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Review on the Development of Nanomaterials from Sri Lankan Natural Resources as a value addition

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Abstract: Sri Lanka is a most amazing islands, which is geographically rich in natural resources. The gemstone, mineral sands (ilmenite, Rutile), Apatite, silica sand, dolomite, Graphite are some of the precious natural minerals found in Sri Lanka. Most industries use natural resources as raw materials & manmade materials. But the inimical side of this occurrence is these natural minerals resources are mined from their natural form and consumed without the addition of value. In recent days, Sri Lankan Government & Private Sectors have drawn their attention towards focusing on Nano-technology development using the natural resources found in the country. These Nanotechnological developments are visible enough to change the monotonous direction of the technological advancements and also lead to value addition to the valuable natural resources found in Sri Lanka. Therefore, Sri Lanka has a high potential for the development of nanomaterials from natural resources as a value addition. It can use minimize the problem related to the raw materials in most industries. As well as Sri Lanka can earn additional income import that nanomaterials to need countries. This paper examines the latest scientific research on the application of Sri Lankan natural resources development of nanomaterials as value addition.

Index Terms: Natural Resources, Nanotechnology, Nanomaterials, Sri Lanka, and value addition.

1 INTRODUCTION

Sri Lanka prevalent with vast number of wet and agricultural land, forests, and coastal and marine systems, which distribute and decide the condition of climate, soil type, and topography found on the island. The country's climatic and geomorphological variances have resulted in a distinct demarcation into broad climatic, floristic, and faunal zones, which have been utilized to identify bioregions. Therefore, the special features of biodiversity are built up due to the wide range of topographic and climatic variations.

The naturally occurring minerals are Earth resources, which are treasures for many countries to develop economic and industrial levels. However, Sri Lanka is also rich in Natural resources/minerals. The major minerals found in Sri Lanka are gemstones, limestone, sedimentary (Miocene), mineral sands (ilmenite, Rutile, zircon, garnet, and monazite), Apatite, silica sand, dolomite, Graphite, vein quartz (silica), kaolin, feldspar, clay, calcite, mica, and minerals in laterites are some of the precious natural minerals found in Sri Lanka [1].

Natural minerals are used as a raw material for a huge number of industry sectors. Such industries are glass products, agriculture, construction, wall and floor tile, packing, handcraft, apparel, rubber, sanitary ware, porcelain, etc. [1]. However, most of the natural resources or minerals of Sri Lanka are exported with low cost or by low upgrading process, or with minimal value addition. Therefore, nanotechnology is the best path to bring sustainable value-added natural resources or minerals for a vast number of industries or exporting purposes. Nanotechnology refers to a technology implemented on the nanoscale and brings real-world applications. This Nano-size minerals or materials can do the same role, as the large size of particles done. As well as Nano-materials are capable enhance the physical, mechanical, biological, and chemical properties of products with small addition [2,3,4]. This shows the sustainable value addition of natural resources. Currently, Several Nanotechnology inventions & development projects are done by Government & private parties to enhance the economic level of the country. such as, Nano-carbon products including single and multi-walled carbon nanotubes, nanofiber, Nano-crystalline nanocomposites, magnetic Nanoparticles, Nano-diamonds, and Nano-silica from natural paddy husk ash are very precise examples that reflect the concern towards the developments of nanotechnology in Sri Lanka [5,6].

2 NATURAL RESOURCES IN SRI LANKA AND THEIR VALUE ADDITION

Sri Lanka available a high amount of natural resources around the country. Natural resources are elements and components found in the natural world. Geodiversity may be found in a variety of environments. There is potential for nanomaterial development from Sri Lanka's natural resources as value addition. Recently, nanotechnology attracted interest due to the huge potential in the use of the nano-scale range. The natural resources available in Sri Lanka and their value addition through nanotechnology were discussed.

2.1 Limestone

Crystalline Limestone (Marvel) covers about 30% of the land area of Sri Lanka, especially distributed in Nalanda, Kandy, Matale, Balangoda, Badulla, Welimada, and Habarana [7]. However, the value-added of calcium carbonate achieve through the nanomaterials or nanoparticles, such as nanocomposite and nanomaterials of magnesium hydroxide, magnesium oxide, precipitated calcium carbonate [8].

In the cement industry-main, raw materials are limestone and clay, which were especially available in the northwestern coastal stretch of the Island. As a valued-added precipitated calcium carbonate (PCC) nanomaterials are in great demand in the industry. Industrial-scale $CaCO_3$ is synthesized from naturally occurring pure calcium carbonate, such as pure carbonate corals, rocks, cockle, pearls, and shells. In biomedical applications, these calcium carbonate nanoparticles show unique properties because of their ideal biocompatibility. The biocompatibility, accessibility, safety, low cost, PH sensitive properties, slow biodegradability, and osteo-conductivity of $CaCO_3$ nanoparticles nominate as the best drug delivery carrier [9]. There is another advantage of using nanoparticles of calcium carbonate with fiber to enhance the rheological properties such as shape retention. The addition suitable amount of nanoparticles with different types of fibers such as steel, glass, carbon improves strength and interlayer bond [10]. Researchers have found that the usage of a suitable amount of $CaCO_3$ nanoparticles in cement plants increases the tensile strength and compression set [11,12].

widely obtainable impure dolomitic marbles instead of natural pure $CaCO_3$ raw materials to produce Amorphous Calcium Carbonate stabilized with poly-(acrylic acid) (PAA) (ACC) nanoparticles in a simple, unique, and cost-effective manner [13]. Dolomite was used to make nano-precipitated calcium carbonate. Calcium extraction from dolomite has proven accomplished using sucrose. The carbonation process has an influence on particle size, according to the findings. When compared to aqueous carbonate ion addition, CO_2 bubbling promotes smaller particle sizes [14]. The broad use of nano calcium carbonate includes in pharmaceutical, paper, textile, adhesives, food industries bactericide, automotive, paint, cosmetic, toothpaste, rubber and plastic industries, ceramic material, catalyst, and sealants [8]. The substance is utilized as a reinforcing functional filler in extruded weather-able pipes, profiles, and conduits in a variety of plastics compounding applications.

2.2 Magnetite

The magnetite can found in Panirendawa, Buttala, Wilagedara, and Seruwila areas of Sri Lanka. Where the magnetite mineral is extracted from the natural ore [15]. It has the highest amount of iron (72.4%) content. These magnetite nanoparticles provide a wide range of applications such as heavy metal removal, magnetic data storage devices, wastewater treatment, magnetic recording devices, toners and inks for electrophotography, pigment, catalytic materials, targeted drug delivery, magnetic resonance imaging [16]. Researchers have found the extract from the tea-pruning waste is used to make super-paramagnetic biogenic iron oxide nanoparticles (SPBIONs) with antioxidant and superparamagnetic characteristics useful in the improvement of antioxidant agents and medicinal purposes [17]. The magnetite nanoparticle developed using magnetic force were applied to tissue-engineering processes [18]. Furthermore, the environmentally friendly magnetite nanoparticles based on hydroelectric cells are found to perform stable, durable, repetitive, and have the potential to replace existing fuel and solar cell clean energy technology [19]. Then the surface charge effect of amino acid-coated magnetite nanoparticle in the physiological saline solution were investigated, accordingly, the nanoparticles with Fe_3O_4-Lysine is more stable as colloids than the Fe_3O_4-Glutamic nanoparticles [20]. These show the value addition of magnetite nanoparticles in several applications [21].

2.3 Apatite

Apatite is also known as rock phosphate is a deposit in the Eppawala area (Anuradhapura district) of Sri Lanka. Phosphate minerals usually contain a group of apatite such as fluorapatite, chlorapatite, and hydroxyapatite. Most commonly Phosphate minerals are used in agricultural fields as a fertilizer. Now a day's hydroxyapatite which is known as hydroxyl apatite is used as nanocomposites. The hydroxyapatite nanoparticle is rich in phosphorus and also where the matrix of hydroxyapatite nanoparticles is used to reduce the high solubility of urea molecules [22-28]. Another important development, where the hydroxyapatite nanoparticles are used as water purifiers with the modification of "Antibacterial activated carbon-containing biocompatible nano-hydroxyapatite and curcumin bi-coating for water purification" [29].

The apatite nanoparticles are mostly useful in cancer treatments, accordingly surface modification of carbonated apatite nanoparticles with Polyethylene glycol (PEG) provides a promising approach to overcome the aggregation issue of hydrophobic drug-loaded apatite particles [30]. The pH-sensitive carbonated apatite (CO_3Ap) nanoparticles bring a promising novel DNA vaccine delivery system to enhance humoral and cellular immunity as well as efficiently bound plasmids to facilitate in vitro transfection of plasmids in cells [31]. The prepared low-crystalline apatite nanoparticles and quartz-coated particles are used as a quartz crystal microbalance device [32]. The hydroxyapatite nanoparticles were used with antibacterial properties with nano-sized silver particles or silver nano coated hydroxyapatite. Other than these greatly motivated the addition of silicon to silver-hydroxyapatite nanoparticles bringing the promising result of antibacterial properties with the enhancement of biological response to compare to along of silver-hydroxyapatite nanoparticles [33]. Applications are included in drug delivery systems, use as a fertilizer, dental and medical, biological, antibacterial properties, polymer composite, etc.

2.4 Beach Sands (Ilmenite)

The Ilmenite is mostly found on the beach sand. Pulmuddai - North-eastern beaches in the area are covered with black sands, this black color is unique to identify them, which is also called ‘black powder’ [34]. This beach sand contains 70 – 80% of ilmenite, were the main source of Titanium products such as metallic titanium, and titanium dioxide. Sri Lankan ilmenite content is 55% of titanium dioxide [35]. The number of applications will depend on the value-added technology, therefore, nanotechnology is used to make a huge change in Titanium minerals-based product properties. Nano titanium dioxide is divided into two crystal forms known as rutile and anatase. Titanium oxide nanoparticles application includes in surface coating, cosmetics, creams, UV-protective coatings, catalysts [5], and anatase crystal form used in photo-catalysts, decomposition of automobile exhaust, and sewage treatment [36]. The rutile crystal form is beneficial for biomedical implants, construction, airplanes, space shuttles [36].

Ilmenite is such a rich source of rutile (TiO_2), that numerous researchers have attempted to synthesize rutile from natural ilmenite using chlorination techniques. Mechanical activation, followed by reduction, leaching with HCl, and calcination, can provide high purity rutile. As a result, it can be utilized as a white pigment or for welding – in chemical industries, rod coatings, ceramics, and papers industries [37]. Further, there is a significant method to produce titanium from titanium oxide by using the magnesium vapor reduction process [38]. Thermoplastic application for the nanoscale heat source found through the nanostructures of titanium nitride (TiN). The nanostructure TiN was created using a low-cost process using natural ilmenite ore. In the visible area, this study shows robust and spectrally broad localized surface plasmon resonance absorption, as well as the nanodnut structure's exceptional solar light-harvesting ability [39]. Furthermore, employing natural ilmenite sand as a source of Fe_2TiO_5 or TiO_2 binary nanocomposite to improve the degradation of environmental contaminants is an appealing alternative. Under solar energy, this heterostructure plays a role in photocatalytic activity [40]. The iron-doped TiO_2 nanorods (Rhodamine B (RHB)) degradation prepared from ilmenite also exhibit the promising photocatalytic in the visible light range rather than TiO_2, where the Titanium dioxide nanoparticle performed in the UV range [41]. Fabrics with UV resistance and fire retardant qualities have been created by coating polyurethane-based MnO_2-$FeTiO_3$ (MFT) nanocomposites. Fabrics coated with MFT exhibit UV blocking and fire retardant properties, as well as offering sustainable and durable smart fabric for protective clothing applications [42].

2.5 Graphite

Graphite is also an amazing and rare type of natural resource, this call-in has several names including Plumbago, Ceylon graphite, crystalline vein, Sri Lankan graphite. This has gained high popularity over the world, because of its high purity, unique composition, and can offer many processing applications including flake graphite, midget electrodes, graphite lubricants, carbon brushes, and nano-technology. Nanotechnology is the best way to make a demand for graphite all over the world with high properties [5]. Technological development synthesizes the expandable graphite, and graphene oxide, which is high cost and marketable in order to improve the economic level of the county [42]. And natural graphite is used for the synthesis of carbon nanotube and Self-Assembled Multilayer Graphene Oxide Membrane [43]. The nanocomposite produces from the homogeneous mixture of tin and graphite mixture (Sn/C) mostly suitable anode for sodium-ion batteries [44], as well as the nano-sized silica-coated onto the surface of particles of modified natural graphite brings the promising result to use as an anode material for lithium-ion batteries [45].

Generally, hydrates-based solidified natural gas storage is better technology and environmentally friendly in mild storage conditions. Besides, the use of graphite nano-fluids for enhancing the CH_4 hydrate formation was investigated. This also indicates a higher gas storage capacity at the concentration of 0.5 wt% than that obtained in other nano-fluids such as ZnO and Fe_3O_4 [46]. The graphite nanoparticles have such remarkable properties, that these particles can be used as a vegetable oil additive to enhance the friction-reduction and anti-wear properties of pure oil because graphite nanoparticles could form a physical deposition film on the friction surfaces [47]. Non-metallic graphite nanoparticles were tested as a fuel additive for CI engines, where the graphite nanoparticles provide the application for the environmentally friendly fuel additives than the iron oxide (Fe_2O_3) nanoparticles [48]. Currently, many researchers focus on the nanocomposite with thermoplastic polymer graphite, where the graphite is used as a nanofiller. There might be some other vast number of value addition to natural graphite in the future days.

2.6 Clay Minerals

There are three main types of clay such as brick clay, kaolinite, and ball clay, as well as yellow, blue, and red color types of ball clay, can find in the hill county of Sri Lanka. Clay is mostly deposited in the northwestern Murunkan area. These clays are applicable for the production of bricks, casts, refractory material, and tiles. In recent developments in polymer-clay nanocomposites, the usage of montmorillonite clay greatly enhances many properties [49]. Another clay is smectite mineral clay, which plays such important role in different fields including intercalation, exfoliation, cation adsorption, and polymer nanocomposites. If smectite clay can be grafted on different surfaces with the use of nanotechnology can use for specials requirements such as a disintegrated agent in drug formation, applications in a high-temperature environment, selective removal of heavy metal contaminants, targeted drug delivery, and conducting polymers in wearable electronics.

Water purification is the most important process for the removal of different contaminants to bring human consumption purposes. There are three main processes such as physical method, chemical method, and biological method, in these methods where the natural clay is used as a water purifier to get rid of pollutant in water such biological, organic, and inorganic contaminants, it was proven that current commercial filter materials, as well as being in nature and their abundance, result in a low-cost, environmentally friendly, and non-toxic technique [50]. Currently, the tannery industry focuses on clay minerals due to their potential advantages (environmentally friendly, traditional flame-retardant additives, efficiency, good impact on mechanical properties), The use of clay minerals on leather has resulted in improved coating and tanning performance, as well as suitable coactive effect on flame-retardant characteristics, this decreases the amount of flame-retardant additives in the polymer [51,52]. Further, chemically modified sodium montmorillonite also proves the flame retardant behavior in polymer nanocomposite (high impact polystyrene) [53]. Clay minerals are employed in a variety of industries due to their versatility, low cost, and abundance, including paint, ceramics, adhesives, health-care, food, paper, petroleum, cement, and asphalt [54,55].

2.7 Nano-silica from natural resources

Nano-silica is a widely used amazing nanomaterial with diverse applications due to its favored properties such as pliability in structure, biocompatibility, versatile functionalization, size, high surface area, immensely stable, and less toxic [56, 57]. Nano-silica has commonly used nanomaterials in fiber optic strands, inks, sealants, coatings, food additives, cement, paints, adhesives, polymers, etc. [4], other than these there is a wide range of commercial applications, biomedical applications, rheology control, moisture resistance, flatting agents, etc. [58, 59]. Further, the recent research being carried out to use nanosilica as a modifier to urea in order to control the release of nitrogen targeting to synthesize slow-release fertilizers [60,61]. There are various techniques used to produce the low graded silica from natural resources to higher grade marketable silica. The surface modification or functionalization process of silica nanoparticles provides effective uses. As a result, recently researchers found the synthesis the nano-silica from paddy husk ash and surface functionalized to make the marketable grade, where the oleic acid used to modify the surface of nano-silica and characterized through gravimetric analysis (TGA), where significant weight loss between 350 ℃ to 400 ℃, and Fourier transform infrared spectroscopy (FTIR) indicated carbonyl stretching peak of the ester bond, which bring the bond between silino group and carboxylic group of oleic acid. The reinforcing ability of nano-silica in polymer composite is lower than that of commercial silica [56, 62, 63]. Composite materials are in high demand in a variety of industries, including military, aerospace, and automobiles due to their lighter and stronger properties. Glass fiber reinforced epoxy nanocomposite with silica nanoparticles improves mechanical capabilities but limits fracture toughness, impact, fatigue, and tensile qualities [63].

8 CONCLUSION

Sri Lanka is blessed with a variety of natural resources, which are reviewed above in the short profile of the major resources. However, the supplement of these resources without value addition is another major loss to the country. There are many processes or methods to bring the material to a higher grade and marketable level. The best way is “Nanotechnology” to develop those materials in a value-added and sustainable manner. Therefore, this paper discussed the natural resources available in Sri Lanka and how those resources become value-added material with the use of nanotechnology. Nanotechnology is required to sustain economic growth and to provide basic amenities to the entire population of the country. Also, all these resources need to be used in a proper and sustainable manner, which can help to overcome industrial issues related to raw materials. Being with nature and its abundance presence makes low-cost green and nontoxic.

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