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Use of Artificial Sea Acidification to Reduce Emission from Gasoline Powered Engine

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Abstract

Carbon dioxide naturally mixes with the water in the ocean and forms organic acids and this carbonic acid reacts with the calcium in a coral to form a basic solution thus converting to acid and basic. Artificial acidification has been done keeping in view the same concept in which a mixture of calcium carbonate and activated carbon is made with water and pollution is reduced when exhaust gas passes through it.

Introduction

Environment oxygen is a necessity for human life. And the life cycle comes into trouble because the environment is poisoned. Petroleum-powered vehicles are a major contributor to spread pollution. The following diseases are on the rise due to the pollution emanating from automobiles. Petroleum-powered automobiles mostly emit emissions including carbon monoxide, carbon dioxide, oxides of nitrogen and hydrocarbons.The cause of carbon dioxide from this pollution is sea acidification i.e. carbon dioxide in the air which is produced due to the combustion of petroleum is absorbed by the water into the sea. When this carbon dioxide has a chemical reaction with water, carbonic acid is produced which causes the amount of hydrogen in the seawater to increase and the pH level of the seawater to decrease. This chemical reaction has also endangered the lives of marine life. If this continues, the day is not far away when even the sea creatures will stand as an imaginary character. Humans are also an animal and this animal also has to live in harmony with every animal in nature. To do this, the level of carbon dioxide in the atmosphere must be reduced. Because many creatures feed on sea creatures and if marine life ends, all of them will be on the verge of extinction. That is, if the pH of water decreases and tends to become acidic, then even the water necessary for life cannot be destined for human beings. Carbon dioxide gas, one of the reasons behindthe greenhouse gas effect, is causing the temperature in the atmosphere to rise. The Himalayan icebergs are melting and affecting the mood of the season, such as rain in winter and heat in monsoon. Similarly, carbon monoxide emitted from automobiles is a toxic gas and if this type of gas enters a person through the nose it can cause diseases like respiratory illness and headache fatigue. Similarly, nitrogen oxides cause diseases like vascular illness. And the production of hydrocarbons causes diseases like cancer, nausea, and skin irritation. [2]

Table 1 Emission & Disease

Emission	Disease
Carbon Dioxide	Sea acidification
	GHG effect

Carbon monoxide	Respiratory illness
	Headache fatigue
Nitrogen oxides	Vascular illness
Hydrocarbon	Nausea
	Skin irritation

Such epidemics can be avoided only if the amount of pollution is reduced. Bharat stage norms have been formulated by the Government of India to reduce pollution from vehicles running on petrol. Bharat Stage is also called BS in short. These norms are designed for a two-wheeler, three-wheeler as well as for a four-wheeler. Here is the information about the norms made for the two-wheeler. BS1 was implemented in the year 2000 in which the amount of carbon dioxide and hydrocarbons was limited to two grams per kilometer. Then BS2 was implemented in the year 2005 in which the quantity was reduced to one point fifty grams. Thus BS3 was implemented in 2010 and within which the quantity was reduced to one gram per kilometer. Then in the year, 2017 BS4 was implemented and within it, the amount of carbon monoxide was increased to 1.4 grams per kilometer, the number of hydrocarbons to 0.5 grams per kilometer, and the number of nitrogen oxides to 0.6 grams per kilometer. It is now assumed that the BS6 standard will be implemented by 2021 or even 2022. In which carbon monoxide, hydrocarbon, and nitrogen oxide limits will be kept at 1, 0.1, and 0.05 g / km respectively. This can be understood from the BS6 petrol vehicles currently sold in the Indian market. [3]

Table 2 BS Standards for Two-wheelers (g/km)

N/A – Not applicable, *- Expected

BS	Year	CO	HC	NO_x
1	2000	2.00	2.00	N/A
2	2005	1.50	1.50	N/A
3	2010	1.00	1.00	N/A
4	2017	1.41	0.79	0.39
6	2022*	1.00	0.10	0.06

Definition of the Problem

According to the income and lifestyle of an Indian citizen, a two-wheeler has become a necessity in his life. If we look at the production of two-wheelers, three-wheelers, commercial vehicles, and passenger vehicles in the automobile industry, the highest sales of two-wheeled vehicles were from 2008 to 2016.

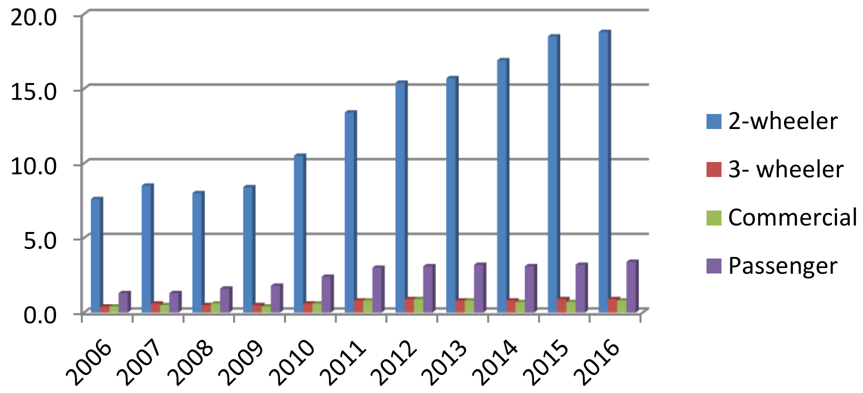

Figure 1 Millions of units sold v/s Year of Production

In the year 2006 - seven and a half million, in 2007/08/09 - eight million, in the year 2010 - ten million, in the year 2011- thirteen million, in the year 2012-13 - fifteen million, in the year 2014- eighteen million, and year 2015 and 16, 19 million two-wheeler vehicles were sold. From this information, it can understand that in the year 2006 i.e. the year in which the BS2 standard was in rule, a total of 40 million two-wheelers are satisfying BS2 standard which has been produced from 2006 to 2010. If you look at the data from 2011 to 2016, it is found that 60 million vehicles are following the BS3 Standard. Such bikes sold in the year 2006, as well as vehicles distributed by the year 2017 which are still not satisfying BS4 standard, are polluting the environment more.

So far, many compromises have been made by scientists to reduce pollution from two-wheelers that pollute such weather. Pollutants such as carbon dioxide and nitrogen oxides can be reduced by using a catalytic converter. In which rhodium is used as oxidizing catalysts which convert carbon monoxide into carbon dioxide. And reduction catalysts such as platinum as well as palladium are used to convert nitrogen oxides to nitrogen. But since minerals like platinum, palladium, and rhodium are very costly, the price of this type of converter is very high. Due to which the owners of BS2 and BS3 vehicles avoid this. As well as compulsory installation of this in vehicles like BS4 and BS6, the price of the vehicle has also gone up a lot. There is one more solution for carbon emission from the chimney is available in the power plant in which a pond is built inside a thermal power plant to collect carbon particles. The carbon particles are mixed with water, and then water and carbon particles are separated by the evaporation process. And these isolated carbon particles are used in road construction as well as in the blocks used in buildings. And according to research, the strength of a substance with carbon particles used in this way is also higher.

Chemical Reactions

Carbon dioxide gas is not considered bad in the case of internal combustion engines because carbon dioxide is a sign of complete combustion. That is, the more carbon dioxide comes out of the engine exhaust, the more petroleum is converted from chemical energy to mechanical energy. Thus, this gas is finally absorbed in the seawater. But the problem here is that carbonic acid is produced when this carbon dioxide gas has a chemical reaction with water. The solution to this problem is associated with limestone. When limestone is processed with carbonic acid generated due to a chemical reaction between carbon dioxide and aqua, the acid solution results in a basic solution. An acid solution is one whose pH value is less than seven and a basic solution is one whose pH value is more than seven. It can be said that carbon dioxide can be absorbed through the use of water and limestone. Similarly, when water comes in contact with carbon monoxide gas, formic acid is produced. And then if the chemical treatment of formic acid is done with limestone it results in a basic solution. Continuing in this series, nitric acid is produced when nitrogen oxide comes in contact with water. This acidic solution is converted to a basic solution by limestone.All these chemical reactions equations are as follows.

Table 3 Chemical Reactions

• $C_8H_{18} + 12.5O_2 = 8CO_2 + 9H_2O$ [4]
• $C_8H_{18} + 8.5O_2 = 8CO + 9H_2O$ [4]
• $CO + H_2O = HCOOH$ [5, 6]
• $HCOOH = CO_2 + H_2$[5]
• $CO_2 + H_2O = H_2CO_3$[5]
• $H_2CO_3 + CaCO_3 = Ca(HCO_3)_2$[6]
• $N_2 + O_2 \rightarrow 2NO$ [7]
• $2NO + O_2 \rightarrow 2NO_2$[7]
• $3NO_2 + H_2O = 2HNO_3 + NO$ [7]
• $CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$[8]

Theoretical calculation

In theoretical calculations, how much water will it take to process carbon monoxide, carbon dioxide, and nitrogen oxides to make an acidic solution? And how much limestone will it take to make an acidic solution basic? The calculation is shown. When incomplete combustion occurs, carbon monoxide or nitrogen oxides are produced. Petrol is also called gasoline in chemical language and the chemical equation of gasoline is C8H18. Oxygen is the most essential factor for the combustion of gasoline or the combustion of anything. And this oxygen is found in the mixture of oxygen and nitrogen in the air. So it can be deduced that the combustion of gasoline requires air. Now the question is how much air is needed? The answer to this question is found by mass analysis in this way.

$C_8H_{18} + O_2 = CO_2 + H_2O$

$C_8H_{18} + 12.5\ O_2 = 8CO_2 + 9H_2O$

$((8*12) + (18*1))$ kg of C_8H_{18} + $(12.5*(2*32))$ kg of O_2 =

$(8*((1*12) + (2*16)))$ kg of CO_2 + $(9*((2*1) + (1*16)))$ kg of H_2O

114 kg of C_8H_{18} + 400 kg of O_2 = 352 kg of CO_2 + 162 kg of H_2O

For, 114 Kg combustion of Gasoline 400kg of Oxygen equired

1 kg of air = 0.232 kg of O_2+ 0.768 kg of N_2

0.232 kg of O_2 in 1 kg of air

400 g of O_2in ? Kg of air

= 400 /0.232

= 1724.14 kg of air

1724.14 kg of air = 400 kg of O_2 + 1324.14 kg of N_2

114 kg of C_8H_{18} + 1724.14 kg of air =

352 kg of CO_2 + 162 kg of H_2O + 1324.14 kg of N_2

For 114 kg combustion of Gasoline
No. of mole of N_2= (1324.14)/28 = 47.29
Theoretical A/F ratio = Mass of air / Mass of fuel
114 kg of C_8H_{18} + 1724.14 kg of air =
352 kg of CO_2 + 162 kg of H_2O + 1324.14 kg of N_2
= 1724.14 / 114 = 15.12

If the air-fuel ratio is 15.2: 1 then complete combustion takes place according to bi-mass analysis and carbon dioxide gas exhaust is obtained. Also for incomplete combustion, the air-fuel ratio should be less than 15.2: 1. To check carbon monoxide emission the engine was mounted on a test rig and the air-fuel ratio was calculated. Air discharge was measured by an orifice meter and fuel consumption was measured by a measuring flask.

Figure 2 A/F ratio measurement

Mass flow of air. -

$m_a = 0.62 \times 4.52 \times 10^{-4} (2 g . h_a)^{0.5} \times 3600 . \rho a /1000$ Kg/hr.

Where, Cd of orifice = 0.62, Area of orifice = 4.52 x 10^{-4} m2, ha = 13 Cm (Menomatric head difference), m_a = 19.58 kg/hr

A/F ratio actually

Fuel Consumption -

Let the time required for 10 ml fuel be t_f sec.

$$FC = \frac{10}{t_f} \times \frac{3600 \times 0.7}{1000} \text{ Kg / hr}$$

$$= \frac{25.2}{t_f} \text{ Kg / hr.}$$

Where, Density of petrol is 0.7 gm /cc.

FC = 25.2 /17.65 = 1 .43 kg/hr

A/F ratio = 19.58 / 1.44= 13.69

The actual air-fuel ratio is less than the theoretical air-fuel ratio. How much more amount of fuel is required?

= 1724.14 / (114+x) = 13.69

X= 11.96 kg more gasoline obtain.

For 11.96 kg amount of gasoline incomplete combustion was observed.

Now if the air-fuel ratio is 13.69: 1, then 13.69 kilograms of air is available for burning one kilogram of gasoline fuel. This is not sufficient in the comparison of the ratio of complete combustion. It can be said that the amount of gasoline is a little too high which cannot be combusted. How much is too much? And how much carbon monoxide gas will come out of that amount of incomplete combustion? The calculation is as shown below.

$C_8H_{18} + 8.5O_2 = 8CO + 9H_2O$

((8*12) + (1*18)) kg of C_8H_{18} + (8.5*(16*2)) kg of O_2 =

(8*(12+16)) kg of CO + (9*((1*2) +16)) kg of H_2O

114 kg of C_8H_{18} + 272 kg of O_2 = 224 kg of CO + 162 kg of H_2O

1 kg of C_8H_{18} + 2.39 kg of O_2 = 1.96 kg of CO + 1.42 kg of H_2O

11.96 kg of C_8H_{18} + 28.58 kg of O_2 = 23.44 kg of CO + 16.98 kg of H_2O

But in PUC it given in terms of % of volume

Table 4 %mass & %mole analysis for CO emission

Product	No. of mole	% of mole	mass, kg	% of mass
CO2	8	12.44	352	19.15
H2O	9	14.00	162	8.81
N2	47.29	73.56	1324.14	72.04
Total	64.29	100.00	1838.14	100.00
Product	No. of mole	% of mole	mass, kg	% of mass
CO2	7.16	**11.14**	328.56	17.87
CO	0.84	**1.30**	23.44	1.28
H2O	9.00	14.00	162	8.81
N2	47.29	73.56	1324.14	72.04
Total	64.29	100.00	1838.14	100.00

The top table provides information on how many moles, how many percent moles, how much mass, and how many percent masses of different substances are found during the process of complete combustion to produce carbon dioxide gas. While the carbon monoxide gas found in the bottom table due to incomplete combustion is produced due to the low amount of air due to the lack of carbon dioxide gas. And similarly, the number of mole and mass of carbon monoxide gas is found from the same mole of carbon dioxide and the calculation of incomplete combustion. Now the details of how much water is required to react when carbon monoxide gas reacts chemically with water, as well as how much limestone is required to make solution basic Details for such conversions are shown in this calculation.

When CO chemically reacts with H_2O formic acid will generate.

$CO + H_2O = HCOOH$

$0.84\ CO + 0.84\ H_2O = 0.84\ HCOOH$

0.84*(12+16) kg of CO + 0.84*((1*2) +16) kg of H2O = 0.84*((1+12+16+16+1)) kg of HCOOH

23.52 kg of CO + 15.12 kg of H2O = 38.64 kg of HCOOH

1 kg of CO + 0.642 kg of H2O = 1.64 kg of HCOOH

To make a solution basic formic acid reacts with limestone.

$HCOOH = CO_2 + H_2$

$CO_2 + H_2O = H_2CO_3$

$0.84\ CO_2 + 0.84\ H_2O = 0.84\ H_2CO_3$

$H_2CO_3 + CaCO_3 = Ca\ (HCO_3)_2$

$0.84\ H_2CO_3 + 0.84\ CaCO_3 = 0.84\ Ca\ (HCO_3)_2$

84 kg of CaCO3 requires for 114kg of Fuel

Table 5 CO chemical reaction with H2O

Product	No. of mole	% of mole	mass, kg	% of mass
CO	0.84	50	23.52	60.87
H2O	0.84	50	15.12	39.13
Total	1.68	100	38.64	100.00
HCOOH	0.84	100	38.64	100
Total	0.84	100	38.64	100

0.737 kg of CaCO3 requires per kg of fuel

CO + H2O = HCOOH

As per table 5, 15.12 kg water per 114kg fuel for

CO reduction

$CO2 + H2O = H2CO3$

$7.16\ CO2 + 7.16\ H2O = 7.16\ H2CO3$

Table 6 CO acid to a basic solution with limestone

Product	No. of mole	% of mole	mass, kg	% of mass
CO2	7.16	50	315.04	70.97
H2O	7.16	50	128.88	29.03
Total	14.32	100	443.92	100.00
H2CO3	7.16	100	443.92	100
Total	7.16	100	443.92	100

As per table 6, 128.88 kg of H_2O is required for CO_2 reduction.

Total = 15.12 + 128.88 = 144 kg of H_2O required

For CO & CO2 reductionon 114 kg of fuel combustion.

1.263 kg of H2O required/kg of fuel

The thing to keep in mind in all the calculations is that this calculation has been done keeping in view 114 kg of gasoline, so the information found in this calculation is also obtained keeping in mind the same amount of fuel. This calculation implies that the combustion of carbon monoxide requires 1.25 kg of water as well as 737 g of limestone.

Carbon monoxide gas was found in the first calculation when the amount of gasoline was high and the amount of air was low. Now in the opposite situation i.e. when the air volume is high and the amount of gasoline is low the air-fuel ratio is calculated for 16.33: 1. Due to the high oxygen content in this situation, the nitrogen in the atmosphere is converted into nitrogen oxide. The temperature is very high during this process because the fuel has enough air available for complete combustion. So this nitrogen oxide chemically processes with oxygen again and forms nitrogen dioxide. This whole process takes place between the cylinder and the piston. This calculation is as shown below.

$N_2 + O_2 \rightarrow 2NO$

(2*14) kg of N_2 + (16*2) kg of O_2 = (2*(14+16)) kg of NO

28 kg of N_2 + 32 kg of O_2 = 60 kg of NO

14 kg of N_2 + 16 kg of O_2 = 30 kg of NO

$2NO + O_2 \rightarrow 2NO_2$

(2*(14+16)) kg of NO + (16*2) kg of O_2 = (2*((14*1)+(16*2))) kg of NO_2

60 kg of NO + 32 kg of O_2 = 92 kg of NO_2

30 kg of NO + 16 kg of O_2 = 46 kg of NO_2

Table 7 NO reaction

Product	No. of mole	% of mole	mass, kg	% of mass
N2	1	50	28	46.67
O2	1	50	32	53.33
Total	2	100	60	100.00
NO	2	100	60	100
Total	2	100	60	100

Table 8 NO2 reaction

Product	No. of mole	% of mole	mass, kg	% of mass
NO	2	66.67	30	65.22
O2	1	33.33	16	34.78
Total	3	100	46	100.00
NO2	2	100	46	100
Total	2	100	46	100

$3NO_2 + H_2O = 2HNO_3 + NO$

(3*(14+ (2*16))) kg of NO_2 + ((1*2) + 16) kg of H_2O

= (2*(1+14+ (3*16))) kg of HNO_3 + (14+16) kg of NO

138 kg of NO_2 + 18 kg of H_2O = 126 kg of HNO_3 + 30 kg of NO

1 kg of NO_2 + 0.130 kg of H_2O = 0.913 kg of HNO_3 + 0.217 kg of NO

46 kg of NO_2 + 5.98 kg of H_2O = 42 kg of HNO_3 +9.98 kg of NO

Table 9 Nitric acid formation

Product	No. of mole	% of mole	mass, kg	% of mass
NO2	3	75.00	46	88.50
H2O	1	25.00	5.98	11.50
Total	4	100	51.98	100.00

HNO3	2	66.67	42	80.80
NO	1	33.33	9.98	19.20
Total	3	100	51.98	100

$CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$

(40+12+48) kg of $CaCO_3$ + (2*(1+14+48)) kg of HNO_3

= (40 + 2*(14+48)) kg of $Ca(NO_3)_2$ + (12+32) kg of CO_2 + (2+16) kg of H_2O

100 kg of $CaCO_3$ + 126 kg of HNO_3 = 164 kg of $Ca(NO_3)_2$ + 44 kg of CO_2

+ 18 kg of H_2O

0.793 kg of $CaCO_3$ + 1 kg of HNO_3 = 1.302 kg of $Ca(NO_3)_2$ + 0.349 kg of CO_2

+ 0.143 kg of H_2O

33.31 kg of $CaCO_3$ + 42 kg of HNO_3 = 54.68 kg of $Ca(NO_3)_2$ + 14.66 kg of CO_2

+ 6 kg of H_2O

33.31 / 114 = 0.292 kg of $CaCO_3$ / kg of fuel is required to remove NO_x

Table 10 Basic solution from NO

Product	No. of mole	% of mole	mass, kg	% of mass
CaCO3	1	33.33	33.31	44.23
HNO3	2	66.67	42	55.77
Total	3	100	75.31	100.00
Ca(NO3)2	1	33.33	54.68	72.58
CO2	1	33.33	14.66	19.46
H2O	1	33.33	6	7.96
Total	3	100.00	75.34	100

Nitrogen dioxide produces nitric acid when it is processed with water and requires about fifty grams of water. As well as this nitric acid results in a basic solution when processed with limestone and this process requires about 300 grams of limestone for 1 kg of fuel combustion.

Table 11 H2O requirement for CO & CO2 for AFR 13 and 14

AFR	CO in % of mole v/s AFR	Etra fuel	mass of CO	No of mole	CO2 in mole	H2O mass for CO2	H2O mass for CO	H2O mass for CO & CO2

								reduction
13	2.03	18.63	36.51	1.30	6.70	120.53	23.44	1.26
14	1.00	9.15	17.94	0.64	7.36	132.47	11.52	1.26

Table 12 H2O requirement for NOx for 16 and 17

AFR	NOx in % of mole v/s AFR	Extra O2	Mass of NO	Mass of NOx	No of mole	HNO3	CO2 in mass	CO2 in mole	H2O for CO2
16	1.13	23.17	21.72	33.30	0.72	30.40	10.61	0.24	4.34
17	2.41	49.62	46.51	71.31	1.55	65.10	22.72	0.52	9.29

Any vehicle generally operates in an air-fuel ratio of 13 to 17. That is, the air-fuel ratio does not go below 13 nor does it go beyond 17. Therefore Table 11 shows the amount of carbon monoxide emitted for air-fuel ratio 13 and 14 and the amount of water required to reduce it.It also shows how much water is needed for the carbon dioxide gas that is produced due to complete combustion. An increase or decrease in air-fuel ratio does not increase or decrease the total water requirement as the emission of carbon dioxide is associated with carbon monoxide emissions. That is, the emission of carbon monoxide increases only if the emission of carbon dioxide decreases. And the total requirement of water is 1.6 kg per kg of fuel. In Table 12 the requirement of water is extracted for NOx emission. Emission of nitrogen oxide is due to excess oxygen and change in air-fuel ratio also increases and decreases NOx emission. As well as water requirements also fluctuate. Thus if table 11 and table 12 are taken into consideration the maximum requirement of water is 9.29 kg/kg of fuel. Therefore, the modified exhaust after-treatment device that has been made within this research has been made keeping in view the capacity of 11 kg of water in which two kg of free space has also been placed.

Experimental setup

Carbon monoxide is measured by MQ 7 sensor and nitrogen oxide is measured by MQ 135 sensor. Both of these are sensors for air quality management that works on the Internet of Things. Hence, a bolt IoT device is used to make graphs or measurements inside digital mobile from this device. Thus both these sensors give relative data i.e. first these sensors are fitted with a direct silencer and the data found is considered as one hundred percent. This world is then fitted with a modified device and the result obtained is compared with the first result.

The experiment uses a Yamaha Fz bike with a BS3 Satisfied engine. First of all the results of pollution under control have been taken. These results are taken both ways i.e. when the device is not in use once and when the device is installed a second time.

First of all, a 3D printed device has been created to determine the number of emissions reduced by activated carbon. The hexagonal base of this device is kept at 2.5mm. As well as it has been wash coated by activated carbon. Water is to be taken inside a frying pan till the frying pan is 75% full. Then 50 g of activated carbon is to be mixed inside it and the device made of 3D printed PLA material is to be kept underwater in the vertical orientation. When it is heated slowly, the water will evaporate at once and the activated carbon in it will be coated in a device with an adhesive solution. This is found in figures 3 and 4.

Now a modified device with a capacity of 11 kg of water is located in Figure Five. Its dimension is 15 cm by 15 cm by 60 cm I.e. total volume 13500 c.c. Since the density of water is 1000 kg per meter cube, it can contain as much water as the space of cc, i.e. 13.5 kg of water can be included here. This device can be mounted inside the backside of the bike keeping in mind the drag force and lift force. Attaching such a device also gives an aerodynamic advantage.

Figure 3 3-D printed activated carbon wash coated device

Figure 4 3-D printed device with IoT sensor

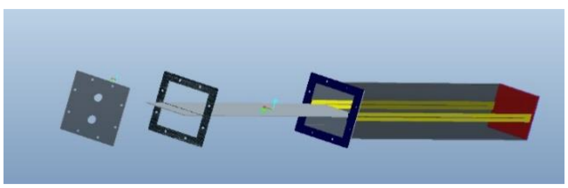

Figure 5 Modified device with 11kg aqua capacity

Figure 6 Modified device attached with a gasoline engine

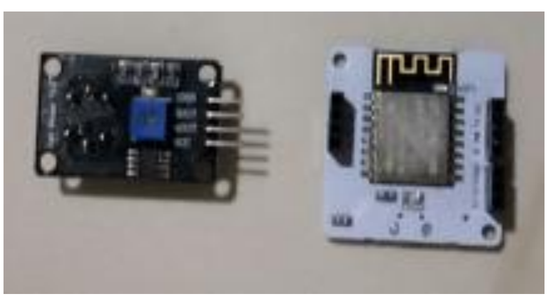

Figure 7 MQ-7 & 135 sensors with a BOLT IOT device

Figure 8 IoT sensor emission measurement

Results and discussion

To find out the effect of activated carbon on carbon monoxide emission, 3D printed devices were washed and coated with 5 gm and up to 50 gm of activated carbon. In which the measurement of carbon monoxide was taken by MQ 7 sensor, and it was found that 45 grams of activated carbon reduce carbon monoxide by 20%. Now the 45 gm wash coated 3D printed device was checked for carbon monoxide emission at different speeds and there was a 20% reduction to 3500 rpm. Such findings suggest that activated carbon also helps reduce the emission of carbon monoxide.

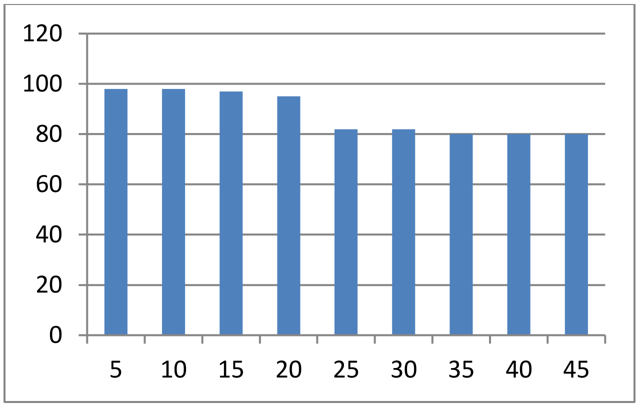

Figure 9 CO emission (Measured with MQ-7 sensor) v/s grams of activated carbon

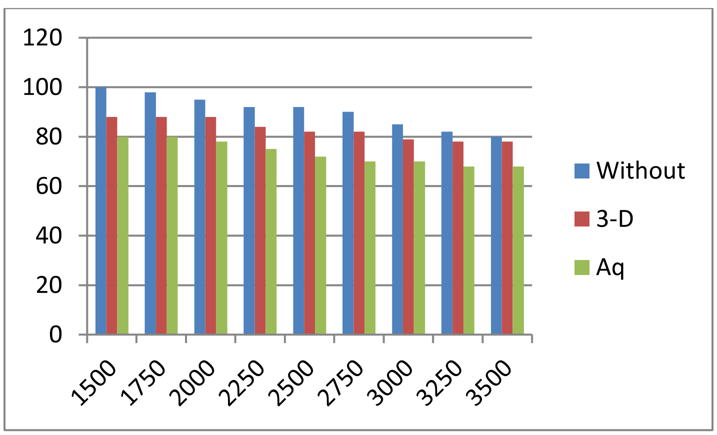

Figure 10 CO emission in % v/s Engine speed

According to the theory calculation, water, limestone, and activated carbon, all help in the reduction of emission. Theoretical calculations show that one kilogram of limestone is required in 10 kg of water and the same amount of activated carbon has been added to the mixture. The idling speed has been chosen for practical as the measurement is done at the same speed as per the pollution control rule. The engine speed is 2000 rpm and the air-fuel ratio is 13.89 constant for all readings. Total 4 parameters are getting varied in this practice which is given below. The total dissolved solids in the water, the temperature of the exhaust from the silencer, the proportion of activated carbon and calcium carbonate in the water, and the temperature of the aqueous solution. A two-level full factorial design of the experiment was carried out keeping in view these four parameters in the following range. From which the Pareto chart indicates that water is the factor that affects the highest emission. Then the proportion of activated carbon and limestone affects.

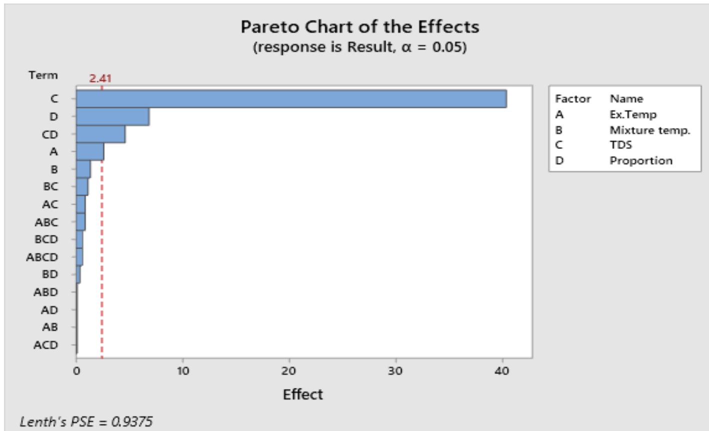

Figure 11 Pareto chart of the effect

This mixture reduces the level of emission. Now the parameter on which the emission of carbon monoxide has been reduced the most is the parameter which is the 40-degree temperature of the exhaust, the 30-degree temperature of solution mixture, 11100 TDS of aqua, and 10: 2: 2 ratio of the mixture. Here the proportion was deliberately taken at 20% which was kept more than the theoretical calculation. Now 4 Factor 3 level design was applied to make this same result more accurate. The parameters of which are given below. Now the question is how much emission reduction is done by the use of water alone? So the experiment was done with water only without mixing and the emission decreases as the TDS in the water increases as shown in the table.

DOE is done by using software Minitab V19.0

Type of design: 3 Level factorial

No. of factors: 4

Mixture temperature: 28^0C, 29^0C, 30^0C

The temperature at exhaust from the silencer: 30^0C , 40^0C, 48^0C

The proportion of calcium and activated carbon in mixture: 0.5, 1, 2

TDS of aqua: 90, 1020, 11100

Table 13 Emission results with different parameters

TDS	CO by MQ-7	Equivalent PUC
Gasoline Engine	100	1.314
90	80	1.051

1020	78	1.025
11100	76	0.988
Mixture	**CO by MQ-7**	**Equivalent PUC**
10:0.5:0.5	66	0.867
10:01:01	56	0.514
10:02:02	55	0.514

And if the mixer is kept 10: 2: 2 or 10: 1: 1 then the emission of carbon monoxide is reduced equally. And now if further reduced it will not be able to reduce emissions per kg combustion of fuel as well as the basic conversion of acid solution due to insufficient amount of water as well as the absence of limestone.In the same way when a vehicle runs at high speed. Then there is the requirement of a rich mixer. But due to the high speed of the engine, there is not enough time for the fuel to burn and due to the high temperature of the engine, the emission of nitrogen oxide is seen and this water mixture is also used to reduce this emission. This can be seen from this graph. The emission of nitrogen oxide can also be reduced by a 3D printed device but the most optimum result is seen only by a modified device using a water mixer.

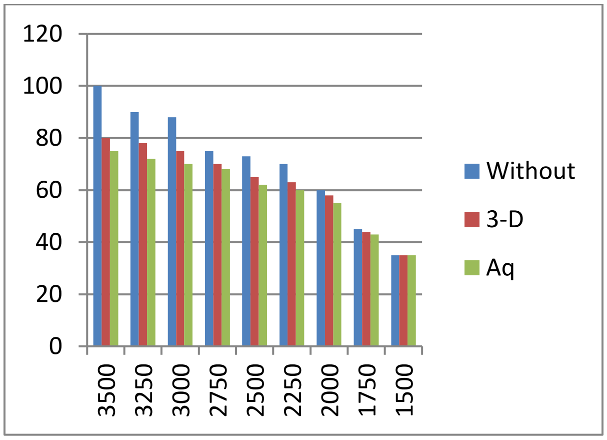

Figure 12 NOx % emission v/s Engine speed

An experiment was also done with ph paper to check whether the solution becomes acidic? In this experiment, the engine was run for seven consecutive hours. Readings were taken from 9 a.m. to 4 p.m. The experiment was carried out by water only from 9:00 a.m. and until 2 p.m. The water was then tested with pH paper in which the color of the pH paper becomes a light red color and which indicates the presence of carbonic acid. Activated carbon and calcium bi-carbonate were now added to this solution in a ratio of 10: 1: 1. And after some time interval was tested again by ph paper in which the same paper indicates the color towards the dark green color which is a sign of a basic solution. From this, it can be deduced that if the ratio of water, as well as limestone, is kept as stated in the chemical reaction and the theory calculation, the emission is reduced and the final result is in the basic solution.

Figure 13 Acidic solution

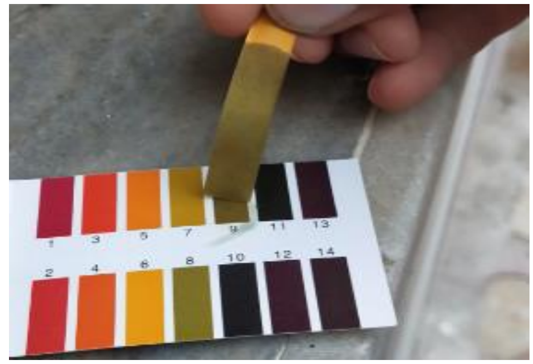

Figure 14 Basic solution

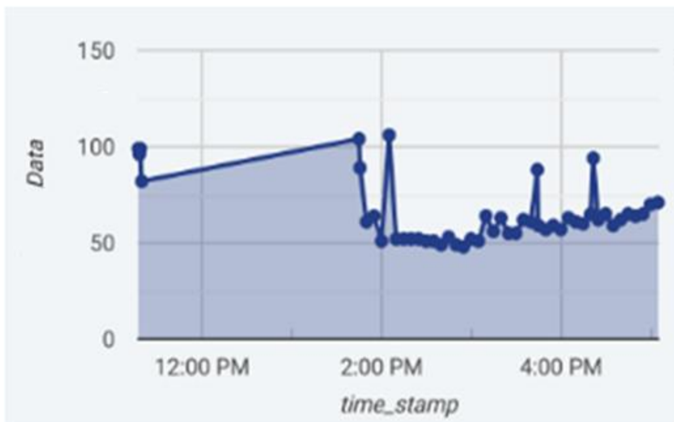

Figure 15 IOT CO emission v/s time stamp

The diagram shows 85 to 110 emissions of carbon monoxide without after-treatment exhaust. The system will be reduced by 60 – 65 after the exhaust has been fixed. At this time it was closer to 14 p.m. graph downwards when the unit is linked. Two more spikes have been found on the left and right side before 4 p.m. due to PH paper dismantling of the unit.

Conclusion

Table 14: With and without modified device comparison

Table 14 With and without modified device data comparison

Sr. no.	Detail of measurement *Modified device*	*CO Emission*	*HC ppm*
s1	Not attached	1.314%	2800
2	Attached	0.614%	1600
3	BOLT IOT Device not attached	100	-
4	BOLT IOT with modified device	50	-

- It is shown by the DOE that the lowest CO emission proportion is observed at 11100TDS and 10:2:2 but the DOE is executed at a minimum and maximum intense level. And there are no effects from the intermediate value. Random effects are obtained by means of Table 1 to verify the effect of the urban water proportions 10:1:1 and TDS 1000 and Table 1 to the effect that a 10:1:1 combination is the optimum outcome.
- Table 1, shows that the MQ-7 sensor tests an average of 100 CO units equal to 1.214 percent of volume CO as compared with PUC without adding a changed exhaust after treatment system.
- Another testing study will be done by filling the highest TDS sea water, 70 units per capita of 0.919 percent of CO volume per PUC reference, by filling 90ppm RO water, 1,020ppm urban water and 11,100 ppm sea water in adjusted exhaust treatment system and lowest pollution in the highest TDS seawater.
- The acidity of the mixture has been tested by the pH test report, which indicates acidic values of approximately 5.5 as exhaust emissions chemically react with aqua and become acidic. This means acidic in nature.
- To allow simple and continuous CO absorption from the exhaust calcium (calcareous stone) and the active carbon combined in marine water at 10:0.5:0.5, 10:1:1 and 10:2:2 respectively.
- The ratio of 0.5/10 is considered not adequate to reduce the CO emission but the 10:1:1 ratio can provide optimum result by reduced CO by a MQ-sensor of up to 50 units equal to 0.514% by the volume of CO as compared to PUC.
- The experiment also took place at 10:2:2, showing the same result as the 10:1:1 ratio and is thus considered an optimal aqueous solution to limit emissions of exhaust.
- Table 2 shows the relation with the PUC data received of the optimal mixing value. It concludes that the amount of CO decreased in the adjusted exhaust after treatment unit from 1.314 percent to 0.514 percent with a 10:1:1 water solution. The same decrease from the MQ-7 sensor shows a decrease in CO from 50 units to 50 units that validates sensor data.
- Data from PUC shows that CO emissions have decreased by 60 percent while data from MQ-7 shows that CO emissions have decreased by 50 percent.
- The PUC certificate also states that reducing HC emissions from 2800 to 1600 ppm ensures that emissions of HC are nearly 40% lower when a revamped exhaust after-treatment system is used.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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