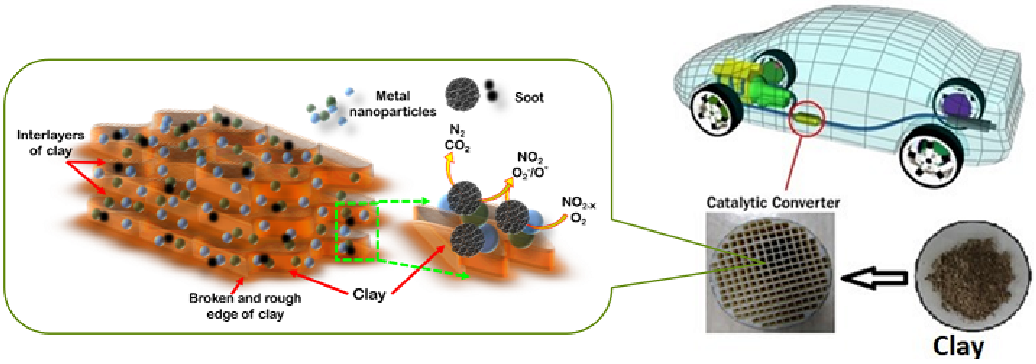
Science and Education Magazine
TechScape: IIT Jodhpur
Volume 01, Issue 01, August 2020

Rajasthani Clay - Solutions to Air and Water Pollution

Rakesh K Sharma

Research Snippet

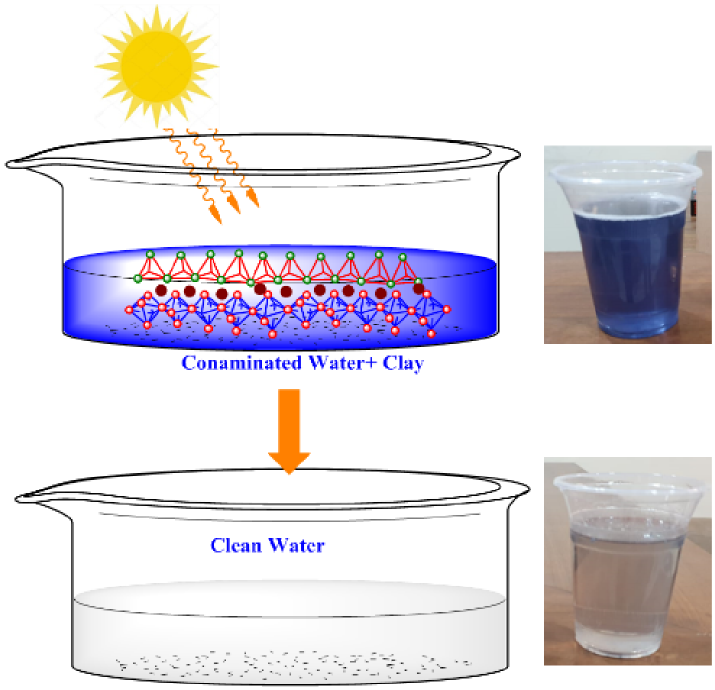


Clay-based catalytic converter.

The exhaust generated by the internal combustion is a major cause for the creation of pollutants such as carbon monoxide, nitrogen dioxide, particle pollution, and sulfur dioxide. The Environment Protection Agency, USA (EPA) implemented the Clean Air Act, 1963, to define air quality standards. To maintain these standards and curb air pollution, the EPA in 1975 mandated the use of catalytic converters in vehicles. Catalytic converters are part of automobile exhaust systems and oxidize or reduce toxic gases such as nitrogen oxides, carbon monoxide, and soot into less hazardous gases such as carbon dioxide, water vapor, and nitrogen. Typically, a catalytic converter is a honeycomb-like structure containing gram levels of precious metals such as platinum, rhodium, and palladium and are therefore expensive. Metal leaching and poor performance over time have also been serious issues with conventional catalytic converters. Since conventional catalytic converters normally work best at high temperatures, they also release toxic pollutants until the vehicle warms up. While engines that work at low temperatures have been designed and developed, designing a low-cost, low-temperature catalytic convertor has led to a resurgence of active research in this area.

The Sustainable Materials and Catalysis Group at IIT Jodhpur has conducted research on clay-based heterogeneous catalysts as potential alternate technological solutions for various challenging problems in the energy and environment domain. The group attempted to address the problems associated with the conventional catalytic converter such as decline in function over time, metal leaching, and high-temperature stability. With time, the palladium particles spread over cerium undergo surface oxidation and decompose into small particles partly due to the high-temperature oxidation process. Therefore, reduction of operating temperature, replacement of palladium and cerium with non-noble metals, and re-design of the converter to prevent metal deactivation were necessary interventions. Clay has inherent properties such as large surface area, broken edge bonds, potential for ion exchange (increases the adsorption of gases). The group has engineered clay containing simple non-noble metals like iron, nickel and cobalt as well as hafnia. The Fe-Ni-Co cooperative nano-particles work as isolated nanospheres (single-site catalyst) while the hafnia-rajasthani clay function as an oxygen reservoir with controlled supply. The catalytic performance of the developed clay-based device was found to be better than the conventional catalytic converter even at high temperatures over several cycles. Further testing and prototype development are currently in progress. Devika Laishram, a Ph.D. student in the Department of Chemistry, played a major role in the development of the device.

Another focus area of the sustainable materials and catalysis group is water treatment. Though water scarcity is emerging as a major problem across the globe, water as a resource is usually taken for granted, which leads to water-insecurity. India’s situation is precarious because the country has to deal with water contamination by industrial and geogenic impurities. The underground water in India, therefore, is often polluted with harmful substances such as dyes, fluoride-rich chemicals, and other industrial discharges. The group has developed Rajasthani clay-based photocatalytic water purification technology using sunlight. In this technology, Rajasthani Clay is modified by a simple chemical process and impregnated with metal nanoparticles. The photocatalytic materials show semiconductor characteristics after incorporation of metal nanoparticles. The metal nanoparticles have multiple roles in the treatment of water such as absorbing sunlight, adsorbing pollutants, decomposition of pollutants etc. The process involves exposing a slurry made of the clay catalyst with the contaminated water followed by sunlight exposure for five hours with frequent agitation. Highly ordered long galleries in the nanoparticle impregnated clay help to absorb the sunlight. This process has been successfully used to treat waste water emerging from textile, dairy, pharmaceutical, and poultry industries.



Process of photochemical wastewater treatment.

Currently, the Sustainable Materials and Catalysis Group at IIT Jodhpur is working on a prototype to modify this technology to provide clean water to remote areas. The studies leading to the development of this technology were performed by a team including Vineet Soni, Toran Roy, Suman Dhara, Ganpat Choudhary, and Pragati Sharma.

Further readings

1. D. Laishram, K. Shejale, and R. K. Sharma, “A Hydrogen-Annealed Bimetallic Oxide and Implementations Thereof,” 201911031662, Aug. 2019 (Patent).
2. D. Laishram, K. P. Shejale, R. Gupta, and R. K. Sharma, “Solution Processed Hafnia Nanoaggregates: Influence of Surface Oxygen on Catalytic Soot Oxidation,” ACS Sustainable Chem. Eng., vol. 6, no. 9, pp. 11286–11294, Sep. 2018, doi: 10.1021/acssuschemeng.8b00674.
3. V. K. Soni, T. Roy, S. Dhara, G. Choudhary, P. R. Sharma, and R. K. Sharma, “On the investigation of acid and surfactant modification of natural clay for photocatalytic water remediation,” J Mater Sci, vol. 53, no. 14, pp. 10095–10110, Jul. 2018, doi: 10.1007/s10853-018-2308-2.

About the author

Rakesh K Sharma

Associate Professor

Department of Chemistry

Webpage (http://home.iitj.ac.in/~rks)