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# Review On Activated Carbon: Synthesis, Properties And Applications

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***Abstract*** *- Many researchers have reported that a number of control methods were used in waste water treatment. In this work, there are several types of agricultural wastes and fruits were employed to synthesis activated carbon via chemical activation and physical activation process. The obtained activated carbons indicated higher surface area and larger adsorption capacity. This paper describes experimental findings on uses of activated carbon in wastewater treatment, which produced under different conditions such as contact time, initial pollutant concentration, temperature, pH value, adsorbent dosage, particle size and agitation. The adsorption capacity and equilibrium data of different pollutants (dyes, oil, grease waste water, organic pollutants, pesticides, herbicides, heavy metal ions, lignin and tannin colour) were studied through various isotherms. Thermodynamic parameters such as entropy, free energy and enthalpy were investigated.*

**Keywords** - *Activated carbon; waste water treatment; surface area, Langmuir isotherm, adsorption.*

## I. INTRODUCTION

In human science history the life and origin of activated carbon cannot be determined precisely by most of the scholars who knew about it and its applications. Earlier, for what currently is known as activated carbon that has formed porous shape, either in a shape of wood char, or in a shape of char, or merely in the shape to some extent degasified carbon material, which has been exploited as an adsorbent new scientific material. The first of what is known scientifically as activated carbon described as back to three thousand seven hundred fifty before the common era, when mutually the Sumerians and Egyptians utilized forest char material as wood to diminish the zinc copper consequence and used this wood char as well in tin metals industrial of bronze, and as well as a fumeless fuel (González, 2018).

The first documented use of the activated carbon as a fume phase adsorptive material in a form of gas, was until 1793, when Kehl utilized forest char in a form of wood to improve the smells of infections. In England it developed a discolorizing mediator in the sugar fabrication business as leading consumption of activated carbon in the industrialized business in 1794. In the middle of the 19th century, the first main gas-phase use of activated carbon was conducted successfully for gas-phase. In 1854, the activated carbon has a major role in all sewage aeration schemes, the London Mayor well-organized woody type filters to be fitted to reduce nasty odors. In 1872, activated carbon-sieved gas covers were utilized in the chemical industry to avoid mercury gases from being gasped (González, 2018.

Activated carbon (AC) that material of which has microporous arrangement of carbon with a perfectly established hole formation, pore capacity, superior inside exterior region, then accordingly a high-level adsorption capability (Galvão et al., 2020). The activated carbon as well displays efficient clusters lying on its face, that affects the pH solution, then therefore the adsorption procedure (Mallek et al., 2018).

In recent years, the incidence of water pollutions has been rising all over the world. Commonly, contamination of water sources such as rivers, lakes, underground water and bays or oceans happened because of unprecedented volumes of waste waters and effluents have been discharged into the environment. Water is an important source of life; its contamination has been a most important question to environmental engineers at present anticipated to the discharge of contaminated heavy metals from several industrial activities (Ho et al., 2018).

Activated carbon considered as one of the approaches for handling with water and wastewater problems, which has main wellbeing threats (Lu et al, 2018). Such problems occur from industrial effluents. Improvements in water and wastewater management activities are reliant on the elimination of pollutions. Mostly, the consumption of activated carbon is one of the highly adequate methods of water and wastewater care, because of the broad variety of fabrication processes and focus system functions for adsorbates.

In this work, activated carbons have been produced by using various precursors under activation process and carbonization process. An extensive survey of preparation, properties and adsorption of pollutants in wastewater treatment using activated carbon during the past twenty years (2000 to 2020) is reported. The adsorption capacity and equilibrium data of different pollutants (dyes, oil, grease waste water, organic pollutants, pesticides, herbicides, heavy metal ions, lignin and tannin colour) were investigated through isotherms.

## II. LITERATURE SURVEY

The activated carbon realizes broad products in scheme of water and wastewater treatment and decontamination. The extensive use of the activated carbon in the scheme of water and wastewater handling and cleansing remains expected to its comparatively extreme adsorption presentation besides serviceability, urging the issue use as a possible replacement to the traditional and innovative water and wastewater conduct knowledges (Liu et al., 2020). The improved knowledges are not only randomly circulated global, however also related through elevated working, conservation, and sustained costs (Palansooriya et al., 2020). For big scale, activated carbons have been mostly discovered from non-renewable sources for example coal, wood coal, *palm oil mill effluent (*pome), and peat. These demonstrate high carbon substance, a high permeability, as well as a low mineral substance, which suited them as AC pioneers.

Throughout the start of twentieth time, the first activated carbon fabrication factory remained appointed in Germany principally for a sugar processing business. Later, several factories began making activated carbon for water and effluent management activities. Not long ago, the activated carbon is amply utilized such as an air cleanser in full of atmosphere air pollutant cleanup, industrial dye elimination and vehicle consume, pharmaceutical and food foodstuffs as well applied as fridge deodorizers as innovative products such as atomic-powered factories. As of late 1930's, activated carbon improved massive lead plus appreciation in manufacturing segments, for mutually aqueous phase applications and gaseous. Many innovative activated carbon fabrication practices have been resolved to catch up the constant rising manufacturing demands.

The basic chemical composition of activated carbon is cautiously projected by the creation of absolute graphite. The sheets of activated carbons are maintained by carbon–carbon binds. Activated carbon cleansing is mainly founded on a fact called adsorption, in which particles of a liquid or gas are blocked by one or the other an internal or external break the surface of a solid. The trend is slightly like iron particles remaining carried by a magnet. Activated carbon has a very elevated internal surface area (up to 1500 $m^2/g$) and is therefore considered a perfect substance for adsorption. The fine shape infatuated by activated carbon improved the surface vicinity (>1000 $m^2/g$) like holes which cause in the control properties of strong adsorptive. The fabrication procedure of transforming the raw material into the completed adsorbent one can be split into chemical (Soonmin, 2020) and thermal processes mutually of which involve the use of high temperatures (Ho, 2018). Production of activated carbon including pyrolysis process (Zhu et al, 2009), physical and chemical activation process, carbonization and steam/thermal activation (Bae and Kim, 2014).

Chemical activation method includes two stages taking place concurrently, along with the chemical activating agents combining with the precursor. Performance stimulation and carbonization concurrently throughout the chemical activation procedure at smaller temperature effects around using enhanced permeable constructions of activated carbon, while worry regarding conservational security could require the utilization of chemical mediators for initiation. Furthermore, nearly chemicals that are greatly applied as initiating mediators are potassium hydroxide (KOH), trihydroxidooxidophosphorus, zinc chloride ($ZnCl_2$), potassium carbonate ($K_2CO_3$), and phosphoric acid ($H_3PO_4$). The agricultural wastes that have been degraded using the stated chemicals which consisted of olive seeds, apricot, peanuts, cosopods, cotton seeds, hazelnut, rice husk and cassava seeds (Ioannidou & Zabaniotou 2007). Newly some scientists started to use Baobab, mostly for its high carbon content, low cost, and potential extent of activation.

The benefit of chemical activation is creating activated carbons through elevated surface region. However, the last step in activated carbon production is the washing of carbons by acid or alkali. This step would eliminate the inorganic excess (residue) and reactants remainders that are generated as of the precursor or are created through initiation, which requires the method tiresome, energy and time-exhausting. Zhang et al. (2012) have used $ZnCl_2$ as a chemical agent to produce activated carbon from Camellia oliefera shell (COS). They discovered that $ZnCl_2$/COS impregnation ratio and the activation temperature are affecting the pore composition and surface area. Yorgun and co-workers (2009) generated an activated carbon from paulownia wood (Paulownia tomentose) showed high surface area (2736 $m^2/g$) and micropore (0.69 $cm^3/g$) with $ZnCl_2$ through chemical activation.

Jin et al. (2014) have been prepared activated carbon from thermally from pyrolysis methods with soluble at 950 °C using potassium hydroxide (KOH) indicated high surface area (2959 $m^2/g$) and large pore size (1.65 $cm^3/g$). Jiang et al. (2008) reported large surface area (2408 $m^2/g$) using Chinese petroleum cake, at 1073 K for 1 h and a mass ratio of potassium hydroxide (KOH) at a ratio of 1:3. Wu et al. (2005) highlighted surface area (2500 to 3000 $m^2/g$) using Shengli petroleum cake and Minxi petroleum cake under various activation techniques including $H_2O$, KOH and/or KOH+$H_2O$. Activated carbons produced using $H_3PO_4$ have remarkable exhibits cation-exchange capacities. They are also thermally and chemically stable. Phosphoric acid was used in the production of activated carbon because of higher percentage of yield, higher surface area, narrow micro pore distribution and lower temperature is required if compared to physical activation method (Table 1). The choice of the activating agent (KOH, NaOH, $ZnCl_2$, and $H_3PO_4$) counts on the carbon precursor (Raymundo et al., 2005). For example, $H_3PO_4$ and $ZnCl_2$ have often utilized precursors of lignocellulosic, whereas for cokes or coals KOH is frequently utilized (Alcañiz & Illán 2008). Phosphoric acid is the most common acidic activating agent used (Wong et al., 2018). It is one of the favored processing agents from both economic and environmental perspectives (Uçar et al., 2009). The $H_3PO_4$ is more preferred since $ZnCl_2$ could give unfriendly environmental impact (Yahya et al., 2015).

$ZnCl_2$ acts as a dehydrating agent it allows more carbon to be kept fixed (Lozano et al., 2002) and alters the structure to make it more porous and well developed (El et al., 2008).

The chemical nature of the activated carbon greatly affects the adsorption, electrochemical, redox, acid-base, hydrophilic-hydrophobic, catalytic, and other properties of activated carbon. Functional groups of surfaces may arise from the starting material used to produce activated carbon. Usually, the raw materials used for activated carbon production, are particularly rich in oxygen following incomplete carbonation. However, the oxygen is associated with hydrogen, which forms several of complexes such as hydroxyl, carboxyl, carbonyl, lactone, and phenol (Figure 1a) in most activated carbon (Shahjahan, 2013). Activated carbon pores can be classified to three categories (figure 1b), which are macropore (>50 nm), mesopore (2–50 nm), and micropore (<2 nm) (Daud & Ali, 2004). The macropores are used as arteries to transport the meso and micropores. The micropores represent 95% of the internal surface and the mesopores 5%. Whereas the macropores make very little contribution to the inner surface (McDougall, 1991). The materials with high lignin content will lead to producing AC with high macropores while materials with a high cellulose content will yield activated carbon with high microporous structure. The total specific surface area of AC is resolute by small micropores, and the transition pore (0.02-1 nm) plays an important role in the channel, and the large micropore (radius is 1-100 nm) is the entrance of the microsystem of the adsorption material.

The adsorption process varies on numerous issues (Ho, 2017), involving the description of the adsorbent, and adsorbate, adsorption conditions. Comparatively different studies worldwide have defined performance of activated carbons are link to oxygen, which comprising basic practical surface groups that functional surface is the main reason of improving sorption of phenolic compounds as an example, also elimination of oxygen coming from acidic formation comprising sets from activated carbons was advised to clear out to intensify absorbability of phenol (Przepiórski, 2006).

Activated carbons considered as an exceptional and flexible for their lengthened exterior zone which is known as surface area, the uniqueness of activated carbon also is in their microporous shape, in their high-level of adsorption capability in addition to elevated intensity of surface responsiveness (Ho, 2020). Their important implementations relay on their usage (Soonmin, 2020) in the elimination of odor, color, unpleasant or nasty taste and all other unwanted organic matters found in water and wastewater during their normal daily treatment, whether from domestic, industrial, schools, restaurants, food, and pharmaceutical processing to eliminate all unwanted hazards as odor, color, dyes, organic materials, inorganic materials that arise from different industrial activities (Ho, 2018). Therefore, the application of activated carbon to the said above industrial activities is crucial for the sustainability of water and wastewater to mankind on earth.

Dye is very difficult to degrade due to complex aromatic molecular structure (Simphiwe et al., 2012). Dyes have been used in in construction, printing inks, pharmaceutical industry, personal care, and leather industry. It is expected that the consumption of dye will be grown from year to year. The top and second largest manufacturer and exporter of dyes in the global market are China and India, respectively. Dyes can be categorized into several groups including direct dyes, reactive dyes, vat dyes, disperse dyes, azo dyes. Among these dyes, reactive dye and disperse dye showed the highest market share because of highly demand in textile and leather industry. Table 2 shows the different types of dyes and their properties. The structure, hazards, chemical formula and molecular weight of various dyes were highlighted.

Date palm seed was used to produce activated carbon, using activation agent (phosphoric acid) [Nasiru et al., 2016] via the carbonization process (90 minutes at 400 °C). The moisture content (15.6 %,), ash (2.9%), volatile matter (22.2%), surface area (781 $m^2/g$), bulk density (0.65 g/mL) and iodine number (711.2 mg/g) were studied. Adsorption data of Alizarin yellow supported Langmuir model and pseudo-second kinetic. Mango seed was used to produce activated carbon via carbonization and activation method [Abdus et al., 2014]. The surface area (819.8 $m^2/g$), percentage of yield (62.3%), and carbon content (52.3 %) were highlighted. The adsorption of Alizarin yellow dye increased with increasing the agitation time and temperature. Thermodynamic parameters indicated negative free energy value (spontaneous), positive enthalpy value (endothermic) and increased randomness (positive entropy value). The pine cone based activated carbon was used to remove dye [Uzun and Kaya, 2020]. The highest removal efficiency was 82 % under the best conditions such as pH=3, temperature= 45 °C, activated carbon (surface area = 259.7 $m^2/g$) dosage=8 g/L, and initial dye concentration =20 ppm. The adsorption data confirmed by pseudo-second order kinetic and Langmuir isotherm. The walnut shell and hazelnut shell were used to produce activated carbon under various carbonization temperatures. The volatile matter content, ash content, carbon content in walnut shell (74%, 5%, 45.32%) and hazelnut shell (84.2%, 1.32%, 47.7%) based activated carbon were described. Surface area (walnut shell) increased (6.3 to 256.9 $m^2/g$) with carbonization temperature from 400 to 700 °C. Hazalnut shell based activated carbon showed the surface area increased from 5.5 $m^2/g$ (400 °C) to 124.34 $m^2/g$ (500 °C), then decreased at higher carbonization temperature (600 and 700 °C), indicating collapse of the structure of carbon. Experimental results showed a decrease in adsorption yield from 52% to 40% (hazelnut shell) and 78% to 57% (walnut shell) with increasing the pH from 3 to 10.

Wood was used to produce activated carbon [Salman et al., 2011]. The activated carbon characteristics such as moisture (4.5%), volatile matter (22.13%), ash (10.5%) and fixed carbon (59.7%) were reported. Adsorption (alizarin yellow) data described the Freundlich isotherm, indicating the multilayer adsorption. Thermodynamic parameters highlighted spontaneous (-3.9

to -8.58 kJ/mol), exothermic (-2.09 X $10^{-3}$ to -3.82 X$10^{-4}$ kJ/mol) for acid (HCl) and base (NaOH) treated wood based activated carbon. Arrhenius energies were 5.36 X $10^{-4}$, -2.13 X $10^{-3}$ and -3.83 X $10^{-4}$ kJ/mol for untreated, acid-treated and base-treated activated carbon.

The Golbasi-Adiyaman (Turkey) lignite was employed to synthesis activated carbon via chemical activation process [Tolga et al., 2012]. The characteristics of the adsorbent such as specific surface area (921 $m^2$/g), microporous volume (0.427 $cm^3$/g), mesoporous volume (0.049 $cm^3$/g) and total pore volume (0.467 $cm^3$/g) were reported. The adsorption of crystal violet is endothermic process, followed Langmuir model and pseudo second order kinetic. The influence of dye concentration on the adsorption of crystal violet was studied. When the dye concentration was increased (50 to 200 mg/$dm^3$), the enthalpy (42.84 to 15.76 kJ/mol) and entropy (173.57 to 55.07 J/mol) were reduced. Coal was used to produce activated carbon at 500 °C, 60 minutes in the presence of activating agent (zinc chloride) [Ramazan et al., 2016]. The characteristics of adsorbents including surface area (696 $m^2$/g), micropore volume (0.44 $cm^3$/g) and total volume (0.59 $cm^3$/g) are reported. Adsorption capacity of crystal violet was observed increased at higher temperature, and matched well Langmuir isotherm.

The KOH (activating agent) was used during the preparation of almond shell based activated carbon [Ahsaine et al., 2018]. The highest adsorption of dye could be observed with increasing the amount of adsorbent. The adsorption data obeyed Freundlich isotherm (multilayer adsorption). The synthesis of date palm fiber based activated carbon was reported [Mashael et al., 2013]. The spontaneous adsorption, and exothermic process were highlighted via thermodynamic studies. Adsorption data were best described using Langmuir model. The removal of crystal violet reduced (94% to 89%) with increasing the temperature (25 °C to 55 °C). Experimental results showed the highest adsorption capacity was 0.66 X$10^{-6}$ mol/g in the best conditions such as 0.25g adsorbent at 25 °C.

The commercial activated carbon (Merck) was used to remove dye [Maliheh et al., 2019]. The maximum adsorption of crystal violet was 84.11 mg/g in the best parameters such as pH=10, 25 °C and the adsorbate:adsorbent ratio of 0.1g/g. The male flowers coconut tree has been used to produce activate carbon in the presence of phosphoric acid and sulphuric acid [Senthilkumaar et al., 2006]. Intraparticle diffusion was confirmed by pseudo second order kinetic during the experiment. Adsorption of crystal violet showed endothermic in nature and supported by Langmuir model. The adsorption capacity of dye was observed to be 60.4 mg/g and 85.8 mg/g for phosphoric acid and sulfuric acid treated activated carbon, respectively.

The mangrove stem barks (Rhizophora mucronat) was employed to produce activated carbon [Oloo et al., 2020]. The highest percentage of removal of crystal violet could be observed when the contact time is 60 minutes (99.8% dye removal), initial dye concentration is 400 mg/g, particle size is 70 µm to 300 µm and adsorbent dose is 0.5 g. The Freundlich isotherm and pseudo-second order kinetic model were chosen to describe adsorption data. The rice husk based activated carbon was synthesized in the presence of activating agent [Kaustubha et al., 2006]. Higher adsorption of crystal violet for sulfuric acid treated activated carbon (surface area=64.9 mg/g) than zinc chloride (surface area=61.6 mg/g) and showed intraparticle diffusion process.

The KOH was used to increase surface area during the synthesis of activated carbon [Egbosiuba et al., 2020]. The highest specific surface area (2114 $m^2$/g) could be found in the best conditions such as 600 °C, 45 minutes and 1.5M KOH. The monolayer adsorption occurred as confirmed with Langmuir model. Higher removal of methylene blue for empty fruit bunch ultra-sonicated activated carbon (435 mg/g) if compared to empty fruit bunch based activated carbon (400 mg/g). The phosphoric acid was used during the production of Eucalyptus waste based activated carbon [Han et al., 2020] for well-developed pore structure. The specific surface area (108-1545 mg/g), yield (30-54.3%), total pore volume (0.085-1.88 $cm^3$/g) and adsorption capacity (114.69-977 mg/g) were studied. The removal of methylene blue is observed spontaneous, exothermic process, supported Langmuir model and pseudo-second order kinetics isotherm.

The sulphuric acid was employed during the preparation of Teak wood based activated carbon [Gurumoorthy et al., 2019]. The characteristics of adsorbent were reported (bulk density=0.53 g/cc, moisture content=6%, iodine number=1012 mg/g, ash=2.3%). The chemisorption was confirmed by Langmuir model. Experimental results concluded that adsorption of methylene blue obeyed pseudo-second order kinetic. The pea shell was employed to produce activated carbon via chemical activation (zinc chloride) process [Unal et al., 2013]. The percentage of dye removal is increased with increasing contact time (20 to 220 minutes) and temperature (25 °C to 55 °C). At the temperature of 55 °C, the percentage of removal dye is 99.85 % (100 mg/L), 99.7 % (150 mg/L), 98.32 % (200 mg/L) and 91.89 % (250 mg/L), 84.84 % (300 mg/L) and 76.91 % (350 mg/L) with increasing the dye concentration. The influence of surfactants on the dye adsorption was investigated also. The highest percentage of removal dye is 84.14%, 99.38% and 36% in the absence of surfactant, by using anionic surfactant, by using cationic surfactant, respectively. Equilibrium data supported Langmuir model and pseudo-second-order kinetic model.

The black cumin seed was used to synthesis activated carbon and treated with sulphuric acid [Thabede et al., 2020]. SEM Images showed irregular surface morphology (without sulphuric acid) and rough surface with cavities (treat with sulphuric acid) for the obtained activated carbon. Experimental results showed higher specific surface area and larger pore size for 20% sulphuric acid (21.54 $m^2$/g; 7.13 nm), 10% sulphuric acid treated (20.14 $m^2$/g; 6.81 nm) if compared to without sulphuric acid (11.67 $m^2$/g; 3.78 nm) activated carbon. The adsorption of methylene blue was 11.63, 12.71 and 16.85 mg/g for the activated carbon treated with 0%, 10% and 20% sulfuric acid, respectively. Freundlich model fitted well the

adsorption data indicating the multi-layer adsorption between adsorbent and adsorbate. The Ficus carica bast was used to produce activated carbon (particle size=10 µm) and treated with sulphuric acid [Deepak et al., 2017]. Energy dispersive X-ray analysis revealed the obtained carbon consisted of 65.9% oxygen, 24.9% carbon, 5.1% silicon, 2.09% aluminium, 1.17% nitrogen and 1.31% potassium. FTIR studies indicated the 3433 $cm^{-1}$ peak, attributed to the presence of O-H stretching vibration of alcohol, phenol and carboxylic acid in the carbon (before adsorption process). The effect of contact time on methylene blue removal was studied and showed that 85% dye removal in 1 hour. The adsorption process was multi-step process, endothermic in nature, spontaneous, obeyed Langmuir model and pseudo second kinetic.

The effect of various surfactants onto the adsorption of methylene blue was studied [Yu et al., 2020]. Experimental findings showed the highest adsorption capacity in sodium lauryl sulfate (anionic surfactant), followed by raw activated carbon, sodium dodecyl sulfonate and hexadecyl trimethyl ammonium bromide (repulsive force with dye cations). Adsorption data supported Langmuir model and pseudo second order model. The percentage of removal dye is reduced from 96.6% to 58.7% in activated carbon modified by sodium lauryl sulfate, while dropped from 80.9% to 41.3% in raw activated carbon, as the dye concentration was increased from 10 to 50 mg/L. The enthalpy and entropy values were 5.9 to 14.46 kJ/mol, and 0.059 to 0.067 kJ/mol, respectively in activated carbon modified by sodium lauryl sulfate. Banana peel was employed to produce activated carbon via activation process by using sulphuric acid [Jawad et al., 2018]. Langmuir model and pseudo first order kinetic model best described the adsorption data. The adsorption of methylene blue reached the highest removal of dye (250 mg/g) at 303 K, indicated endothermic process.

The coconut shell (cocos nucifera) was used to produce activated carbon by using sulphuric acid (activating agent). The highest adsorption capacity of methylene blue was 50.6 mg/g at 303 K [Jawad et al., 2020], obeyed Freundlich isotherm and pseudo-second order kinetic model. The watermelon (citrullus lanatus) rinds were used to prepare activated carbon (particle size= 1 to 2 mm) [Ngoh et al., 2018]. The ultimate elemental analysis indicated 51.5% oxygen, 41.5% carbon, 6.12% hydrogen and 0.88% nitrogen. FTIR spectra confirmed that the obtained activated carbon rich in carboxylic acid and hydroxyl group. The adsorption data obeyed Langmuir isotherm (monolayer adsorption capacity =188.68 mg/g) and pseudo-second order kinetic. The spontaneous reaction (free energy= -5.811 kJ/mol to -5.781 kJ/mol), exothermic (enthalpy= -6.267 kJ/mol), and adsorption capacity of methylene blue was 188.68 mg/g at 303 K.

The Citrus limetta was employed to produce activated carbon [Sonika et al., 2019] to remove methylene blue in waste water. The adsorption kinetic supported pseudo-second order kinetic and Langmuir model. The tobacco stalks were used to produce activated carbon via microwave heating, using radiation power of 280 W, 6 minutes, impregnated with 30% zinc chloride [Henry et al., 2017]. The characteristics of carbons such as percentage of yield (49.43%), iodine number (1264.51 mg/g) and point of zero charge (5.81) were reported. Adsorption data described by Langmuir model and pseudo second order kinetic. The adsorption capacity of methylene blue was 123.45 mg/g in the best conditions such as pH=6.5, adsorbent dosage=0.2g/50 mL at 25 °C. The perlite was employed to prepare activated carbon to remove methylene blue. The kinetic studies obeyed pseudo second order based on the results. Activation energy was 10.3 kJ/mol indicating, adsorption process was supported by intra particle diffusion [Bilal, 2005]. The removal of methylene blue onto Ficus carica bast based activated carbon [Pathania e al., 2017]. Experimental results revealed that higher correlation coefficient value in Langmuir model, pseudo second order, and Tempkin isotherm. Enthalpy (21.5 kJ/mol), entropy (76.2 J/mol.K) and free energy (-1.55 kJ/mol) were studied.

Activated carbon was prepared from banana stem waste [Misran et al., 2018] via chemical activation (phosphoric acid). Higher removal efficiency (>99%) was observed at room temperature, 90 minutes, 0.2 g (activated carbon), 100 mL methylene blue solution and constant rate (100 rpm). Corncob was used to produce activated carbon through microwave assisted pyrolysis [Tharaneedhar et al., 2017]. The adsorption capacity was 82.8 mg/g and followed Freundlich isotherm. The thermodynamic studies supported spontaneous and exothermic process. Activated carbon was produced by using tea seed shell through chemical activation [Gao et al., 2013]. Surface area and total pore volume were 1530 $mg^2/g$ ad 0.78 $cm^3/g$, respectively. The Langmuir isotherm (313 to 324 mg/g) and pseudo second order produced the best equilibrium data.

The coconut shell fibers were employed to synthesis activated carbon [Kunwar et al., 2003]. The adsorption data (methyl orange) supported Freundlich model and first order rate. Experiment findings showed adsorption happened via film diffusion and particle diffusion at low concentration and high concentration, respectively. Nitric acid treated activated carbons were used to remove methyl orange [Chengle et al., 2019]. The presence of nitric acid (as carriers) enhanced the surface functional groups (C=O and COOH group). The coffee grounds were used to synthesis activated carbon [Supaporn et al., 2017] at 500 °C in the presence of nitric acid. The highest percentage of removal of dye was 658 mg/g at pH 3, initial concentration= 300 mg/L, 90 minutes. Adsorption thermodynamics showed delta H, delta S and delta G values are -43.3 kJ/mol, -0.114 kJ/Mol.K and -1.51 to -3.104 kJ/mol, respectively. Activated carbons were produced by using scrap of tires showed mesoporous structure (Nunes et al., 2011). The carbons were treated with potassium hydroxide and zinc chloride. The highest efficiency of dye is 98.7% at pH 7, KOH, 700 °C.

Removal of acid blue 40 and acid yellow 17 by using granular activated carbon was investigated [Mahmut and Ayhan, 2002]. The adsorption (acid blue 40) obeyed first order adsorption rate expression (rate constant=$8.41X10^{-2}$ $min^{-1}$), equilibrium saturation

adsorption capacity (212.8 mg dye/g) and the adsorption capacity (57.47 mg dye /g). The results showed that rate constant = 10.04 X $10^{-2}$ $min^{-1}$, equilibrium saturation adsorption capacity =151.5 mg dye/g and the adsorption capacity =133.3 mg dye /g) for acid yellow 17 were discussed. Soya bean waste and Azolla pinnata were employed to synthesis activated carbon [Linda et al., 2016]. The best conditions such as pH (2) and contact time (3 hours) were determined. Adsorption of acid blue 25 confirmed pseudo-second order model. The Langmuir isotherm was employed to study adsorption data and the maximum monolayer capacities were 38.3 and 50.5 mg/g for soya bean based and Azolla pinnata based activated carbon, respectively. Thermodynamic studies indicated that endothermic (Azolla pinnata) and exothermic (soya bean based) for different adsorbents.

The acid brilliant blue was removed by using coir pith based activated carbon [Kavitha and Namasivayam, 2008]. The adsorption capacity was 15.2 mg/g based on Langmuir model. Entropy (185.45 J/mol.K) and enthalpy (48.02 kJ/mol) were reported. Almond shell was used to produce activated carbon [Arash et al., 2014]. Monolayer coverage of acid blue 120 was confirmed by using Langmuir model. Experimental results indicated more than 98% of dye was successfully removed by using 0.4 g activated carbon, in 14 minutes, for 40 mg/L dye concentration at pH 2. Thermodynamic parameters revealed the endothermic process (enthalpy=43.9 kJ/mol) and entropy=168.74 J/mol.K.

Production of activated carbon from wood of Ailanthus altissima (particle size= 150 to 180 µm) by using KOH solution [Bangash and Alam, 2009]. Physical properties of raw activated carbon such as pH (8.9), ash (6.3%), bulk density (210 $kg/m^3$), surface area (74.15 $m^2/g$), pore volume (0.02 $cm^3/g$) and moisture content (1.5%) were investigated. The rate of adsorption (first order) of acid blue 1 (2 $X10^{-5}$ $mol/dm^3$) is very high within 15 seconds at temperature 10 °C and 45 °C. The reduce in the disorder of the adsorption was confirmed by the negative entropy value and activation energy is 0.78 kJ/mol. Acid blue was removed by using powder activated carbon (Merck) [Farman et al., 2020]. Adsorption increases with reducing pH value due to increasing the concentration of hydrogen ions. The adsorption data confirmed the spontaneous (-42.72 to -43.56 kJ/mol), exothermic (-46.66 kJ/mol), Langmuir model and chemisorption process. The adsorption capacity of dye was 151.3 mg/g at 55 °C, by using 10 mg adsorbent and 2.5 ppm (concentration of acid blue).

Apricot stone was used to produce activated carbon (treated with phosphoric acid) [Moussa et al., 2015]. The Fourier-transform infrared spectroscopy (FTIR) studies showed the presence of hydroxyl group (3122 – 3680 $cm^{-1}$), $CH_2$ group (1508 and 2929 $cm^{-1}$), C=C group (1600 – 1665 $cm^{-1}$), C=O group (1732 $cm^{-1}$) in carboxylic acid. The surface area (88 $m^2/g$), percentage of carbon (48.45%), percentage of oxygen (45.08%), average pore diameter (176.3 Å), average pore volume (0.264 mL/g), and ash content (1.68%) were reported. The maximum adsorption of Coomassie blue (acid dye) from aqueous solutions was observed for 300 rpm (stirring speed), 55 minutes (contact time), 7g/L (adsorbent dosage), and particle size (315-800 µm). The adsorption data were correlated with pseudo-second order model and Freundlich model. The adsorption capacity was increased from 10.04 mg/g (22.5 °C) to 98.04 mg/g (50 °C) with increasing the temperature.

The bark of Ficus racemose has been used to produce activated carbon (particle size=75 µm) via carbonization in muffle furnace [Sujitha and Ravindhranath, 2016]. The removal of Coomassie brilliant blue R-250 Dye achieved 100% in pH 2 to 4 if compared to higher pH values (pH 4 to 10). The enthalpy (7.19 kJ/mol), entropy (31.27 kJ/mole) and free energy (-9.167 to -12.124 kJ/mol) values were studied. The multilayer adsorption was highlighted using Freundlich model. The hazelnut bagasse was employed to produce activated carbon via chemical activation (zinc chloride) [Hakan et al., 2008]. The textural properties such as surface area (1489 $m^2/g$), microporous volume (0.454 $cm^3/g$) and total pore volume (0.932 $cm^3/g$) were studied. The correlation coefficient of pseudo second order kinetic ($R^2$=0.988) is higher than pseudo first order ($R^2$=0.972) and intraparticle diffusion model ($R^2$=0.979). Adsorption capacity of acid blue 350 was increased from 357.14, 370.37 to 450.25 mg/g with increasing temperature (25 to 45 °C).

Preparation of activated carbon (particle size=0.2 to 0.3 cm) from car scrap tire via furnace, at 700 °C, 120 minutes, chemical agent (KOH) [Edris et al., 2012]. The characteristics of adsorbents including BET surface area (185 $m^2/g$), total pore volume (0.58 $cm^3/g$), pore size (52.46 nm) were highlighted. The adsorption capacities of acid black 1 increased (2.47 to 13.3 mg/g) with increasing the initial dye concentration (50 to 400 mg/L). Generally, lower adsorption of dye could be observed at higher concentration due to resistance to adsorption mass transfer increases. Kinetic study was conducted and the correlation coefficient (R) values were 0.8046 (pseudo first order), 0.999 (pseudo second order), and 0.8067 (intraparticle diffusion model). The synthesis of activated carbon (particle size=0.5 mm) by using Kenya tea residue, treated with phosphoric acid (ratio of 3:1), carbonized under various temperatures [Behnaz et al., 2017]. These carbons showed amorphous structure and surface area was 832 $m^2/g$. The percentage of absorption rate was studied in raw activated carbon (80.27%), treated with phosphoric acid (68.5%), carbonized at 350 (45.6%), 450 (34.47%) and 500 °C (29.47%). Adsorption data obeyed Freundlich model (R=0.97) due to higher correlation coefficient if compared to Langmuir model (R=0.85). The adsorption of acid orange 7 reached 98.41% in the best conditions such as pH 2, adsorbent dose (10 g/L), contact time (2 hours), dye concentration (50 mg/L).

Synthesis of activated carbon by using rice husk (86.9 mg/g) and sawdust (183.8 mg/g) was used to remove acid yellow 36 from aqueous solution [Malik, 2003]. Experimental results indicated pH 3 is the best condition and rate limiting was controlled by intraparticle diffusion of dye within the particle. Production of activated carbon using Jatropha husk via activation process (zinc

chloride) [Kumaravel et al., 2018]. The highest adsorption capacity of acid blue 83 reached 7.59 and 27.9 mg/g (at 35 C and pH 2) for raw activated carbon and treated with zinc chloride, respectively.

Oil and grease were defined as combination of substances, which do not mix with water (Pintor et al., 2016). Generally, were used in daily activities such as motor oils, fuels, lubricating oils, animal fats and cooking oils (Pardue et al., 2014). Total petroleum hydrocarbon is considered as the main component in oil and grease. Palm kernel shell was used to produce activated carbon (2.36 nm) in order to remove oil and grease in wastewater [Ramli and Ghazi, 2020]. The obtained carbons were carbonized at under KOH (activation agent), showed the well-developed porous structure. The percentage removal was 99.93% (1% oil and grease), 99.89% (5% oil and grease) and 99.87% (10% oil and grease) after 20 hours, 6 hours and 2 hours, respectively. Synthesis of activated carbon by using biochar [Mazlan and Yasin, 2016] via chemical activation (phosphoric acid). Adsorption of oil reached equilibrium in 30 minutes. Experiment results confirmed that the activated carbon treated with phosphoric acid indicated higher potential for oil spills treatment if compared to raw activated carbon. The investigation of oil spill clean-up from activated carbon produced by coconut coir [Ukpong et al., 2020]. The carbons (size particle= 1 to 2 mm) were carbonized at 800 °C in the presence of KOH (impregnation ratio of 1:2). The characterization of activated carbon such as specific surface area (691.8 $m^2/g$), moisture content (1 %), bulk density (0.132 $g/cm^3$), volatile matter content (1 %) and ash content (2%) was reported. Experiment findings showed that the treatment with KOH remove cellulose, lignin and hemicellulose on the surface of activated carbon. Freundlich isotherm and Temkin model showed the highest (8628 mg/g) and the least adsorption capacity (7913 mg/g), respectively. The adsorption kinetic confirms pseudo-second order if compared to other models. The thermodynamic investigations revealed that endothermic in nature (enthalpy = 134.3 kJ/mol), spontaneity (free energy= -18.68 to -23.2 kJ/mol).

Benzoic acid is white crystalline solid form (Hongbo et al., 2020), slightly soluble in water, can cause environmental damage (Table 3). It contained benzene ring core carrying a carboxylic acid substituent (Saikat et al., 2020). Generally, benzoic acid was used as antimicrobial food preservative and inhibitor in order to keep food safe. The commercial activated carbons (16-40 mesh) were treated with chemicals (ammonium hydroxide, ammonium carbonate, urea and melamine) in order to enhance the nitrogen containing functional group [Hangdao et al., 2018]. These carbons showed mesoporous (55.8% to 66.2%) with large surface area (1272 to 1495 $m^2/g$). Experimental results revealed that pseudo-second-order kinetic and Langmuir model fitted well to the adsorption data. The highest adsorption of benzoic acid was found at pH 3.8 if compared to other pH values. The granular activated carbon (30-35 mesh) was used to remove benzoic acid from wastewater [Ghanadi et al., 2007]. The Radke and Prausnitz fitted well adsorption data. The petroleum coke was used to produce activated carbon and treated with KOH at 1023 K (Reham et al., 2011). This carbon showed the highest surface area (766 $m^2/g$), good ash content and high percentage of carbon content (84.8%). Adsorption data confirmed that second order rate. The free energy (6.558 to 6.736 kJ/mol), enthalpy (9.6 kJ/mol) and entropy (19.3 J/mol.K) values were recorded during the adsorption of benzoic acid onto adsorbent. The industrial waste lignin was employed to produce activated carbon [Mankar et al., 2015] by using phosphoric acid (activating agent). The highest removal of benzoic acid (99%) occurred at the best conditions such as 0.7g of activated carbon, pH =3.5, 50 mL of 100 ppm adsorbate and 4 hours. The Langmuir model and Freundlich model fitted well the adsorption data.

Phenol contained phenyl group bonded to hydroxyl group (Izabela et al., 2004), has the molecular formula $C_6H_5OH$ (Table 4). Phenol is very cheap (Abdelwahab et al.2009), could be used as antiseptic, removal of epoxy, polyurethane and chemically resistant coatings. Oil sludge causes internal combustion engine problem (Berdnikov et al., 2019). It is a solid in motor oil caused by the oil solidifying at higher temperature (more than 100 °C). Generally, it consisted of large amounts of cycloalkanes, polycyclic aromatic hydrocarbons and benzene series (York et al., 2021). Currently, several methods including solvent extraction, flotation, pyrolysis, centrifugation, electronal treatment, and ultrasonic treatment have been used to for the treatment of oily sludge. The oily sludge was employed to prepare activated carbon via chemical activation (KOH) [Mojoudi et al., 2019]. The surface area (2263 $m^2/g$), total pore volume (1.37 $cm^3/g$) and micro pore volume (1.004 $cm^3/g$) were reported. The adsorption data supported Freundlich model and pseudo second order. The iodine number increases (248 to 1023) as the activation temperature (600 to 800 °C) and impregnation ratio increased (1:1 to 2:1). The highest removal of phenol (434 mg/g) was observed at 800 °C and impregnation ration of 2:1. The coconut shell was employed to synthesis activated carbon [Sunil et al., 2013]. The percent saturation decreases with increases in particle size and reduces in concentration. During the experiment, the adsorption was conducted in fluidized bed and found that particle size of 0.42 mm needs minimum time (46 minutes) to reach maximum $C/C_o$ value of 1. The coconut based activated carbon (0.4 to 2 mm) [Pratarn and Tongprem, 2009] showed surface area=1154 $m^2/g$, total pore volume=0.49 $cm^3/g$, average pore diameter=1.4 nm and average micro pore diameter=0.6 nm. The adsorption equilibrium was attained after 6 hours and obeyed pseudo second order kinetic. The percentage of removal (phenol) by using almond shell based activated carbon (85.54%) and walnut shell based activated carbon (65.49%) in industrial effluents was reported [Seyed and Mohsen, 2009]. Tobacco residues were employed to synthesis activated carbon (chemical activation agents=KOH and $K_2CO_3$) [Murat et al., 2011]. The highest surface area was observed when the impregnation ratio was 75% for KOH (1474 $m^2/g$) and $K_2CO_3$ (1635 $m^2/g$).

Methoxychlor was employed to protect crops, livestock, pets and ornamentals against cockroaches, fleas, mosquitoes (Vinod and Ali, 2008). It is synthetic organochloride insecticide, was used to replace dichlorodiphenyl trichloroethane (Fuentes et al., 2014). It is harmful to human health due to acute toxicity and endocrine disruption activity. Malathion is organophosphate (Behloul et al., 2013), play an important role as acetylcholinesterase inhibitor. It is employed in public recreation, agriculture, residential landscaping and public health pest control programs (Imran et al., 2002). Generally, malathion is utilized to kill aphids, mosquitoes, white flies, red spider mites and mealy bugs. Table 5 indicated the different types of herbicides and insecticides.

The activated carbons were produced by using waste rubber tire (Gupta et al., 2011). The adsorbent obtained via chemical and thermal treatment showed higher mesopore and macropore content. The maximum removal methoxychlor (112 mg/g), atrazine (104.9 mg/g) and methyl parathion (88.9 mg/g) were observed at pH 2, 60 minutes and the initial concentration of pesticide of 12 mg/L. Langmuir model (adsorption equilibrium), pseudo first order model (kinetic data), exothermic and spontaneous (thermodynamic studies) were confirmed during the experiment. The coconut shell and palm shell were used to produce activated carbon [Ahmad et al., 2014]. The removal of pesticide containing malathion reached 71.4 % (palm shell) and 82.9% (coconut shell) for these carbons. The Adam-Bohart equation fitted data well in fixed bed column test. Activated carbon was synthesized from silkworm feces [Somaia and Sahar, 2017], treated with phosphoric acid (impregnation ratio of 1:1). Scanning electron microscopy images showed that the pores have been fully covered by oxamyl after adsorption process. The $N_2$-adsorption-desorption isotherms confirmed that the surface area (75.2 $m^2/g$) and mean pore diameter (0.2035 $cm^3/g$). The removal efficiency increased (99.18 % to 99.49 %) when the adsorbent dose was increased from 0.1g to 1g. The adsorption system followed the pseudo-second-order kinetic and Freundlich model.

Terbuthylazine contained tert-butyl group, and was selective herbicide. Herbicide was utilized to destroy weeds, woody plants and grasses. Triazines were used to control grass and broadleaf weeds in cereal, horticultural crops and oilseed. It is selective herbicides and grouped nitrogen containing heterocycles. Triazines resist biological and chemical degradation. Several techniques such as photocatalytic decomposition on semiconductor, homogeneous photo catalysis, photo sensitized reaction and photolysis by high energy UV radiation have been used to degrade them into environmentally compatible compounds. The 4-chloro-2-methylphenoxyacetic acid (MCPA) is used to control broad leaf weeds in agriculture (in pasture and cereal crops). It is very powerful phenoxy herbicide (esterified form) and showed brown coloured powder. MCPA is inexpensive, its carboxylic acid group permits the formation of conjugated complexes with metals. MCPA can irritate the skin, eye, nose and throat when breathed in. It also causes nausea, abdominal pain, diarrhea, vomiting, headache, dizziness and convulsions. There are various types of adsorbents such as goethite, biochar, and clay mineral were used to remove MCPA. The 2,4-dichlorophenoxyacetic acid (2,4-D) is one of the oldest herbicide as weed killer (dandelion, clover, crabgrass and other invasive grassy) on cereal crops, orchards and pastures. The toxicity strongly depended on its chemical forms such as esters, salts and acid form. Generally, it can cause eye irritation, cancer in human. Also, slightly toxic to fish and aquatic invertebrates. The 2,4-D herbicide degrades faster in soil. Nanofiltration, electro coagulation process, combined photo Fenton and biological oxidation have been selected to remove 2,4-D herbicide.

Adsorption of benazolin, bentazone, triclopyr and imazapyr [Horner and Streat, 2000] was observed at pH 3 and pH 10. Terbuthylazine is removed from water [Andrea et al., 2019] by using hydrochar-based activated carbon (treated with KOH). Proximate analysis of the carbons such as moisture (5.36%), volatile matter (21.94%), ash (26.03%) and fixed carbon (46.67%) was reported. The adsorption capacity was 422 mg/g at 6 hours. The triazine herbicides were removed [Jan et al., 2020] by using Norit 1240 W and Filtrasorb 400. Experimental results indicated the efficiency of Filtrasorb F400 (18 To 60%) was better than Norit 1240. The 4-chloro-2-methylphenoxyacetic acid (MCPA) and 2,4-dichlorophenoxyacetic acid (2,4-D) were removed from waste water [Blachnio et al., 2010] by using activated carbon (Filtrasorb 300). The increase of adsorption when the temperature was increased (288 K to 318 K) showed the endothermic process. The kinetic data supported that MCPA is faster than 2,4-D. Production of activated carbon using coconut shell under various pH values [Njoku et al., 2014]. Adsorption data supported Brouers –Sotolongo isotherm and followed Avrami model. The adsorption of herbicide reduced with increasing the pH values (pH 3 to pH 9). Synthesis of activated carbon using coffee waste [Zaben and Mekhamer, 2017]. The obtained carbons showed narrow particle size distribution (37.84 nm), crystalline structure and deep pore. Adsorption data obeyed pseudo-second order kinetic and Langmuir model. The granular activated carbon was used [Aksu and Kabasakal, 2004] to remove 2,4-D herbicide. The highest uptake capacity of herbicide (518 mg/g) was observed at pH=2, temperature of 45 °C. Adsorption data supported Freundlich isotherm and Koble-Corrigan model.

Lignin is a class of organic polymers [Suhas and Carrott, 2007] and could be considered as important in the production of cell walls. The major source of lignin is in pulp and paper mill industry (Haq et al., 2020). Several available methods such as chemical oxidation and coagulation were used to remove lignin in waste water. Adsorption of tannin and lignin reached 74% and 86%, respectively after contact time is 60 minutes using commercial activated carbon. Higher removal of pollutants at lower pH value, indicating minimize competition between hydroxide ions and colour anion/zwitter ions for binding sites [Mohan and Karthikeyan, 1997]. Oil palm trunk (Adeline et al., 2020) was employed to synthesis activated carbon via chemical activation process

(phosphoric acid). These carbons showed higher surface area (1657 $m^2/g$), contained micropores and mesopores. Higher removal of tannin at lower pH (pH=2) could be observed and obeyed Langmuir model. Adsorption kinetics revealed that chemisorption occurred at higher pH value (pH=2,4, and 8). The polymeric waste [Cigdem S, Yunus, 2010] was used to synthesis activated under chemical activation (KOH). The surface area about 2390 $m^2/g$. Adsorption of tannic acid indicated endothermic process, and followed pseudo second order reaction. Removal of tannic using commercial activated carbon [Shubhjeet and Jai, 2014]. The best conditions were observed at pH 3, adsorbent dose (15g/L). Adsorption process is endothermic and heat of adsorption was 89.5 kJ/mol.

Heavy metal is defined as metallic elements, which showed high density compared to water (Ezzat et al., 2013). Heavy metals have been reported from industrial, agricultural, domestic effluents and pharmaceutical. These metals are high stability, non-biodegradable and easy accumulate in living beings. There are many researchers concluded that acute or chronic poisonings (Hazrat et al., 2019) may occur (Mahdi et al., 2021). Table 6 shows WHO permissible limits for heavy metals in water.

The Eichhornia crassipes Mart was used to produce activated carbon [Pramod and Lalji, 2017] at various carbonization temperatures [450 to 900 °C]. The adsorption of cadmium ions increased when the agitation time was increased, reached maximum at 280 minutes with 76.56%. The coconut shell [Gaikwad, 2004] was employed to produce activated carbon under chemical activation (barium chloride). The Freundlich model matched adsorption data, indicating surface heterogeneity of the activated carbon. Thermodynamic parameters such as entropy (-24. To -28.5 J), free energy (-355 to -1232 kJ) and enthalpy values (-8910 Kcal/k/mol) were studied. The soybean oil cake was employed to prepare activated carbon under $K_2CO_3$ activation [Erdem et al., 2013]. The removal of lead ions increased when the Pb2+ ions concentration was increased, reached maximum at 500 mg/L (lead ion). The kinetic parameters indicated higher correlation coefficients in pseudo second order kinetic. The Acacia catechu [Lakshmikandhan and Ramadevi, 2019] was used to synthesis activated carbon (treated with sodium bicarbonate solution). Characteristics of carbon such as pH (pH=4.84), moisture (9.14%), ash content (2.15%), bulk density (0.77g/L) and surface area (326 $m^2/g$) were reported. The results revealed that 98% ($Pb^{2+}$) removal in the specific conditions such as dosage (100 mg/100mL) and initial concentration of lead ions (10 mg/L). The equilibrium data matched well Langmuir isotherm and obeyed film diffusion, indicating the rate limiting factor.

Production of activated carbon by using date pits (Phoenix dactylifera L)[Dana et al., 2019]. The presence of oxygen and sulfur functional group enhanced the adsorption of mercury ions as indicated in FTIR spectra. The maximum removal of mercury ions at pH 4, and showed exothermic process. Preparation of activated carbon from Bambusa Vulgaris var striata [Eka et al., 2019] under chemical activation [NaOH]. The highest removal of mercury ions at 50 mg/L of mercury ions concentration, 20 mL/min (flow rate) was 218 mg/g based on the Thomas Model. The synthesis of activated carbon by using coconut shell [Asha et al., 2011]. The adsorption of chromium ions increased with increasing the adsorbent dose from 0.2 to 1.2 mg/100 mL. The influence of pH on adsorption was studied. The results showed chromium solution contained large amount of $CrO_2^{-4}$ *ion and* $Cr_2O_2^{-7}$ when the pH was above pH 8 and lower pH values, respectively. Palm shell [Owlad et al., 2010] was used to produce activated carbon by using impregnation agent (low molecular weight polyethyleneimine). Adsorption of chromium ions obeyed Freundlich model, and reached maximum removal about 228 mg/g.

Production of activated carbon by using orange peel [Ferda, 2012]. Greater percentage removal of nickel ions could be observed at pH 5, and increase in adsorbent dosage. Synthesis of activated carbon using doum palm red coat under chemical activation (phosphoric acid) [Manal and Ola, 2014]. The highest adsorption of nickel ions reached 40.68% at pH 7. Experimental results indicated that lower binding is because of reduced solubility of the metal and its precipitation when the pH more than 7. Removal of nickel ions followed Freundlich isotherm and was monitored by film diffusion. The removal of zinc ions about 55.5% when the carbonization temperature was 700 °C, by using almond husk based activated carbon [Halil et al., 2003]. In this temperature, maximum internal surface area and larger pore structure was well developed. Production of activated carbon from Xanthoceras Sorbifolia Bunge hull [Zhang et al., 2017] under chemical activation (phosphoric acid) showed surface area=688 $m^2/g$, total pore volume=0.37 $cm^3/g$, meso pore volume=0.252 $cm^3/g$ and average pore size=2.2 nm. Removal of zinc ions increased (10 to 40 minutes), until equilibrium stage. Correlation coefficients in pseudo first model ($R^2$=0.6349), pseudo second order ($R^2$=0.941), intra particle diffusion ($R^2$=0.79), Elovich ($R^2$=0.87) and Bangham Model ($R^2$=0.757) were reported.

Two commercial grades (Merck) activated carbon, namely powdered and granulated activated carbon were used to remove arsenic ions [Ansari and Sadegh, 2007]. The uptake of As (III) ions about 78% and 90% in granulated and powdered activated carbon, respectively. The Moringa oleifera has been sued to produce activated carbon [Sumathi and Alagumuthu, 2014] via carbonization process. Experiment results revealed that removal of arsenic ions increased when higher dose of activated carbon, reached maximum at 1.2 g of activated carbon. Thermodynamic parameters such as entropy (20.35 kJ/mol), free energy (-5.56 kJ/mol) and enthalpy (608.4 kJ/mol) were studied. The apricot fruit nucleus was used to produce activated carbon [Fatemeh et al., 2017]. Removal of thallium ions reached equilibrium within 30 minutes.

## III. CONCLUSIONS

Adsorption has been extensively investigated by using activated carbon. The synthesis of activated carbon by using various types of precursors were described via carbonization, chemical, and physical activation process.

The obtained activated carbon showed higher surface area and developed porosity. Experimental results confirmed that the obtained activated carbon could be used for removal pollutant in waste water. Equilibrium data and kinetic data were reported under various models to find out the most suitable way of the adsorption process (based on the coefficient value).

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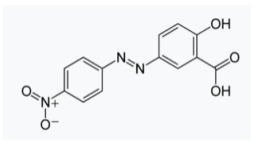
**Table 1. Comparison between Chemical and Physical Activation**

| Parameters | Chemical Activation | Physical Activation |
|---|---|---|
| Activation temperature | Low | High |
| Yield | High | Low |
| Surface area | High | Low |

**Table 2: Different types of dyes and their properties**

| Common name | Structure | Hazards | Chemical formula (molecular weight) |
|---|---|---|---|
| Alizarin Yellow |  | Cause skin irritation, digestive tract irritation. | $C_{13}H_9N_3O_5$ (287.23 g/mol) |

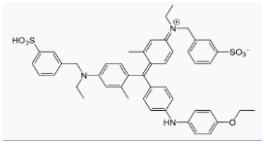
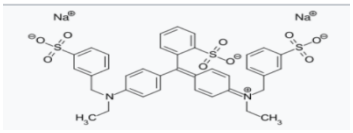
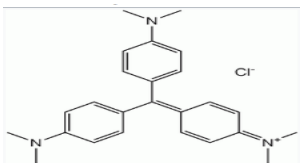
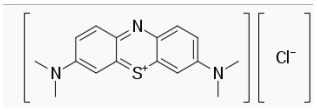
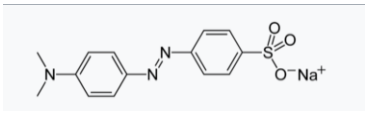
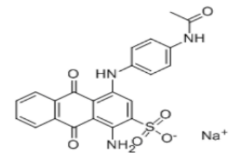
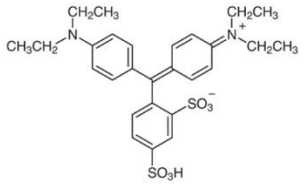
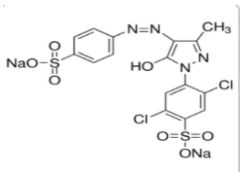
| | | | |
|---|---|---|---|
| Coomassie blue |  | Harmful to aquatic life | $C_{45}H_{44}N_3NaO_7S_2$ (825.97 g/mol) |
| acid brilliant blue |  | irritation of the digestive tract | $C_{47}H_{48}N_3O_7S_2Na$ (854.02) |
| crystal violet |  | mitotic poison, potent carcinogen | $C_{25}H_{30}ClN_3$ (407.99 g·mol$^{-1}$) |
| methylene blue |  | skin irritation | $C_{16}H_{18}ClN_3S$ (319.85 g·mol$^{-1}$) |
| methyl orange |  | gastrointestinal irritation | $C_{14}H_{14}N_3NaO_3S$ (327.33 g/mol) |
| acid blue 40 |  | respiratory irritation | $C_{22}H_{16}N_3NaO_6S$ (473.43 g/mol) |
| acid blue 1 |  | eye irritation | $C_{27}H_{32}N_2O_6S_2$ (544.68 g/mol) |
| acid yellow 17 |  | eye irritation | $C_{16}H_{10}Cl_2N_4Na_2O_7S_2$ (551.3 g/mol) |

**Table 3: Some facts about benzoic acid**

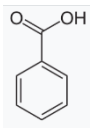
| | |
|---|---|
| Sources | major chemical intermediate for a number of chemical industries |
| Hazards | Irritation to the nose, throat and lungs |
| Removal methods | Emulsion liquid membrane, biodegradation processes, oxidation methods |
| Safe limit range | World Health Organization at 5 mg/kg |
| Chemical formula (molecular weight) | $C_7H_6O_2$ (122.123 g/mol) |
| Structure |  |

**Table 4: Some facts about phenol**

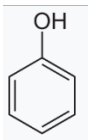
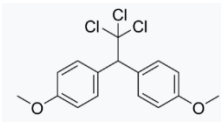
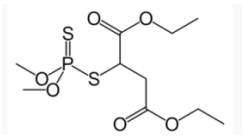
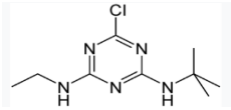
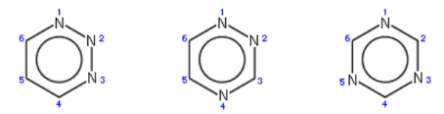
| | |
|---|---|
| Sources | Household items, pharmaceutical, rubber, textile, agrochemical, production plastics, manufacturing resins, pulp and paper |
| Hazards | Long term exposure to skin, affect the central nervous system |
| Removal methods | Adsorption, Nyex™ Rosalox, ozone |
| Safe limit range | 2 mg/L by environmental protection agency |
| Chemical formula (molecular weight) | $C_6H_6O$ (94.113 g/mol) |
| Structure |  |

**Table 5: Molecular structure and properties of herbicides and pesticides**

| Name | Molecular Structure | Chemical formula | Molar Mass |
|---|---|---|---|
| Methoxychlor |  | $C_{16}H_{15}Cl_3O_2$ | 345.65 g/mol |
| Malathion |  | $C_{10}H_{19}O_6PS_2$ | 330.35 g/mol |
| Terbuthylazine |  | $C_9H_{16}ClN_5$ | 229.71 g/mol |
| Triazine |  | $C_3H_3N_3$ | 81.08 g/mol |

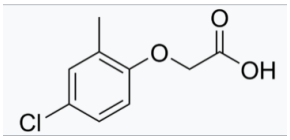
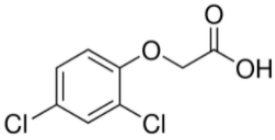
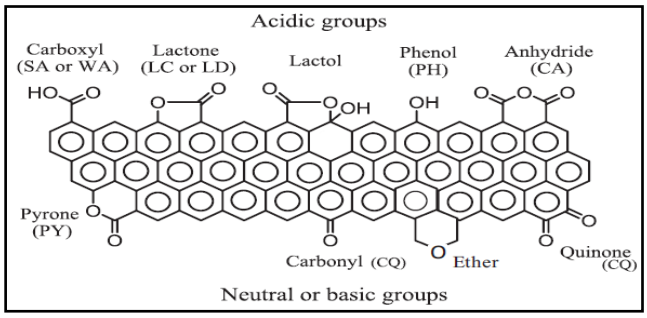
| | | | |
|---|---|---|---|
| 2-methyl-4-chlorophenoxyacetic acid |  | $C_9H_9ClO_3$ | 200.6 g/mol |
| 2,4-Dichlorophenoxyacetic acid |  | $C_8H_6Cl_2O_3$ | 221 g/mol |

**Table 6: WHO Safe limits (ppm) for drinking water and their adverse effects**

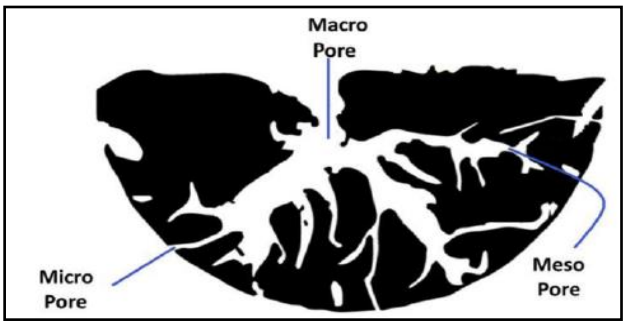
| | WHO Safe limits (ppm) | Effect of lifting |
|---|---|---|
| Lead | 0.05 | Visual disturbance anemia |
| Chromium | 0.05 | Carcinogenic acuity |
| Copper | 0.05 to 1.5 | Liver damage |
| Mercury | 0.001 | Blue baby disease |
| Nickel | 0.02 | DNA damage |
| Zinc | 5 to 15 | Astringent taste |
| iron | 0.1 to 0.3 | Bad taste |
| Manganese | 0.05 to 0.5 | Bad taste |
| Arsenic | 0.05 | Skin damage |

**Figure Captions**

Figure 1. [a] Typical oxygen-containing functional groups on the surface of activated carbon
[b] Scheme of Different Pores Types in a Particle of Activated Carbon.




[a]




[b]

Figure 1. [a] Typical oxygen-containing functional groups on the surface of activated carbon
[b] Scheme of Different Pores Types in a Particle of Activated Carbon.