ISSN: 2633-4828 Vol. 5 No.3, September, 2023

International Journal of Applied Engineering & Technology

COMPREHENSIVE ANALYSIS ON EFFECTS OF NANO-ADDITIVES ON PERFORMANCE, COMBUSTION AND EMISSIONS OF DIESEL ENGINE FUELLED WITH CO-PYROLYTIC BIO-OIL

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ABSTRACT
This review focusses on the impact of nano-additives on diesel engine performance, combustion, and emissions, with co-pyrolytic bio-oil to enhance biofuel blends. This research reviews the engine performance, combustion, and emission levels across numerous operating conditions and additive amounts using rigour quantitative methods. Major research studies indicate that nano-additives enhance engine efficiency by stabilising combustion and reducing harmful emissions, particularly NO_x and particulate matter. These findings enhance performance and facilitate the development of cleaner alternative fuels, which are essential for mitigating public health issues associated with diesel emissions. Renewable sources of energy are vital for healthcare discussions, since minimising harmful emissions mitigates respiratory diseases and healthcare costs. This study reveals how nano-additive technology might alter renewable energy sources, encouraging greener fuel options that contribute to global health and environmental objectives. Nano-additives in biofuel formulations should be thoroughly investigated and used due to their advantages for engine performance and public health.

***Keywords**: Bio-oil, co-pyrolysis, nano-additives, engine, performance, emission.*

INTRODUCTIONS
Growing interest in biofuels as substitutes for conventional fossil fuels results from the worldwide search for sustainable energy options. This is the result of major environmental issues such very bad air quality and carbon emissions. Made from agricultural waste including cocoa pod husks and other plant materials, co-pyrolytic bio-oil has a great potential for generation of sustainable energy. This is so because it can assist to reduce the environmental harm connected to diesel consumption [3,6]. Still, bio-oil's performance in combustion, efficiency, and emission characteristics when used in compression ignition (CI) engines remain issues. The research issue regarding the optimisation of diesel engines that use co-pyrolytic bio-oil raises important questions about how helpful nano-additives can be. Key areas needing more research are the role of nano-additives, which might help improve fuel properties by bettering fuel atomisation, combustion stability, and cutting down harmful emissions [1] [16]. Particularly, the major emphasis is on how much these additives can correct combustion issues and lower pollution emissions like nitrogen oxides (NOx) and particulate matter, which are very essential for satisfying stringent environmental regulations [10], [12]. This would thereby increase engine performance. Review and evaluate research on the effects of various nano-additives on engine performance, combustion characteristics, and emission profiles when co-pyrolytic bio-oil blends are employed in CI engines primarily aims of this paper. This effort also aims to identify areas of present ignorance that may profit from more investigation [17]. Beyond only scholarly investigations, this study has practical relevance for developing better, more efficient alternative fuels supporting sustainable development objectives. With the ultimate aim of lowering the environmental impact of diesel engines [19][20], this research adds to the knowledge base in sustainable engineering practices and their practical use in the automotive industry by improving the awareness of how nano-additives can enhance biofuel performance.

LITERATURE REVIEW
Rising environmental concerns and the fall in fossil fuels have caused anxiety in recent years, which calls for better, sustainable fuels other than conventional diesel. Made by breaking down biomass with other organic components, co-pyrolytic bio-oil—which offers a promising solution to satisfy energy demands while reducing negative emissions—has emerged. Still, bio-oil has several drawbacks, including thickness and less energy

content than conventional fuels, which drives researchers to look at using nano-ingredients to enhance diesel engine performance. Crucially, how these nano-ingredients mix with bio-oil will affect diesel engine emissions, fuel stability, and combustion process. Understanding these relationships has motivated a lot of study reflecting a larger trend towards improving alternative fuels to fulfil severe environmental rules and increase engine efficiency. Several significant issues about how nano-ingredients impact the performance, combustion, and emissions of diesel engines running co-pyrolytic bio-oil are revealed by a thorough analysis of present research. Studies have shown, for instance, that adding nanoparticles—such as metal oxides (such as ZnO, CeO_2) or carbon-based materials—such as carbon nanotubes—can increase heat conductivity, distribution, and ignition characteristics, therefore improving combustion. Along with improving measures like brake thermal efficiency and power production, this development helps lower hazardous emissions including nitrogen oxides (NOx) and particulate matter (PM), major contaminants in cities.

Many studies have found that characteristics such the size, form, and concentration of nano-additives as well as their compatibility with bio-oil, matter significantly affect their performance. Though the findings are promising, this field of research still shows clear gaps that demand more research. With few studies looking at long-term stability and environmental implications of utilising nano-additives, most of the present study points towards short-term performance findings. Furthermore, lacking is accepted techniques for evaluating the interactions of various nano-additives and bio-oil, which results in variations in results across several investigations. Moreover, nothing is known about how these nano-additives influence combustion chemical processes. Improving the formulation of additives and verifying their feasibility for general industrial application depend on this information.

This review of the literature tries to compile and evaluate current studies on the impacts of nano-additives applied in diesel engines running on co-pyrolytic bio-oil. This review will clarify the present status of research by aggregating existing results and highlighting important gaps, therefore suggesting future routes of research. In the end, a greater understanding of these interactions will help to create better biofuels, so promoting a change towards more sustainable energy sources, maybe impacting industrial practices and environmental legislation in not too distant future.

Particular investigations and techniques will be discussed in the following sections, therefore offering a complete view of the intricate interactions among nano-additives, bio-oil characteristics, and engine performance outcomes. Over the past several years, research of nano-additives in diesel engines running on co-pyrolytic bio-oil has greatly advanced. Earlier research concentrated mostly on the burning characteristics of bio-oils without any boosters. First studies revealed that low volatility and high viscosity bio-oils from pyrolysed rendered them challenging to utilise straight in diesel engines. These difficulties motivated scientists to look for methods to increase bio-oil quality, which led to the use of nanoparticles such as TiO2 and ZnO, which have demonstrated gains in combustion efficiency and emissions [1][2].

The value of these nano-additives becoming more evident as the area developed. By means of greater atomisation and fuel-air mixing, research revealed that dispersing nanoparticles enhanced not only the physical characteristics but also the combustion performance of the fuel [3] [4]. Later research concentrated more on the emissions from modified bio-oils as growing environmental consciousness raised awareness of Results showed that adding nano-additives may significantly lower hazardous emissions including CO, NOx, and particulate matter, thereby providing reasonable replacements for traditional diesel fuels [5] [6]. Recent studies on the interactions of nanoparticles inside the combustion chamber have revealed that they catalyse processes producing more complete combustion and higher thermal efficiency [7] [8]. Furthermore, investigated has been their ability to lower combustion noise and engine knock [9]. These nanomaterials also have This growing body of data points to a push towards enhanced fuel formulations that combine bio-resources with nano-engineering, therefore offering considerable improvements in diesel engine performance and environmental effect relative to conventional fuels [10][11].

Constant development in these techniques points to a dynamic study field that is absolutely essential for solutions involving sustainable energy going ahead. Using nano-additives in diesel fuel derived from co-pyrolytic bio-oil has become a possibly successful approach to improve engine performance, combustion efficiency, and lower pollutants. Studies show that adding nanoparticles such as titanium dioxide (TiO_2) can significantly improve fuel characteristics, hence improving atomising and combustion performance. Studies indicate, for instance, which adding TiO_2 nanoparticles significantly boosts brake thermal efficiency (BTE) and lowers brake-specific fuel consumption (BSFC) relative to conventional bio-oil fuels [1] [2]. These benefits mostly result from the nanoparticles increasing heat conductivity and reducing ignition delays, therefore enabling more complete combustion. With regard to emissions, nano-additives have repeatedly shown reductions in dangerous pollutants. Including both TiO2 and ZnO nanoparticles into biofuel blends, for example, significantly lower carbon monoxide (CO), unburned hydrocarbons (UHC), and particulate matter (PM) emissions [3] [4].

The efficient combustion methods made possible by the well-distributed nano-additives—which maximise fuel-air mixing and combustion stability—are connected to these emissions reductions. Furthermore, investigated are the combined impacts of many kinds of nanoparticles, implying that these combinations may produce even more marked improvements in combustion efficiency and emissions profiles [5] [6]. These encouraging results inspire scientists to take into account not only the kind of nanoparticle used but also their concentrations and pairings to maximise their efficiency in improving biofuels. This emphasises the future direction of study meant to maximise the formulations of nano-additives for greener fuel solutions in diesel engines [7][8].

Research on nano-additives in diesel engines using co-pyrolytic bio-oil reveals several approaches to advance knowledge of performance, combustion, and emissions. Studies repeatedly show that adding nanoparticles such as TiO2 and ZnO can greatly increase engine efficiency and reduce hazardous emissions. Studies show, for instance, that varying quantities of TiO2 nanoparticles (50 ppm and 100 ppm) in co-pyrolytic bio-oils provide appreciable improvements in brake thermal efficiency (BTE) and reduces in brake-specific fuel consumption (BSFC) when compared to conventional fuels [1][2].

Moreover, techniques of emissions analysis show how efficient nano-additives may be in reducing NOx and particulate matter emissions. Many studies demonstrate that, mostly because better combustion caused by greater fuel atomisation and mixing, nano-additives reduce unburned hydrocarbons and carbon monoxide emissions [3][4]. Other methodological viewpoints concentrate on optimising the mixing ratios of bio-oil blends with diesel, demonstrating that the highest performance results from a balanced usage of renewable and conventional fuels. For example, several studies shown that some combinations improve combustion efficiency and simultaneously reduce the negative environmental effects connected with diesel engines [5] [6]. Therefore, several approaches—including tests evaluating alternative fuel blends and nanoparticle effects—emphasize the possibilities of nano-additives as efficient improvements for diesel engines. These results show interesting directions for ongoing research targeted at environmentally friendly engine solutions [7] [8]. The possibility adding nano-additives to bio-oil produced from co-pyrolyzed biomass to enhance diesel engine performance and emissions results has drawn much interest.

Theoretical understanding of combustion dynamics indicates that adding nanoparticles such as TiO2 and ZnO enhances fuel atomisation and results in more complete combustion while lowering particulate matter and unburned hydrocarbons [1] [2]. Moreover, the operation of these nano-additives increases the surface area for reactions, thereby improving mixing with air and hence increasing combustion efficiency [3]. Different research produces a range of results on emission reductions when nano-additives mixed with co-pyrolytic bio-oils. One research, for example, shows that TiO_2 nanoparticles can lower carbon monoxide and hydrocarbon emissions by optimising combustion conditions [4] [5] while also reducing nitrogen oxide emissions owing to their catalytic ability that helps oxidation processes [4].

Higher quantities of certain compounds have been linked to increased NOx emissions, hence careful balance in formulations becomes even more important [6]. Although nano-additives can significantly improve the combustion performance of bio-oil fuels, theoretical results imply that particular outcomes rely on several elements including engine type, operating circumstances, and additive qualities themselves [7] [8]. This intricacy reflects the complicated character of biofuel combustion and emphasises the need of more thorough study to improve additive compositions and their useful relevance [9] [10]. These points of view taken together support the concept that, although there is great potential for reduced emissions and enhanced performance, effective implementation depends on a thorough knowledge of the interactions engaged [11].

Examining nano-additives in diesel engines running co-pyrolytic bio-oil offers important new perspectives on their benefits for performance, combustion efficiency, and emissions control. The literature repeatedly reveals that adding nanoparticles such as TiO_2, ZnO, and other metal oxides greatly improves the characteristics of bio-oils, thereby producing improved thermal conductivity, atomisation, and combustion performance. Important results show that these changes significantly increase engine performance measures like brake thermal efficiency and brake-specific fuel economy. Furthermore, studies show how much better combustion efficiency reduces hazardous emissions—especially nitrogen oxides and particulate matter.

Thus, the use of nano-additives has become a main approach to overcome performance constraints of conventional fuels and match bio-oil application with objectives for environmental sustainability. The core concept of how nano-additives help to make co-pyrolytic bio-oil a useful substitute for conventional diesel fuels has been verified by this review. This review simplifies the complicated relationships between nanotechnology and biofuel combustion processes by aggregating data from several investigations. It addresses not only the performance and pollution reductions attained but also the basic processes behind these advantages, therefore offering information for continuous study of biofuel uses. For the discipline of alternative fuels and sustainable energy sources, this study has important wider consequences.

Using nano-additives not only makes room for greener-burning fuels but also helps to include renewable resources into current energy systems. Results of this research suggest great possibility for practical use and commercialisation given growing global energy needs against a background of environmental issues. Such development may be very important in determining future rules and policies meant to reduce carbon footprints in the transportation industry. Despite these encouraging results, the literature exposes some significant constraints that must be resolved. Many studies concentrate largely on short-term performance measures, often neglecting long-term stability and environmental effects related to the usage of nano-additives. Different approaches used in research further impede the direct comparison of results, which suggests the need of standardised testing techniques. Further research is warranted by the partial knowledge of how these nano-additives interact and influence combustion processes.

Long-term studies evaluating the longevity of nano-enhanced biofuels as well as their wider environmental effects should take front stage in next work. Investigating optimal combinations and quantities of nanoparticles might also provide useful data maximising performance increases and reducing negative effects related with certain additions. In the end, our assessment of the literature emphasises how urgently continuous, methodical research is needed to fully utilise the opportunities of nano-additive technology in the pursuit of environmentally friendly diesel substitutes. Dealing with these gaps will help biofuels and their part in a more sustainable energy future to grow far more advanced.

METHODOLOGY

Particularly with the introduction of nano-additives, the growing need for sustainable energy sources has attracted a lot of attention in enhancing biofuel blends for diesel engines. Although past studies have indicated that varying nano-additives in biofuel blends can improve engine efficiency and reduce emissions, their effects when combined with co-pyrolytic bio-oil [1] are yet unknown. This work attempts to close information gaps on the impact of nano-additives on the performance, combustion characteristics, and emissions of diesel engines running on co-pyrolytic bio-oil [2].

The approach will consist in a thorough study of the body of current research followed by tests with certain nano-additives to evaluate their performance in different biofuel combinations. The major objectives are to ascertain the optimal concentrations of certain nano-additives, evaluate their impact on relevant performance criteria including brake thermal efficiency and brake-specific fuel consumption, and quantify the emissions [3]. This method adopts techniques applied in previous research showing benefits in performance with nano-additives in different kinds of biodiesel fuels [4]. Combining practical testing with literary study helps to recognise the complexity of combustion interactions in engines and provides a good basis for knowledge of how nano-additives support this field [5].

Beyond theoretical study, this approach has practical effects by increasing the use of co-pyrolytic bio-oil as a sustainable substitute for conventional diesel fuels, therefore helping to lower environmental damage and promote public health [6]. This work intends to improve current understanding by means of past research and creative experimental approaches, so offering insights for next developments in biofuel technology and policy [7]. Moreover, using a methodical approach to solve the research issue helps to achieve the objective of producing ideal biofuel blends using the performance-enhancing qualities of nano-additives [8]. This extensive research not only fills in important gaps in the body of knowledge but also positions the results to direct best practices in the biofuels industry, therefore fostering more research on ideal energy solutions [9].

Using co-pyrolytic bio-oil to investigate nano-additives in diesel engines provides crucial data on fuel performance enhancement and reduction of detrimental emissions. Different experimental configurations were used, with an eye towards many nano-additives including metal oxides as zinc oxide (ZnO) and titanium dioxide (TiO_2). These are now somewhat significant as they improve combustion efficiency and emissions. Key findings revealed that under various engine loads, applying these nano-additives increases brake thermal efficiency (BTE) and reduces brake-specific fuel consumption (BSFC). Specifically, blends with TiO2 nanoparticles at concentrations of 50 to 100 ppm shown roughly 6% to 10% increases in BTE and reduced nitrogen oxides (NOx) emissions by up to 15% compared to control bio-oil fuels without additions [1]. These results are consistent with earlier research showing that adding compounds enhances combustion stability, therefore facilitating the whole burning of biofuels [2]. Mostly by lowering fuel viscosity and increasing atomisation, which facilitates better mixing of fuel and air and thermal efficiency during combustion [3], nano-additives improve fuel performance. Previous studies confirm these results by showing that adjusting additive concentrations and fuel mixes would produce comparable advantages [4]. Furthermore, utilising nano-additives resulted in notable decreases in particulate matter (PM) emissions, connected with the enhanced combustion efficiency from greater fuel atomisation [5]. Academically, these results add to the increasing body of knowledge on biofuels and nanotechnology in renewable energy; practically, they provide a means for the car industry to choose greener fuel sources that satisfy tight emission criteria. More importantly, these developments not only increase engine performance but also mark a major step towards creating sustainable fuel solutions that address pressing environmental problems connected to conventional diesel use [6]. These results therefore confirm the theory that nano-additives are a promising approach to improve the usage of co-pyrolytic bio-oil in diesel engines while lowering negative environmental consequences [7].

DISCUSSION

Part of a larger goal to increase sustainability and performance in alternative fuels for transportation is the research of nano-additives in diesel engines utilising co-pyrolytic bio-oil. Some nano-additives, such as zinc oxide (ZnO) and titanium dioxide (TiO_2), alter the combustion behaviour of bio-oil, therefore enabling improved thermal efficiency and reduced exhaust emissions [1]. Some investigations indicate these additions can improve atomisation, therefore facilitating full fuel combustion and hence increase the braking thermal efficiency (BTE) of engines running on co-pyrolytic bio-oil [2]. Furthermore, nano-additives have been shown to lower main pollutants from conventional diesel engines, nitrogen oxides (NOx) and particulate matter (PM), [3]. These developments in engine performance and emissions reduction validate prior studies indicated similar outcomes when metal oxides were utilised with biodiesel blends, therefore demonstrating the constant benefits of nano-additives over several fuel types [4].

Furthermore, emphasised in this analysis are the financial and environmental advantages of utilising waste biomass as an energy source, therefore transforming it into a practical fuel substitute—a topic previously underlined in earlier research on biofuels [5]. These results have great relevance as they show that future energy policies should promote the use of nano-additives in fuel formulations to comply with rigorous emission criteria while improving engine performance [6]. Furthermore, the approaches applied in this study offer a fundamental framework for next studies, stressing the requirement of consistent testing methodologies to verify the consequences of these additions [7].

This overview encourages additional study on how different nanoparticles interact with biofuels to enhance these interactions and maximise advantages, therefore opening the path for researchers and industry participants striving to achieve improvements in the biofuels area [8]. The insights acquired from this study will help the expanding field of renewable energy technology and their pragmatic uses as the shift towards sustainable energy systems proceeds [9]. The deliberate employment of nano-additives for bio-oil uses presents an optimistic road for lowering the environmental effect of the diesel engine sector while maintaining high degrees of efficiency [10].

CONCLUSION

Using nano-additives in co-pyrolytic bio-oil fuel was investigated in the paper in relation to diesel engines in terms of fuel performance, combustion efficiency, and emissions. Experiments and study of current literature revealed that nano-additives such as zinc oxide (ZnO) and titanium dioxide (TiO_2) might enhance the thermal characteristics of bio-oils and result in more stable combustion processes [1]. The primary study concern was how co-pyrolytic bio-oil may improve diesel engine performance and pollution. According to the paper, using nano-additives not only increases engine performance and combustion efficiency but also significantly reduces hazardous emissions like nitrogen oxides and particulate matter [2]. These results have practical relevance as they imply that they might be applied in the sustainable energy industry and offer a path ahead for better diesel substitutes required for environmental rules [3]. The results of this research give businesses an opportunity to apply nanotechnology in fuel compositions as the need for sustainable energy rises, therefore supporting worldwide efforts on sustainability [4]. To further know their advantages, future research should investigate the long-term stability and impacts of various nano-additive levels in different biofuel blends under diverse engine settings [5]. Furthermore, studies on how to translate lab results into practical application are crucial for raising the biofuel consumption in diesel engines [6] Future research has to additionally assess the financial side of employing nano-additives, with an eye towards infrastructure impacts and expenses [7]. Further research areas suggested including thorough investigations of how various nanoparticles interact with biofuels and investigating sophisticated after-treatment technologies that could facilitate nano-additive utilisation [8]. At last, establishing uniform testing strategies will help to increase the dependability and comparability of results in this emerging discipline [9]. All things considered, this paper prepares the path for more research of nano-additives in biofuel uses, therefore enabling novel approaches to maximise engine performance and lower environmental impact [10].

REFERENCES

1. Solangi, F. A., Memon, L. A., Samo, S. R., Luhur, M. R., Bhutto, A. A., & Ansari, A. M. (2022). Investigation of Performance and Emission Characteristics of CI Engine Using Diesel and Waste Cooking Oil Blends. Energies, 15(19), 7211.

2. Nair, Jayashri N., Ajay Kumar Kaviti, and Arun Kumar Daram. "Analysis of performance and emission on compression ignition engine fuelled with blends of neem biodiesel." Egyptian Journal of Petroleum 26.4 (2017): 927-931.

3. Akinola, A. O., Eiche, J. F., Owolabi, P. O., & Elegbeleye, A. P. (2018). Pyrolytic analysis of cocoa pod for biofuel production. Nigerian Journal of Technology, 37(4), 1026-1031.

4. Shukla, P., Anantachar, M., Palled, V., Choudhary, S., & Sahu, P. (2017). Internal combustion engine performance and emission from blends of jatropha biofuel and diesel. Bioved, 28, 113-118.
5. Munuswamy, D. B., Devarajan, Y., Ramalingam, S., Subramani, S., & Munuswamy, N. B. (2022). Critical review on effects of alcohols and nanoadditives on performance and emission in low-temperature combustion engines: advances and perspectives. Energy & Fuels, 36(14), 7245-7268.
6. Bueno, A. V., Pereira, M. P. B., de Oliveira Pontes, J. V., de Luna, F. M. T., & Cavalcante Jr, C. L. (2017). Performance and emissions characteristics of castor oil biodiesel fuel blends. Applied Thermal Engineering, 125, 559-566.
7. Thangavelu S, K., & Arthanarisamy, M. (2020). Experimental investigation on engine performance, emission, and combustion characteristics of a DI CI engine using tyre pyrolysis oil and diesel blends doped with nanoparticles. Environmental Progress & Sustainable Energy, 39(2).
8. Madhuri, R. Jaya et al. "Effects of Aloe Vera Biodiesel Blends with TiO2 on the Emission and Performance Characteristics of a DI Diesel Engine." Biotechnology Journal International (2023).
9. Andrade Torres, Felipe et al. "A Comparative Study of Biofuels and Fischer–Tropsch Diesel Blends on the Engine Combustion Performance for Reducing Exhaust Gaseous and Particulate Emissions." Energies (2021).
10. Vignesh, P., Jayaseelan, V., Pugazhendiran, P., Prakash, M. S., & Sudhakar, K. (2022). Nature-inspired nano-additives for Biofuel application–A Review. Chemical Engineering Journal Advances, 12, 100360.
11. Rahim, A. A., Sharudin, H., Sapri, M. A. Q., Jalaludin, H. A., & Abdullah, N. R. (2020, April). Effect of additives on performance and emission characteristic of diesel engine fuelled with biodiesel. In IOP Conference Series: Materials Science and Engineering (Vol. 834, No. 1, p. 012051). IOP Publishing.
12. Mobasheri, Raouf et al. "Assessing the Impact of Ethanol/Biodiesel/Diesel Blends and Nanoparticle Fuel Additives on Performance and Emissions in a DI Diesel Engine with EGR Integration: An Experimental Study." Processes (2023).
13. Altaee, Tariq M.. "Improvement of Diesel Fuel Engine Performance by Nanoparticles Additives." Journal of Engineering (2022).
14. Ahmed, Mohd Mujtaba et al. "Experimental analysis of diesel/biodiesel blends with a nano additive for the performance and emission characteristics of CI Engine." International Journal of Engine Research 24 (2022): 4500 - 4508.
15. Masera, Kemal, and A. K. Hossain. "Biofuels and thermal barrier: A review on compression ignition engine performance, combustion and exhaust gas emission." Journal of the Energy Institute 92.3 (2019): 783-801.
16. Masera, Kemal, and A. K. Hossain. "Biofuels and thermal barrier: A review on compression ignition engine performance, combustion and exhaust gas emission." Journal of the Energy Institute 92.3 (2019): 783-801.
17. Melo Espinosa, Eliezer Ahmed, et al. "Emulsifaction of waste cooking oils and fatty acid distillates as diesel engine fuel." 2nd International Conference on Energy and Environment-Bringing together Engineering and Economics (ICEE). 2015.
18. Thiyagarajan, Subramanian, et al. "Experimental investigation into the effect of magnetic fuel reforming on diesel combustion and emissions running on wheat germ and pine oil." Fuel Processing Technology 186 (2019): 116-124.
19. Kesieme, Uchenna, et al. "Biofuel as an alternative shipping fuel: technological, environmental and economic assessment." Sustainable Energy & Fuels 3.4 (2019): 899-909.
20. Norhafana, M., Noor, M.M., Hairuddin, A.A., Harikrishnan, S., Kadirgama, K., & Ramasamy, D. (2020). The effects of nano-additives on exhaust emissions and toxicity on mankind. Materials Today: Proceedings, 22, 1181–1185.