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Snail Shell as an Inspiring Engineering Material in Science and Technology Development: A Review

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Abstract:

This review article provides a comprehensive overview of the research status on snail shells as inspiring engineering materials in Science and Technology development. Snail shells which represent the bio-shell waste of snails' remnants from restaurants, eateries or snail sellers constitute a serious degree of environmental threat with little or no economic value. Their effective utilization can bring immense economic prosperity. They are very useful raw materials in the treatment of waste water and the purification of aqueous solutions. They can also be used in the production of naturally based materials and for the preparation of calcium for medicinal purposes. Snail shells can be used as fillers in the paper industry to improve the paper capacity or in the cosmetic industries as face powder. Snail shells are suitable reinforcement materials for the production of composites applicable in the automotive components such as pistons, connecting rods and brake pads. Where flexural strength, hardness and impact strength are of paramount importance such as automobile parts, snail shells reinforced unsaturated polyester composites should be given priority. They are good alloying agents for aluminum based composites. The researches in this area are growing very fast, there is need therefore for continuous and upgraded review on this theme.

Keywords: snail shells, inspiring engineering materials, reinforcement, composites.

1. Introduction

New materials have been among the greatest achievements of every age and they have been central to the growth, prosperity, security and quality of life of humans since the beginning of history. It is always new materials that open the door to new technologies, whether they are in civil, chemical, construction, nuclear, aeronautical, agricultural, mechanical, biomedical or electrical engineering (Buranyi, 2015). There is an increasing demand for new materials every day to achieve good combination of strength, toughness, wear resistance, high temperature performance and corrosion resistance. Consequently, researchers are focusing on combining two or more materials to form new composites.

The gastropod shell is a shell which is part of the body of a gastropod or snail, one kind of mollusk. The gastropod shell is an external skeleton or exoskeleton, which serves not only for land snails, in some fresh water snails and in intertidal marine snails, the shell is also an essential protection against the sun, predators and against drying out. Snails shells have been the subject of research work that has been almost exponential growth in the last decade. They have formed the bases of some work in biology, chemistry, engineering (Buranyi, 2015).

Snail shells which represent the discarded bio-shell waste of snails' remnants from restaurants, eateries, or snail sellers constitute a serious degree of environmental threat with little or no economic value. They are usually abandoned indiscriminately after consumption of the edible meat. Thus, effective utilization of snail shells can bring immense economic prosperity (Kolawole *et al*, 2017).

Snail shells are inspiring engineering materials in science and technology development. A lot of researchers have worked with snail shells in so many different ways. Snail shells have been used as raw materials to produce new ones or refine some other products. Snail shells have also been used to treat waste water and purification of aqueous solutions (Jatta *et al*, 2010; Udeozor and Evhuomuan, 2014; Adiotome,2015; Edokpayi *et al*, 2015; Odoemelam and Eddy, 2008). They have also been used to produced biomaterials and drugs in medicine (Leelarawonchen and Laonapakul, 2014; Andrade *et al*, 2015; Rao *et al*, 2016). They are extensively used as reinforcing phases in the production of composite materials (Odunsaya *et al*, 2014; Kolawole *et al*, 2017; Asafa *et al*, 2015; Njoku et al, 2011; Atuanya *at el*, 2016). Other areas that snail shells are being utilized as engineering raw materials are in the chemical, construction and automobile industries.

The objective of this paper is to attempt to bring to the scientific community a review on the main developments and trends on the use of snail shells as inspiring engineering materials in science and technology development to improve the living standard of mankind.

2. Waste Water Treatment

Water is one of the most precious natural resources that exist in our planet comprising over two third of the earth surface, that is why its pollution by both organic and inorganic chemicals is a serious environmental concern. Public awareness over the quality of drinking water has attracted interest in the global world. This is reflected in the demand for home water filter, designed to remove objectionable taste, odour and organic contaminants from water (Gumus and Okpeku, 2015). According to Gumus and Okpeku (2015), activated carbon is widely used for this purpose due to the large surface area available for adsorption or chemical reactions. Gumus and Okpeku (2015) evaluated snail shell waste as raw materials for the preparation of activated carbon using $ZnCl_2$ and $CaCl_2$ with the temperature ranging from 500^oC to 800^oC. The activated carbon prepared was characterized showing effect of temperature on ash content, pore volume and porosity. The adsorption thermal for methylene blue was carried out on the activated carbon in a batch study. The adsorbent exhibited excellent adsorption for methylene blue. From the results obtained, they concluded that activated carbon impregnated with $CaCl_2$ and $ZnCl_2$ is favourable for adsorption of methylene blue under the conditions used in the study.

However, Udeozor and Evhuomwan (2014) had argued that pollution problems in water have been created by increase in population and that absorption process is one of the most available and extensively used technologies to remove organic contaminates in wastewater treatment. According to Jatta *et al* (2010), food and beverage industries are major sources of industrial waste water. Waste water from food-factory was characterized and treated using snail shells (Jatta *et al*, 2010). The aim was to find out the effectiveness of snail shell as a coagulant in waste water treatment. The result of the parameter studies showed a change in colour from dark brown before treatment to light brown after treatment. There was reduction in turbidity and phosphate was completely removed. They concluded from the results that snail shell is effective in the treatment of waste water. According to Udeozor and Evbuomwan (2014), the use of snail shell has been found efficient as an adsorbent, especially in the removal of heavy metals like lead, based on its absorption capacity, available surface area, distribution ratio and percentage sorption. Udeozor and Evbuuomwan (2014) investigated the effectiveness of snail shells as adsorbent for the treatment of waste water from beverage industries, using phosphoric acid (H_3PO_4) as activating agent. The snail shells were pyrolysed at 500^oC and divided into two parts, A and B, Part B was treated with the activating agent and were characterized. From the results obtained, they concluded that the activated carbon produced from snail shells can compete favourably with the conventional activated carbons in treating wastewater from beverage industry, using H_3PO_4 as an activating agent.

Carbon is an industrial adsorbent both in the carbonized and the activated form. Snail shell is one of the raw materials which carbon can be produced from. According to Adiotome (2015), carbon gotten from snail shell is cheap to obtain due to their availability as waste. Carbon adsorbent has a lot of importance in our day to day life, even in the industries such as the sugar and starch industry it is used to remove the colored matter in the syrup (Adiotome, 2015). He further stated that in water purifications, it is also used as a decolonizer, which also removes odor and taste from the underground water in treating industrial waste effluent both for primary and tertiary treatment. Adiotome (2015) investigated the effectiveness of snail shell as an adsorbent for the treatment of waste water. He carefully removed the snail from the shell, washed, dried and cabonized at various temperatures between 300^oC and 1000^oC with a range of 100^oC and characterized. The results he obtained from the snail shell showed that the best form that can be used as an absorbent was at 800^oC because it possesses the highest porosity value. Adiotome (2015) concluded that the treatment of waste water with snail shell activated carbon improved for all the parameters tested and varied with time as compared with that of the raw water before treatment.

3. Purification of Aqueous Solutions.

Heavy metals are a group of pollutants occurring naturally in the earth crust. The risk posed by indiscriminate discharge of lead-containing wastes into the environment is enormous because lead is acutely toxic and can bio-accumulate from one tropic level to the other through the food chain. The pollution of environmental matrices has been of global concern due to their relative presence in the environment (Edokpayi *et al*, 2015). According to Odoemelam and Eddy (2008), lead is one of the most toxic heavy metals known to man and that Pb^{2+} is known to be part of the composition of effluents that are found in both domestic and industrial sources. Edokpayi *et al* (2015) studied the biopolymeric chitosan synthesized from snail shell for its potential to remove heavy metals from aqueous solution. The experiments were conducted in the range of 1 – 50mg/lit initial Pb^{2+} concentration at 298K. They investigated and optimized the effects of pH, adsorbent dosage and contact time on the adsorptive property of the adsorbent, and thereafter characterized the derived chitosan. From the results they obtained, they concluded that synthesized biopolymers from land snail shells has the potential for the removal of Pb^{2+} from aqueous solutions.

On the other hand, Odoemelam and Eddy (2008), investigated the removal of Pb^{2+} from aqueous solutions by oyster, snail and periwinkle shells. They examined the effects of contact time and concentration on adsorption, thermodynamics of sorption distribution coefficients of the absorption to optimize the conditions to be utilized for decontamination of effluents containing Pb^{2+}. Their study revealed that these materials are good absorbents that can be used for the removal of Pb^{2+} from aqueous solution. They therefore advocated that these materials be used for the removal of lead ion from aqueous solution.

4. Enhancing the Strength of Concrete

Considerable effort are being taken worldwide to improve on the strength and durability performance of concrete through the use of pozzolanic materials. The commonly used pozzolans have been fly ash, silica fume, meta-kaolin and blast furnace slag, according to Olusola and Umoh (2013). Olusola and Umoh (2013) investigated the effect of periwinkle shell ash (PSA) as cement substitutes on the strengths of concrete. The results revealed that compressive strength increased with the increase in cunning age but decreased as the PSA contents increased. The relationship between tensile splitting strength and compressive strength of PSA blended cement concrete is similar to that of the conventional concrete. They concluded from the results that 10% PSA content is adequate as content substitution for structural concrete. Adekitan *et al* (2016), on the other hand, investigated the potentials of calcined African Giant Snail Shell Powder as a pozzolan. They observed that the colour changed to grey during calcinations of the snail shells. They concluded that the snail shells possess chemical constituents as cement but with lesser percentages. They achieved more than the 75% requirement of compressive strength index as prescribed by ASTM C311.

5. In Medicine and Biomaterials

Nature is a primary source of effective mechanical agents, and folk medicine has been the basis for the development of a large number of drugs. According to Andrade et al (2015), many years of observation and experimentation have provided medical knowledge in the use of natural products. Also, that a great number of these natural products have come to the market from the scientific study of remedies traditionally used by various culture around the world. Grounded in established knowledge of the mechanism of wound repair, while also drawing an evidence from folk mechanic, Andrade et al (2015) evaluated the wound healing and tissue regenerative properties of an ointment containing powdered snail shells applied to coetaneous wounds in rats. They also investigated the augiogenic properties of the ointment and its influence on inflammatory cellular response. The results lend support to the southern Brazilian false use of M. Lopesi powdered snail shells as shown by the enhance secondary – intention healing achieved with their topical administration to wounds in rats.

Rao *et al* (2016) had stated that sea shells are formed by the process of bio-mineralization where living organism produce organic solids. Sea shells are protective layers of marine animals called mollusk and other sea animals, this include clams, oysters and snail (Rao *et al*, 2016). They also said that sea shells are excreted from the outer surface of the animal called the mantle and are made up of mostly calcium carbonate. Rao *et al* (2016), made an attempt to study the range of concentration of calcium carbonate in the shells of various gastropods in the sea shore of Bay of Bengal, India. The percentage of ash content and calcium content was determined using EDTA litrimetrically. They observed from the data that these was a significant variation in the ash and calcium content of different species of gastropod shells. They concluded that two different forms of calcium carbonate have identical chemical composition, but look different and have different properties such as solubility. Also, the flat, clear crystal is calcite, the pinkish multifaceted one is aragonite. They also observed biodiversity in the shell calcium content in the various gastropods. The Rao *et al* (2016) finally concluded that the shell can be used for preparation of calcium for the medicinal purpose. On other hand, calcium phosphate based bio-ceramics are currently used in various types of orthopedic, maxillofacial and drug delivery applications. Leelarawonchen and Laonapakul (2014), investigated heavy metal content, phase transformation and physical characterization of Golden Apple Snail Shell for use as a calcium service in the production of naturally based biomaterials. In order to investigate phase transformation, they calcined the Golden Apple Shells between 600^0C and 900^0C. The conclusion was that the $CaCO_3$ (calcite phase) was completely transformed into a CaO phase at 800^0C, this phase transformation depended on calcinations temperature and time.

Among the families of biological macromolecules, whose relevance is becoming increasingly evident are chitin and its main derivatives, chitosan. Potential and usual applications of chitin, chitosan and their derivatives are estimated to be more than 200 (Abdulkarim *et al*, 2013). They are natural polysaccharides. According to Abdulkarim *et al* (2013), chitosan has been widely used in vastly diverse fields, ranging from waste management to food processing, medicine and biotechnology. Also, that in agriculture, the use of chitosan has been established to improve the yield of rice and orchid production. Abdulkarim *et al* (2013), investigated the extraction and characterization of chitin and chitosan from Mussel shells. They obtained the mussel shells from the Gubi Dam bank of Bauchi, north eastern part of Nigeria. They extracted the chitosan in four steps; pretreatment, demineralization, deproteinization and deaccetylation and then characterized. The results they obtained revealed that carbon nitrogen ratio of the chitosan extracted was 5.9 with a degree of 60.69% and 60.66% calculated from the elemental analysis and FTIR spectra of chitosan respectively. They discovered from the results that the mussel shell contained a mineral content of 51.62% and a chitin composition of 21.32%.

6. As a Reinforcing Phase

The limited availability and high cost of commonly used synthetic reinforcement material in metal matrix composites (MMCs) had hindered the industrial production of MMCs on a large scale for instance, in the automotive industry (Kolawole, et al 2017). Thus researchers are now focusing on the use of industrial and agro allied waste products as an alternative source of reinforcement materials in the MMCs production at low costs that are future assured as a way out of the current limitation. According to Kolawole et al, (2017), most of these wastes are borne out of the increasing human population and activities which had resulted in the generation of colossal wastes without a viable economic benefit as well as disposal challenges and environmental threats. They also said that a crystal clear fact of such evidence of wastes in Nigeria and other tropical regions of the world are snail shells. Kolawole *et al* (2017) studied the potential utilization of snail shell as a low cost reinforcement materials in the metal matrix composites (MMC_s) by means of a characterization technique. From the results they obtained, implied that snail shells with 9.4 – 25.9% lesser density, when compared with agro or industrial wastes reinforcement material (fly ash, coconut shell ash, maize husk, bagasse) in the metal matrix composites hooks promising as reinforcing material in the production of light weight metal matrix composites at low costs. They also discovered the high refractory temperature of the snail shell particle suggested it is a suitable reinforcement material in the production of thermal resistance MMCs applicable in automotive components such as pistons and connecting rods.

On the other hand, Odunsanya, *et al* (2014) evaluate the property of hybrid, see shell/snail shell filler (combination of seashell and snail shell) reinforced unsaturated polyester composite in comparison with seashell and snail shell filler reinforced unsaturated polyester composite. They investigated the mechanical (flexural, tensile, impact and hardness) and physical (water absorption) properties of sea shell, snail shell and sea shell-snail shell-reinforced composites. The shells were ground and sieved using 250 microns hand sieved. They discovered that snail shell sample of 5wt% reinforcement showed to absorb the highest amount of energy before shattering relative to other samples, for this, snail shell reinforcement of 5wt% can be used in place of pure polyester where impact strength is a major factor. It is also a known fact that snail shell particles are known for their hardness, and this considered as good alloying agent for aluminum based composites (Asafa *et al*, 2015). The potential of snail shell as a reinforcement for discarded aluminum based materials was investigated by Asafa *et al* (2015). They added snail shell particles of weight fraction ranging from 16 to 48 wt% and size of 200, 400 and 600μm to aluminum obtained from discarded aluminum pistons during casting. The results they obtained showed that at 48wt% and 600μm particle size, they tensile strength and hardness are maximum (236 MPa and 48.3HRF) compared to the tensile strength of 92.4MPa and hardness of 29.2 HRF for the unalloyed samples. They concluded that both the tensile strength and hardness are significantly enhanced and snail shells can be used as a low-cost reinforcement for engineering applications.

Njoku *et al*, (2011) stated that composite materials, plastics and ceramics have been the dominant emerging materials over the last three decades. They also said that the number of applications of composites (particularly polymeric composites reinforced with synthetic fibers such as glass, carbon and aramid) has grown steadily due to their unique properties of high stiffness and strength-to-weight ratio. The potency of periwinkle shell particles as reinforcement of polyester matrix was investigated by Njoku et al (2011). They also investigated the effects of particle size and Varian of weight fraction of each particle size on the tensile strength and Young’s Modulus of a particulate reinforced polymer composite. They found out that increase in strength with small particle sizes and increased particle loading was attributed to increase in surface area which enhanced load transfer between the polyester matrix and periwinkle shell particles.

Most research and development are focusing on the development of composite materials because of the unique properties they offer when compared with polymer, metal or alloys (Atuanya *et al*, 2016). According to them, natural fillers in the form of fibres of particulate have gained the attention of researchers in recent time as reinforcing materials in polymers, metals and ceramics. Atuanya *et al* (2016), investigated the empirical models for estimating the mechanical properties and morphological of recycled low density polyethylene/snail shell bio-composites. The ability to convert wastes (snail shells and pure water sachets) into useful engineering materials like composites sharpened the focus of their research work. They found out from available literature that investigation had not been conducted on the application of snail shells particles in polymer composite materials. They used compounding and compressive moulding technique to prepare the snail shell particles sizes and weight percentages of the recycled polyethylene samples for the experiments. They then subjected these samples to mechanical testing such as tensile, flexural and impact energy. Seaming electron microscope was used to analyze the fracture surface of the samples. Atuanya *et al* (2016) observed from their work that increase in wt% snail shell particles, raised the both the tensile and flexural strengths. They also observed that increase in the snail shell particle size from 75µm to 500µm decreased the tensile, flexural and impact strengths. Atuanya *et al* (2016) concluded that the work can be used for both indoor and outdoor structural applications.

On the other hand, according to Madueke *et al* (2014), polymers have numerous applications ranging from domestic articles to their use as matrix in composite applications. They also stated that the major reasons for a huge growth in the area of polymeric composite materials are low weight, low price and minimization of environmental impact. The influences of filler locating of unsaturated polyester/snail shell composite was studied by Madueke *et al* (2014). They focused on the comparison of the mechanical properties of charcoal unsaturated polyester matrix composite and snail shell unsaturated polyester matrix composite. They introduced ground charcoal powder into the unsaturated polyester at different concentrations. The same concentrations of ground snail shell (625 µm) were incorporated into the same percentage of unsaturated polyester. They compared the two resulting composites by characterizing them. They found out that the flexural strength snail shell unsaturated polyester matrix composite at 20wt% reinforcement was better than that of the charcoal at the same concentration. Also, snail shell unsaturated polyester composite showed better hardness and impact strengths than its charcoal counterparts and those of unreinforced unsaturated polyester. Madueke *et al* (2014) therefore concluded that where flexural strength, hardness and impact strength are of paramount importance such as in some automobile parts, snail shell reinforced unsaturated polyester composite should be given priority.

Fillers greatly enhance the dimensional stability, impact resistance, tensile and compressive strength, abrasion resistance and thermal stability when incorporated into polymers. The ones that improve the mechanical properties particularly tensile strength are termed as reinforcing fillers (Onuegbu and Igwe, 2011). The investigation of the effects of filler contents and particles sizes on the mechanical and end-use properties of snail shell powder filled polypropylene was carried out by Onuegbu and Igwe (2011). The polypropylene composites of snail shell powder were prepared at filler contents, 0 to 40wt %. The particle sizes of the snail shell powder investigated were 0.15, 0.30, and 0.42µm, Talc of particle size 0.15µm was used as the reference filler. The polypropylene composites were prepared in an injection moulding machine and the resulting composites were extruded as sheets and characterized. They observed that the snail shells and powder improved the tensile, modules, flexural strength and impact strength of polypropylene and these properties increased with increase in the filler content and decreases with increase in the filler particle size. While the elongation of break of the composites was observed to decrease with increase in filler content and particle size, according to them, the elongation of tale filled polypropylene was zero, an indication of the brittle nature of polypropylene composites of talc.

They concluded that snail shell powder was found to show greater property to improvement over talc in the prepared composites. Snail shell is a waste, the use of snail shell powder in filling polypropylene or any other thermoplastic had not been reported in the scientific literature to their knowledge as at the time this paper was published.

7. In Physics and the Chemical Industries

In most species of land snails, shells are frequently exposed to direct or indirect sunlight, which contains substantial amounts of near-ultraviolet and near infrared radiations in addition to visible light. Solar radiation in the visible and infrared ranges contributes to the heating of snail shells and contained tissues (Savazzi *et al*, 2013). Literature on the appearance of land snail shells according to Savazzi *et al* (2013) imaged in the near ultraviolet and near infrared appeared to be absent. Savazzi *et al* (2013), studied the appearance of land snail shells in the near-ultraviolet (NUV), visible (VIS) and near-infrared radiation (NIR) with a modified digital camera. The results of their observations were categorized according to whether the observed originated from the periostracum or underlying shell (or a combination of both). They concluded that the majority of land snail species studied here, shell colour patterns that are detectable in VIS appeared in enhanced contrast in NUV and were totally or almost totally, undetectable in incident NIR images.

The snail shells are known as rich source of calcium and have been used as fillers in the ceramic, paint, animal feed, construction and paper industries. They are also known to increase the hardness of products (composites), resistance to weathering and strength of the materials (Sunday and Magu, 2017). The investigation of metal contents of ashed and unashed shell powders of snail shells was carried out by Sunday and Magu (2017). They determined potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), zinc (Zn) and iron (Fc) in the ashed and unashed snail shell powder. From the results, they concluded that the concentration of the metals in the unashed snail shell powder was higher than that of the ashed powder. At very high temperature, Ca (in the form of calcium carbonate), from their result, had very high concentration in both the ashed and unashed snail shells powder. It indicated that snail shells powder can be used as filler in paper industry to improve the paper capacity or in the cosmetic industries as face powder.

8. In the Construction Industries

The concrete remains and will remain the most widely used material in construction around the world and more interesting when reinforced with steel and other reinforcing materials. The high and steady increase in the cost of cement has made construction very expensive. The deleterious effect of CO_2 generated from the cement production on the environment makes the use of cement more challenging (Adelatan *et al*, 2016).

The feasibility of using shells from marine coasts of the Souss Massa region in Agadir (Morrocco), as aggregates in the production of a composite material called ecological concrete was investigated by Barbachi *et al* (2017). After collecting and sorting the shells from different locations under investigation, the shells were given thermal treatment to eliminate any kind of impurities and then crushed. The different aggregates of the shells were characterized to determine bulk density, apparent particle density and compactness of shells. They compared the obtained parameters with those of the sand dim and quarry sand. The results obtained by calculating the percentage of vacuum showed that the crushed shells have a low compactness compared to the sands studied. Barbachi *et al* (2017) further suggested that as a perspective, it would be necessary to study the preparation of a concrete based partially or totally on the aggregates resulting from the crushed shells with different granulometric sizes while seeking the best compromise between the physical and mechanical properties.

9. In The Automobile Industries

Brakes are one of the most important safety and performance components in automobiles, while brake pads are important parts of braking systems for all types of automobiles that are equipped with disc brake (Abhulimen and Orumwenser, 2017). The materials engineer is faced with the need to develop a replacement and brake pads having asbestos free friction materials. Abhulimen and Orumwenser (2017) investigated the development of asbestos free brake pad with using snail shell and rubber husk. They used the snail shell as a reinforcement and robber seed husk as the frictional filler materials. After pulverizing the snail shells, the composite brake pad was produced in the ratio of 65% snail shell – 10% rubber seed husk – 25% resin using compression moulding. The break pad composites were characterized. The results they obtained showed that the finer the sieve size, the better the properties. They further stated that the results compared favourably with that of common brake pads (asbestos and palm kernel shell based). Thus they concluded that snail shells and rubber seed husk can actually be used in the production of brake pads.

10. Conclusion

This paper reviewed the research status on snail shells as inspiring engineering materials in the science and technology development. Snail shells represent the discarded bio-shell waste of snails' remnants from restaurants, eateries or snail sellers.

They constitute serious degree of environmental threat with little or no economic value. Researchers have done a lot in the utilization of snail shells to bring immense economic prosperity and save the environment from pollution as a result of the indiscriminate dumping of these wastes.

Snail shells are very useful raw materials in the treatment of waste water and the purification of aqueous solutions, they are good absorbents that can be used for the removal of Pb^{2+} from aqueous solution. They can also be used as a calcium service in the production of naturally based biomaterials. Snail shells are suitable reinforcement materials in the production of thermal resistance Metal Matrix Composites (MMCs) application in the automotive components such as pistons and connecting rods. Where flexural strength, hardness and impact strength are of paramount importance, snail shells reinforced unsaturated polyester composites should be given priority. They are good alloying agent for aluminum based composites. Snail Shells and rubber seed husk can actually be used in the production of brake pads, and can also be used as a low-cost reinforcement for engineering applications. Snail shells powder can be used as filler in paper industry to improve the paper capacity or in the cosmetic industries as face powder. The use of snail shells as inspiring engineering materials in science and technology development is growing very fast and the next years will demonstrate the need for a continuous and updated review on this theme.

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