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A Novel Model for Transforming Harmful Vehicle Exhaust Emissions into Useful Products

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ABSTRACT

The use of a vehicle is a great convenience for the individual but society pays a very high price for it, especially in crowded cities where there are more cars than in smaller cities. Motor vehicles are a source of air pollution in cities with various environmental problems. The main pollutants emitted by gasoline cars are carbon monoxide, nitrogen oxides, hydrocarbons, sulphur dioxide, volatile organic compounds and other particles. In order to reduce air pollution caused by motor vehicles several control measures have been imposed including strict environmental standard, upgradation of gasoline quality and the promotion of new energy vehicles.

According to the classification of air pollutant sources, in urban area motor vehicle emission accounts for more than 80% of the air pollution in major cities. The statistics tells that the level of carbon monoxide and nitrogen oxide exceeds national standard where the average speed of vehicles is high.

Nitrogen oxides are a group of air polluting chemical compounds including nitrogen dioxide and nitrogen monoxide. Nitrogen dioxide is the most harmful of these compounds and is generated from the combustion of fuel engines and industry.

This paper puts forward a vehicle exhaust emission treatment model based on the oxidation of pollutant gases and then reaction with calcium oxide. Our model can remove major pollutants, that is carbon dioxide, carbon monoxide and nitrogen oxide, from car exhaust by converting them into calcium carbonate and calcium nitrate respectively.

This model provides a simple, easy and effective measure to control the vehicle exhaust emissions.

KEYWORDS

Air pollution, Calcium carbonate, Calcium nitrate, Calcium oxide, Carbon monoxide, Harmful emissions, Nitrogen oxide, Oxidation, Reaction, Vehicle exhaust

INTRODUCTION

Everyday a person inhales 10,000 – 20,000 L of air; so even relatively small amounts of any harmful substances, long inhaled with contaminated atmospheric air, adversely affect his health and often cause various diseases.

Carbon monoxide is a colourless, odourless toxic gas which is produced as a result of incomplete combustion of organic compounds. The primary health effect of carbon monoxide is that it reduces the oxygen carrying capacity of the blood. At atmospheric concentrations, carbon monoxide can affect the functions of the brain, lungs and heart – all of which are sensitive to blood oxygen levels.

Nitrogen oxide is a critical precursor to the formation of ground - level ozone. Ground-level ozone can cause health problems such as respiratory irritation, asthma, reduced lung function, and premature death. It can also damage crops, forests, and ecosystems.

The United Nations Environment Programme (UNEP) plays a major role in helping to reduce air pollution. UNEP facilitates the "International day of clean air for blue skies" and co-leads "The breathe life campaign", which aims to mobilize countries, cities and individuals to protect human health and the planet from air pollution.

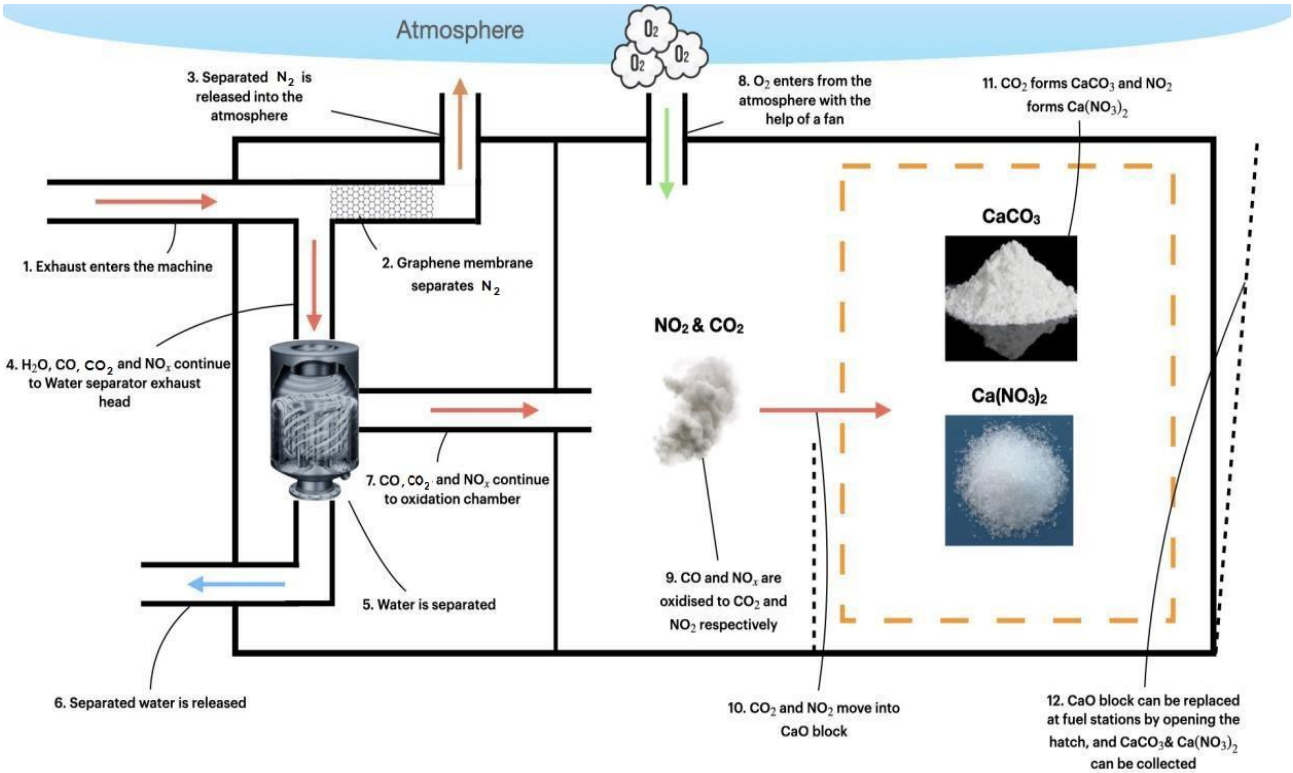
The emission factor is a key parameter in the calculation of vehicle pollutant emission. Vehicle exhaust emission is affected by many factors including the features of vehicles (such as vehicle type, technical level, emission control devices and operation condition), urban road conditions, maintenance frequency, fuel type, the levels and effect of maintenance and the characteristics of roads (altitude, temperature and humidity, road conditions and traffic conditions).

Dangerous emissions are mainly caused by the engine warming up at idle and the vehicle movement when parked. These exhaust emissions are consequently influenced by the age of the vehicle, vehicle model, engine size, fuel type and delivery system, vehicle maintenance and road network.

The motor vehicle operation conditions are different between urban roads and highways. The former confirms to the standard conditions while the latter confirms to the constant speed condition.

The differences between two emission factors for different operation conditions are relatively large, so it is necessary to consider the average speed of vehicles for the calculation of vehicle emission factors.

This study will focus on conversion of the harmful vehicle exhaust emissions into useful products.



METHODOLOGY

Components

1. Inlet Pipe
2. Graphene Membrane
3. Water separator Exhaust Head
4. Water outlet pipe
5. Oxidation chamber
6. Blower
7. Contractible Wall
8. Honeycomb Structure Porous CaO block

Purpose of the components

1. Inlet Pipe

- This will be made up of stainless steel.
- This will connect the exhaust pipe to our machine.

2. Graphene Membrane

- This will be made up of graphene.
- Zhong et al. reported that graphene sheets modified with the appropriate pore size of 4.06 Å could efficiently separate N_2 and CO_2 by molecular dynamic (MD) simulation and found that the graphene sheets behaved like a mesh that blocked CO_2 permeance but allowed N_2 to pass through. [10-13]
- This graphene membrane will be used for separating N_2 from the car exhaust.
- This N_2 will be released into the atmosphere.

3. Water separator Exhaust Head

- As water vapour is 13% of the car exhaust [14], we will separate it by a water separator exhaust head.
- Car exhaust enters at the inlet of the exhaust head where it is directed into a centrifugal upward motion. The water droplets are separated out by a reduction in velocity. The water droplets will fall towards the water outlet.
- In the end of this process, we will be left majorly with Carbon monoxide (CO), Carbon dioxide (CO_2) and Nitrogen oxides (NOx).

4. Oxidation Chamber

- Once the water has been separated, the car exhaust will be passed to the oxidation chamber.
- CO and NOx will react with O2 in this chamber.
- Hence, CO2 and NO2 will be formed.
- This enclosed chamber will have a blower to suck in air from the atmosphere for bringing in excess O2.

5. Honeycomb Shaped Porous CaO **block**

- The CO2 and NO2 will enter the CaO chamber, wherein it will react with CaO.
- The Honeycomb structure will ensure maximum efficiency.

- This reaction will therefore create, CaCO3 (Calcium Carbonate) and Ca(NO3)2 (Calcium Nitrate).

6. Contractible Wall

- When the CaO block is being replaced, the contractible wall will expand so that the internal other parts can't be accessed except just the block.
- This will increase the lifetime of the machine.

Calculations

Emissions that our machine aims to reduce:
Carbon Dioxide ≈ 1.224×10^{-4} kg/m [15] ≈ 2.78×10^{-3} moles/m
Carbon Monoxide ≈ 2.1×10^{-6} kg/m [16] ≈ 8×10^{-5} moles/m
Nitrogen Oxides ≈ 8×10^{-8} kg/m [17] ≈ 2×10^{-6} moles/m
After reaction with CaO block, formed products are:
Calcium Carbonate - CaCO3 = 2.86×10^{-4} kg/m
Calcium Nitrate - Ca(NO3)2 = 1.64×10^{-7} kg/m

Reactions

$CO + (½)\ O_2 \longrightarrow CO_2$
$CO_2 + CaO \longrightarrow CaCO_3$
$2NO_2 + CaO + (½)\ O_2 \longrightarrow Ca(NO_3)_2$
The compounds thus formed are $CaCO_3$ and $Ca(NO_3)_2$
This will get stored at fuel stations and can be transported to a factory where they get separated.
$Ca(NO_3)_2$ soluble in water but $CaCO_3$ is not, hence the substances can be separated.

OBJECTIVE / BENEFITS

The purpose of this research is to find solution of harmful vehicle exhaust emissions.
Our model transforms carbon monoxide, carbon dioxide and nitrogen oxide from vehicle exhaust emission, by reaction with calcium oxide, into calcium carbonate and calcium nitrate which have a wide range of uses.
Calcium carbonate is widely used in medicinal industries and also play a role in agricultural sector and animal husbandry. Calcium carbonate is used as calcium supplement and to manufacture antacids and tablets made of base materials. In agriculture, calcium fertiliser enriches impoverished soil and the content of calcium carbonate in the soil is an indicator that shows the soil quality. Mixes containing calcium carbonate are perfect dietary supplements for animals. Calcium carbonate is used in blast furnace to remove impurities in iron ore.
Calcium nitrate is widely used in fertilizers and pyrotechnics. Calcium nitrate stimulates root growth in plants making them healthier and more vigorous plants. Calcium nitrate is used in match industries as oxidizing agent and also used to manufacture fireworks and incandescent lamp chimneys in the light industry. Calcium nitrate is also used in waste water pre-conditioning for odour emission prevention as it prevents the formation of hydrogen sulfide.

SUGGESTIONS

It is necessary to note 3 main sources of air pollution with the toxic substances emitted by cars.

1. The fulfilled gases which are going out of the muffler.
2. The crank case gases coming to the atmosphere from the engine case ventilation system.
3. The evaporating fuel getting to a surrounding medium from the fuel system of the engine and the fuel tank.

The qualitative and quantitative indicators of the release of harmful pollutants with exhaust gases of vehicles during their transport work are ambiguous and depend on many factors.

- On the type of the used fuel.
- From the design conditions and operating conditions of the engine.
- On the amount of the done work.
- On the type and characteristics of the car's movement.

Therefore, real quantitative assessment of emissions of pollutants in the atmosphere from the motor transport is a difficult task.

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CONCLUSION

Many efforts have been applied to developing air purification technologies to address the problem of vehicle exhaust pollution at the source.

However, most highly efficient catalysts are modified with precious metals and the economic cost is too high which limits their wide application.

According to CARFAX, more than 150,000 catalytic converters were stolen in 2022.[18] Reason being that, catalytic converters are rich in precious metals, such as platinum, palladium, and rhodium. A thief can earn a couple hundred bucks from a typical catalytic converter.

Another big disadvantage is that carbon deposits can build up inside catalytic converter, meaning it can become clogged, contaminated, overheated or physically damaged, leading to sluggish engine performance and, eventually, engine shutdown.

Therefore, our model is an effective way to control the air pollution to a great extent.

We hope this research paper will inform the full description of our model and its working.

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