AGRO WASTE A SUSTAINABLE SOURCE FOR STEEL REINFORCEMENT-REVIEW

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Abstract

In this review paper the use of agro waste as a sustainable source for steel reinforcing steel was investigated. Agro waste is said to have certain amount of carbon which can be useful for steel reinforcement, as stated by different authors the carbon derived from agro waste is said to be of high quality. From literature it was observed that there is an increase in demand of agricultural produce which mean automatic increase in agricultural waste and this threat on humans, plants and the environment, this alone shows that agro waste is sustainable as it is currently been underutilized in the steel or iron making industry. In this review different agro waste such as macadamia nut shell, potato peel, husk from cereal, rice husk etc, and it was observed that macadamia nut shell has the highest carbon content which is about 92%. Agro waste is a sustainable source of obtaining carbon and should considered by steel producing companies as the carbon content is high and its environmentally friendly.

Keywords: Nanoparticle; Characterization; Waste; Synthesis.

1.0 Introduction

Every year, agricultural industries produce a great deal of residues. If such waste are disposed inappropriately without following the right procedure, it can result in environmental pollution and harm to animal and human health [1]. Agro-waste can be subdivided into: animal waste, crop waste, food waste, dangerous waste and toxic waste. Most agro-industrial waste are either not properly treated or utilized, which leads to inappropriate disposals such as burning and dumping in undesignated areas [2].

Climate change problems occur due to increase in several greenhouse gasses which is as result of untreated waste. In addition, the utilization of non-renewable energy sources additionally affects ozone depleting substance emanations [3]. Therefore, the development of other cleaner and renewable energy resources is now a global priority [4,5]. Increase in demand for agricultural end products cause increase in waste which causes disposal issues [6].

Taking a clear look at some products that are consumed daily such as juice, coffee and cereal. It can therefore be said that wastes or byproducts are produced in large quantity. Peels are produced in large quantities as byproducts from juice industries, coffee pulp produced as a byproduct of coffee makers and husks produced from cereal industries. Globally it was estimated that 147.2 million metric tons are discovered meanwhile in the 1990s an estimate of 673.3 and 709.2 million metric tons of rice straw and wheat residue was recorded which has been used since the 19th century until the moment, is one of the utmost significant in the human
evolution. The main characteristics of steel are its malleability and strength, in which the case strength determines the higher boundary of the force on the materials and the latter decides the greatest deformations. However, it is quite difficult to improve steel properties. The characteristic of steel depends principally on the chemical composition and the process parameters. Steel is mainly composed of iron, carbon and 10 other elements of alloy [7]. The parameter of the steel process is occasionally complex, for instance during heat treatment the properties and microstructure of steel is change at transitional phase. Common used heat treatment method for steel are quenching, tempering, annealing, and normalizing. The heating time and temperature, alongside with many other parameters must be studied in order to achieve the optimal microstructure. Hence, more than a great many candidates with various mixes of components and procedure parameters would be available, and the majority of that can barely be examined today. Moreover, this factor of influence ought to be carefully selected to reduce steel production cost.

(Mayyas, et al., [8] stated that biomass is generally considered a serious disposal problem, it can become valuable source of carbon for a wide range of applications, like metal processing and industries that produces steel. The iron and steel trade which make up 27% of the world's industrial sector contributes greatly to CO2 emission [9]. Biomass, as opposed to coal, is a renewable carbon source. v [10].

There are certain technologies used in production of steel and they can be divided into four main part which are, smelting reduction iron in basic oxygen furnace, blast furnace – basic oxygen furnace, direct smelting of scrap in electric arc furnace, direct decrease of iron in electric arc furnace [11]. The carbon source must fulfill a specific task for each technology. The carbon cause is, for instance, mainly used as a combustible and reduction agent in the furnace. A decent graphitizing carbon (for example coke) is the primary wellspring of carbon [12]. The carbon is primarily used to decrease the iron oxide in the direct smelting of scrap in electric arc furnace and to maintain the appropriate conditions for slag foaming. In the blast furnace, carbon is the fuel used and should have certain chemical and physical characteristic which must comply with stern operating necessities. Utmost study on the use of biomass in steel manufacturing aimed at specific types of virgin biomass properties, such as rigid timber from eucalyptus planting [13]. There is limited or lack of information regarding further kinds of indigestible biomass waste in the metal production sector (e.g. lignin waste). Lignin is a biopolymer that occurs with hemicellulose and cellulose in plant matter (or biomass). It makes up 15 to 40 wt% dry of the biomass [14]. In the process of biofuel fermentation, cellulose is recovered through biomass produce and in the process of Kraft-pulping paper. Lignin-rich biomass residues are created as by-products of waste during this process (in press-mud or LPM). In thermal power plants only 40% of the fuel, while the other fuel is aimed at waste disposal plants [15], has been reported. In addition, carbonization is characterized by important disparities in its chemical and physical characteristics depending upon the plant's type precursor. These dissimilarities could limit the usefulness of certain kinds of biomass in steel production also, consequently, lessons necessary for individual type of vegetal residue too its use in the steel business worked on the usage of nutshell macadamia as iron oxide reduction agent, that is to replace the traditional metallurgical coke in steel production [16]. This study shows the high performance and reduction in biomass-derived carbon which is equivalent to the coke used traditionally. Another example of the use of biomass in biochar was discussed by [17] as a source of carbon (i.e. carburizer) for increasing steel carbon content. During the dissolution of high carbon in steel 5.18 wt% obtained due to the type of waste used and it is more superior in
comparison to further forms of coke. While these educations provides a basis for the evolution from coal to biomass in the steel industry, an extensive study to cover all likelihoods and mechanical issues is required [18].

This remaining part of this paper explains in detail different views on several authors that use agro waste as sustainable source of carbon for steel improvement. The next segments which is literature review discussed agro waste as viewed by different authors. The subsequent segment discussed different types of agro waste in details and their carbon content, and finally the last segment reviewed the use of agro waste in reinforcement of steel.

2.0 Conceptual framework of agro waste

Palm kernel shells are gotten from palm oil fruits as waste products after the extraction of the fruit which is used in the production of oil. Palm kernel shell is very suitable as a carburizer as it possesses a fairly high fixed carbon constituent of around 19%w/w and a small ash formation of around 0.1%w/w. This high carbon content and low ash formation means the palm kernel shell is a great choice for the manufacture of quality grade coal as well as being employed as the carburizing agent in this experiment [19]. Coconut shell is obtained as waste products from coconut fruits from which coconut oil is derived as well as the fruit itself serving other purposes. Coconut shell was chosen as the energizer for this experiment because of it’s relatively high carbon content of 88.92%, it’s low ash formation of 1.5% and a low moisture content of 2.2%. This high carbon content and low ash formation proves the suitability of the coconut shell to act as the energizer for the carburization process[20].

According to the effects of temperature and time alterations on nanoproducts treating mild steel in machining. At melting temperature of 1539°C and pouring temperature of 1545°C respectively, mild steel with a weight of 150 kg containing a 0.56% carbon has been let into a furnace. The mild steel furnace was filled with 0.05% max phosphorus and some sulphur [21]. The samples were cooled and cured at 900 °C for nine hours, then allowed to cool at 300 °C respectively for hardening, normalizing and tempering [22]. The treated samples are then soaked at a respective temperature (800, 850, 900 and 950 ° C) and time modifications (60, 90 and 120 minutes) with pulverized palm kernel and barium carbonate energizer at a muffle furnace.

Many organic residues and associated effluents are generated annually from industries that process food, such as chips, meat, and fruit. Organic residues are used as various sources of energy. The increasing population also increases the demand for food and its consumption. Thus, different food and beverage industries have remarkably improved in most countries in the region in order to meet food requirements [23]. The following are various compositions of industrial wastes of fruit, which establish the diverse structures of cellulose, hemicellulose, lignin, moisture, ash, carbon, nitrogen, etc. and which are biochemical digested in such a way that they produce useful goods such as the production of biogas and bioethanol. With the increase in production in the country, the waste produced from them also increased [24]. However, because of the high cost of producing and the process involved in regeneration the application of activated carbon is restricted [25]. There have therefore been major efforts to find new, cheaper and more efficient equipment for use. Bio - based materials have been given the most attention, especially agro - manufacturing waste like fruit coverings, because it can be easily accessible in large quantities [26].

Peels from fruit can be used as adsorbents economically and ecologically as they are available at lower cost, minimize agro - waste build - ups, offer possibility of adsorbent regeneration and
the ability for metals to be extracted from adsorbents[27]. Due to its availability worldwide, citrus skins from diverse roots, which include mandarins, grape fruits and oranges have recently been evaluated in the dealing of heavy and colored steel contaminated wastewater. On the other hand, fruit peels have been shown not to have a large surface area because of their high lignocellulosic component content [28].

Focused on the carbonization of peel in addition the removal of metal ions from aqueous solution with the use of biochar to increase the efficacy of fruit peeling. The elimination of dyes and metal ions from aquatic solutions was investigated recently for lemon peel [29]. For example, investigated the adsorption of lemon peel from green malachite and blue methylene, while lemon peel activated carbon was used to adsorb green malachite, congo red and methyl orange. In most cases, altered lemon peel was used to improve the efficiency of biosorbent which aids the collection of metal ions from aqueous solutions [30]. Citric acid refined lemon peel was used to eliminate lead ions, refined lemon peel from lemon juice were used for subtraction several heavy metals, refined lemon granola peel from aqueous solution is used for the removal of lemon peels, arsenate ions that are carbon activated for the elimination of lead ions and cobalt, activated carbon lemon skin further processed with phosphoric acid, to remove nickel and lead ions from rice and cadmium ions, improved lemon skin for elimination of cadmium ions from aqueous solutions with Al2O3 nanoparticles [31].

Across the world, citrus fruit is being consumed for various industrial uses such as jam and fruit juices. This kind of industry likewise produces huge quantities of waste, either in a peel deposit or in another form, but this citrus waste is suitable for fermentation as it is highly carbohydrated. For the manufacture of Poly (3-HB), used orange peel waste. They showed that there are rich and unused agro-industrial waste on orange peel. The making of Poly (3HB) via the use of orange skin as a sole carbon basis with a very easy pretreatment process was reported for the first time [32].

Globally potato is consumed on a large scale daily because of its ease to prepare and also to convert it to different product that can be preserved for a long time. As at 2013 376 million tons of potato was produced worldwide. About 4% of the entire potato production was channeled to industries for processing, this produces potato peel waste of about 15-40% (m/m). It is one of highest producer of agricultural waste. Peels from potato are usually thrown away or used for animal feed [33]. But the amount of potato waste generated is too much for it to be disposed economically through this avenues. In addition to this, the rapid effect of microorganism on the potato waste leads to contamination and make it difficult to be disposed. This means that changing potato waste to new products such activated carbon is a good way to make use of the vast amount of potato peels produced, even though there are reports about the use of potato waste as carbon absorbent precursor.

3.0 Agro waste and their Carbon content

The Australian waste biochar shell Macadamia nut was pyrolyzed to manufacture bio chars with a lab scale parallel tube furnace at temperatures ranging from 500 °C to 1300 °C. The bio char was characterized by [16] in order to validate the importance of carbon material used in process of producing iron. Thermogravimetry and kinetic studies have been used to analyze the waste macadamia biomass thermal decomposition. Variations in the chemical nature and structure of the bio chars made were analyzed by means of different methods. Biochar made at 1300 °C has a highly ordered graphic structure and carbon content of around 92 percent. In order to diminish iron oxides to metal iron at unlike temperatures (e.g. 1000 °C, 1100 oC, 1200 oC and 1300 °C).
biochar has been used as a carbon source. The analysis of the X-ray deflection and scanning electron microscopes in reduced samples were carried out to examine the respective morphologic and sample phases. The results in this paper shows that biomass waste of macadamia nut shell produces biochar which is useful and also the carbon is from a renewable source which leads to cleaner iron production [16].

According to the food processing industry potato stands out to be one of the most processed agricultural produce in the world of which is directed after rice maize and wheat. The increase in production of potato chips has led to an increase in potato waste that most times poses serious threat because of it degrades fast and are mostly discarded inappropriately. Although they are found to be of nutritional benefit as it can be used for as fertilizer or low value animal feed.

The solid waste by product for the adsorption of the endocrine disruptor Bisphenol-A from aqueous solutions was investigated as activated Carbon from potato peels. In order to evaluate the impact of the activating agent, potato peels biomass were activated with H3PO4, KOH and ZnCl2. In order to determine the effect of carbonization temperature on the texture, the adsorption properties and surface chemistry, the active biomass was carbonized at 400, 600 or 800 °C.

The characteristics of the activated carbons developed were nitrogen adsorption, Scanning Electron Microscope, heat testing and Fourier Transform Infrared Spectroscopy. Balance adsorption data have followed Langmuir as well as Friendly isotherms. Second order rate kinetics followed adsorption. For the Phosphoric acid-activated carbon carbonated at 400 °C which is the best adsorbent, the adsorption capacity calculated from Langmuire isotherm was found to be 454.62 mg g−1 at initial Ph. 3 at 25 °C [34].

Rice husk has physical and biochemical characteristics which are appropriate for the production of activated carbon as a potential precursor. It is a biomass that consists of lignin, cellulose and hemicellulose [35] of these, lignin is the primary component of the adsorption process in the formation of char [36]. In general, rice husks activated carbon has previously been prepared by either physical activation or chemical activation. The combination of the physicochemical activation method to activate lignocellulosic biomass such as bamboo has been successfully carried out, meanwhile its effect on rice husk has not been investigated properly [37].

Despite various research findings carried out regarding rice husks activated carbon, current reviews are mainly related to the use of rice husk activated carbon to remove heavy metals dyes from water and waste water

3.1 Steel Reinforcement using Agro Waste

Shi et al., [38] stated that metallic materials (for example steels) have numerous applications requiring both high quality and great malleability, yet for most metals or composites, quality and flexibility are totally unrelated. For instance, by refining the grain size to nano-scaling, the quality can be generously improved by a size request, which unavoidably results in impressive versatility misfortune. Along these lines, maintaining a strategic distance from the trade off between the quality and pliability of materials is dependably a test. A feasible way to deal with creating progressed basic materials by structure blemishes on various lengths has as of late been supported to accomplish an uncommon blend of high quality and ductility[39].

As indicated by hydrogenated or metal doped carbon movies can be utilized especially for tribological applications in view of their brilliant mechanical attributes and wear characteristics[40]. Since the mid seventies, such flimsy movies have been stored with various
testimony techniques. Physical vapor deposition (PVD) methods are often used because they are fairly straightforward, flexible, temperature - low when deposited, relative high deposition frequency etc. Carbon films for the most part have a low attachment to metal substrates in light of high internal pressure and low thermal stability. A few methodologies have along these lines been attempted to date, for example, embeddings change layers/multilayer between the movies and the substrate, dissemination or doping forms. The impact on the smaller scale basic, mechanical and destructive conduct of carbon based movies was accounted for as having doping impacts of different parts (Si, W, Ti, Zr) [41].

Guo et al.[24] reports that Ti and Zr dopants positively affect the attributes of carbon movies created by receptive attractive embed sputters. Moreover, Cemin et al. introduced a positive effect on the tribological conduct of the carbon-put together flimsy movies saved with respect to the steel at different preparing temperatures (100–550 °C) and testimony periods. As far as adherence to the substratum, the basic burden required for film disappointment has been expanded at temperatures more than 300 °C [42].

4.0 Conclusion
The use of agro waste as a sustainable means of reinforcement steel is feasible according to the reports from literatures. Increase in the output of agricultural product means that waste product will on the increase as well and this agro waste product are known to have high content in carbon which improves the durability and flexibility of steel. Therefore, from studies it was concluded that agro waste especially potato peel waste can be used as a sustainable means of reinforcing steel.

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References
[1] Sadh, P. K., Duhan, S., & Duhan, J. S. (2018). Agro-industrial wastes and their utilization using solid state fermentation: a review. *Bioresources and Bioprocessing*, 5(1), 1–15.
[2] Reddy, Dareddy Ramana, and Banoth Balunaik. 2013. “Development of a Composite Material from Agro Waste for Wear Resistance Application.” *Materials Science Forum*. https://doi.org/10.4028/www.scientific.net/msf.773-774.319.
[3] Lamers, Patrick, Frank Rosillo-Calle, Luc Pelkmans, and Carlo Hamelinck. 2014. “Developments in International Liquid Biofuel Trade.” *Lecture Notes in Energy*. https://doi.org/10.1007/978-94-007-6982-3_2.
[4] Tomke, Prerana D., and Virendra K. Rathod. 2018. “A Novel Step towards Immobilization of Biocatalyst Using Agro Waste and Its Application for Ester Synthesis.” *International Journal of Biological Macromolecules*. https://doi.org/10.1016/j.ijbiomac.2018.05.005
[5] Hazarika, Dipshika, Nabaneeta Gogoi, Seiko Jose, Robin Das, and Gautam Basu. 2017. “Exploration of Future Prospects of Indian Pineapple Leaf, an Agro Waste for Textile Application.” *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.09.092.
[6] Rodríguez Couto, Susana. 2008. “Exploitation of Biological Wastes for the Production of Value-Added Products under Solid-State Fermentation Conditions.” *Biotechnology Journal* 3 (7): 859–70.

[7] Bhatnagar, Amit, Mika Sillanpää, and Anna Witek-Krowiak. 2015. “Agricultural Waste Peels as Versatile Biomass for Water Purification – A Review.” *Chemical Engineering Journal*. https://doi.org/10.1016/j.cej.2015.01.135.

[8] Mayyas, M., Nekouei, R. K., & Sahajwalla, V. (2019). Valorization of lignin biomass as a carbon feedstock in steel industry: Iron oxide reduction, steel carburizing and slag foaming. *Journal of Cleaner Production, 219*, 971–980

[9] Hasanbeigi, Ali, Zeyi Jiang, and Lynn Price. 2014. “Retrospective and Prospective Analysis of the Trends of Energy Use in Chinese Iron and Steel Industry.” *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2014.03.065.

[10] Morfeldt, Johannes, Wouter Nijs, and Semida Silveira. 2015. “The Impact of Climate Targets on Future Steel Production – an Analysis Based on a Global Energy System Model.” *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2014.04.045.

[11] Sakaranaho, Matti, Anne Heikkilä, Hannu Suopajärvi, Mika Päättalo, and Timo Fabritius. 2018. “Charcoal Use in Chromite Pellets – Effect on Sintering Process, Pellet Properties, and Electrical Conductivity.” *Steel Research International*. https://doi.org/10.1002/srin.201700260.

[12] Horst, Diogo José, Jhon Jairo Ramirez Behainne, and Pedro Paulo de Andrade Junior. 2017. “Lignin as Alternative Fuel: An Estimate of the Thermal Energy Generation Potential from Brazilian Crops.” *Environmental Progress & Sustainable Energy*. https://doi.org/10.1002/ep.12441

[13] Mousa, Elsayed, Chuan Wang, Johan Riesbeck, and Mikael Larsson. 2016. “Biomass Applications in Iron and Steel Industry: An Overview of Challenges and Opportunities.” *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2016.07.061

[14] Adetunji O.R., Adegbola A.O., & Afolalu, S.A. (2015). Comparative Study of Case-Hardening and Water-Quenching of Mild Steel Rod on Its Mechanical Properties. *International Journal of Advance Research, 3*(6), 1-9.

[15] Afolalu, Sunday A., Abiodun A. Abioye, Mfon O. Udo, Olayide R. Adetunji, Omolayo M. Ikumapayi, and Samuel B. Adejuyigbe. 2018. “Data Showing the Effects of Temperature and Time Variances on Nano-Additives Treatment of Mild Steel during Machining.” *Data in Brief* 19 (August): 456–61.

[16] Kumar, Uttam, Samane Maroufi, Ravindra Rajarao, Mohannad Mayyas, Irshad Mansuri, Rakesh K. Joshi, and Veena Sahajwalla. 2017. “Cleaner Production of Iron by Using Waste Macadamia Biomass as a Carbon Resource.” *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2017.04.115

[17] Mansuri, Irshad, Rifat Farzana, Ravindra Rajarao, and Veena Sahajwalla. 2018. “Carbon Dissolution Using Waste Biomass—A Sustainable Approach for Iron-Carbon Alloy Production.” *Metals*. https://doi.org/10.3390/met8040290.

[18] Afolalu, S. A., Adejuyigbe, S. B., Adetunji, O. R., & Olusola, O. I. (2015). Production of Cutting Tools from Recycled Steel with Palm Kernel Shell as Carbon Additives. *International Journal of Innovation and Applied Studies, 12*(1), 110.

[19] Fernandez, M. E., B. Ledesma, S. Román, P. R. Bonelli, and A. L. Cukierman. 2015. “Development and Characterization of Activated Hydrochars from Orange Peels as
Potential Adsorbents for Emerging Organic Contaminants.” Bioresource Technology. https://doi.org/10.1016/j.biortech.2015.02.035.

[20] Xu, D. M., Li, G. Q., Wan, X. L., Misra, R. D. K., Zhang, X. G., Xu, G., & Wu, K. M. (2018). The effect of annealing on the microstructural evolution and mechanical properties in phase reversed 316LN austenitic stainless steel. Materials Science & Engineering 720(Febuary), 36–48.

[21] Afolalu, S. A., Adejuyigbe, S. B., & Adetunji, O. R. (2015) Impacts of Carburizing Temperature and Holding Time on Wear of High Speed Steel Cutting Tools. International Journal of Scientific and Engineering Research. 6 (5), 905-909.

[22] Afolalu, S. A., Adejuyigbe, S. B., Adetunji, O. R., & Olusola, O. I. (2015). Production of Cutting Tools from Recycled Steel with Palm Kernel Shell as Carbon Additives. International Journal of Innovation and Applied Studies, 12(1), 110.

[23] Anastopoulos, Ioannis, and George Z. Kyzas. 2014. “Agricultural Peels for Adsorption: A Review of Recent Literature.” Journal of Molecular Liquids. https://doi.org/10.1016/j.molliq.2014.11.006.

[24] Guo, S., Yu, J., Liu, X., Wang, C., & Jiang, Q. (2019). A predicting model for properties of steel using the industrial big data based on machine learning. Computational Materials Science, 160, 95–104.

[25] Kumar, Rajeev, and M. A. Barakat. 2013. “Decolourization of Hazardous Brilliant from Aqueous Solution Using Binary Oxidized Cactus Fruit Peel.” Chemical Engineering Journal. https://doi.org/10.1016/j.cej.2013.04.063.

[26] Usovic, T., Nesic, A., & Vukelic, N. (2019). Utilization of agro-industrial waste for removal of copper ions from aqueous solutions and mining-wastewater. Journal of Industrial and Engineering Chemistry.

[27] Munteanu, D. (2019). Deposition temperature influence on the wear behaviour of carbon-based coatings deposited on hardened steel. Applied Surface Science, 475, 762–773.

[28] Rosales, E., J. Meijide, T. Tavares, M. Pazos, and M. A. Sanromán. 2016. “Grapefruit Peelings as a Promising Biosorbent for the Removal of Leather Dyes and Hexavalent Chromium.” Process Safety and Environmental Protection. https://doi.org/10.1016/j.psep.2016.03.006.

[29] Yang, Q., Ren, X., Gao, Y., Li, Y., Zhao, Y., & Yao, M. (2005). Effect of carburization on residual stress field of 20CrMnTi specimen and its numerical simulation. Materials Science and Engineering: A, 392(1–2), 240–247.

[30] Okokpujie, I. P., Ikumapayi, O. M., Okonkwo, U. C., Salawu, E. Y., Afolalu, S. A., Dirisu, J. O., ... & Ajayi, O. O. (2017). Experimental and Mathematical Modeling for Prediction of Tool Wear on the Machining of Aluminum 6061 Alloy by High Speed Steel Tools. Open Engineering, 7(1), 461-469.

[31] Ikumapayi, O. M., Okokpujie, I. P., Afolalu, S. A., Ajayi, O. O., Akilabi, E. T., & Bodunde, O. P. (2018, July). Effects of Quenchants on Impact Strength of Single-Vee Butt Welded Joint of Mild Steel. In IOP Conference Series: Materials Science and Engineering (Vol. 391, No. 1, p. 012007). IOP Publishing

[32] Bogdanov, A. G., Gromushkin, D. M., Kokoulin, R. P., Mancocchi, G., Petrukhin, A. A., Saavedra, O.,& Yashin, I. I. (2010). Investigation of the properties of the flux and interaction of ultrahigh-energy cosmic rays by the method of local-muon-density spectra. Physics of Atomic Nuclei, 73(11), 1852-1869
[33] Khan, I., Abdalla, A., and Qurashi, A. (2017). Synthesis of hierarchical WO3 and Bi2O3/WO3 nanocomposite for solar-driven water splitting applications. International Journal of Hydrogen Energy, 42(5), 3431-3439.

[34] Sarki, J., Hassan, S. B., Aigbodion, V. S., and Oghenevweta, J. E. (2011). Potential of using coconut shell particle fillers in eco-composite materials. Journal of alloys and compounds, 509(5), 2381-2385.

[35] Dirisu, J. O., Oyedepe, S. O., Fayomi, O. S. I., Okokpujie, I. P., Asere, A. A., Oyekunle, J. A., ... & Abioye, A. A. (2018). Effects of Emission Characteristics on Elemental Composition of Selected PVC Ceiling Materials. Materials Focus, 7(4), 566-572.

[36] Shi, Y., Li, B., Gao, F., Wang, L., Qin, F., Liu, H., & Li, S. (2019). An outstanding synergy of high strength and ductility in gradient structured low-carbon steel. Materialia, 5, 100181.

[37] Adetunji, O. R., Ude, O. O., Kuye, S. I., Dare, E. O., Alamu, K. O., & Afolalu, S. A. (2016). Potentiodynamic Polarization of Brass, Stainless and Coated Mild Steel in 1M Sodium Chloride Solution. In International Journal of Engineering Research in Africa (Vol. 23, pp. 1-6). Trans Tech Publications.

[38] Ikumapayi, O. M., Ojolo, S. J., & Afolalu, S. A. (2015). EXPERIMENTAL AND THEORETICAL INVESTIGATION OF TENSILE STRESS DISTRIBUTION DURING ALUMINIUM WIRE DRAWING. European Scientific Journal, ESJ, 11(18).

[39] Adetunji O.R., Adegbola A.O., & Afolalu, S.A. (2015). Comparative Study of Case-Hardening and Water-Quenching of Mild Steel Rod on Its Mechanical Properties. International Journal of Advance Research, 3(6), 1-9.

[40] Dirisu, J.O., Asere, A.A., Oyekunle, J.A., Adewole, B.Z., Ajayi, O.O., Afolalu, S.A., Joseph, O.O., & Abioye, A.A. (2017). Comparison of the Elemental Structure and Emission Characteristics of Selected PVC and Non PVC Ceiling Materials Available in Nigerian Markets. International Journal of Applied Engineering Research. 12(23), 13755-13758.

[41] Vilardi, Giorgio, Javier Rodriguez-Rodriguez, Javier Miguel Ochando-Pulido, Luca Di Palma, and Nicola Verdone. 2019. “Fixed-Bed Reactor Scale-up and Modelling for Cr(VI) Removal Using Nano Iron-Based Coated Biomass as Packing Material.” Chemical Engineering Journal. https://doi.org/10.1016/j.cej.2018.12.166.

[42] Wu, Di. 2016. “Recycle Technology for Potato Peel Waste Processing: A Review.” Procedia Environmental Sciences: https://doi.org/10.1016/j.proenv.2016.02.014.