditions.)

Consequently to avoid this misleading the mileage and driving style of the vehicles were recorded throughout the test of the purified filter. On the other hand several tested were repeated to monitor on the effect of the purified filters using different vehicles, driver, and different roads path.

The tested cars were driven normally inside and outside downtown of Amman, airport road, and inside Karak area (north of Jordan) and they follow the following procedure:-

- The fuel tank was filled with diesel fuel. And the vehicle was traveled 200 km as a round trip, which it was consumed during this trip (35) liter.
- The purified filter had been installed on the same vehicle and the fuel tank was filed again with fuel, and the vehicle was traveled the same trip, and it was consumed during the same trip which it consumed (26) liters.

Consequently 9 liters of diesel was saved as a result of installing purified Filter which mean $(\frac{35-26}{35}) \equiv 26\%$ reduction in fuel consumption.

Since only the clean fuel rises to the top, which providing a cleaner burning fuel for quicker ignition and better combustion.

- The Purifying filter make the diesel fuel more clean, consequently the combustion process will be enhancement and the gaseous emission will be reduced.

**3.1. 6 Gas Sampling Technique**

A typical gas analyzer was used to determine the volumetric concentration of the exhaust gas. Table 7 shows result of gaseous emissions which taken from exhaust gases before and after installing the purified filter. The volumetric concentration of the exhaust gas were reduced as a result of installing the Purifying filter on fuel circuit.

Table 8 shows the results of chemical analysis of diesel fuel sample. As seen, the sample No. 2 is the worst sample while sample No.3 is a good refined one.

Usually the black color appearance in the exhaust gas is due to the presence of soot particles or suspended particles. This fact was consisted with the result of table 8 in which the black color disappeared from the smoke in exhaust. As a result of decreasing of suspended solid particle in diesel fuel that has purifying filter. This fact was consisted with the first stage of the purifying filter process principle. In the first stage, the velocity of the fuel slows down considerably, allowing any free water droplets and other contaminates to maintain their mass and not emulsify with the fuel.

### 3.1.7 Water Removal

Although water does not damage diesel engines, its presence can block fuel injectors and cause the engine to stall.

Mixing five liters of clean diesel fuel (the same diesel fuel is clean sample was brought from petrol stations), with 300 milliliter of water in the purifier filter apparatus to a diesel with the operation of the electric heater added to the refined and then draw (800) milliliter of fuel Clean-up exercise.

A second nuclear test has been confusion by adding 500 grams of sand (brought from the desert sands) clean diesel fuel with and then draw (800) milliliter of fuel after Clean-up process.

The amount of water blended in diesel fuel was tested. It was found that the amount of water in the sample test is (290ppm) or the equivalent (0.029% wt) which lie within the Jordanian standard for diesel fuel (No. 195) in 1980, which allows for the existence of (00.15% wt.) of water in diesel fuel.

The amount of impurities in the diesel fuel purifier was measured. it was found that the percentage is (0.0065 % wt )where this value is located within the boundaries of Jordan for diesel fuel No. 195 in 1980, which allows for the existence of (0.01 % wt )of diesel fuel at a maximum.

### 3.2 Results and Evaluation

Tables 3 -8 show the results that obtained from the carried out experiment

**Table 3: Smoke Particle Measurements**

| | Distance Traveled (km) | Smoke particulate $m^3$ |
|---|---|---|
| Without purifier | 3000 km | 1.045 $m^3$ |
| With purifier | 3000 km (the end of the trip | 0.43 $m^3$ |
| Reduction percent of Smoke particulates $= \frac{1.045 - 0.43}{1.045} * 100\% = 59\%$ | | |

**Table 4: Total Acid Number**

| | With out Purifier filter | With Purifier filter |
|---|---|---|
| **Total Acid Number** at point 1 (inlet of filter) | 0.55 mgKOH/g | 0.55 mgKOH/g |
| **Total Acid Number** at point 2 (bottom of filter) | | 0.18 mgKOH/g (Will drain from drain valve) |
| **Total Acid Number** at point 3 (Filter output) | | 0.16 mgKOH/g |
| Percentage of Acid remove from tank = $\frac{0.55-0.16}{0.55} * 100\% = 71\%$ | | |

**Table 5: Sulfur (%)**

| | With out Purifier filter | With Purifier filter |
|---|---|---|
| Sulfur at point 1 (inlet of filter) | 52 mg/kg | 52 mg/kg |
| Sulfur at point 2 (bottom of filter) | | 50 mg/kg |
| Sulfur at point 3 (Filter output) | | 49 mg/kg |
| Percentage of sulfur remove from fuel = $\frac{52-49}{52} * 100\% = 5.8\%$ | | |

**Table 6: Percentage of particulate matter in diesel fuel**

| Parameter | Value found | |
|---|---|---|
| | Non Purified Diesel | Purified Diesel |
| Water (mille-liter) | 1 | 0.4 |
| Particulate Matter (mg/l) | 10800 | 4988 |
| Sulfur ( g/l ) | 7.2 | 6.0 |

**Table 7: Volumetric concentration of CO2, CO, NO in the exhaust gas**

| Exhaust gas | Non-Purified | Purified |
|---|---|---|
| CO2 | 52 | 19 |
| CO | 23 | 11 |
| NO | 27 | 13 |

**Table 8: The result of the chemical Analysis of diesel fuel**

| Ref | pH | Water content | Suspended Solid (%) |
|---|---|---|---|
| Sample No. 1 | 6.05 | 1.20 | 0.16 |
| Sample No.2 | 6.20 | 8.01 | 1.32 |
| Sample No.3 | 7.02 | 0.18 | 0.05 |

Finally figure 9 summaries the result of the installing diesel purifier filter on vehicle engine network

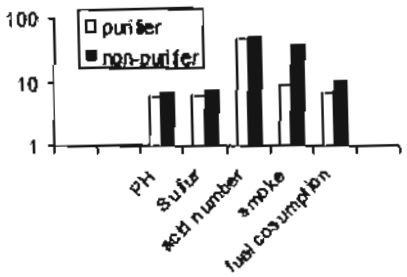


**Figure 9: Effect of fitting purifying filter on the diesel engine network**

**4. Conclusion:**

Diesel engines cause pollution in the form of excessive smoke, NOx, CO, hydrocarbons; and suspended particulates matter. Moreover, the various parts and components associated with the diesel engine are subjected to high level of wear and tear and needs frequent replacement.

The diesel fuel purifier is a single solution to the two-pronged problems mentioned earlier visa-a-visa parts replacement and increasing pollution.

Several test vehicles were driven under normal conditions for 3000km. The test vehicles were then fitted with the test Diesel fuel purifier. Another 3000km was driven using the test vehicles. Thus 6000km were driven in total.

Mileage and driving type were recorded throughout these tests. Smoke measurement was carried out at intervals of approximately 1000km.

At the completion of the second 3000km samples were taken and the following analysis was carried out: acidity in diesel fuel, sulfur oxides, and determination of Sediment. The effect and availability of the filter were evaluated on the tested car, diesel fuel consumption was calculated and gas analysis of exhaust emissions was carried out.

The following conclusions can be deduced:

- The filter removes the water from the fuel system which will greatly reduce the damage that if it happened it needs a long time to be repaired.
- Sulfuric acid is prevented from forming by (5.9%). All hard substance such as oxidizes, dirt and all kind of deposits could have higher density of diesel are reduced.
- The filter reduces 75% of the smoke 10.4% of carbon monoxide and 5.9% of nitrogen oxide in the exhaust gas.
- The filter reduces the fuel consumption by about 25%

**5. Acknowledgements**

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