International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 6 | Issue: 4 | Jul – Aug 2025 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v6i4.9

Environmental Impact Assessment of Constituents' Nanomaterials in Automobile Tires: A Conceptual Framework

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ABSTRACT

Nanomaterials have often been considered as matters with dimensions in the region of 1 to 100 nanometers in all directions, having unique properties for novel and diverse applications. Due to their sheer size, they possess physical, chemical, and biological properties, which differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter. This paper proposes a conceptual framework for environmental impact assessment of constituents' nanomaterials in automobile tires (EXACT) based on an overview review of the existing literature. The conceptual framework comprises five assessment factors, namely, 1. Identify nanomaterials (NM) in automobile tires during the manufacturing process. Characterization of nanomaterials properties, 3. Predictive tire model, 4. Tire testing, 5. Atmosphere, Integrated Environmental Predictive Model. It is envisaged that this theoretical model provides a useful tool for industry practitioners in developing a more comprehensive overall environmental impact assessment (EIA) strategy.

Keywords: nanomaterials; automobile; tires; rubber compound; environmental impact; characterization; tire testing; atmosphere.

BACKGROUND

Nanomaterials have frequently been considered as matters with confines in the region of 1 to 100 nanometers in all directions, having unique parcels for new and different operations. Due to their sheer size, they retain physical, chemical, and natural parcels, which differ in abecedarian and precious ways from the parcels of individual titles and motes or bulk matter.

Over the years, these materials have found a sphere of usefulness in virtually every industry and daily life. Nanomaterials such as Polymer nanocomposites, Metallic structural & metal matrix composites and Ceramic structural & ceramic matrix composites can be found in several products in the automotive industry. For example, nanomaterials such as carbon black and silica are often used to improve the rubber like wear resistance, abrasion, stiffness and hardness or fatigue characteristics. Other industries such as the Aeronautics, Agricultural, Health, Information Technology etc, are known to benefit from the products performance enhancements offer by nanomaterials.

In light of increasing efforts to the discovery, development, and deployment of nanomaterials, the need to support responsible development and applications of such materials by way of evaluating their environmental, health, and safety impacts clearly become highly essential.

For instance, the use of nanomaterials in automobile tyres is known to enhance vehicle performance and fuel efficiency; however, the wear and degradation of tyre components such as the tread and sidewall would inevitably lead to the release of these nanomaterials into the environment. Similarly, rubber fumes and rubber dust, which are produced during the tyre manufacturing process, also constitute both occupational and environmental hazards. Overall, the growing developments of innovative, ultrafine nanomaterials for automobile tyres such as Polyhedral Oligomeric Silsesquioxanes (POSS), Nano Oxides (Silica, Allumina), Carbon Nano Fibers (CNF), Carbon Nano Tubes (SWNT & MWNT) etc., have thus necessitated the urgent need to develop effective methods and tools to detect, assess, and monitor the presence and impacts of such automobile tyres' nanomaterials in environmental samples.

PURPOSE OF THE PAPER

The purpose of this study is to propose a conceptual framework for environmental impact assessment of constituent nanomaterials in automobile tires (EIACNAT) based on an overview review of the existing literature.

SIGNIFICANCE AND RELEVANT LITERATURE REVIEW

In recent times, understanding the safety, environmental, and mortal health counteraccusations of nanotechnology- grounded products is of worldwide significance [1]; [2]; [3]; [4]. Notwithstanding, several research studies on Nanomaterials (NP) are constantly being carried out to increase basic understanding of such materials' interaction with the environment and also to increase the understanding of the destiny, transportation, and conversion of NP in the environment and their life cycles. [5] examined the current state of knowledge of the fate, behaviour, and impacts of NM in freshwater, marine, and terrestrial ecosystems. Furthermore, the authors reasoned that without quantitative measures of both exposure and effects, ecological risk assessment cannot be conducted, and regulators will not have the tools to adequately manage NM in the environment. By using a model formulation based on a mass balance equation with some assumptions, [6], predicted the concentrations of some Nanoparticles. It was reported that concentrations of manufactured carbon-based nanoparticles (MCNPs) in aquatic sediments will be negligible compared to levels of black carbon nanoparticles (BCNPs) - soots.

Manufactured NMs enter the terrain through purposeful releases as well as unintentional releases similar as atmospheric emigrations and solid or liquid waste aqueducts from product installations. Notwithstanding, with strengthening take charge of fleeting passing so quickly as to make apprehending difficult within the manufacturing process, the biggest risks for environmental release come from spillages associated with the automobile of manufactured NPs from production facilities to other manufacturing sites, intentional releases for environmental applications, and diffuse releases associated with wear and erosion from general use [5] and [7] Consequently, the distributions and concentrations of such manufactured NMs throughout their life cycle must, therefore, be correctly measured and characterized to facilitate quantitative environmental risk assessment. Furthermore, [8] reported a proposed pragmatic methodology for supporting the systematic identification of knowledge gaps and of priority starting points for conceptual model and empirical research of risk assessment. Although the proposed methodology can be used to analyse the full life cycle of products, its feasibility and usefulness were only demonstrated for the post-use phase of automobiles and paper products.

Based on the relevant literature review, a conceptual model of constituents' nanomaterials in automobile tyres (CNAT) consisting of various assessments is derived as shown in Figure 1.

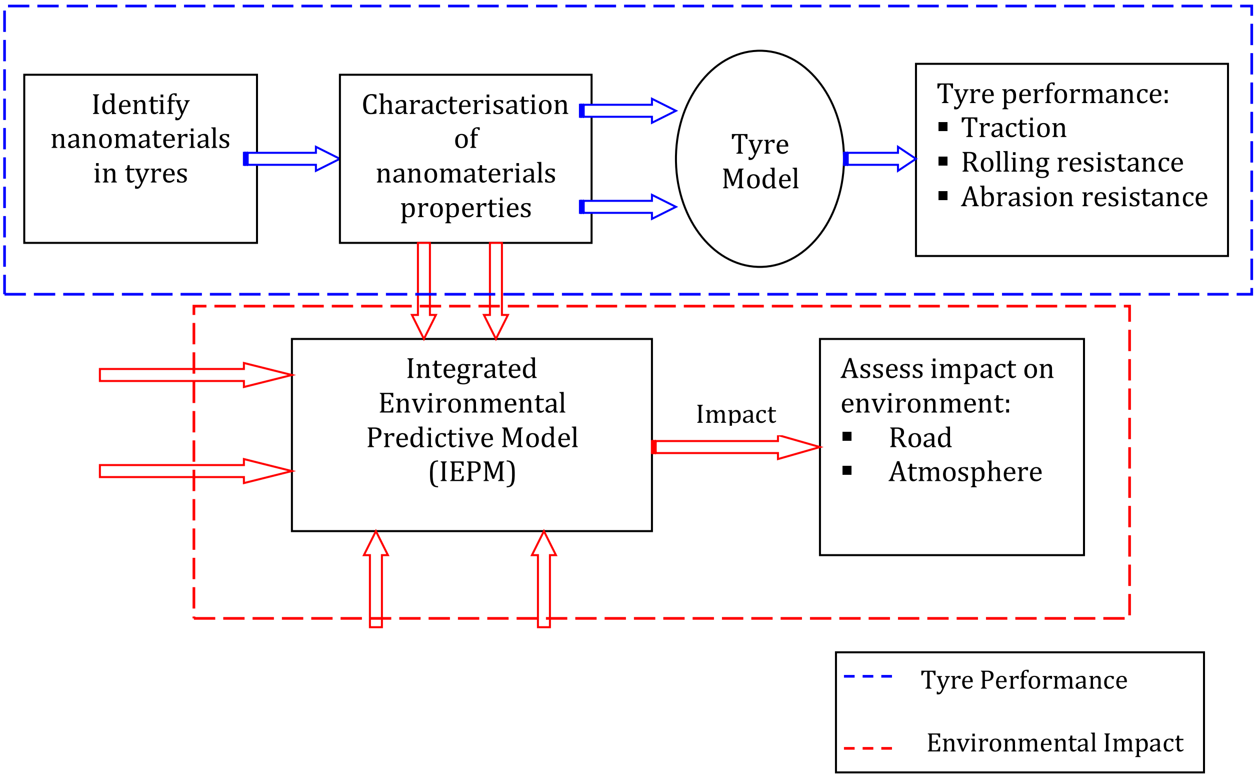

FIGURE 1: Conceptual Framework.

RUBBER COMPOUND MIXTURE OF SEVERAL INGREDIENTS

A tyre typifies a complex composite product composed of an elastomeric matrix or rubber compound and cord reinforcements, both of which have to undergo a variety of processes prior to being brought together to form the tyre cord fabric. Similarly, the rubber compound is formulated from a mixture of several ingredients. The basic ones of which are:

- Polymers
  - Constitute the backbone of rubber compounds.
  - Consist of natural or synthetic rubber.

- Fillers
  - Reinforce rubber compounds – strength and modulus.
  - Most common filler is carbon black.
  - Silica is now widely used to improve rolling resistance.

- Softners
  - Serve as processing aids and to improve stickiness of unvulcanised rubber compounds.
  - Examples – petroleum oils, pine tar, resins and waxes.

- Antidegradents
  - Help to protect tyres against deterioration by ozone, oxygen and heat.
  - Examples – waxes, antioxidants and antiozonants.

- Curatives
  - Help to achieve the desired properties during the vulcanization or curing process.
  - Examples – sulphur along with accelerators and activators.

Furthermore, a tyre requires different rubber compounds in order to perform satisfactorily in service, with each compound having different physical properties and function depending on its use in the tread, sidewall, liner and other important tyre components. For example, the proportion of rubber and the type of carbon black for a radial tyre are selected to give the best balance of performance and durability for the tread; while the compounds for the sidewalls are formulated for greater fatigue resistance due to its higher circumferential compliance.

It is evident from the foregoing that tyre performance parameters are largely sensitive to the constituents' physical properties. Hence compounds must be "engineered" to meet the performance criteria for both the original equipment vehicle manufacture and the aftermarket customers. In addition to these, the chosen compound must be cost-effective and processable in manufacturing plants. These requirements constantly possess a strong challenge to a tyre compounder.

In recent times, innovations in tyre materials, such as nanomaterials have been increasingly used to selectively modify one of the compounds physical properties, without having to "engineer" the rubber compound. Some of the nanomaterials currently being investigated by some tyre manufacturers are:

- Polyhedral Oligomeric Silsesquioxanes (POSS).
- Nano Oxides (Silica, Allumina).
- Carbon Nano Fibers (CNF).
- Carbon Nano Tubes (SWNT & MWNT).
- Lamellar Nanomaterials e.g. Montmorillonite Clay (MMT).
- Graphene (delaminated Graphite).

While some of the key drivers for material selections for tyre are:

- Better performance.
- Reduced fuel consumption.
- Reduced noise emission.
- Reduced weight.
- Recyclability – improved recycling.
- Longer service life.
- Reduced air pollution.

Although the use of nanomaterials in the automobile tyres has been reported to offer most of the foregoing drivers; the wear and degradation of tyre components such as the tread and sidewall would inevitably lead to the release of these nanomaterials into the environments, aside from the exposure to rubber fumes and rubber dust during the manufacturing process. Hence the need to monitor and assess the environmental impact of such nanomaterials becomes very important

CONCLUSION

The paper constructs an abstract frame for environmental impact assessment of ingredients nanomaterials in machine tires (EIACNAT), furnishing the applicability of five essential environmental impact assessment of ingredients' nanomaterials in machine tires. It's imaged that the conceptual model will form the beginning base towards the development of a further comprehensive model in future. Furthermore, the present study represents the starting point for more future research. It should be noted that its worthwhile theoretical analysis and empirical research lie in proposing a broad and thorough framework for impact of nanoparticles in automobile tires decision making.

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