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Synthesis and Mechanical Analysis of Green Hydrophilic Composite Sheets as Dioxin-Free Alternative to Chlorinated Plastics

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This paper discusses the successful preparation of green composites plastics, resulting in a decrease in chlorine concentration. Mechanical properties, water uptake and moisture absorption tests were conducted on green plastic sheets with different HA content. Accelerated aging tests were performed to assess the plastic's performance under harsh environmental conditions, including UV exposure, elevated temperatures, and humidity chambers. The use of green hydrophilic composite sheets as an alternative to chlorinated plastics shows promise in reducing dioxin emissions and is considered environmentally friendly. The treatment using a hydroxyapatite powder has been successful in selectively hydrophilizing the surface of green plastic, improving the surface's wetting ability and making it easier to detach from E-waste plastics through froth flotation are actions that can be employed, but smaller reductions in carbon intensity were observed in the utilities sector.

Keywords: Green composites: Hydrophilicity; Dioxin emission; Chlorinated plastics
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1. Introduction

Yet another major plastic of environmental concern is PVC which is also chlorine-rich. Extensive pollution is generated as the organochlorine toxins are released during the production, use, and disposal of PVC [1]. Such toxins accumulate in the environment and represent serious threats to human and animal health alike.

In fertility, and dioxins are highly toxic substances produced during the making, using, and burning of chlorine-based products like PVC. Dioxins, which can injure health, are produced innately through the burning of PVC, setting up a risk to humans, even at very low concentrations [2]. Some immediate steps must be taken to reduce exposure hazards and control dioxin emissions. An introduction to chlorinated plastics and the emission of dioxins. The development of green hydrophilic composite sheets as an environmentally friendly alternative is being examined [3]. These composite sheets can eventually save the environment and promote sustainability and supplant PVC [4,5]. It is imperative that developing and implementing such alternatives is prioritized to save our planet for generations to come.

Identification of the substitute materials is of utmost importance to arrest dioxin emissions. Dioxins are highly toxic, persistent pollutants that jeopardize the environment and human health. The information assimilated from various research sources provides an irrefutable conclusion regarding the negative impact polymers, specifically PVC, have on dioxin emissions. PVC is the most environmentally damaging plastic in terms of dioxin pollution over its whole life-cycle. It releases toxic chlorine-based compounds that accumulate in the water, atmosphere, and food chain [6-8]. Particularly relevant are the burning and dioxin release from incinerators; thus, the development of effective emission abatement strategies is critical for these sources [9-11]

Such life cycle analyses have shown plastic materials, as compared to their alternative materials, to have the least carbon footprints and trade-offs with the environment through the years. Lowering emissions from transportation, increasing product lives to reduce food waste, and providing durable features for safety during extreme weather events, have all contributed to plastics playing a very important part in improving social well-being [12]. Banning plastics would be detrimental to human welfare as well as the sustainability of the environment.

To properly understand and realize the actual significance of plastics, there is requirement to bring innovative solution to the problem of recycling. Investigation on green hydrophilic composite sheets as a green alternative to chlorine-based plastics is therefore a must in this case. Some promising results of selective hydrophilizing PVC surfaces with a nanometallic hydroxyapatite composite for further separation from other polymers of e-waste through froth flotation have been obtained. Such hybrid treatment managely separates hazardous chlorinated plastics and reduces its environmental impact [12-15].

To breathe fresh air, substitute materials must be found that will eliminate dioxin emissions entirely from the environment. Dioxins are especially found to be a significant contributor from the PVC end with serious health concerns. By using intelligent recycling technology and exploring green hydrophilic composites as substitutes like green hydrophilic composite sheets [5,16,17], dioxins can be reduced and the effect of plastics on sustainability can be minimized.

The green hydrophilic composite sheets are developed along with possible employment as a safer environmentally kind replacement for further chlorinated plastics in order to reduce dioxin emissions. Also, these composites could be effectively employed in their unique properties and characteristics for various end-uses [18]. PVC and plastics from e-waste can be successfully separated using foam flotation at the optimum mixing speed of 100 rpm, with a purity of the settled fraction reaching 96.4%. This process is capable of recovering more than 100% of the PVC-free plastics in the floating fraction, which already represents a significant improvement over the classical wet gravity separation even when the polymers introduced into the reactor differ in their sizes and shapes [19-21].

Besides the nanometallic Ca/CaO application on chlorinated polymers, surface modification and hydrophilization techniques have also been investigated. Non-PVC microplastics can be in situ coated by fine magnetite (Fe_3O_4) nanoparticles, which lead to a 94 per cent reduction in their contact angle because of the high density of hydroxyl groups found on the Fe_3O_4 NPs surface. However, there seems to lack an effective coating process for PVC because of the weak interaction between Fe^{3+}/Fe^{2+} and PVC surface [22].

Comparison of emissions of dioxins and impact on environment between green hydrophilic composites and chlorinated plastics determines their viability as alternatives in dioxin emission reduction. Basic small-scale waste incinerators without any air pollution control devices release dioxin emissions proportionally higher than municipality solid waste incinerators. Chlorinated plastics, especially PVC, are the most in-chlorine chemical releases and highly health-impacting [23]. Green hydrophilic composites are a better option by containing lesser chlorine and having a few innovative surface modifications to allow better recycling processes [24]. Assessment parameters include waste composition, catalytic metals, and treatment methods for fly ash high in dioxin content. Life cycle assessments are important for the evaluation of the sustainability of materials [25], which would include, but not be limited to, plastics, which have some benefits, such as lower carbon emissions and reduced energy and water consumption during production. However, there should be investments in innovations that recycle plastics to the highest levels while minimizing the cost to the environment [26,27].

Green hydrophilic composites present some advantages in dioxin emission reduction compared to chlorinated plastics [28]. Chlorinated plastics such as polyvinyl chloride (PVC), classified as the most hazardous to the environment in view of their entire lifecycle, meant production, use, or disposal-pose threats of severe environmental degradation. Chlorine, beginning from the very production of PVC, is thereby used significantly, with the discharge of chlorine-based toxic chemicals along the entire lifecycle of PVC. These toxins reside in the environment, constituting grave health hazards to humankind and ecosystems. These green hydrophilic composites can also be a solution for plastic pollution. Each year tons of very much underused plastic pour into the oceans, where they do so much damage to the alluring world of marine life and complex ecosystems [25,29,30].

The cessation of dioxin emissions is an essential goal toward the well-being of humankind and the ecological system. Dioxins are obnoxious contaminants that can exert toxic effects upon the nervous system. The studies have established a correlation between dioxin exposure and neurodegenerative diseases and neurodevelopmental disorders. Acetylcholine-esterase (AChE) has been recognized as a biomarker for the monitoring of dioxin pollution. Dioxins are capable of interfering with AChE expression, adversely affecting the nervous system. Production of dioxins through uncontrolled incineration of waste presents a danger to human health and the environment. Green hydrophilic composite sheets could be used as substitute materials for chlorinated plastics to diminish dioxin production [28,31]. This would guarantee the health of human beings and the environment through reduced exposure to toxins and lesser pollution. Recycling presents opportunities for achieving environmental sustainability. Stopping plastic use altogether would have negative effects. Green hydrophilic composite sheets, as well as considering the sustainability of plastics in general, are important avenues leading to human well-being and environmental protection. [16,32]

Green hydrophilic composite sheets could provide sustainable alternatives to many areas of application like the health and manufacturing sectors [2,30,33,34]. In healthcare, using such sheets could considerably minimize the dioxin emissions from waste incinerators that normally work without proper air pollution controls and act as barriers for dioxin release. Accordingly, their use could translate to drastically diminished emissions. Another concrete benefit would be the substitution of chlorinated plastics in the manufacture of these composite sheets, thereby minimizing the chlorine content and reducing the risk of dioxin generation during pyrolysis processes [24,35]. In contrast to chlorinated plastics, green hydrophilic composite sheets would help mitigate dioxin emissions and associated health and environmental risks of plastic waste [30,36-41]. These sheets, therefore, become a sustainable alternative with a smaller carbon footprint than other materials.

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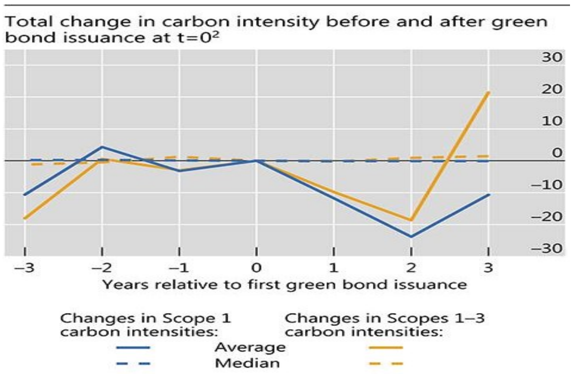
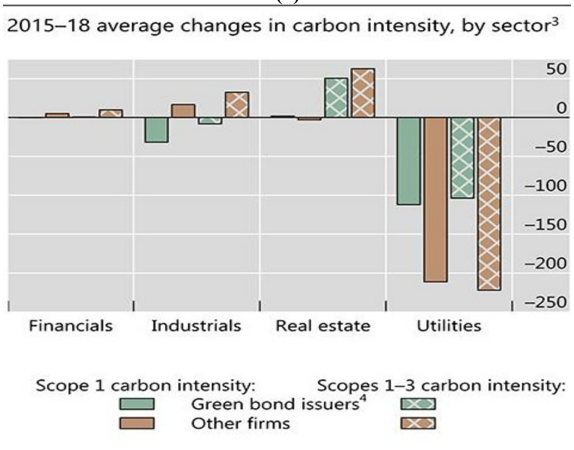
The use of such sustainable materials for dioxin emission reduction must become a priority in further promoting the long-term welfare of society and sustainability of the environment [42].



(a)



(b)

Fig. (1) (A) Total change in carbon intensity before and after green bond issuance at t=02 (B) 2015-18 average changes in carbon intensity, by sector [43]

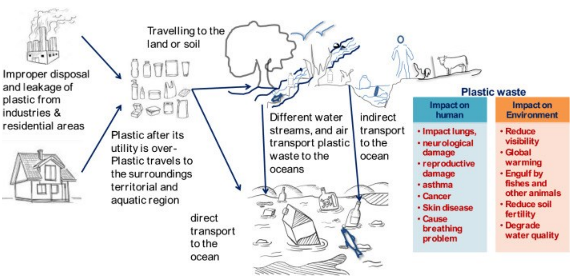


Fig. (2) Illustration of improper disposal and leakage of plastic after its utility is over and their impact [30]

2. Experimental Part

Hydroxyapatite nanoparticles (a naturally occurring mineral that can enhance the properties of green plastics) were integrated, making them stronger and more versatile. In this study, the production of HA via calcined eggshells and trimethyl phosphate was developed. The eggshells were collected and cleaned before calcination at 900°C for 1 hour. This process served to decompose organic matter and convert calcium carbonate into calcium oxide. Then following the steps below to get fine powder of hydroxyapatite:

1. A precise measure of 50 milliliters of distilled water, known as D.W., was incorporated into 5 grams of calcium oxide, also referred to as CaO, while gently blending the components together.
2. To commence, a volume of 50 milliliters was meticulously prepared, consisting of a 0.3M solution of H_3PO_4. Subsequently, an additional 20 milliliters of the same 0.3M solution of H_3PO_4 was meticulously added drop by drop to the amalgamation of CaO and D.W. This process ensured that the pH level remained steady at an impressive 9 through the gradual addition of ammonium hydroxide, commonly known as NH4OH. Furthermore, the maintenance of the pH level was meticulously monitored by employing the assistance of a pH test paper.
3. The amalgamation was then allowed an ample span of 4 days, during which it was left undisturbed.
4. After a duration of 4 days, the mixture underwent a vigorous stirring process for 30 minutes, facilitated by the use of a heating stirrer.
5. Subsequently, the amalgamation was once again granted a period of 24 hours, during which it was left untouched.
6. The ensuing step involved the implementation of the filtration process, skillfully carried out through the utilization of filter paper. Once the filtration had been successfully completed, the filter paper was subjected to the drying procedure within an oven, specifically at a temperature of 100 degrees Celsius, for a duration of 2 hours.
7. The final step, known as calcination, involved exposing the filtered mixture to a scorching temperature of 900 degrees Celsius for a duration of 2 hours

Fig. (3) The preparation steps of HA

The overall reactions are as follow

Calcination: $2CaCO_3$ + Heat → $2CaO + 2CO_2$

Hydration: $CaO + 2HNO_3 \rightarrow 2Ca(NO_3)_2 + H_2O$

$Ca(NO_3)_2$ + 2NH4O3 → $Ca(OH)_2 + 2NH_4NO_3$

Precipitation $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Formation of hydroxyapatite

$10Ca(NO_3)_2.4H_2O + 6(NH_4)_2HPO_4 + 8\ NH_4OH \rightarrow Ca10(PO_4)_6(OH)_2 + 20NH_4NO_3 + 20\ H_2O$

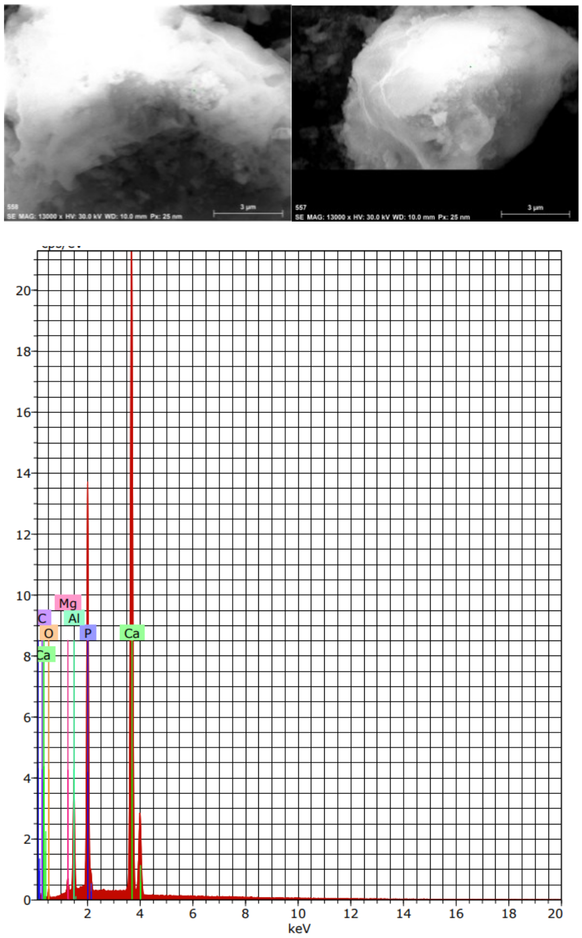
Green plastics with hydroxyapatite nanoparticles include one extra step: adding the nanoparticles to the mixture. Hydroxyapatite is a naturally occurring mineral, and it appears it could be a good ingredient for improving green plastic and making it possibly stronger and more versatile.

The ingredients include cornstarch (corn flour), vinegar, water, hydroxyapatite nanoparticles (prepared from egg shell). These ingredients were mixed starting by mixing 1 cup of cornstarch and 1/2 cup of water in a bowl. They were thoroughly mixed until a smooth paste is obtained. The cornstarch was dissolved in a pot, 1 cup of water was added and the mixture was brought a boil. As stirring is continued, the cornstarch paste was gradually drizzled into the boiling water. Stirring is continued until the mixture thickens and becomes translucent. Vinegar and hydroxyapatite powder are then added to the mixture. After the mixture is thickened, take it from the heat. Two tablespoons of vinegar were added to the mixture and stirred properly. In another container, the hydroxyapatite nanoparticles suspension is prepared by slowly adding the hydroxyapatite powder suspension to the cornstarch mixture while stirring continuously. This will help achieve a good dispersion of HA in the green plastic mixture.

The mixture is left to cool a little until it is safe to handle in order to shape the green plastic. Small amounts of the mixture are taken and shaped into the desired forms. Molds can be used as well as shaping by hand. The shaped green plastic articles are allowed to dry and harden in a dry and well-ventilated location. This drying process may take a few days depending on the size and thickness of the articles.

3. Results and Discussion

Hydroxyapatite nanoparticles are observed in the SEM images with respect to their overall size and shape. Hydroxyapatite is a crystalline, spherical material and the images may show information on its crystal orientations or grain boundaries as shown in FIG3. The EDS data would be available together with the SEM, and elemental analysis would confirm the composition of the nanoparticles. Hydroxyapatite consists of calcium, phosphorus, oxygen, and hydrogen, and their relative concentrations can be obtained using EDS.



El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Ca	20	K-series	40.08	51.85	37.07	1.20
P	15	K-series	18.23	23.58	21.81	0.76
O	8	K-series	7.32	9.47	16.97	1.45
Al	13	K-series	5.95	7.70	8.17	0.33
C	6	K-series	4.64	6.01	14.33	1.07
Mg	12	K-series	1.08	1.40	1.65	0.09
		Total:	77.31	100.00	100.00	

Fig. (4) SEM for the prepared HA

It is very important to train green plastics (biodegradable plastics or plastics that are more environmentally friendly) against aging to check for durability, stability, and, of course, its eco-friendliness over time. Aging may trigger different factors such as light exposure heat moisture oxygen mechanical stress and eventually, microorganisms. Here are the common tests and things to consider in aging green plastics. Accelerated aging tests would simulate an otherwise very harsh environment to predict the behavior of the plastic for an extended period in a much shorter time. Examples include exposure to UV light, raised temperatures, and humidity chambers-the whole spectrum of accelerated aging. The impact and benefits of ultraviolet exposure tests are usually focused on the resistance of plastics against degradation instigated upon the exposure of the products to ultraviolet radiation from the sun.

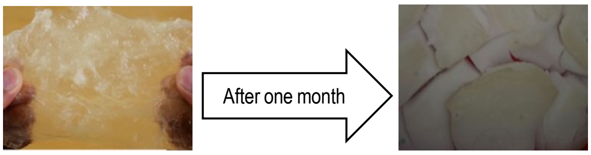


Fig. (5) After a month, the prepared slides had shifted in color density from its original state, now decomposing because of natural factors of aging

The plastic's mechanical properties, including tensile strength, elongation, and impact resistance. Aging can affect a plastic's mechanical integrity, so monitoring these properties is essential.

Water uptake and moisture absorption tests assess the ability of the plastics to resist water infiltration and swelling. A critical point to consider is that green plastics normally degrade more quickly in the presence of moisture. Table (1) indicates that the lower content of HA shows the best mechanical properties. Therefore, the moisture absorption test was chosen to provide the results in table (2).

Table (1) Mechanical properties of different hydroxyapatite percent to reinforce green plastics

Mechanical test	5%	10%	15%	20%	25%
Tensile Strength (MPa)	278–780	230–700	180-660	120–170	186–673
Young's Modulus (GPa)	16	12–16	5.7–14	4–6	10–55
Elongation at break (%)	1.1	1.4	7–8	30	1.5–1.8

Table (2) Water uptake by the green plastic sheet with 5% HA content

Liquid concentration salt and distilled water	Weight (g) of green plastics\HA composite sheet before immersion	Weight (g) of green plastics\HA composite after immersion
0.005 M	2.34	2.624
0.01 M	2.65	2.723
0.015 M	2.74	2.881

Green hydrophilic composites offer many advantages over chlorinated plastics. Beyond their environment-friendly advantages, the hydrophilicity properties might also be exploited for processes involving separation, such as flotation during the recycling of plastics. In this operation, hydrophilicity is one of the properties exploited to differentiate waste plastics having similar physical and chemical characteristics. Surface modification can be used to enhance the hydrophilicity properties of these composites and, therefore, facilitate efficient separation and recycling [25]. While green hydrophilic composites offer numerous advantages over chlorinated plastics, some disadvantages also exist. One limitation could be that they might be costly to produce relative to petroleum-based plastics due to the incorporation of biodegradable constituents and the environmentally friendly nature of production processes. More studies are thus necessary to improve surface modification and gauge its feasibility and effectiveness in large-scale applications [12].

4. Conclusion

Green hydrophilic composite she'll develop to be environment friendly like chlorinated plastics for reducing dioxin emissions in future. Such adoption can lead to less dependency on chlorinated plastics, which are associated with various health and environmental concerns. Such an approach will advocate the use of sustainable materials in different sectors. Improvement in the emission of toxic dioxins from the incineration of chlorinated plastics implies improved air conditions and consequently positive effects on public health.

This green hydrophilic composite has fairly good mechanical properties, and will find applications in the packaging, construction, and manufacturing industries among others. This would lead to more sustainable and eco-friendly approaches in different sectors. In other words, green hydrophilic composite sheets as an environmentally friendly alternative to chlorinated plastics for dioxin emission reduction will have some prospects in the application arena. Successful selective hydrophilization treatment using a nanometallic Ca/CaO composite increases the wettability of PVC and enhances its separation from E-waste plastics through froth flotation. The last part of the opportunity involves handling production costs and conducting further research in these areas to ensure the optimal utilization of these composites in minimizing dioxin emissions while paving the way to a future of sustainability. The impact of this research will not just end in the laboratory but would stretch beyond environmental conservation, innovative materials science, industrial practices, adherence to regulations, public health, and of course, global sustainability efforts.

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