AUTOMOBILE EXHAUSTS IMPACT ON ENVIRONMENT-RAMEDIAL STEPS TO REMOVE HARMFULL CONTAMINANTS FROM EXHAUSTS- THE ROLE OF THREE WAY CATALYTIC SYSTEMS

Dr. Divya T

Assistant Professor (Ad hoc), PG Department of Chemistry, KAHM Unity Women's College, Manjeri, Kerala-676122, India
E-mail: divyapattambi.88@gmail.com

INTRODUCTION

Environmental pollution is a major issue faced by human beings. Among these, air pollution and water pollution cause serious health issues. Remediation from these undesirable conditions is highly demanding on considering their impact on human health. The effects of air pollution on health are very complex as there are many different sources and their individual effects vary from one to the other. Huge amount of noxious gaseous substances are expelled to the atmosphere as a result of transportation, power plants, anthropogenic or manmade activities and also through various industrial processes. Since the onset of the industrial revolution, there has been a steady change in the composition of the atmosphere mainly due to the combustion of fossil fuels used for the generation of energy and transportation.These pollutants even at parts per million levels will lead to several serious environmental and health hazards. Air pollutants that are inhaled have serious impact on human health affecting the lungs and the respiratory system; they are also taken up by the blood and pumped all-round the body. These pollutants are also deposited on soil, plants, and in the water, further contributing to human exposure. Ensuring good quality air is essential for the protection of public health. Governments worldwide have adopted a range of increasingly demanding measures to curb air pollution with a particular focus on the emissions from motor vehicles. An important part of this strategy has been the development of the three-way catalytic converter to remove exhaust pollutants such as carbon monoxide, unburnt hydrocarbons and nitrogen oxides. In urban areas, three way catalytic converters play a pivotal role in improving quality of air and offer a clean and healthy environment.

EXHAUST POLLUTANTS

The most important chemical reaction in a petrol engine – that is, the one that provides the energy to drive the vehicle – is the combustion of fuel in air. In an 'ideal' system, combustion would be complete so that the only exhaust products would be carbon dioxide and steam. In practice, the complete oxidation of the fuel depends on a number of factors: first, there must be sufficient oxygen present; second, there must be adequate mixing of the petrol and air; and finally, there must be sufficient time for the mixture to react at high temperature before the gases are cooled. In internal combustion engines, the time available for combustion is limited by the engine's cycle to just a few milliseconds. There is incomplete combustion of the fuel and this leads to emissions of the partial oxidation product, carbon monoxide (CO), and a wide range of volatile organic compounds (VOC), including hydrocarbons (HC), aromatics and oxygenated species. These emissions are particularly high during both idling and deceleration, when insufficient air is taken in for complete combustion to occur.

ISBN 978-93-5396-526-6

Another important result of the combustion process, particularly during acceleration, is the production of the oxides of nitrogen – nitric oxide (nitrogen monoxide, NO) and nitrogen dioxide (NO_2). Conventionally, these two oxides of nitrogen are considered together and represented as NO_x. At the high temperatures involved (in excess of 1 500 °C) nitrogen and oxygen in the air drawn in with the fuel may combine together to form NO. On leaving the engine, this monoxide cools down and is oxidized by oxidants in the atmosphere to form the dioxide. Although the 'fixing' of nitrogen from the air is the major source of NO_x, it may also arise from the oxidation of any nitrogeneous components in the fuel.

Primary pollutants are defined as those gases emitted directly from the exhaust of a vehicle. None of these is a desirable addition to the atmosphere, but perhaps the most notorious consequence of exhaust emissions is their role in the production of photochemical smog – a mixture of ozone, nitrogen dioxide, other secondary products and small particulates. These secondary pollutants can cause severe damage to human health.

The role of an emission control catalyst is to simultaneously remove the primary pollutants CO, VOCs and NO_x by catalyzing their conversion to carbon dioxide (CO_2), steam (H_2O) and nitrogen (N_2).

DANGEROUS EFFECT OF NOXIOUS EXHAUST GASES ON HUMAN HEALTH

Nowadays exhaust gas emissions containing hazardous constituents is tremendously increasing due to population explosion. Negative impact of various hazardous pollutants on the green environment is not in our control. According to the World Health Organization, six major air pollutants include particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Long and short term exposure to air suspended toxicants has a different toxicological impact on human including respiratory and cardiovascular diseases, neuropsychiatric complications, the eyes irritation, skin diseases, and long-term chronic diseases such as cancer. Several reports have revealed the direct association between exposure to the poor air quality and increasing rate of morbidity and mortality mostly due to cardiovascular and respiratory diseases. Exposure to these toxic pollutants is unbearable to human beings, which leads to some chronic disorders such as asthma, Alzheimer's and Parkinson's diseases,lung disorders, emphysema and mainly the malfunctioning of heart functions. Among these various air pollutants, carbon monoxide poses major threat to human beings. CO is one of the major constituents of exhausts from automobiles, industrial processes and coal fired power stations. Concentration of carbon monoxide in the environment increases as a result of certain natural and anthropogenic activities. Vehicular exhausts are contributing much (73%) to this effect. Increased population is the prime cause of the excessive emission of toxic gases from various sources. The maximum permissible level of carbon monoxide in the atmosphere is 40ppm and above this critical level it will cause adverse effects on the ecosystem. It is a major threat to plantations on earth by adversely affecting N_2 fixation, photosynthesis and plant respiration. Exposure to CO gas causes a lot of health hazard issues in human beings such as dizziness, headache, vomiting, nausea, heart diseases, anemia and various respiratory disorders. Carbon monoxide promotes the ground level ozone formation also.

Even trace amount of carbon monoxide is very harmful that will lead to brain damage or even death due to anoxia. Anoxia is the condition of oxygen starvation in tissues due to the inability of hemoglobin to carry enough oxygen to tissues. CO has 200 times higher binding capacity with iron in hemoglobin than oxygen leading to the deficiency of oxygen in the blood. Hence sufficient amount of oxygen cannot be pumped into brain which makes the victims unconscious. Carbon monoxide is recognized as a silent killer which possesses

ISBN 978-93-5396-526-6

remarkable affinity towards myoglobin also. The presence of carbon monoxide creates some unbalanced conditions in human beings related to oxygen deficiency. The CO abatement techniques continue to be a hot research topic in today's era owing to the hazardous impact of carbon monoxide.

The main effect of breathing in raised levels of nitrogen dioxide is the increased likelihood of respiratory problems. These compounds are of the same family as nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. When NO_x is released into the air, it reacts, stimulated by sunlight, with organic compounds in the air; the result is smog. Smog is a pollutant and has adverse effects on children's lungs. NO_x reacting with sulfur dioxide produces acid rain, which is highly destructive to everything it lands on. Acid rain corrodes cars, plants, buildings, national monuments and pollutes lakes and streams to an acidity unsuitable for fish. NO_x can also bind with ozone to create biological mutations (such as smog), and reduce the transmission of light. Nitrogen dioxide inflames the lining of the lungs, and it can reduce immunity to lung infections. This can cause problems such as wheezing, coughing, colds, flu and bronchitis. NO_2 might be a marker for the contribution of NO_x to the formation of secondary pollutants such as secondary particles and O_3. Sulphur dioxideSO_2 (sulphur dioxide) in the air is caused due to the rise in combustion of fossil fuels. It can oxidize and form sulphuric acid mist. SO_2 in the air leads to diseases of the lung and other lung disorders such as wheezing and shortness of breath. Long-term effects are more difficult to ascertain as SO_2 exposure is often combined with that of SPM. Inhaling hydrocarbons from gasoline, household cleaners, propellants, kerosene and other fuels can be fatal to children. Further complications include central nervous system impairments and cardiovascular problems.

THE THREE-WAY CATALYTIC CONVERTER

The catalytic converter was first invented by Eugene Houdry in the 1950's. The catalytic converter has emerged as the emission-control method of the late 1970s and will probably continue that role well into the 1980s. Because the converter is an engine add-on that does not require fundamental changes in the conventional spark-ignition engine, the enormous technology and investment in these engines is retained. A catalytic converter is a simple device that uses basic redox reactions to reduce the pollutants a car makes. It converts around 98% of the harmful fumes produced by a car engine into less harmful gases. It is composed of a metal housing with a ceramic honeycomb-like interior with insulating layers. This honeycomb interior has thin wall channels that are coated with a washcoat of aluminum oxide. This coating is porous and increases the surface area, allowing more reactions to take place and containing precious metals such as platinum, rhodium, and palladium. No more than 4-9 grams of these precious metals are used in a single converter. The converter uses simple oxidation and reduction reactions to convert the unwanted fumes. Recall that oxidation is the loss of electrons and that reduction is the gaining of electrons. The precious metals mentioned earlier promote the transfer of electrons and, in turn, the conversion of toxic fumes.

There are two types of converters in use—the two-way and the three-way units. The two-way oxidation catalyst was first added to new cars in model year 1975. These units use platinum and palladium to oxidize the HC and CO and can meet the 0.41- and 3.4-g/mile standards specified for these constituents for 1981. Three way catalytic converter is a multicomponent material which primarily consist of a ceramic monolith ($2Mg .2 Al_2O_3. 5SiO_2$), which withstand high temperature and allow thermal expansion, precious metals (Rhodium, platinum, palladium and gold), CeO_2, gamma alumina and other metal oxides. Ceramic monolith has strong walls enclosing an array of parallel channels, a typical monolith

ISBN 978-93-5396-526-6

has 4 channel openings per cm^2, this type of design allows a high rate of flow of exhaust gases. Cordierite is used because it can withstand the high temperatures in the exhaust, and the high rate of thermal expansion encountered when the engine first starts – typically, the exhaust gas temperature can reach several hundred degrees in less than a minute. Metallic monoliths are also used, particularly for small converters, but these are more expensive

The satisfactory operation of both the two-way and the three-way catalysts depends on controlling the composition of the exhaust products entering the catalysts. The three-way catalysts can be either dual-bed or single-bed systems. A dual-bed system requires that the engine operate with a rich air/fuel mixture so that the NO_x, can be reduced in the first bed. Air is then added to the exhaust leaving the first bed so that the oxidation reaction to control HC and CO can proceed in the second bed. Three way catalytic converters are gaining more attraction when considering its role in environmental pollution abatement. On properly combining three way catalytic systems with automobile engine system, almost 90 % air pollution from automobile exhausts can be controlled effectively. The partially combusted hydrocarbons, CO, NOx are converted to environmentally friendly products CO_2, H_2O and N_2 by three way catalytic reactions in a single step. Noble metals are widely investigated as promoters in three way catalytic systems due to its low temperature reducibility. But their ever increasing cost and poor thermal stability holds back its application from this field. An alternative to noble metals can be achieved by incorporating a low temperature reducible catalyst in three way catalytic converters.

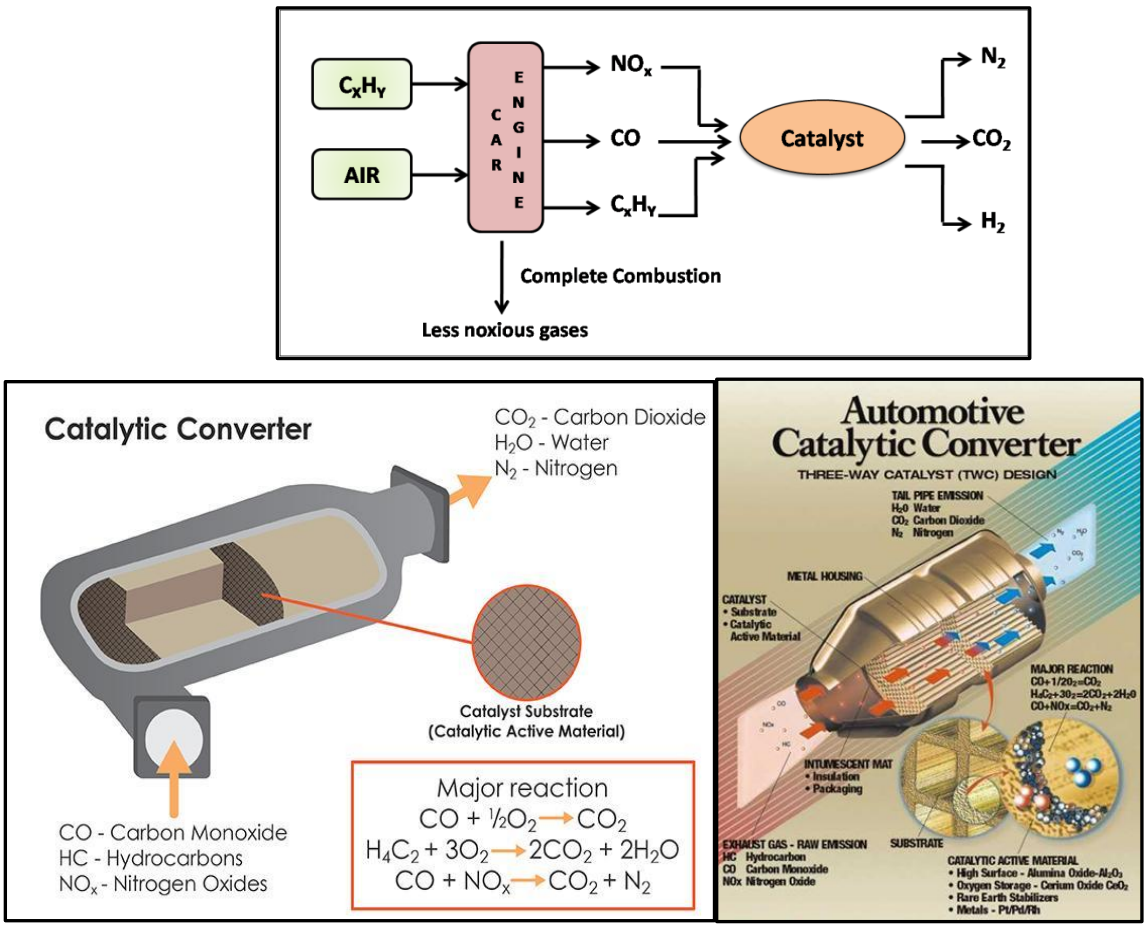

Fig.1. Three way catalytic reactions in exhaust gas engine of vehicles in the presence of catalyst

ISBN 978-93-5396-526-6

As a major and common component in three way automotive exhaust catalyst system, ceria plays an outstanding role in purification. High oxygen storage and buffering capacity, low cost and good thermal stability of ceria make it an elite member for this application. It can release oxygen under oxygen lean atmosphere and store oxygen at oxygen rich atmosphere. Surface defects, large surface to volume ratio of atoms, structural defects and oxygen vacancy in the system have positive contribution to the oxidation efficiency of the catalyst.

CONCLUSION

A catalytic converter provides an environment for a chemical reaction wherein toxic combustion by-products are converted to less-toxic substances. Catalytic converters are most commonly used in motor vehicleexhaust systems. Catalytic converters are also used on generator sets, forklifts, mining equipment, trucks, buses, trains, and other engine-equipped machines. Although the catalytic converter has a significant role in reducing toxic emissions from car engines, it also has detrimental environmental effects. In the conversion of hydrocarbons and carbon monoxide, carbon dioxide is produced. Carbon dioxide is one of the most common greenhouse gases and contributes significantly to global warming. Along with carbon dioxide, the converters sometimes rearrange the nitrogen-oxygen compounds to form nitrous oxide. This is the same compound used in laughing gas and as a speed enhancer in vehicles. As a greenhouse gas, nitrous oxide is a 300 times more potent than carbon dioxide, and contributes proportionally to global warming.Tetra-ethyl lead present in gasoline "poisoned" the converter by forming a coating on the catalyst's surface, effectively disabling it. Some early converter designs created a great deal of restriction to the flow of exhaust, which negatively affected vehicle performance, drivability, and fuel economy. The use of precious metals in the coating of the inner ceramic structure, many catalytic converters has been targeted for theft. Initially, automakers believed the catalytic converter would make cars prohibitively expensive. On the contrary, catalytic converters only add about two percent to the cost of a vehicle. In 1985, the Environmental Protection Agency estimated that catalytic converters saved at least 10 times more in health costs than the price of a catalytic converter.It had been stated that catalytic converters are known in a lot of cases to have an excessively long warm-up time period, in a great deal of cases ranging up to thirty-minutes. Even though catalytic converters aren’t 100% effective at cutting emissions, they are an essential step on the road to reducing pollution from automobiles.

REFERENCES

1. B. P. Pundir, Engine Emissions: Pollutant Formation and Advances in Control Technology, Chapter 4, pp. 115-155.
2. R. Heck, and R. Farrauto, ″Automobile exhaust catalysts″, Applied Catalysis A: General, vol. 221, pp. 443-457, 2001.
3. M. Shelef, and R.W. McCabe, “Twenty-five years after introduction of automotive catalysts: What next?”, Catalysis Today, vol. 62, pp. 35-50, 2000.
4. M. Shelef, and R.W. McCabe, “Twenty-five years after introduction of automotive catalysts: What next?”, Catalysis Today, vol. 62, pp. 35-50, 2000.
5. C. Koltsakis and A. Stamateios, ″Catalytic automotive exhaust after treatment″, Progress in Energy Combustion Science, vol. 23, pp.1- 39, 1997.

ISBN 978-93-5396-526-6