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Comparative Evaluation of Dodders, Giloy, Onion Peels and Fruit Waste-Prepared Composite Biochar Polymeric Adsorbent (CBPA) For Use in Wastewater Treatment

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Abstract

Due to pollutants that have a negative impact on water bodies, wastewater treatment has attracted a lot of attention throughout the years. In many developing countries domestic and industrial wastewater treatment plants are lacking or not working efficiently for detergents due to the refractory nature of such chemicals. Generally the industrial wastewater is directly discharged into the existing water bodies (drains, nallahs etc.) after primary settling tanks. These refractory contaminants either settle in soil and sediments by their process half-lives. In water, the aesthetic colour resulting from dyes is a visual turnoff and hence red and purple hues are really problematic as it appears virtually impossible to attribute any natural cause for their occurrence unlike with blue, green or brown colours generally considered as normal colours. The degree of toxicity and mutagenicity featured by such pollutants because they have a very strong structural integrity that reacts with living systems resulting in long term environmental problems. Untreated dyes containing wastewater (WW), is highly undesirable and requires elaborate treatments for the purpose of environmental health welfare, sustainability. The reactor based on composite charcoal polymeric adsorbent is regarded as a notable technology because of its straightforward design, high efficiency, high-grade effluent, and financial viability. This paper gives a general overview to usage of Composite Biochar Polymeric Adsorbent (CBPA) and different adsorbent materials.

Keywords: Giloy, dodders, composite biochar polymeric adsorbent (CBPA), methylene blue, methylene red, polymeric industrial wastewater

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INTRODUCTION

Among environmental factors providing potable water is a major concern of humankind. Among all the industries, the textile sector is one of the worst for water pollution. The textile industry produces a large amount of persistent organic pollutants (POPs) such as dyes and pigments, which are at levels ranging from 5 to 1,500 mg/L. Many other industries like leather, foods and beverages, pharmaceuticals, cosmetic industry etc are also discharging the large amount of these pollutants in their effluent[1]. However, limited power supply and cost of treatment facilities are one such roadblock[2]. Further to freshwater ecology defeating from the route. Dyes are very broad group xenobiotica (~100000 species) which have properties that light and oxygen stable in the environment natural, however also of man-made but these contaminants (dye molecules) from other chemical compounds differ mutually[3, 4]. Colour also absorbs sunlight in water, which thus constrains the gross ecological production (photosynthesis) of aquatic environment[1, 3]. Under such conditions, the natural processes would not be able to maintain a biological balance in response to bacterial consumption or the decomposition of DBPs and other pollutants; these chemicals are biologically persistent so that they remain available as food for bacteria. These contaminants also vary water chemistry at the chemical level by its loading in terms of TDS, CODs and BOD quality indicators. Depletion of oxygenic levels induces oxidative stress which impairs a multitude of respiratory physiology in life. Although TDS reading in higher results means increased toxicity by way of electric conductivity[5]. All of this eventually ends up in killing & decay of plant and animal life underwater. Textile dyes and WW from industries have been the focus for usage of various physio-chemical techniques, worldwide inclusive use adsorption etc, ozonation, photo-catalytic treatment using UV + H_2O_2, coagulation, electrochemical oxidation etc., these are all traditional and advanced treatments methods[6]. The two most used techniques are adsorption and coagulation. It is not effective on photo-stable dyes, however it is quite effective elsewhere. Membrane filtration, while very efficient is only technically feasible with nano or ultrafiltration membranes[7]. Chemical or electro-chemical treatment such as ozonation, Fenton and Electro-Fenton process (EF), advanced oxidation processes (AOPs) appeared to be a highly promising method for the degradation of soluble-dyes pollutants but have been limited application due to high operating cost and sludge problem; other chemicals/reactants-slurry, Besides, WWs only 20–30% of dyes removed using both chemical and physical method. Biological wastewater treatment processes consist of a wide range of living organisms (i.e. bacteria, fungi and plants) that are combined in various suspended or attached growth reactors. They are considered as an ultimate due to various physiological activity of organism aerobic conditions/anaerobic conditions for dyes complete degradation. However, they are nevertheless long to evolve and also towards functionalizing clear of increased technology companies or possibly applications[8, 9]. It can be like re-innovation of some other potential produces with the proper biological process in organic waste (renewable energy & Industrial products). In addition, they are even eco-friendly too so cost-effective and very sustainable. The past two decades have seen significant advances in numerous microbial electrochemical technologies (METs) Microbial fuel cell (MFC) and microbial electrochemical cells (MEC) have been developed for the treatment of different types of pollutants associated with domestic/industrial sectors. METs mostly operate on the anaerobic bio-catalysis of contaminants for energy generation [electrical or gaseous (H_2) fuel]. Recently, the MEF process has been in recent years processed to MEFP using MXCs (bio-electro-Fenton processes) as this prevails superior relying on developed WWT technologies already provided comprising EFP, AOP, biologic treatments and MES. MEFS have made a series of advances and innovations. Lin and Chang, reported a combined sequential application of EF followed by biological processes for treatment landfill leachate containing refractory compounds in their work [10, 11]. It was followed by 1st MEFS in the year 2009 which is rigorously aerobic stable for pollutants especially dyes and opened a new horizon to conduct such novelty research. Unlike classic EF technologies, the MEF technology is around 10 times more efficient and cost effective for recalcitrant WWT compounds. This also generates an almost inconsequential amount of sludge. This will provide excellent options for treating hazardous, and persistent organic pollutants (POPs) of xenobiotic nature in WW industrial effluents containing toxic dyes, pesticides pesticide residues by-products from pharmaceuticals paper pulp sugar extraction industries including lignin (paper and pulp), bagasse & molasses. Further, this system also works as effectively for municipal and agriculture waste treatment with different physicochemical loading[12, 13]. A simple MEFS consist the same METs configuration (for anaerobic degradation of biodegradable compounds) in anodic chamber but is additionally complemented by a Fenton Process for simultaneous treatment of refractory chemical oxygen demand COD compounds such as dyes, pesticides or aromatic substances respectively in a non-selective manner within cathodic Baffled Digester. The cathodic oxidation of contaminants will lead to the creation of highly reactive oxygen species as hydroxyl radicals produced by Fe^{2+} catalysis, H_2O_2. Fenton's reagent oxidises the organic molecules and this is a fast exothermic process that can almost completely mineralise contamination to inorganics (CO_2) as well as water. Furthermore, several reports also indicate the prospects of integrating photo-catalytic (oxidation via UV/light source) with conventional FP for boosting up the performance MEFS. Another benefit from this new technology is that it seems to be capable of treating two different wastewater (pollutants) in the same reactor. In recent years, the architectural improvement and scope of MEFS for designing new reactors at pilot to large scale facilities has improved further[14, 15]. Although many technologies, including physical, chemical, and biological ones, have been employed, the treatment of wastewater containing dyes from the textile industry remains a difficulty. Recent developments in the use of ionizing radiation, specifically electron beam (EB) radiation, to treat wastewater containing dyes were compiled and examined, with an emphasis on the decolorization and degradation of different dyes[16]. Four chitosan-based sponges were made using a sustainable and environmentally friendly method by preparing chemically modified chitosan with various alkyl chains in an aqueous medium at ambient temperature. The resulting sponges displayed excellent stability in water with outstanding dye removal efficiency[17]. The adsorption capacity was associated with the alkyl chain length incorporated to the polymer backbone.

When it came to methyl orange (MO), all sponges showed a high adsorption capacity ranging from 238 to 380 mg g^{-1}, but methylene blue (MB) and rhodamine B (RB) showed a low capacity [18, 19]. The presence of exogenous redox mediators and electron donors is essential for the bio-reduction of azo dyes. In this study, an azo dye of Acid Orange 7 (AO7) was biologically reduced by supplementing the naturally occurring henna plant biomass. Additionally, the complex process of henna-assisted azo dye removal was deciphered using the machine learning (ML) approach [17, 19]. A large portion of synthetic dyes are made of harmful azo chemicals. Because of their harmful impacts on both human health and the environment, the eradication of poisonous azo dyes, organic contaminants, and radioactive elements from the global ecosystem has garnered significant attention. The scientific community is now heavily researching the use of nanotechnology in the catalytic breakdown of pollutants from aqueous ecosystems in order to establish an efficient and economical method [18]. Using an agitated batch adsorber, the adsorption of basic dyes from aqueous solution onto granular activated carbon and natural zeolite has been investigated. Studies have been done on the effects of agitation, starting dye concentration, and adsorbent mass [19].

Two pillared clays are synthesized by intercalation of solutions of aluminium and zirconium and evaluated as adsorbents for the removal of Orange II and Methylene Blue from aqueous solutions[20].

MATERIALS AND METHODS

Materials and Reagents

Natural sources such as Giloy, Dodders, Onion peels and fruit waste were used. Collected the creepers of Giloy (Tinospora Cordifolia), Dodders (cuscutta reflexa) within the periphery of HBTU campus near chemical department and girls hostel respectively. Collected the Fruit waste from nearby Sweet lime shop which contains 95% of sweet lime (Citrus Limetta) and waste and 5% of pineapple (Ananus Comosus) waste from nearby fruit juice vendor. Collected the Onion (Allium Cepa) peels from local vendors. (Kanpur, Uttar Pradesh, India). Methylene red dye, Methylene blue dye, were purchased from Thermo Fisher Scientific India Pvt. Ltd. Whatman paper in size of Grade B59501 in 125 mm and deionised water were used for dissolving dyes in it. Leather Industrial wastewater was collected from Model Tanners (Unnao, Uttar Pradesh, India).

Preparation of Composite Biochar Polymeric Adsorbent (CBPA) and Synthetic Wastewater

Dodders and Giloy dried for 3 days in open sunlight and afterwards 3-4 hours in hot air oven. In same way fruit waste and onion peels were allowed to dry for 2-3 days in open sunlight. All four samples were pulverized and grinded in a mixer and are collected in different flask in equal quantity for each sample. All four samples are kept in muffle furnace (600 deg. C, 1h) and each sample is further divided into 3 equal parts for making CBPA through hand mixing in ratio (1:1:1:1). Prepared the dyes with 0.2 g/L concentration each of Methylene blue and Methylene red.

The flowchart of methodology shown in Figure 1.

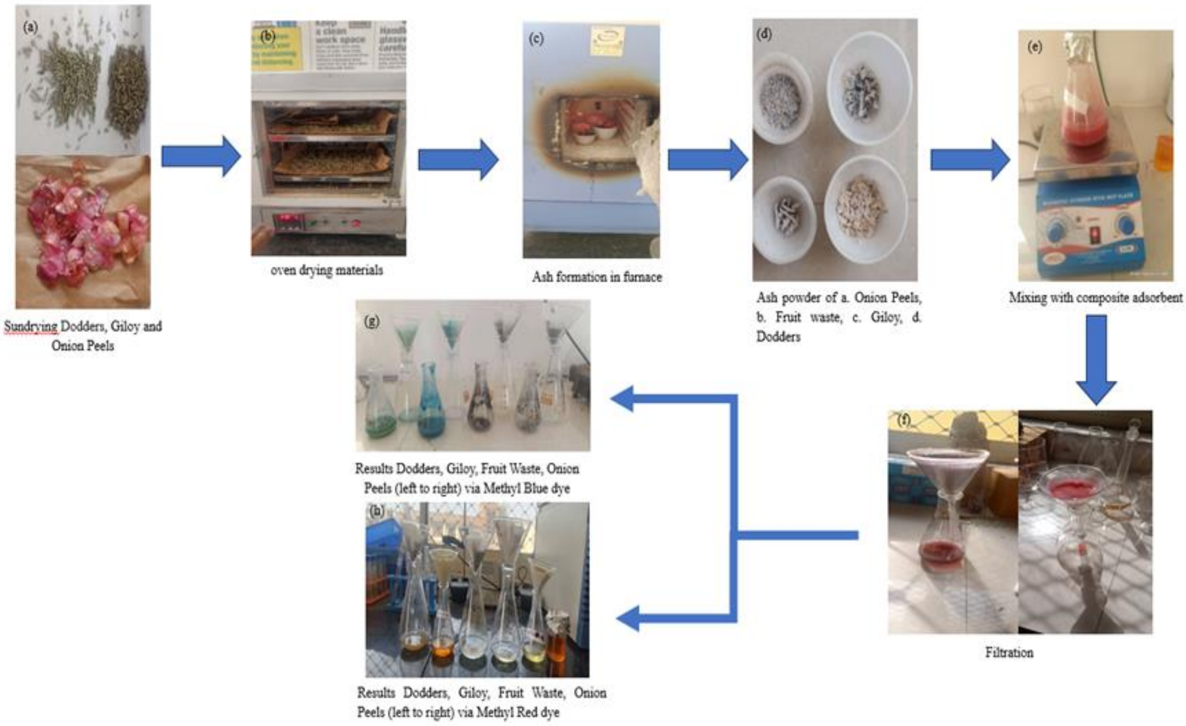


Figure 1. (a) Sundrying Dodders, Giloy and Onion Peels, (b) oven drying materials, (c) Ash formation in furnace, (d) Ash powder of a. Onion Peels, b. Fruit Waste, c. Giloy, d. Dodders, (e) Mixing with composite adsorbent (f) Filtration, (g) Results Dodders, Giloy, Fruit Waste, Onion Peels (left to right) via Methyl Red dye and (h) Results Dodders, Giloy, Fruit Waste, Onion Peels (left to right) via Methylene Blue dye.

Removal of Dye from Synthetic Water

Measured 0.2 g of dye powder of two dyes and mixed them in 1 Litre of distilled water. Stirred the solution of dyes on magnetic stirrer for 10-20 minutes approximately. The concentration of dye was made to be 200 ppm. Methylene blue solution is divided into eight parts of 100 ml each in 8 different conical flasks. 5g CBPA of fruit waste, Dodders powder, Giloy powder, Onion peel was mixed in conical flask containing 100 ml solution of Methylene blue. Then solution is stirred in magnetic stirrer for 40-50 minutes. The newly formed solution is then kept for 20-30 minutes in the conical flask. The solution is then filtered out using filter paper and filtrate is stored in test tubes with accurate labelling. The residue is taken out of filter paper and is stored as sample for further test in zip sample bag. Similarly, 5g ash content of each sample is measured and mixed in remaining 4 conical flasks with 100ml of solution. Ash Powder and dye solution is then stirred in magnetic stirrer for 40-50 minutes and then allowed the solution to be at rest for 20-30 min. Then solution is filtered out using filter paper and filtrate is stored in 4 different well labelled test tubes for further experiments and residue (Dye adsorbed ash content) is stored. Test tubes are kept in incubator.

The above procedure is repeated with methylene red. Some of the above samples were also checked in waste water collected from leather industry named "Model Tanners" in Unnao near Kanpur city by using Composite Biochar Polymeric Adsorbent (CBPA).

The use of Composite Biochar Polymeric Adsorbent (CBPA) for treatment of industrial wastewater is shown in Figure 2.

CHARACTERIZATION

Fourier Transform Infrared Spectroscopy (FTIR): The FTIR data for the product were obtained using Fourier Transform Infrared Spectroscopy (PerkinElmer Spectrum IR version 10.6.1, USA). This is used for the analyze contaminants and composition of adsorbent. It helps to identifying functional groups, Monitoring Adsorption Mechanism, Assessing Adsorbent Modifications and Analyzing Pollutant Composition; FTIR can detect specific organic or inorganic pollutants in wastewater by identifying their characteristic absorption peaks. This technique is valuable in understanding the adsorption capacity and efficiency of materials used in wastewater treatment.

(a) Treatment of industrial waste water with CBPA

(b) Result by using Giloy ash

(c) Result by using Composite Biochar Polymeric Adsorbent (CBPA)

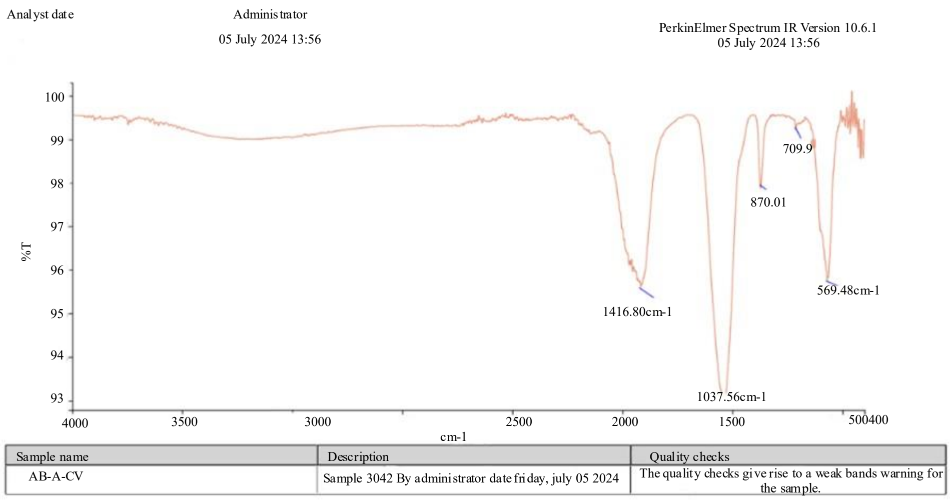
(d) Result by using Fruit Waste

Figure 2. (a) Treatment of industrial waste water with composite adsorbent, (b) result by using giloy ash, (c) result by using composite biochar polymeric adsorbent and (d) result by using fruit waste.

RESULT AND DISCUSSION

Ftir Analysis

CBPA in Methylene blue dye solution; The bond present at 1416.80 /cm is alkane bond i.e. C-H bond shown in Figure 3(a). Similarly, 1037/cm corresponds to alkyl amine bond. Similarly, 569.48/cm certainly indicates towards halogen containing compounds which shows that CBPA has extracted certain halogen from Dye water from Methylene Blue. Dodders Ash in Methylene blue; The first 3 data is same as above which depicts that first 3 wavenumber represents characteristics bonds of Dodders Ash shown in Figure 3(b). The 874/cm represents the bending C double bond O. The wavelength 563/cm represents Carbon Iodine or Bromine single bond so either Iodine or Bromine are extracted from Methylene blue dye solution. Fruit Waste Ash in Methylene Blue; Bond corresponding to wavenumber 417 represents the Metal halogen bond shown in Figure 3(c). The wavelength 563/cm represents Carbon Iodine or Bromine single bond so either Iodine or Bromine are extracted from Methylene blue dye solution. Similarly, 872.6 wavenumber represents C-H out of plane vibrations. Giloy Ash in Methylene Blue; The wavelength 707/cm represents the C-H bond in Giloy ash in Methylene Blue shown in Figure 3(d). The wavelength 563/cm represents Carbon Iodine or Bromine single bond. Similarly bond 870.6 wavenumber represents C-H out of plane vibrations. Onion Peels Ash in Methylene Blue solution; The bond present at 1416.80 /cm is alkane bond i.e C-H bond shown in Figure 3(e). Similarly, 1037/cm corresponds to alkyl amine bond. Similarly, 569.48/cm certainly indicates towards halogen containing compounds.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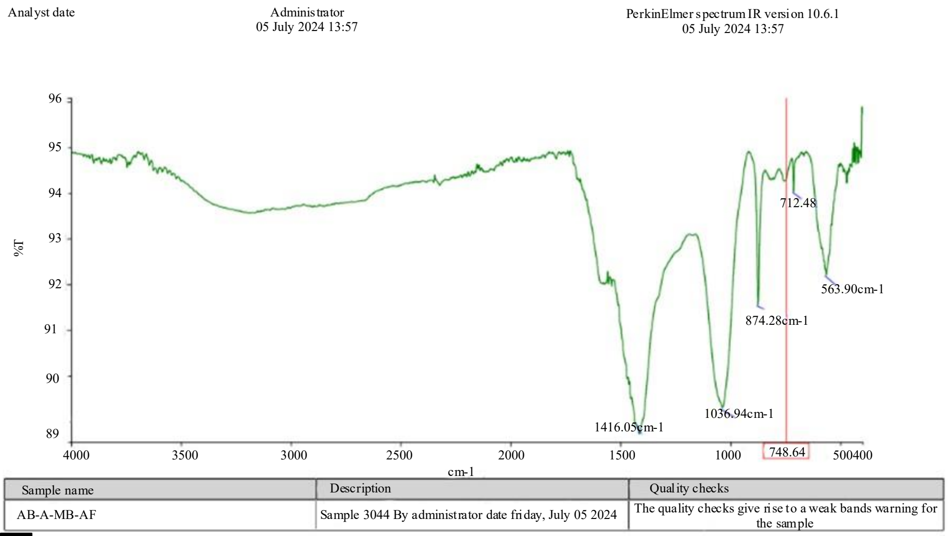
Quality checks
AB-A-CV
Sample 3042 By administrator date friday, july 05 2024
The quality checks give rise to a weak bands warning for the sample.

(a)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874.28cm-1
1036.94cm-1
1416.05cm-1
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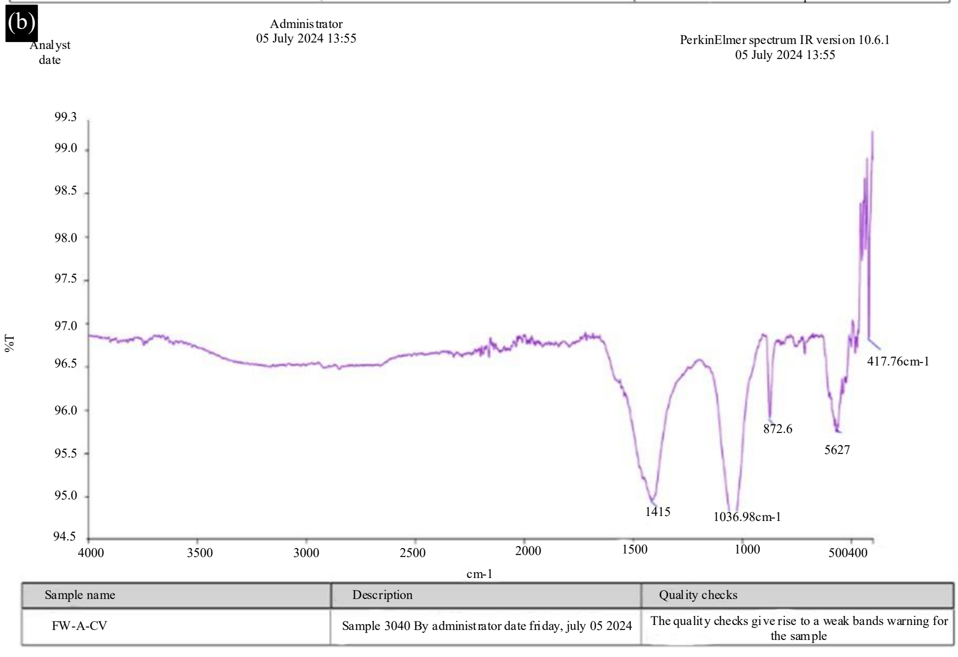
Sample 3044 By administrator date friday, July 05 2024
The quality checks give rise to a weak bands warning for the sample

(b)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94.5
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872.6
5627
1415
1036.98cm-1
4000
3500
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2000
1500
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Description
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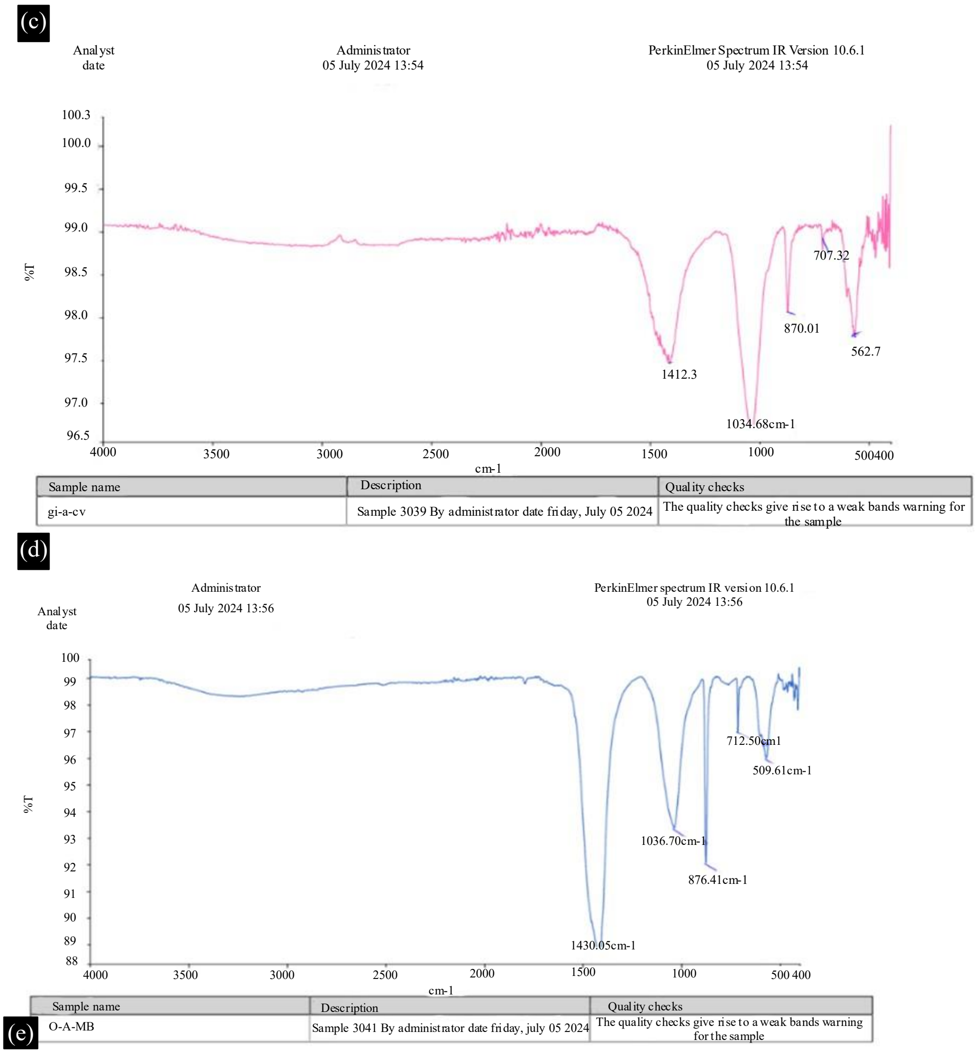

Figure 3. FTIR results (a) CBPA in methylene blue dye solution, (b) dodders ash in methylene blue, (c) fruit waste ash in methylene blue (d) giloy ash in methylene blue and (e) onion peels ash in methylene blue solution.

CONCLUSION

There is a lot of promise for the removal of dyes in wastewater treatment when comparing Composite Biochar Polymeric Adsorbent (CBPA) and biochar made from Dodders, Giloy, and fruit waste. According to the study, CBPA and biochar both have good adsorption capacities, but because of its increased surface area and porosity, CBPA often performs better. The materials that were examined revealed that CBPA was the most effective in removing color, followed by biochar of Giloy and Dodders, Fruit Waste and Onion peel. According to this hierarchy, the kind and source of the biomass have a big impact on the final Composite Biochar Polymeric Adsorbent (CBPA), adsorption capabilities. Fruit waste combined with Dodders and Giloy offers a novel and environmentally friendly method of treating wastewater by utilizing easily accessible and frequently neglected natural resources. By eliminating dyes, this method not only reduces pollution to the environment but also helps to value waste by converting plant and agricultural waste into useful adsorbents. Subsequent investigations thought to concentrate on refining the method of producing biochar and Composite Biochar Polymeric Adsorbent (CBPA), investigating the regeneration and reutilization of the adsorbents, and evaluating the financial viability of extensive implementations. Overall, the study highlights the potential contribution of biomass and biochar to the development of affordable and environmentally friendly wastewater treatment methods for dye contamination.

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