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ACTIVATED CARBONS AS POTENTIAL ADSORBENTS FOR REMOVAL OF ORGANIC POLLUTANTS FROM WATER/WASTEWATER: A REVIEW

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ABSTRACT

Activated carbon is versatile adsorbent which has extraordinarily large specific surface area, high degree of surface reactivity and tunable chemical and porous structure. Due to its remarkable properties, activated carbon find utility in many applications including environmental remediation, adsorptive removal of color and odor, catalysis, solvent recovery, energy storage, recovery of precious metals and biomedical application. In this paper, the application of activated carbons towards drinking water purification and wastewater treatment will be discussed. Different organic and inorganic chemicals are being discharged into water bodies from untreated urban and rural sanitary and domestic waste, release of toxic industrial and pharmaceutical effluents and runoff from agricultural fields and municipal corporations. This causes the pollution of ground and surface water making it unfit for drinking purpose. The contamination of water due to organic pollutants is serious issue due to their various side effects and carcinogenic nature. This review highlights the importance of activated carbons in removal of organic contaminants from drinking as well as waste water. The focus of this review will be on studies pertaining to removal of specific organic pollutants, the parameters and modification techniques to improve the adsorption efficiency of activated carbons for removal of these pollutants.

Keywords: Activated Carbons, Adsorption, Organic Pollutants, Wastewater Treatment

I. INTRODUCTION

Scarcity of clean drinking water has become worldwide problem due to unplanned development of industries and urban areas, population expansion and uncontrolled use of natural resources. A large number of inorganic and synthetic organic compounds have been identified in surface and ground waters. Organic pollutants include pesticides, herbicides, aliphatic and aromatic hydrocarbons and their halogen derivatives, dyes, surfactants, organosulphur compounds, ethers, amines, nitro compounds, phenols, plasticizers, biphenyls, fertilizers,

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pharmaceuticals and many more. In addition, several halogenated compounds such as trihalomethanes and chlorophenols are produced during chlorination practices from disinfections of drinking water. These organic compounds get decomposed in the water bodies and consume the dissolved oxygen in receiving water at greater rate than it can be replenished, causing oxygen depletion and having severe consequences for the stream biota. Toxic organic pollutants cause several environmental problems and have adverse effects on aquatic ecosystems and human health. The common water borne diseases are Cholera, Typhoid, Hepatitis and Diarrhea gastrointestinal diseases, reproductive problems, cardiovascular diseases, kidney disorders, neurological disorders and even cancer [1]. According to the World Health Organisation (WHO), waterborne diseases are the world's leading killer, claiming over 3.4 million lives each year, including 1.2 million children [1]. It is well known that 70–80% of all illnesses in developing countries are related to water contamination, particularly susceptible for women and children [2]. A brief list of selected organic pollutants along with their permissible limit, potential health hazards and their sources is presented in Table 1.

Table 1: EPA maximum allowed contaminant level (MCL), potential health effects above MCL and sources of some common water pollutants[a]

Name of Pollutant	MCL (mg/l)	Potential health effects above MCL	Sources of contaminant in drinking water
1,1,2-trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industries
tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Polychlorinated biphenyls	0.005	Skin changes, thymus gland problems, immune deficiencies, reproductive/ nervous system difficulties, increased risk of cancer	Runoff from landfills; discharge of waste chemicals
o- dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p- dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1, 2-dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural factories
Benzene	0.005	Anemia, Increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Toluene	1.0	Nervous system, kidney, liver problems	Discharge from petroleum factories
Xylene (total)	10	Nervous system damage	Discharge from petroleum and chemical factories
Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories
Carbon	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants

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tetrachloride			and other industrial activities
TCE	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
Ethylbenzene	0.7	Liver or Kidney problems	Discharge from petroleum refineries

[a]https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants

In view of the utmost importance of water for survival of life and potential health hazards caused by contaminated water, the awareness has grown towards preservation and improvement of quality of water. Therefore, it is essential to remove hazardous organic compounds from wastewater before it is discharged to water bodies.

1.1. Technologies for waste water treatment

As the environmental pollution regulations are becoming more and more stringent, a number of technologies have been developed for removal of organic contaminants from water. Several biological and chemical methods such as membrane filtration, ozonisation, precipitation, coagulation, photo oxidation, ion-exchange, reverse osmosis, electrolysis, fungal degradation, Bacterial remediation and adsorption have been used for the treatment of waste water [3-6]. Each method is associated with their own advantages and disadvantages. Applicability of these methods has been found to be limited due to their relatively high investment and operational cost. Among these processes, Adsorption has been found to be a feasible and an effective method for treatment of polluted water. Adsorption has been considered to be superior to other techniques in terms of universal nature, low initial cost, simplicity of design, ease of operation and pollutant binding capacity. Adsorption can efficiently remove both soluble and insoluble organic contaminants. Moreover, it produces effluents without harmful compounds. Consequently, a considerable amount of work has been carried out for water pollution control using adsorption technology. In literature, several adsorbents such as alumina, microporous clay, zeolites, silica and carbon materials are reported for the adsorptive removal of contaminants from water. Among the all available solid adsorbents, activated carbons are highly effective at removing a variety of organic pollutants from a wide range of contaminated water sources.

1.2. Activated carbons

Activated carbons are processed carbon based materials which contains 85-95% carbon, 6-7% oxygen with traces of other elements (N, S, H). Activated carbons can be prepared from any material which has high carbon content and low inorganics. The commonly used source materials are fruit stones, nutshells, saw dust, peat, wood, lignite, coal and petroleum pitch etc. The manufacture of activated carbon involves mainly two steps: carbonisation and activation. Carbonisation involves pyrolytic decomposition of raw material is done at temperatures below 800 in absence of air. During carbonisation, the non carbon elements oxygen and hydrogen are removed in form of gaseous products. After elimination of non carbon elements during carbonisation, the residual elementary carbon atoms are grouped into stacks of flat aromatic sheets crosslinked in a random manner. This irregular mutual arrangement of these aromatic sheets leaves free interstices which give rise to pore. The carbonized product has low porosity and surface area because of deposition of tar in the pores between the crystallites. The porous structure is mainly developed by activation of carbonized material when tarry product is removed from the pores. Activation can be of 2 types: Physical activation i.e. heating at elevated

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temperatures in presence of steam or carbon dioxide or oxygen and chemical activation i.e. in presence of chemical activating agents such as phosphoric acid, potassium sulphide, potassium thiocyanate, zinc chloride and sulfuric chloride. The structure of pores and their pore size distribution is determined by the nature of source raw material and the history of the preparation [5,6]. According to IUPAC classification pores in activated carbon can classified as follows:

macropores: $d_0 > 50nm$

mesopores: $2 \leq d_0 \leq 50nm$

micropores: $d_0 < 2nm$

ultramicropores: $d_0 < 0.7nm$

supermicropores: $0.7 < d_0 < 2nm$

where d_0 is the pore width for slit type pores or the pore diameter for cylindrical pores.

Besides the porous structure, activated carbons have chemical structure. Active carbons are associated with appreciable amounts of heteroatoms such as oxygen, hydrogen, chlorine, nitrogen and sulfur. These heteroatoms are bonded at the edges of the aromatic sheets and form surface complexes or functional groups. Surface functional groups can be acidic, basic or neutral depending on the nature of the main heteroatom and its position in the carbon matrix. The most common are oxygen functional groups such as carboxylic acids, carbonyls, phenols, and lactones. The adsorption capacity of active carbons is determined by their physical or porous structure but is strongly influenced by the chemical structure. Furthermore, activated carbons are produced in various forms, including powders, cylindrical extrudates, spherical beads, granules and fibers which differs in their particle size and shape [5, 6].

II. ADSORPTIVE REMOVAL OF ORGANICS FROM WATER

A huge amount of literature is available on adsorption studies of the organic compounds from aqueous phase. However, in this review, more attention has been paid to the recent researches on adsorption of benzene and its derivatives, polyaromatic hydrocarbons, phenolic compounds, chlorinated alkanes, ethanes and trihalomethanes and humic acids.

2.1 Removal of phenol and its derivatives

Among the different organic pollutants in wastewater, phenols are considered as priority pollutants since they are harmful to plants, animals and human, even at low concentrations. The major sources of phenolic are steel mills, petroleum refineries, pharmaceuticals, petrochemical, coke oven plants, paints, coal gas, synthetic resins, plywood industries and mine discharge. Phenol and its derivatives are common water pollutants which causes adverse effect on human health such as protein degeneration, tissue erosion and damage of kidney, liver, pancreas and central nervous system [7].

Removal of phenol and its derivatives has been studied by different researchers on activated carbons from different precursors. Mourao et. al [8] and Nabis et al [9] studied the adsorption of phenol and p-nitrophenol on activated carbon obtained from lignocellulosic precursors before and after oxidation of nitric acid. Wu et al. [10] investigated the removal of 2, 4-dichloropenol, 4-chloropenol and p-cresol using KOH and steam-activated carbons obtained from Fir wood. The effective particle diffusivities within carbon particles were also evaluated.

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Alam et al. [11] studied the effect of different synthesis conditions of activated carbon obtained from oil palm empty fruit bunches on phenol removal. These parameters include temperature, activation time and CO_2 flow rate. Activated carbons prepared from different raw materials such as $ZnCl_2$ activated coir pith [12], pecan and castile nutshells [13] , jackfruit peel [14] and oak cup pulps after and H_3PO_4 acid treatment [15], palm seed coat [16], coal, residual coal and residual coal treated with H_3PO_4 [17] , have been used for the adsorption of phenol and its derivatives from wastewater. These activated carbons were found to be quite effective for adsorption of phenol from waste water.

The studies were also carried out to determine modification methods and factors affecting the performance of activated carbons for adsorption of phenolic compounds. Cansado et. al. [18] investigated the capacity of activated carbon (AC) for phenolic compounds removal after modification with sodium hydroxide and urea. Urea impregnation treatment increased the pore volume and mean pore size while sodium hydroxide treatment led to reduction in pore volume and mean pore size. Activated carbons modified with urea exhibited higher removal capacity for phenolic compounds. Przepiorski [19] studied the influence of treatment with gaseous ammonia on adsorption properties toward phenol from water between temperature range 400-800 ^{o} C. Ammonia treated activated carbons demonstrated enhanced uptake of phenol from water. The enhancement was found to be dependent on the treatment temperature and porous structure of activated carbons. Stavropoulos et. al. [20] modified the AC using partial oxygen gasification, nitric acid treatment, urea impregnation followed by pyrolysis in a urea saturated stream. Urea treatment introduced high nitrogen content and basic character while nitric acid and oxygen treatment introduced acidic surface functionality on carbons. Oxidized samples showed low phenol adsorption capacity as compared to urea impregnated indicating that the presence of basic surface functional groups enhances phenol adsorption. This fact was further supported by the studies of Alvarez and coworkers [21] and Salame and Bandosz [22] and Haydar et. al. [23] for adsorption of phenol and its nitro and chloro derivatives on activated carbons after oxidation with ozone [21], ammonium persulfate [22], nitric acid and sodium hypochlorite [23]. These workers were also of view that phenol adsorption decreases with the presence of acidic carbon –oxygen groups. These researchers [21-23] further explained that carboxylic groups on the carbon surface remove the π-electron from the activated carbon aromatic ring matrix, causing a decrease in the strength of interactions between the benzene ring of phenol and the carbon's basal planes, which decreases the uptake of phenol. The results showed that the phenol adsorption is strong dependent on the number of carboxylic groups and dispersive interactions between π electrons of the ring of the aromatics and those of the carbon basal planes are the primary forces responsible for the adsorption. On the other hand, Leng and Pinto [24] and Teng and Hsieh [25-26] observed that higher adsorption was attributed to the larger concentration of associated oxygen on the carbon surface. Hayder et al [23] also found that the presence of CO-evolving groups showed no influence on p-nitrophenol uptakes. On the other hand, Goyal [27] and Bansal et. al. [28] suggested that the presence of non-acidic quinonic groups enhances the adsorption of p-nitro phenol and phenol.

Canizares et. al. [29] measured the adsorption equilibrium of phenol onto activated carbon modified by treatment with hydrochloric acid and found that it influenced significantly surface functionality and thus its adsorption properties. It is seen that the solution pH markedly affected the sorption process. The isotherms obtained at pH 3 and 7 showed a higher adsorption capacity compared with that obtained at pH 13. Nouri et.al. [30] carried out adsorption of p-nitrophenol on activated carbon F100 before and after treatment with H_2,

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H_2SO_4 and Urea. Both maximum adsorption capacity and the adsorption affinity coefficient were dependent on the PZC of the carbons and solution pH due to its combined effects on the carbon surface and on the solute molecules. Mohanty et al [31], Srivastava et al [32] and Hameed et al [33] evaluated the influence of initial pH, contact time, agitation time, adsorbent dose and initial concentration on the removal of phenolic compounds by commercial carbons and carbon prepared from coconut shell and saw dust. Adsorption capacity of 2,4,6- TCP was found to increase with increase in initial concentration and agitation time, while that of 2,4-DCP increases with decrease in the initial concentration and increase in adsorbent dosage. All were of view that acidic pH was more favourable for the adsorption.

Kinetic Studies by Srivastava et al [32], Hameed et. al. [33] M. Sathishkumar [34-35], Tseng and Juang [36-37], Bayram et. al [38], Leyva-Ramos et al [39] have shown that the adsorption of phenol and its derivatives obeys pseudo-second-order rate law and the adsorption process was mainly governed by intraparticle/intrafiber diffusion. Further, the overall adsorption rate was controlled by the external mass transfer and the controlling mechanism in the adsorption rate is a function of the molecular size of the organic compound.

2.2 Removal of Aromatic compounds and Polyaromatic hydrocarbons

Aromatics are the major volatile organic compounds that contaminate the ground water and industrial waste waters.

Zhongqi and Lu [40] studied the influence of surface area and the pore size distribution of the activated carbon on the equilibrium and dynamic adsorption of nitrobenzene from aqueous solution. While Nouri [41] and Nouri and Haghseresht [42] reported that the adsorption of nitrobenzene under controlled pH was affected by the solubility of the adsorbate and the electron density of its aromatic ring.

Utilization of modified AC for removal of dissolved aromatics was the subject of study for several researchers. Ma and Shi [43] and Jain and Bryce [44], Terzyk et al [45-46], Radovic et al [47], Villacanas et. al. [48] investigated the effect of chemical treatment of activated carbon with ozone, concentrated HNO_3, fuming H_2SO_4, gaseous NH_3 and thermal treatment under a flow of H_2 on the adsorption of benzene, aniline and nitrobenzene. The modification procedures lead to changes in carbon surface layer chemistry but do not have much effect on the porosity. These workers observed that while the adsorption of benzene and aniline involved both the dispersive and electrostatic interactions, the adsorption nitrobenzene involved dispersive interactions only. Franz et al [49] also studied the influence of oxygen-containing groups, particularly carboxylic and carbonyl groups, on the adsorption of dissolved aromatics (phenol, aniline, nitrobenzene, and benzoic acid) on ash-free activated carbon. It was observed that water adsorption, hydrogen-bonding and dispersive/repulsive interactions were the main mechanisms by which oxygen surface groups influence the adsorption capacity. Moreover, the adsorption mechanism was also found to be influenced by the properties of the functional group i.e. its ability to hydrogen-bond and its activating/deactivating effect on the aromatic ring. Abe et al [50] observed that the introduction of amino groups lowered the adsorption characteristics of activated carbon towards adsorption of benzoic acid from solution. Daifullah et al [51] compared the removal capacity of activated carbon from different precursors i.e. date pits (DP), cotton stalks (CS), peach stones (PS), almond shells (ALS), and olive stones (OS) towards adsorption of BTEX. The adsorption capacity was found to decrease in the order: PS, ALS, CS, OS and DP, respectively. The decrease in amount adsorbed was correlated to decrease in content of acidic type surface oxygen functionalities and reduction in porosity. On the other hand,

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Basso and Cukierman [52] measured the adsorption isotherms of benzene and toluene on Arundo donax-based activated carbons developed by H_3PO_4 acid activation under four different atmospheres and found that the carbons activated under flowing N_2 were most effective due to their smallest total content of polar/acidic surface oxygen functional groups.

Fochtman and Dobbs [53] tested the efficiency of Darco and Filtrasorb activated carbons for the removal of hydrocarbons such as naphthalene and benzidine from water and observed that appreciable amounts of these compounds were removed. The extent of adsorption was dependent on the nature, molecular weight and the molecular dimensions of the compound. Kumagai et. al. [54] evaluated the sorption capability of rice husk activated carbon (RHAC) to adsorb dibenzothiophenes (DBTs) from commercial kerosene. They found that ultramicropores act as DBTs adsorption sites.

Guoa et al [55] investigated the adsorption of polyaromatic compounds (i.e., phenanthrene, biphenyl and 2-chlorobiphenyl) on activated carbons with similar physicochemical properties but different molecular conformations (i.e., planar and nonplanar). The results revealed that adsorbent pore structure characteristics and molecular conformation and dimensions of adsorbate play important role in the adsorption process. The adsorbate molecules can access and fill the slit-shape pores than ellipsoidal pores more efficiently, whereas the ellipsoidal pores create higher adsorption potential than slit-shape pores. Planar molecules appear to access and pack in slit-shape pores more efficiently as compared to nonplanar molecules. Nonplanar molecular conformation weakens the interactions between adsorbate molecules and carbon surfaces.

Zhang et al [56] studied the influences of solvent (acetone, carbon tetrachloride, tetrahydrofuran, ethanol or distilled water), time and manner (with ultrasonic or not) on the desorption efficiency of phenanthrene on activated carbon. It was observed that the de-sorption efficiency was highest (91.40%) when the ethanol is used as the de-sorption solvent and the system was treated with ultrasonic technology. Okoniewska et al [57] evaluated that ultrasonication had a positive effect on the removal efficiency of sorption of organic compounds (benzoic and phthalic acids). The highest sorption capacities were obtained for activated carbons modified with ultrasonic waves with the amplitude of 100% and the exposure time of 5 min.

Djilani et al [58] tested the adsorption efficiency of activated carbon prepared from agricultural wastes such as coffee grounds (CG), melon seeds (MS) and orange peels (OP) for elimination of two model organic pollutants: o-nitrophenol and p-nitrotoluene. The elimination ratio was in the range from 70% to 90%. The kinetics of adsorption was described using a pseudo-second-order model. It was demonstrated that the adsorption kinetics as well as the maximum uptake of the pollutants were dependent mainly on the chemical properties of the adsorbates.

Ayranci and coworkers [59-60] determined the order of rates and extents of adsorption of the aromatic organic acids (benzoic acid (BA), salicylic acid (SA), *p*-aminobenzoic acid (*p*ABA) and nicotinic acid (NA) phthalic acid) in four solutions (water, solution of pH 7.0, H_2SO_4 and NaOH solution). The adsorption kinetics obeys the first-order rate law. The rates and extents of adsorption of the organic acids were the highest from water or H_2SO_4 solutions and the lowest from NaOH solution. These observed orders were explained in terms of electrostatic, dispersion and hydrogen bonding interactions between the surface and the adsorbate species, taking the point of zero charge (pH_{pzc}) of the carbon surface and the adsorbate in each solution into account.

2.3 Removal of Chlorinated compounds

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Chlorinated compounds especially TCE and chloroform are classified **as** priority pollutants by the United States Environmental Protection Agency. Chloroform and trihalomethanes are byproduct of reaction of humic substances with dissolved chlorine used to disinfect the water [61].

Youssefi and Faust [62] carried out dynamic adsorption studies for adsorption of chloroform, bromoform, bromodichloromethane, dibromochloromethane and carbon tetrachloride on activated carbon from aqueous solutions at a controlled pH = 7. The results indicated that the high potential of activated carbons for the control of THM (trihalomethane) in drinking water. Analytical studies by Yu and Chou [63] and Pavoni [64] also showed that adsorption on activated carbon has potential ability to remove chlorinated pollutants from wastewaters efficiently.

Karanfil and Kilduff [65] compared the uptake of trichloroethylene and trichlorobenzene on coal-based and wood-based granular activated carbon (GAC) after nitric acid oxidation and heat treatment in an inert atmosphere (N_2). It was found that increasing surface acidity reduced adsorption of these molecules due to increase in the polarity of the carbon surface. Li et al [66] systematically evaluated effects of pore structure and surface chemistry on adsorption characteristics of trichloroethene (TCE). Adsorption of TCE takes place primarily in micropores in 7–10 Å width range. It is also seen that hydrophobic adsorbents were more effective than hydrophilic adsorbents in removing TCE from aqueous solution due to enhanced water adsorption on hydrophilic surfaces. This fact was also supported by Ishizaki et al [67]. They observed that the degassed carbon samples adsorbed larger amounts of chloroform compared to the as-received activated carbons due to their hydrophobic surface.

Xiao et al [68] studied the adsorption of chlorobenzene and 1,3-dichlorobenzene on a wood based charcoal activated with CO_2. The amount adsorbed was found to be dependent on the total pore volume of the carbon and the temperature of adsorption. The adsorption was physical in nature. The results of adsorption studies of He et al [69] also suggested that physisorption play important roles for adsorption of TCE onto activated carbon fibers. Erto et al [70] found that the TCE adsorption capacity is enhanced by a high B.E.T. surface area, micropore volume and carbon content. Further, presence of a non-ionic compound of similar structure (PCE) significantly affect the adsorption, however it does not depend on the presence of an organic salt (sodium acetate). These results confirmed that TCE adsorption mechanism is based on dispersion forces.

Erto et al [71] also performed dynamic (fixed-bed column) adsorption of trichloroethylene onto granular activated carbon (GAC). Experimental data on fixed-bed column showed that an increase in TCE initial concentration and flow rate lead to a shorter breakpoint time. In fact, the breakthrough curves become steeper as a consequence of higher velocity that enhances the external mass transport. Miguet et al [72] Zeinali et al [73-74] carried out the equilibrium uptake and column dynamics study for adsorption of Perchloroethylene (PCE) and dichloromethane from the aqueous phase on activated carbon. The variations in adsorption breakthrough curves were investigated with respect to operational parameters such as initial concentration, flow rate, column length, and temperature.

Alhooshani [75] studied the effect of contact time, initial concentration, and the adsorbent dosage on removal of dichloromethane, chloroform, and carbon tetrachloride from aqueous solutions by cerium oxide-activated carbon composite. It was found that at optimum conditions, 82.72%, 99.40% and 89.42% of dichloromethane,

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chloroform, and tetrachloride respectively, were removed by these composites. Kinetic of the adsorption process was well-described by the pseudo second-order model.

Perrad and Descorme [76] carried out the static and dynamic adsorption studies of PolyChloroBiphenyls (PCBs) over activated carbons. The activated carbon texture (specific surface area, porosity) is the key parameter determining the adsorption capacity. Moreover, the hydrophobicity of PCBs is the main driving force for their adsorption over activated carbon. Under static conditions, activated carbons were shown to be highly efficient at long contact time. Surface diffusion limitations control the adsorption of PCBs under dynamic conditions and the operating parameters, especially the activated carbon bed morphology played a major role. Sotelo et al [77] found that the adsorption kinetics of chlorinated organics was dominated by macropore diffusion.

III. CONCLUSIONS AND FUTURE PERSPECTIVES

With this brief perusal of recent literature, it can be concluded that activated carbons are promising materials for treatment of industrial waste water and consequently in reduction of environmental pollution. It is seen that both porosity and surface chemistry of activated carbons play key role in determining their adsorption performance in wastewater treatment. The nature of surface functional groups and size & shape of pores can be varied by the using appropriate precursor and activation method. Due to its tunable porous and chemical structure, its surface can be modified by different treatments to maximize the adsorption efficiency for particular type of pollutant. .Adsorption of organic compounds is physical in nature and involves diverse adsorption mechanisms such as electrostatic interactions, dispersive interactions and in some cases, hydrogen bonding too. Besides the characteristics of adsorbent and adsorbate, the effectiveness of treatment also depends on various parameters: pH, temperature, contact time, concentration. Therefore, special attention should be given to optimize synthesis conditions for improving adsorption properties of activated carbon towards removal of organic pollutants. At the end, it is suggested that the studies should be focused on examining the potential of these materials for multipollutant system and real industrial effluents for commercial application purposes. Further, to decrease treatment costs, attempts should be made to prepare low cost activated carbons (AC) from industrial, domestic and agricultural waste material.

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