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Utilization of fruit peel waste as low-cost bio-adsorbent

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ABSTRACT
With the rapid industrialization and consumer choices, there is an increasing pressure on the apparel industries to produce diverse types of color shades which in turn is leading to excessive use of synthetic chemicals. These practices are imposing an extra burden on textile industries and local dyeing houses for the processing of waste effluent and removal of color before discharging them into local sewage treatment facilities or water bodies. With the increasing environmental awareness at a global scale, industries are aiming at eco-friendly approaches to tackle their waste products, furthermore, waste fruit peels such as banana and orange peels can be employed as potent bio-adsorbents for the treatment of textile and local dye effluents. The current study is aimed at the removal of dyes and decreasing water pollution levels from textile and local dye effluent by utilizing orange and banana peels powder derived from waste fruit peels. The studies were conducted in batch mode for optimization of removal efficiencies. The results showed that an adsorbent dosage of 0.8 g and pH-1 showed maximum colour removal efficiency for both orange and banana peels. Orange peels exhibited93% colour removal efficiency within 60 minutes of contact time for both effluents. While the banana peels based bio-adsorbent was found to have 93% removal efficiency within 180 minutes of contact time fortextile effluent and 72% maximum removal efficiency within 120 minutes of contact time forlocal dye effluent.
Keywords: *Orange peels, Banana peels, Textile, Dyes, Bioadsorbent.*

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INTRODUCTION

Many industries produce a large amount of wastewater containing various organic and inorganic pollutants. For instance, the textile industry employs huge amount of water in its wet processes and hence produces a large amount of wastewater containing dyes, dispersing agents, salts, leveling agents, and heavy metals. When this effluent is released into different ecosystems, it affects aquatic flora and fauna. According to the World Bank's report, 17-20% of water pollution is caused by the textile industry and their finishing processes used to produce fabrics. Therefore, this effluent needs to be treated before its release into water bodies [1]. Textile industry can be categorized into two types based on the type of waste being produced: a) Dry fabric industry- which produces solid wastes, b) Wet fabric industry- which produces liquid wastes. Dyeing industries are one of the dominant enterprises in India. Dyestuff industry in India is the second highest exporter among chemical industries. Textiles, Paper, printing ink and food industries are the major consumers of dyes. The textile sector has the highest consumption share ofaround 80% of total production. According to Christie [2], dye molecules have two key components; the chromophores and the auxochromes. Auxochromes have two functions; firstly, they supplement the chromophore and secondly, they enhanced the affinity of dyes towards different kind of fibres. On the other hand, chromophores are only responsible for producing the colour. Mishra and Tripathy [3], classified dyes in three categories; anionic dye, non- ionic dye and cationic dye. Anionic dyes cover direct dye, acid dye and Reactive dyes. Non–ionic dyes include disperse dye and cationic dyes described as a Basic dye. These all dyes have one common characteristic that is they all can absorb light in the visible region. Dyes used in textile industries are Azo dyes, Reactive dyes, Sulphur dyes, disperse dye, vat dye, Acid dye, Basic (cationic) dyes and direct dyes. Examples are Allura Red AC, Direct orange 62, Reactive blue 19, Reactive yellow 8, Indophenol and Sulphur black, Reactive Red 198, Malachite Green, Red 2B and Yellow Brown 2RH. The textile effluent consists of natural or synthetic dyes. It also consists of acids, alkalis, surfactants, dispersing agents, detergents, heavy metals, oil and grease[4]. It is high in pH, colour, solids, metals, temperature and salts accompanied by increased biochemical oxygen demand (BOD) and chemical oxygen demand (COD). It also contains organic matter which includes total organic carbon, ammonium- nitrogen, nitrate- nitrogen, orthophosphate phosphorus. Even if a little amount of dye is

present in textile effluent, it imparts color and is detrimental. Because of the chemical structures of these dyes, they cannot be easily faded by just exposing to light, water and various chemicals [5,6].
Jeyajothi [7] reported that dyes that are used in paper industries, textile industries and in many medicinal purposes have a major influence on the environment including water pollution and also have carcinogenic and allergic effects on human life and can cause DNA damage. Chemical compositions and reacting groups are main reasons for dye's resistant nature and its impact on the environment. Dyes have injurious impacts on microbial inhabitants and even fatal to mammals, resulting in medical conditions like eczema, irritation of skin, mutation and cancer in human. Decolourization of the effluent containing a complex mixture of dyes cannot be achieved by aerobic and anaerobic treatment in sewage treatment plants [8]. For this additional treatments are used, which can be categorized into- chemical, physical and biological methods. Biological methods show significant results in the case of azo dyes [9]. Treatment by physical methods implies, the removal of contaminants by physical means i.e. precipitation, grills, filtration and reverse osmosis. It includes simple processes, easy operation and less energy. These methods have certain drawbacks such as high cost, low efficacy, and disposal problems. Thus, these methods do not have commercial applicability. Chemical methods include electrolysis, redox, neutralization, ion- exchange, electrodialysis, Fenton's method etc. The main disadvantages of these methods are the high cost of electricity and chemicals used and the most important is the formation of toxic by-products during the main reactions. These methods proved to be environmentally hazardous thus are not employed commercially. In order to search for an ecofriendly alternative route, studies are being focused on employing physicochemical method such as adsorption. Adsorption is the surface phenomenon where different components (molecules, ions and atoms) of a gas or a liquid get attached to the available surface. Various studies reported, adsorption as a better alternative for wastewater treatment [10]. Acid Dye is highly water-soluble thus it shows poor adsorption. Reactive Dye is highly water-soluble unrelated to several sulphonic acid groups. Thus, ease of hydrolysis occurs and it is poorly absorbed. Direct Dyes and basic dyes show a high level of adsorption. Disperse Dyes shows high to medium level of adsorption. There are many chemicals, micro-organisms, toxic metals dissolved in water which poses a great challenge of their removal to the existing techniques. For this purpose, many Bio-adsorbents are used for purification of the water. Bio-adsorbents comprises plant or microbial biomass which offers various charged functional groups as available binding sites for adsorption of pollutants from different types of aqueous solution. Their increasing popularity owes to their capability to remove contaminants from diluted effluents which is not possible in conventional treatment schemes, less operational costs and low amount of waste sludge production. Adsorbent made by peels is normally used for its environmentally friendly behaviour, cost-effectiveness and high availability. The orange peel comprises of pectin, lignin, cellulose, hemicelluloses, terpenes etc. Saleem and Saeed [11] had reported antimicrobial activity of orange peels. The solvent extracts made from orange peels have shown 20% to 30% more antimicrobial activity on gram-negative bacteria than gram-positive bacteria. Thus, it can be efficiently used as a bio-adsorbent for removal of variety of components from effluent viz., organic pollutants, metals and dyes. Thus, in the current studies, utilisation of the orange peel as a natural adsorbent involving different parameters such as different dosage concentration, pH and contact time were studied. Banana peels comprised of starch, crude protein and fat, various types of polyunsaturated fatty acids such as linoleic acid and alpha-linolic acid, lignin, pectin, essential amino acids, cellulose, hemicelluloses and galactouroninc acid. These peels can be harnessed as bio adsorbent for the treatment of textile effluents. The presence of acidic group in banana peels makes them a promising bioadsorbent as the acidic group aids in removal of contaminants from the waste effluent. Studies reported successful use of banana peels for removal of cobalt and nickel from the experimental solution[12].

MATERIAL AND METHODS

The wastewater samples were collected from local dye store, Zirakpur, Distt, Mohali, Punjab and woolen dyeing Industry, Ludhiana, Punjab. Both the effluents were collected in translucent plastic bottles and were capped tightly. The samples were kept at room temperature till further use.Banana and orange peels were used as adsorbents in this study. The peels were collected from a Juice shop of the local market from sector 32-D, Chandigarh. The peels were collected in clean, dry and transparent plastic bags and were brought to the laboratory. Peels have been washed under the tap water to remove any dirt particles. The peels were then cut into small pieces and placed separately on a tray. An oven was set at 90°C temperature and the tray was placed carefully in it (one could also dry the peels in sunlight during summers as it's an economical and cost-effective technique). Up to 90% of the moisture was removed in approximately 24 hours. The peels were then crushed in pestle and mortar to make a homogenized fine powder. When the peels were finely powdered, they have been sieved using a 300-600 micron sieve and were collected in Petri plates. For soaking the powdered samples of peels 1N HCl was prepared by adding

24 ml of concentrated HCl in 800 ml of distilled water[13]. The particles were subjected to soaking in hydrochloric acid for approximately 5 hours. After completion of 5 hours, the soaked powder was filtered through a muslin cloth[14].Thecolor of the collected samples was first visually observed and the odor was examined organoleptically. The pH was measured by using pH strips and pH meter (Labline pH meter). The organic and inorganic components of the samples were measured by applying tests such as dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD). Solid components were measured with the help of TDS and TSS tests [15]. The batch adsorption studies were designed to find the optimum colour removal efficiency of fruit peels from local dye and textile effluents. The required quantity of different concentrations of orange and banana peelswere added to Erlenmeyer flaskscontaining 50 ml textile effluent. The bottles were kept in shaker at 30°C and 150 r.p.m. The contents were collected after regular intervals and were filtered before analysis using whatman filter paper. The procedure was repeated to get optimum time and dosage of adsorbent required for maximum color removal [14]. Using a 100 ml measuring cylinder, 50ml of local dye effluent sample was measured and poured into eight 250ml clean flasks and 50ml textile dye effluent sample was measured and poured into eight 250ml clean flasks each. Different doses of banana peel adsorbent were weighed (0.2g, 0.4g, 0.6g and 0.8g respectively) using an analytical weighing balance and was added into the four flasks containing local dye and four flasks of textile dye effluent. Orange peels adsorbent batch was made by following the same steps as that for banana peels. Subsequently, a duplicate batch was made. The flasks were kept in an orbital shaker at temperatures 37° C at 150 rpm and were taken out at different time intervals (1 hour, 2 hours, 3 hours, 4 hours and 5 hours) and the contents were filtered each time using Whatman filter paper. Absorbance for each filtrate sample of both original and duplicate batch was noted down. The time of contact, adsorbent dose and pH were optimized by repeating the experiments at different conditions such as time intervals, concentrations and pH.From batch adsorption tests of contact time and different doses, 0.8g concentration of banana and orange peels was found out to absorb the maximum amount of dye color from both Local and Woolen dye samples. Thus optimized concentration of 0.8 g of Banana and orange peels was used for both samples followed by adding them into six flasks (triplicates). Solutions of 1N Hydrochloric acid and 1N sodium hydroxide was used to find out the pH of the samples at which maximum colour of the samples get removed; three different pH (pH 1, pH 3 and 7) had been set for both the samples (woolen and local dye effluents) by using the HCl and NaOH solutions. Subsequently, a duplicate batch was prepared. The flasks were kept in an orbital shaker at temperatures 37° C at 150 rpm. The flasks were taken out at different time intervals (1 hour, 2 hours, 3 hours, 4 hours and 5 hours) and the contents were filtered each time using Whatman filter paper. Absorbance for each filtrate sample of the original and duplicate batch was taken in a UV-vis spectrophotometer at 575nm wavelength.

RESULTS

The results of physicochemical characteristics of woolen and local dye effluent are given in Table 1.

Table1. Physiochemical characteristics of effluents

S.No.	Parameters	Woolen dye effluent	Local dye effluent
1.	Colour	Purplish-red	Greenish blue
2.	Odor	Odourless	odorless
3.	pH	5.41	7.23
4.	DO -Day1	8.6 mg/l	3.2 mg/l
	DO -Day3	1.2 mg/l	2.8 mg/l
5.	BOD	7.4 mg/l	0.4 mg/l
6.	COD	6.4 mg/l	10.4 mg/l
7.	TDS	0.2275 g	0.121g
8.	TSS	0.372g	0.1555g

To study the bio adsorbent potential, the experiment was carried out at different doses of orange and banana peels such as 0.2g, 0.4g, 0.6g and 0.8g with 50 ml textile effluent and local dye effluent each in 100ml conical flasks in orbital shaker at 37°C and 150 rpm for different intervals of time (up to 5 hours). As a result, orange peels worked best for woolen dye effluent when compared with local dye effluent. The adsorption by banana peels showed best results in woolen dye effluent giving 79.23% removal with 0.8g dose. From the comparative results for woolen dye effluent, it was found out that banana peels are the most effective adsorbents removing 79.23% colour with 0.8g dosage while orange peels could remove 74.28% with 0.8g dose in 300 minutes as shown graphically in figure 1.

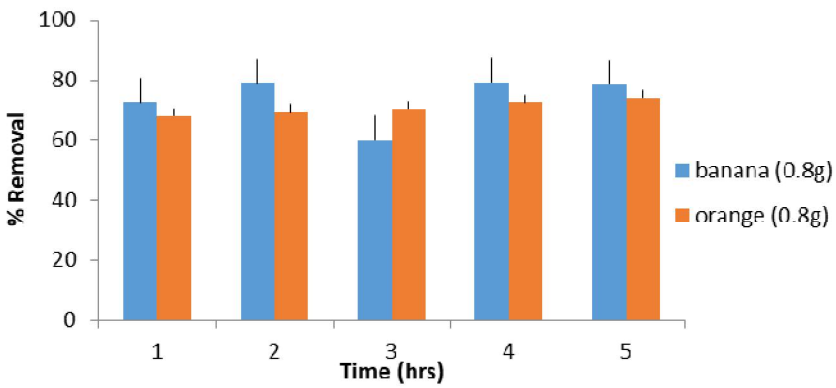

Figure 1. Plot showing % removal vs. time with maximum dose of both banana and orange peels as adsorbents with woolen dye effluent.

For local dye effluent, banana peels depicted the best results giving 75.03% removal efficiency in 5 hours while orange peels gave 40.05% removal with 0.8g dose in 5 hours as shown graphically in figure 2.

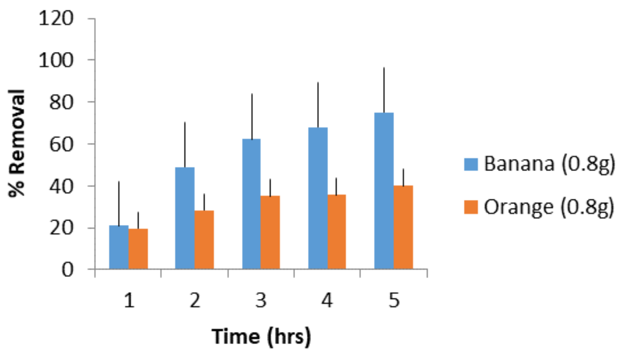

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Figure 2. Plot showing % removal vs. time with the maximum dose of both banana and orange peels as adsorbents with Local dye effluent.

In conclusion, the banana peels acted best as adsorbent for both woolen as well as local dye effluent at 0.8g concentration within 300 minutes of incubation.To study the impact of pH , the effect of adsorbent was studied with pH 1, 3 and 7 for woolen effluent and pH 1, 3 and 5 for local dye effluent for up to 5 hours with 50ml of sample and 0.8g concentration of the adsorbent. The best adsorption was observed by orange peels with maximum removal of 93.23% from woolen effluent within 60 minutes of shaking at pH-1 (Figure 3). While with banana peels, maximum absorption from woolen dye effluent was observed after 120 minutes removing 73.05% colour at pH 3 (Figure 4). Thus, the orange peels acted best as an adsorbent for the textile effluent at pH -1. To study the effect of pH on colour removal capacity of fruit peels, studies were carried out at pH ranging from 4 to 10 by maintaining pH of wastewater sample with IN HCl and 1N NaOH solution. The banana peels efficiently removed up to 93.97% of colour at pH -1 from local dye effluent (Figure 5) while orange peels removed 93.17% at pH -1 with the same sample effluent (Figure 6). During the experiment, it was observed that at lower pH, oxidized functional groups of the peels were promoted and thus the availability of the active sites for binding of dye became available. As a result, removal efficiency increased while there was a decrease in this pattern after certain time interval due to the saturation of active sites of the adsorbents with the dye causing the process of desorption. The more acidic the pH is, the better the removal of colour from the effluent. At the acidic pH the number of positively charged sites increase, which favours the adsorption of the anions due to electrostatic attraction. Thus the greatest adsorption occurred at pH-1. With textile effluent, orange peels adsorbed better and with local dye effluent banana peels adsorbed better.

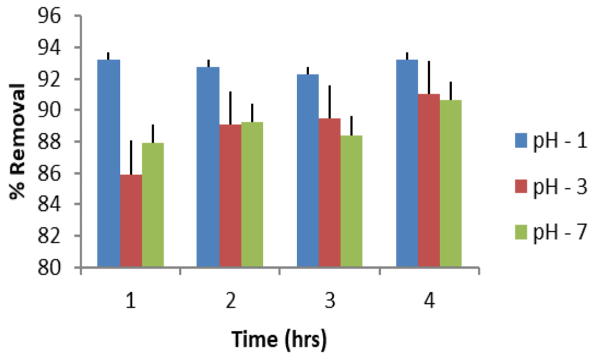

Figure 3. Effect of pH on the removal of dyes from woolen effluent by adsorption onto orange peels (Initial Concentration: 0.016g/ml, amount of orange peels: 0.8g, pH values-1, 3, 7).

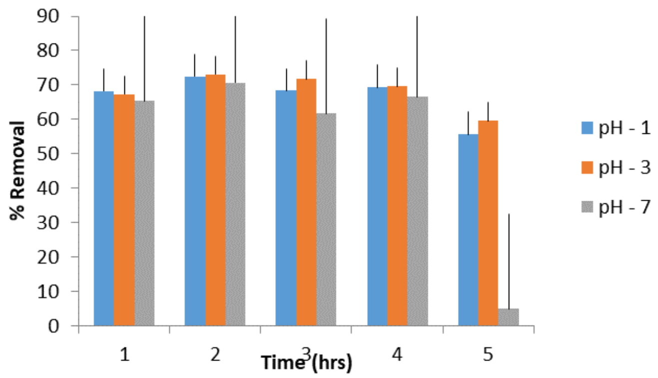

Figure 4. Effect of pH on the removal of dyes from woollen industry effluent by adsorption onto banana peels (Initial Concentration: 0.016g/ml, amount of orange peels: 0.8g, pH values-1, 3, 7).

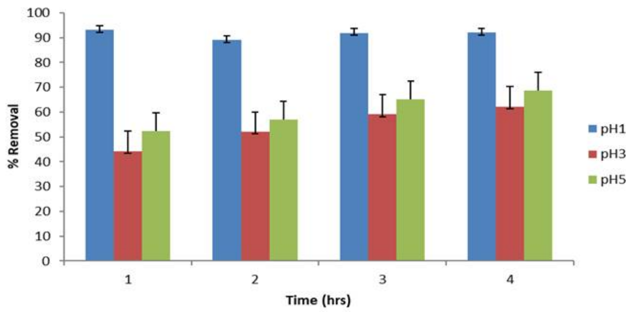

Figure 5. Orange peels as asorbent in local dye effluent with different pH values.

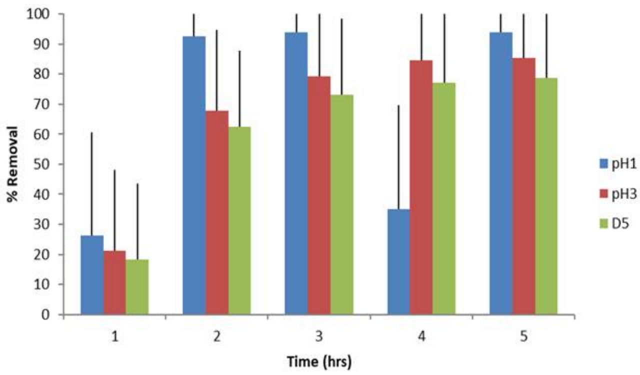

Figure 5. Banana peels as adsorbent in local dye effluent with different pH values.

DISCUSSION

The maximum color removal efficiency with orange peels in woolen effluent was 74.28% at a dose of 0.8g while for local dye effluent was 40.05% under the same conditions. Banana peels gave 79.23% of color removal at 0.8g dosage after 4 hours while in local dye effluent, it removed up to 75.03% of color at the same dosage after 5 hours. [16] concluded the removal of dye as a function of adsorbent dosage. According to them, for quantitative removal of 10mg/l, dye from 5o ml of sample, a maximum of 0.6g is required. The present studies revealed maximum removal percentage within 300 minutes of contact time with an adsorbent dosage of 0.8g. Hence, more is the contact time, more is the percentage of removal of color from the effluent. Rahman *et al*. [17] reported 1.5 gm of peel adsorbent with a contact time of 120 gave the maximum removal percentage. The more acidic the pH, the better the removal of color from the effluent. With woolen effluent, orange peels adsorbed better, and with dye effluent bananas adsorbed better. Earlier studies reported that the maximum dye adsorption occurred at pH 2 [18].Similar observations were reported by Rapo & Tonk [19] that increase in adsorbent dosage and decrease in pH increases the effectively of adsorption.

CONCLUSION

The adsorbent potential of discarded waste fruit peels can be exploited for the removal of colour from the woolen and local dye effluent and hence preventing pollution of recipient water bodies. The current studies demonstrated the utilization of orange and banana peels for the treatment of wastewater by adsorption of dyes which was influenced by the contact time, adsorbent dosage andpH. For maximum colour removal, adsorbent dose of 0.8 g was favourable, furthermore, the adsorption was found to increase with the increase in the contact time. With the statistical data, it was shown that for the treatment of woolen dye effluent, orange peels gave best results when the optimum contact time given was 300 minutes which removed up to 74% of colour and with the banana peels the optimum contact time was calculated as 240 minutes with 79% removal. For the treatment of local dye effluent, the orange peels removed 40% of dye after 300 minutes of incubation while banana peels removed up to 75% of dye at the same contact time. When pH varied, marvellous results were obtained. Within 60 minutes, at pH -1 the orange peels removed 93% of colour from woolen as well as local dye effluent. With banana peels 93% of colour was removed in 180 minutes at pH -1 in woolen effluent and up to 72% removal in 120 minutes at pH-1 for local dye effluent. This treatment brought certain parameters like COD, DO and TSS within the permissible limits of CPCB. Constant monitoring of water quality and adopted policies by CPCB is necessary to avoid further dreadful conditions. Although the color removal efficiency of banana and orange peels does not match with the available bio- adsorbents but their easy availability and eco-friendly characteristics make them promising candidates for treatment of textile effluents. More studies are required to have complete information about their functional groups offering binding sites and the conditions under which their activity can be further increased in order to make these peels competitive with available bioadsorbents.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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