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Nano Technolgy Application to Enhance the Emission Control by Using Activated Carbons Modified by Magnesium Oxide

***Abstract:* -** One of the fundamental processes for planet safety is the catalytic conversion of carbon monoxide (CO). CO has even been named one of the unseen toxins of this century. Inhaling CO can lead to hypoxic damage, neurological break, and even death. CO poisoning decays greenery life and accumulations in global warming and ozone layer depletion. CO is created in the atmosphere by the partial oxidation of carbon-containing mixtures. The primary origin of CO emissions is vehicles. Therefore, oxidizing contaminated CO to nonpoisonous CO2 under ambient conditions is essential for life protection in multiple applications. Additionally, low-temperature CO oxidation is crucial in reducing emissions at the cold start of an internal explosion in the engine. For controlling pollution, the available methods are pre-pollution control and post-pollution. This project depends on the post-pollution control method in Peugeot ROA automobiles using Activated Carbons Modified by Magnesium Oxide as a catalyst. An innovative catalytic converter design activated carbons modified by magnesium oxide nanoparticles as a catalyst to control pollution with different NPs lodgings and carbon structures. This proposed method aims for the reduction environmental pollution contributed by automobiles. It involves using more affordable materials than the existing rhodium nanoparticles, platinum, and palladium technique. The dispersion states of the grafted nanoparticles were examined with scanning electron microscopy (SEM) and X-ray diffraction analysis (XRD), confirming the correlation between high grafted ratio states and improved properties. The nanocomposites' desired properties were significantly enhanced when the graft density was high.

Keywords: CO1 capture, CO1 utilization, Carbon Black, Nanoparticles, Engine, Catalytic Converter, magnesium oxide, Activated Carbons, Emission.

I. INTRODUCTION

Air pollution reduction is most important to public health because every person breathes approximately 23000 times daily.[1–3] Contaminated air brings out physically unfavorable effects and unwanted biological and chemical impacts.[4–6] The produced air pollution might be considered an extra additive to our atmosphere of any material that negatively impacts life on our planet.[3] The primary pollutants of vehicles are carbon monoxide, partially and unburned hydrocarbon, nitroxides, and lead oxides.[7,8] For air pollution, not only automobiles are responsible but also other sources such as electric power generating stations and industrial and domestic fuel intake; the industrial process also contributes severely to the contamination of our planet.[9–11] Hence, serious attempts must be made to preserve our environment from degradation. Facts have proved that the discharge of many air pollutants will negatively affect public health and the natural environment. The primary pollutant discharges from automobile engines include hydrocarbons, carbon monoxide, nitrogen oxide, and sulfur oxides.[12–15]

Hydrocarbons (HC) are burned or partially burned class of fuel and are considered poisonous.[16,17] Hydrocarbons are a substantial contributor to pollution and a significant problem in civilized areas.[18] The region suffered prolonged hydrocarbons contributing to several health diseases.[19,20] Laws ruling hydrocarbons differ according to motor type and country.[21,22] In some cases, "non-methane hydrocarbons" are controlled, while "total hydrocarbons" are kept in others.[23,24] Technology for a single application may not be appropriate for an application that must meet an aggregate hydrocarbon bar in that region.[25] Methane is not directly toxic but is challenging to break down in the fuel vent lines, and the charcoal canister is intended to collect, contain, and direct fuel vapors either to the fuel tank or, after the engine has been started and warmed up, to the air intake to be burned in the engine.[26–29]

The incomplete combustion of different processes produces carbon monoxide (CO). Carbon monoxide attaches to hemoglobin responsible for carrying the oxygen in red blood cells, where oxygen (O_2) would attach.[30–32] The bonding of CO bans O2 and decreases the hemoglobin's capability to release already-bound oxygen, causing the red blood cells to be inadequate. Inhaling CO affects the oxygen level in the blood, and overexposure to it may be fatal.[33,34] Rehabilitation is performed by limiting the slow release of CO and the generation of new hemoglobin, and comprehensive recovery from moderate to severe CO poisoning may take hours or days.[35,36]

Particles of the micrometer size that makeup smoke are particulate matter.[37–39] This particulate matter has been connected to cardiovascular diseases.[40] It has adverse effects on health, including but not limited to cancer and respiratory disease. Volatile organic compounds are natural mixtures of organic chemicals that commonly have a limit not exactly or equivalent to 250 °C of boiling points, formaldehyde, for instance, comes from chlorofluorocarbons.[41] Unpredictable natural mixtures are a subsection of hydrocarbons referenced independently due to their threats to general well-being.[1,2,25]

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Nanoparticles are molecular assemblies between 1 and 100 nm in diameter in at least one direction.[42–46] The physicochemical properties of these materials are effectively changed compared to bulk materials that include microparticles and larger particles.[47] These unusual properties may lead to different environmental fates and behaviors than their bulk counterparts.[48] Due to the widespread use of nanoparticles in recent years, concerns about their possible release into the environment and their potential effects on living organisms have increased.

The main goal of the current study has been to know that activated carbon is a carbon-activated and carefully controlled oxidation process to improve carbon's pores structure. Activated carbon has a height of volume to adsorbing porosity of any material available in humankind. The improper structure of carbons in a high degree of porosity and over a broad range of pour sizes, visible cracks to gaps, and voids of molecular dimensions the determined structure of carbon will give it an extensive surface area which undergoes the carbon to absorb a considerable amount of carbons molecules. One of the most promising solid base catalysts is Magnesium Oxide (MgO), which has attracted much attention because of its superior performance. The extent of catalytic properties of MgO is highly controlled by its morphology, particle size, crystallinity, and surface area. The MgO has shown an excellent CO2 ability at high temperatures, which is more than 300 °C.

II.EXPERIMENTAL:

Materials. Magnesium Oxide ($Mg(NO_3)_2.6H_2O$) was purchased from ThermoFisher Scientific. Activated Charcoal with different sizes of honeycomb mesh (1.5, 3, 5) mm. All other reagents were used as received.

Preparation of Magnesium Oxide Nanoparticles. Weight of Mg (NO3)2.6H2O was depend of honeycomb weight with three type of proportion (10% and20% and 30% of Charcoal weight) first dissolved into a 200- ml flask and stirred slowly. The solution pH reached 10, while the solution was kept vigorously agitated for 1 hour by a magnet shaker. During the reaction of $Mg(NO_3)_2.6H_2O$ with NaOH, $Mg(OH)_2$ precipitates are formed. The suspension was separated from the solution by centrifuging at 5000 rpm for 7 min. After that, the resulting gel was washed twice with DI water and then dissolved NPs.[46]

Dynamic Light Scattering (DLS) Analysis: The particle size distribution and zeta potential of MgO nanoparticles were monitored using DLS measurements which determine particle size by measuring the rate of fluctuations in the laser light intensity scattered by particles as they diffuse through the solvent. A particle size analyzer (Beckman Delsa Nano C) was used to measure and confirm nanoparticle size distribution.

Preparation of Activated Carbon Grafted with MgO. was sprayed on the top of the carbon cube. The resulting grafted carbon was evaporated in an oven at 100 °C for 24 h, and, finally, the sample was calculated by an electric furnace at 400 °C for 2 hours.

X-ray diffraction analysis (XRD):

We use copper target material in the tube to produce an x-ray with a 1.5406-angstrom wavelength. We use a K alpha one beam of copper as an X-ray source acquired after filtering the convexity of the X-ray using divergence slits. After the beams interact with the sample in the sample holder, the reflected beam goes through some slits again, and a monochromatic filter it to avoid the entering of K beta and K alpha 2, then the detector counts the number of photons received, and it displayed as a spectrum in our monitor screen.

Emission test. Peugeot ROA engine capacity of 1587 cc, four cylinders, and a complete ejection fuel system was assembled and used with the gasoline fuel to generate the gases. All cooling and exhaust gases system was used with a gas analyzer made of BK-EA401, which analyses HC, CO1, CO2, and O2.

BK-EA401 automotive emission analyzer operation method:

1-preheating: put power plug into AC220v test switch is off "power source" switch is on. The LED display will show 401, and the analyzer is under preheating; after 5 seconds it shows, it shows time (year, month) and (date, hour) and (minute, second).

The time could be changed after 20 minutes it is on; the analyzer shows time and is automatically changed into measuring from preheating at the moment the LED display shows the following:

HC 0 PPmvol
CO 0.00% vol
CO2 0.0% vol
02 xx,xx% vol

If the process wants to be ahead, then can press the "RST" key

2- After the analyzer automatically rests and before the formal operation, the step of self-calibrating for O_2 are the following:

The "TEST" switch on the front panel is on, and press "CLP," wait for two minutes, and simultaneously press "∨" and "D" two keys, make 02 show "20.9". Last, put "TEST" at the position so self-calibrating is finished because oxygen in the sensor output has a floating range; this procedure often be repeated to ensure the precision of oxygen density.

3- Firmly connect the sampling hose to the input with a 5 m flexible hose (Do not pre-insert the sampling hose into the exhauster. After preheating is over and begin to measure, insert it into the exhauster).

Measuring the sample by connecting the sampling hose to the input on the back front with 5m plastic flexible hose. Before measuring, put the "TEST" switch in the on position and keep the sampling hose in the fresh air. Press the "CLR" key, and fresh air directly goes into the measurement chamber (Not through sampling)

Table1. Gas Analyzer specifications.

Gas	HC/CO/CO_2/O_2	Model NO	BK-EA401
Gas Analyzers	Automotive Exhaust Analyzer	Type	Electrochemical Gas Analyzer
Stability	Moment Drift≤±3%	Measuring Range	Hc 0~10000*10-6(Ppm)Vol Co:0~10*10-2(%)Vol CO2: 0
Response Time	95% Response Is Not More Than 10 Seconds	Repeatability	2%
Power Supply	AC 110/220V±10%, 50/60Hz	Preheating Time	8min (Preheating 3min Emergency Detection)
Gross Weight	12 kg	Packing Size	680*385*265mm
Specification	Automobile Exhaust Analyzer	Transport Package	International Standard

Scanning Electron Microscopy (SEM):
The morphology of films was observed by scanning electron microscopy (SEM, Model JEOL JSM-6460 LA). The films were frozen in liquid nitrogen and then snapped immediately. All the specimens' samples were fixed on stubs with double-sided tape and then sputtered with gold in a sputter coater. Then, the specimens were examined with a scanning electron microscope under high vacuum conditions and at an accelerating voltage of 15.0 kV to cross-section (2000 x) Design the Shell dimension for the container and read the emission before and after the treatment. Manufacturing the shell for the container. Analysis of the emission Exhaust Gases before and after using the Activated Charcoal by the exhaust gas Analyzer with different sizes of honeycomb mesh (1.5,3,5) mm.

III.Result and Discussion:

In general, the ultimate characteristics of the materials are greatly influenced by all of the nanoparticles used in a nanocomposite. In order to create the composites needed to evaluate the impact of MgO NPs on the vehicle engine's ability to reduce CO, pre-synthetic activated carbon black was combined with MgO. MgO NPs were loaded and dispersed across the surface of carbon black to accomplish this. This work's primary goal was to demonstrate the integration of carbon black and MgO NPs. Based on hydrodynamic diameter, the particle size of MgO nanoparticles was examined by DLS using a particle size analyzer (Fig. XXX). The average hydrodynamic diameter, as shown by the intensity distribution histogram, is 20 nm. The polydispersity index (PDI) of 0.293 indicates the monodispersed uniform of the particles. SEM studies further showed the size. The interaction between nanoparticles and molecules, specifically systems like carbon black, depends significantly on the surface charge of the nanoparticles. Following confirmation of the nanoparticle's size, it was exposed to SEM for in-depth morphological examinations.

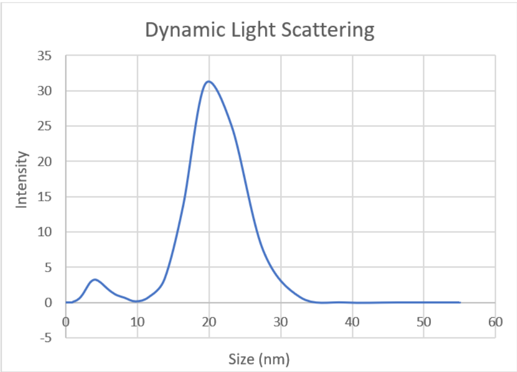

Figure 1. DLS histogram showing the intensity distribution of MgO nanoparticles for particle size analysis.

XRD analysis is carried out between 10 and 80 degrees. Figure 2 displays the results of XRD analyses of MgO nanoparticles. It displays the peaks showing how the MgO nanoparticles' polycrystalline cubic structure formed. The XRD pattern does not contain any additional impurity phases. The excellent crystallinity of the produced material is visible in the XRD pattern. Using (002) reflection to calculate particle size, the mean crystallite size is 27 nm.

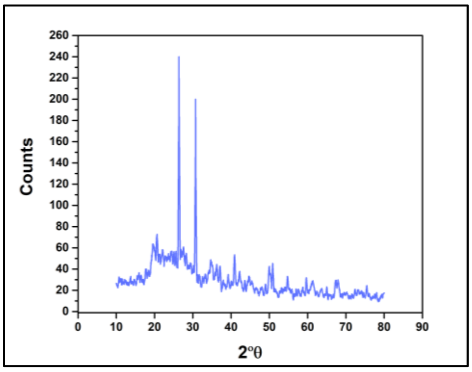

Figure 2. XRD patterns for prepared solid MgO nanoparticles.

The extremely heat-durable filler was constructed using such a design as its primary building block. SEM was used to examine the carbon black morphologies. It was evident that the surface was relatively smooth, and that the acid-treated activated carbon black surface had noticeable gaps. As seen in Figure 2, MgO nanoparticles were successfully deposited on the surface of the carbon black. A micrograph demonstrates the MgO nanoparticles' rough outer surface and shows how evenly distributed the particles are.

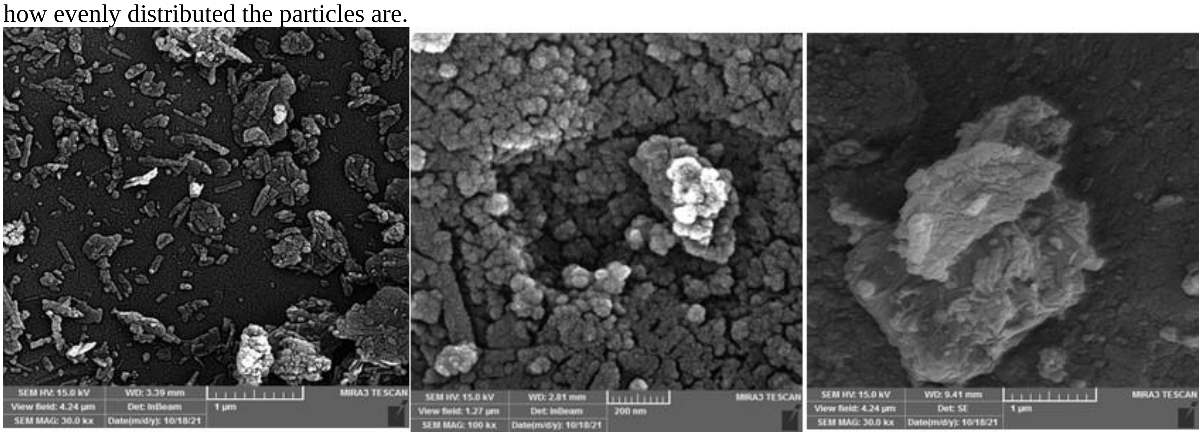

Figure 2. SEM micrograph of monodisperse MgO nanoparticle at 1µm and 200 nm scale bar.

Table 2 displays how composite materials affect carbon capture and storage techniques' ability to reduce HC, CO, and CO2 emissions. Adsorption is the method used to reduce carbon emissions from exhaust gases. It is a measure used by the automotive industry to regulate the amount of HC, CO, and CO2 emissions from vehicle exhaust. To reduce motor emissions, carbon capture and storage are deployed in stages. Eventually, utilizing the manufactured composite reduced the emission of HC, CO, and CO2 gases for four-stroke petrol engines.

Table 2. Emissions with and without using the Catalytic Converter.

Gases	Without Catalytic Converter	With Catalytic Converter (Carbon black)	With Catalytic Converter (Mgo NP-g-Carbon black)		
O2	13.98	14.64	16.41	17.23	16.26
CO1	1.11	0.95	0.75	0.78	0.75
CO2	3.7	3.7	4.1	4.2	4
HC	226	183	79	74	69

IV.CONCLUSION:

In this study, dynamic work has been done to lower HC, CO, and CO_2 emissions by carbon capture and storage technologies has been provided. Adsorption is the method used to reduce carbon emissions from exhaust gases. MgO nanoparticles grafted on activated carbon black, the solid adsorbent employed in this study, lock and retain the carbon molecules from the exhaust. For the purpose of reducing engine emissions, carbon capture and storage are deployed in stages. In comparison, the activated carbon contained very high micropores, contributing to higher gas adsorption. Combining highly porous supported materials and metal oxide can increase active sites and dispersion for better adsorption of weakly acidic gas, especially CO_2. The efficiency of the catalytic converter is expected to increase by using magnesium oxide with different grafted ratios on activated carbon by reducing the CO in and HC into lower ratio in the emission exhaust gases. Finally, this approach effectively decreased the emission of HC, CO, and CO2 emissions from four-stroke petrol engines.

REFERENCES

[1] A Daly, A.; Zannetti, P. An Introduction to Air Pollution – Definitions , Classifications , and History. Sci. Technol. 2007, 1–14.

[2] Manisalidis, I.; Stavropoulou, E.; Stavropoulos, A.; Bezirtzoglou, E. Environmental and Health Impacts of Air Pollution: A Review. Front. Public Heal. 2020, 8 (February), 1–13. https://doi.org/10.3389/fpubh.2020.00014.
[3] Wang, S.; Yuan, W.; Shang, K. The Impacts of Different Kinds of Dust Events on PM10 Pollution in Northern China. Atmos. Environ. 2006, 40 (40), 7975–7982. https://doi.org/10.1016/j.atmosenv.2006.06.058.
[4] Shane Hendricks, G.; Hall, M. J. The History and Science of CBRNE Agents, Part I. Chemist 2007, 84 (1).
[5] Length, F. Heavy Metal Pollution and Human Biotoxic Effects. Int. J. Phys. Sci. 2007, 2 (5), 112–118.
[6] Verma, R.; Dwivedi, P. Heavy Metal Water Pollution- A Case Study. Recent Res. Sci. Technol. 2013, 5 (5), 98–99.
[7] Potoglou, D.; Kanaroglou, P. S. Carbon Monoxide Emissions from Passenger Vehicles: Predictive Mapping with an Application to Hamilton, Canada. Transp. Res. Part D Transp. Environ. 2005, 10 (2), 97–109. https://doi.org/10.1016/j.trd.2004.11.003.
[8] Ukpebor, E. E.; Ukpebor, J. E.; Eromomene, F.; Odiase, J. I.; Okoro, D. Spatial and Diurnal Variations of Carbon Monoxide (CO) Pollution from Motor Vehicles in an Urban Centre. Polish J. Environ. Stud. 2010, 19 (4), 817–823.
[9] Raskin, I.; Ensley, B. D. (Burt D. Phytoremediation of Toxic Metals: Using Plants to Clean the Environment. J. Plant Biotechnol. 1999, 1 (1), 304.
[10] Jacobson, M. Z. Review of Solutions to Global Warming, Air Pollution, and Energy Security. Energy Environ. Sci. 2009, 2 (2), 148–173. https://doi.org/10.1039/b809990c.
[11] Rowe, D. B. Green Roofs as a Means of Pollution Abatement. Environ. Pollut. 2011, 159 (8–9), 2100–2110. https://doi.org/10.1016/j.envpol.2010.10.029.
[12] Zolfani, S. H.; Esfahani, M. H.; Bitarafan, M.; Zavadskas, E. K.; Arefi, S. L. Developing a New Hybrid MCDM Method for Selection of the Optimal Alternative of Mechanical Longitudinal Ventilation of Tunnel Pollutants during Automobile Accidents. Transport 2013, 28 (1), 89–96. https://doi.org/10.3846/16484142.2013.782567.
[13] Wu, B. J. S.; Allan, C. J.; Saunders, W. L.; Evett, J. B. CHARACTERIZATION AND POLLUTANT LOADING.
[14] Malik, M. A.; Ghaffar, A.; Malik, S. A. Water Purification by Electrical Discharges. Plasma Sources Sci. Technol. 2001, 10 (1), 82–91. https://doi.org/10.1088/0963-0252/10/1/311.
[15] Mohapatro, S.; Allamsetty, S.; Madhukar, A.; Sharma, N. K. Nanosecond Pulse Discharge Based Nitrogen Oxides Treatment Using Different Electrode Configurations. High Volt. 2017, 2 (2), 60–68. https://doi.org/10.1049/hve.2017.0011.
[16] Skolnick, S. R. Air Pollution Exposing Airports' Poison Circles. 2000, 2001.
[17] Najjar, Y. S. H. Gaseous Pollutants Formation and Their Harmful Effects on Health and Environment. Innov. Energy Policies 2011, 1 (May), 1–9. https://doi.org/10.4303/iep/e101203.
[18] Kanthavelkumaran, N.; Seenikannan, P.; Bibin, C. Investigational Study and Manage the Poisonous Emissions in IC Engines by Nano Materials. Life Sci. J. 2013, 10 (3), 102–107.
[19] Burkart, K.; Nehls, I.; Win, T.; Endlicher, W. The Carcinogenic Risk and Variability of Particulate-Bound Polycyclic Aromatic Hydrocarbons with Consideration of Meteorological Conditions. Air Qual. Atmos. Heal. 2013, 6 (1), 27–38. https://doi.org/10.1007/s11869-011-0135-6.
[20] Ghiboub, M.; Verburgt, C. M.; Sovran, B.; Benninga, M. A.; de Jonge, W. J.; Van Limbergen, J. E. Nutritional Therapy to Modulate Tryptophan Metabolism and Aryl Hydrocarbon-Receptor Signaling Activation in Human Diseases. Nutrients 2020, 12 (9), 1–21. https://doi.org/10.3390/nu12092846.
[21] Bossel, U. Well-to-Wheel Studies, Heating Values, and the Energy Conservation Principle. Proc. Eur. Fuel Cell Forum 2003, 1–5.
[22] Ahmad, I.; Rehan, M.; Balkhyour, M. A.; Abbas, M.; Jalal, M.; Almeelbi, T.; Ismail, I. M. I. REVIEW OF ENVIRONMENTAL POLLUTION AND HEALTH RISKS AT MOTOR VEHICLE REPAIR WORKSHOPS: CHALLENGES AND PERSPECTIVES FOR SAUDI ARABIA. 2016, 2 (1), 1–23.
[23] Dai, K.; Yu, Q.; Zhang, Z.; Wang, Y.; Wang, X. Non-Methane Hydrocarbons in a Controlled Ecological Life Support System. Chemosphere 2018, 193, 207–212. https://doi.org/10.1016/j.chemosphere.2017.11.026.
[24] Wang, B.; Shao, M.; Lu, S. H.; Yuan, B.; Zhao, Y.; Wang, M.; Zhang, S. Q.; Wu, D. Variation of Ambient Non-Methane Hydrocarbons in Beijing City in Summer 2008. Atmos. Chem. Phys. 2010, 10 (13), 5911–5923. https://doi.org/10.5194/acp-10-5911-2010.
[25] Srivastava, M.; Srivastava, A.; Yadav, A.; Rawat, V. Source and Control of Hydrocarbon Pollution. Hydrocarb. Pollut. its Eff. Environ. 2019, 1–21. https://doi.org/10.5772/intechopen.86487.
[26] Paul Choudhury, S.; Dalasingh, B.; Haq, I.; Kalamdhad, A. S. Methane Production and Toxicity Evaluation of Petroleum Refinery Biosludge through Optimization of Different Modes of Heat. Process Saf. Environ. Prot. 2021, 154, 236–248. https://doi.org/10.1016/j.psep.2021.08.019.
[27] Field, J. A. The Effect of Tannic Compounds on Anaerobic Wastewater Treatment, Agricultural University. Promotor(en): G. Lettinga. - Wageningen : Landbouwuniversiteit Wageningen - 198, 1989.
[28] Yang, J.; Speece, R. E. Effects of Engineering Controls on Methane Fermentation Toxicity Response. J. Water Pollut. Control Fed. 1985, 57 (12), 1134–1141. https://doi.org/10.2307/25042815.
[29] Owen, W. F.; Stuckey, D. C.; Jr., J. B. H.; Young, L. Y.; McCarty, P. L. Bioassay for Monitoring Biochemical Methane Potential and Anaerobic Toxicity. Water Res. 1979, 13 (6), 485–492.
[30] Chukwuezie, O. C.; Polytechnic, I. S.; Nwakuba, N. R.; Asoegwu, S.; Nwaigwe, K. N. Cetane Number Effect on Engine Performance and Gas Emission : A Review American Journal of Engineering Research (AJER) Open Access Cetane Number Effect on Engine Performance and Gas Emission : A Review. 2017, No. January.
[31] Kalam, M. A.; Masjuki, H. H.; Amalina, M. A.; Abdesselam, H.; Mahlia, T. M. I.; Aslam, M. U. Emission Characteristics of a Modified CNG Gasoline-Cycle Engine. 2005 SPE Asia Pacific Oil Gas Conf. Exhib. - Proc. 2005, No. May 2015, 549–557. https://doi.org/10.2118/93350-ms.
[32] Scheepers, P. T. J.; Bos, R. P. Combustion of Diesel Fuel from a Toxicological Perspective - I. Origin of Incomplete Combustion Products. Int. Arch. Occup. Environ. Health 1992, 64 (3), 149–161. https://doi.org/10.1007/BF00380904.

[33] MEREDITH, T.; VALE, A. Carbon Monoxide Poisoning Carbon. Br. Med. J. 1988, 296 (6615), 77–78. https://doi.org/10.1346/ccmn.1980.0280406.

[34] Lukin, J. A.; Ho, C. The Structure-Function Relationship of Hemoglobin in Solution at Atomic Resolution. Chem. Rev. 2004, 104 (3), 1219–1230. https://doi.org/10.1021/cr940325w.

[35] Won, Y. H.; Cho, Y. S.; Joo, S. Y.; Seo, C. H. The Effect of a Pulmonary Rehabilitation on Lung Function and Exercise Capacity in Patients with Burn: A Prospective Randomized Single-Blind Study. J. Clin. Med. 2020, 9 (7), 1–11. https://doi.org/10.3390/jcm9072250.

[36] Ho, R. C. M.; Cheng, W.; Chua, A. N. C.; Mak, A. Neuropsychiatric Aspects of Carbon Monoxide Poisoning: Diagnosis and Management. Adv. Psychiatr. Treat. 2012, 18 (2), 94–101. https://doi.org/10.1192/apt.bp.110.008441.

[37] Kant, N.; Müller, R.; Braun, M.; Gerber, A.; Groneberg, D. Particulate Matter in Second-Hand Smoke Emitted from Different Cigarette Sizes and Types of the Brand Vogue Mainly Smoked by Women. Int. J. Environ. Res. Public Health 2016, 13 (8), 1–10. https://doi.org/10.3390/ijerph13080799.

[38] Son, Y.; Mainelis, G.; Delnevo, C.; Wackowski, O. A.; Schwander, S.; Meng, Q. Investigating E-Cigarette Particle Emissions and Human Airway Depositions under Various E-Cigarette-Use Conditions. Chem Res Toxicol 2020, 33 (2), 343–352. https://doi.org/10.4049/jimmunol.1801473.The.

[39] Siao, W. S.; Balasubramanian, R.; Rianawati, E.; Karthikeyan, S.; Streets, D. G. Characterization and Source Apportionment of Particulate Matter ≤ 2.5 Mm in Sumatra, Indonesia, during a Recent Peat Fire Episode. Environ. Sci. Technol. 2007, 41 (10), 3488–3494. https://doi.org/10.1021/es061943k.

[40] Martinelli, N.; Olivieri, O.; Girelli, D. Air Particulate Matter and Cardiovascular Disease: A Narrative Review. Eur. J. Intern. Med. 2013, 24 (4), 295–302. https://doi.org/10.1016/j.ejim.2013.04.001.

[41] GUENTHER, A.; Atmospheric. SEASONAL AND SPATIAL VARIATIONS IN NATURAL VOLATILE ORGANIC COMPOUND EMISSIONS. Ecol. Appl. 1997, 7 (1), 34–45. https://doi.org/10.1890/1051-0761(1997)007.

[42] Rahman, I. A.; Jafarzadeh, M.; Sipaut, C. S. Synthesis of Organo-Functionalized Nanosilica via a Co-Condensation Modification Using ??-Aminopropyltriethoxysilane (APTES). Ceram. Int. 2009, 35 (5), 1883–1888. https://doi.org/10.1016/j.ceramint.2008.10.028.

[43] Gu, H.; Soucek, M. D. Preparation and Characterization of Monodisperse Cerium Oxide Nanoparticles in Hydrocarbon Solvents. Chem. Mater. 2007, 19 (5), 1103–1110. https://doi.org/10.1021/cm061332r.

[44] Merza, K. S.; Al-Attabi, H. D.; Abbas, Z. M.; Yusr, H. A. Comparative Study on Methods for Preparation of Gold Nanoparticles. Green Sustain. Chem. 2012, 2 (February), 26–28. https://doi.org/10.4236/gsc.2012.21005.

[45] Asgari, G.; Salari, M. Optimized Synthesis of Carbon-Doped Nano-MgO and Its Performance Study in Catalyzed Ozonation of Humic Acid in Aqueous Solutions: Modeling Based on Response Surface Methodology. J. Environ. Manage. 2019, 239 (March), 198–210. https://doi.org/10.1016/j.jenvman.2019.03.055.

[46] Zhou, K.; Li, L.; Ma, X.; Mo, Y.; Chen, R.; Li, H.; Li, H. Activated Carbons Modified by Magnesium Oxide as Highly Efficient Sorbents for Acetone. RSC Adv. 2018, 8 (6), 2922–2932. https://doi.org/10.1039/c7ra11740j.

[47] Lue, J. T.; Department. Physical Properties of Nanomaterials; 2007; Vol. X. https://doi.org/10.5937/vojtehg67-18251.

[48] Esposito, M. C.; Corsi, I.; Russo, G. L.; Punta, C.; Tosti, E.; Gallo, A. The Era of Nanomaterials: A Safe Solution or a Risk for Marine Environmental Pollution? Biomolecules 2021, 11 (3), 1–25. https://doi.org/10.3390/biom11030441.