2.0 Introduction

During the past three decades, several physical, chemical and biological decolorization methods have been reported few, however have been accepted by the paper and textile industries [1]. Amongst the numerous techniques of dye removal, adsorption is the procedure of choice and gives the best results as it can be used to remove different types of colouring materials [2-4]. Recently, numerous approaches have been studied for the development of cheaper and effective adsorbents. Many non-conventional low-cost adsorbents, including natural materials, biosorbents and waste materials from agriculture industries have been proposed by several authors. These materials could be used as adsorbents for the removal of dyes from solution.

2.1 Commercial adsorbents

A number of materials have been extensively investigated as adsorbents in water pollution control. Some of the important ones include silica gel, activated alumina, zeolites and activated carbon, etc.

2.1.1 Silica gel

Silica gels are classified into three types regular, intermediate and low density gels. Regular density silica gel is prepared in an acid medium and shows high surface area (750 m² g⁻¹). Intermediate and low density silica gels have low surface areas (300 - 500 and 100 - 200 m² g⁻¹, respectively). The gel is considered as a good adsorbent
and is used in many industries [5, 6]. Modified forms of silica have also been widely explored for the removal of different pollutants [7-9].

2.1.2 Activated alumina

The activated alumina comprises a series of non equilibrium forms of partially hydroxylated aluminum oxide (Al₂O₃). In general, as a hydrous alumina precursor is heated, hydroxyl groups are driven off leaving a porous solid structure of activated alumina. It is also used to remove water from organic liquids including gasoline, kerosene, oils, aromatic hydrocarbons and many chlorinated hydrocarbons, having the surface area ranging from 200 to 300 m² g⁻¹. The activated alumina is receiving renewed attention as an adsorbent and a wealth of information has been published on its adsorption characteristics [10-15].

2.1.3 Zeolites

Zeolites are alumino silicates with Si / Al ratios between 1 and infinity. There are 40 natural and over 100 synthetic zeolites. They are also considered as selective adsorbents. Zeolites - based materials are extremely versatile and their main use include detergent manufacture, ion-exchange resins (i.e., water softeners), catalytic application in the petroleum industry, separation process (i.e., molecular sieves) and as an adsorbent for water, carbon di oxide and hydrogen sulfide. Various zeolites have been employed for the removal of pollutants [16-19].
2.1.4 Commercial Activated Carbon

Activated carbon has undoubtedly been the most popular and widely used adsorbent in wastewater treatment throughout the world. Charcoal, the forerunner of modern activated carbon has been recognized as the oldest adsorbent known in wastewater treatment. Commercial Activated Carbon (CAC) is produced by a process consisting of raw material dehydration and carbonization followed by activation. The product obtained is known as activated carbon and generally has a very porous structure with a large surface area ranging from 600 to 2000 m² g⁻¹. Commercial Activated Carbon (CAC) has been found to be a versatile adsorbent, which can remove various types of pollutants such as metal ions, anions, dyes, phenols, detergents, pesticides, humic substances, chlorinated hydrocarbons and many other chemicals and organisms [20]. In spite of abundant uses of activated carbon, its applications are sometime restricted due to its higher cost. Therefore, researchers are looking for low-cost adsorbents for water pollution control, where cost factors plays a major role. As such, for quite sometimes, efforts have been directed towards developing low-cost alternative adsorbents. Low-cost alternative adsorbents can be prepared from a wide variety of raw materials, which are abundant and cheap, having high organic (carbon) content and low inorganic content and these can be easily activated [21].

2.2 Agricultural waste as low-cost adsorbents

Agricultural materials particularly those containing cellulose shows potential sorption capacity for various pollutants. The basic components of the agricultural waste materials include hemicelluloses, lignin, lipids, proteins, simple sugars, hydrocarbons and
starch, containing variety of functional groups. Agricultural waste materials being economic and eco-friendly due to their unique chemical composition, availability in abundance, renewable nature and low-cost are viable option for water and wastewater remediation. Agricultural waste is a rich source for activated carbon production due to its low ash content and reasonable hardness [22], therefore, conversion of agricultural wastes into low-cost adsorbents is a promising alternative to solve environmental problems and also to reduce the preparation costs.

2.2.1 Adsorbents from rice and wheat waste

The adsorption behaviour of rice husks for antimony ions from aqueous solutions has been investigated by Khalid et al. [23]. The sorption was studied as a function of appropriate electrolyte, equilibrium time, hydrogen ions, amount of adsorbent, concentration of adsorbate, effect of diverse ions and temperature. Quantitative adsorption of antimony from aqueous solutions on rice husks was achieved within a short contact time of 10 min. The reaction was found to be endothermic and occurred in presence of a variety of anions, with maximum adsorption in the presence of 0.01M HNO₃. The same authors also studied the removal of Pb(II) and Hg(II) using rice husk as an adsorbent [24, 25].

Rice husk has also been explored for the removal of dyes and phenols from wastewater. McKay et al. [26] examined the potential of rice husk for the removal of two basic dyes viz., safranine and their methylene blue and adsorption capacity was 838 and 312 mg g⁻¹. Kaur and Prasad [27] studied the removal of acidic dyes, viz., acid violet 54, acid violet 17, acid blue 15, acid violet 49 and acid red 119 from aqueous solutions using
rice husk ash. The adsorption capacity was found to vary from 99.4 to 155 mg g\(^{-1}\), suggesting rice husk ash as a good adsorbent for dyes removal.

The possible utilization of rice husk ash as an adsorbent for methylene blue dye from aqueous solutions has been investigated by Chandrasekhar and Pramada [28]. The highest adsorption capacity was found to be approximately 690 mg g\(^{-1}\). Rice husk ash as an absorbent was also tested for Indigo carmine dye removal from aqueous solution by Lakshmi et al. [29]. An adsorption capacity in the range of 29.3 - 65.9 mg g\(^{-1}\) was reported at different temperatures (293 - 323 K). Several other researchers also studied the application of rice husk as an adsorbent for the removal of different pollutants from water [30-34].

Wheat is another important staple food generally used to make flour. Similar to the rice industry, wheat industry also produces some by-products such as wheat bran, wheat husk, etc., which have been examined as adsorbents. Wheat bran has been utilized for the removal of cadmium (II) from wastewater by Singh et al. [35]. The maximum removal of cadmium (II) was reported to be 87.15% with initial Cd(II) concentration of 12.5 mg L\(^{-1}\) at 20 °C and pH 8.6.

Activated wheat husk has also been found efficient as an adsorbent for the adsorption of dye reactofix navy blue 2 GFN from aqueous solution by Gupta et al. [36]. The contact time of 40 min., was found sufficient to achieve equilibrium conditions. Moreover, low pH and low temperature were found suitable for maximum adsorption. The same adsorbent was also used for the removal of reactofix golden yellow 3 RFN dye
from aqueous solution [37] and it was found efficient for dye removal. The adsorption of dyes, viz., reactive blue 19 (RB 19), reactive red 195 (RR 195) and reactive yellow (RY 145) was examined by wheat bran by Fatma et al. [38]. The monolayer coverage capacities of wheat bran for RB 19, RR 195 and RY 145 dyes were found as 117.6, 119.1 and 196.1 mg g$^{-1}$ at 60 °C respectively.

### 2.2.2 Adsorbents from tea waste

Waste tea leaves have been used for the removal of lead, iron, zinc and nickel ions from water by Ahluwalia and Goyal [39]. The order of adsorption of metal ions was: Pb > Fe > Zn > Ni from 5 to 100 mg L$^{-1}$ of metal solution. Adsorption of copper and lead ions onto tea waste from aqueous solutions was studied by Amarasinghe and Williams [40]. The highest metal ion uptake of 48 and 65 mg g$^{-1}$ was observed for Cu and Pb, respectively. Mozumder et al. [41] also investigated the potential of tea-leaves waste for Cr(VI) removal and reported that adsorption of Cr(VI) was highly pH dependent, and the removal efficiency dropped sharply from 95% to 10% when pH of the system increased from 2 to 5. The adsorption ability of turkish tea waste (fibrous) was investigated for the removal of Cu(II) and Cd(II) from single (non-competitive) and binary (competitive) aqueous systems [42].

Spent tea leaves were used for cationic dye (methylene blue) removal by Hameed [43]. The high adsorption capacity (300.05 mg g$^{-1}$) of this adsorbent was reported for methylene blue dye removal at 30 °C. The potentiality of tea waste for the adsorptive removal of methylene blue from aqueous solution was also studied by Uddin et al. [44]. The nature of the adsorbent and methylene blue interactions was examined by the fourier
transform infrared (FT-IR) spectroscopy. Adsorption equilibrium of tea waste was reached within 5h for methylene blue concentrations of 20-50 mg L\(^{-1}\). The sorption was found to follow a pseudo - second order kinetic model. The extent of the dye removal increased with increasing initial dye concentration. The adsorption capacity of methylene blue onto tea waste was found to be 85.16 mg g\(^{-1}\). Besides, several other researchers also investigated the potential of tea waste as adsorbent for the removal of different pollutants from water [45, 46].

### 2.2.3 Adsorbents from coconut waste

Coconut wastes such as coir pith, coconut bunch waste, coconut husk, copra meal, male flowers of coconut tree, etc. have been widely explored as adsorbents for the removal of various pollutants from a water. Coir pith waste was used for the adsorptive removal of Pb(II) from aqueous solution by Kadirvelu and Namasivayam [47]. The adsorption capacity was reported to be 263 mg g\(^{-1}\) for Pb(II) removal which was found to increase with increasing pH from 2 to 4 and remained constant up to pH 10.

Namasivayam et al. [48], investigated coir pith as an adsorbent for the adsorption of rhodamine B and acid violet dyes. The low adsorption capacities, viz., 2.56 and 8.06 mg g\(^{-1}\) of the adsorbent for rhodamine B and acid violet, respectively were reported. Coir pith was also examined for cango red dye removal and an adsorption capacity of 6.72 mg g\(^{-1}\) was reported [49].

The coconut bunch waste (CBW) was used to remove methylene blue from aqueous solution [50]. The monolayer capacity was found to be 70.92 mg g\(^{-1}\) at 30 °C.
The kinetic data obtained at different concentrations fitted very well with the pseudo-second order kinetic model.

Adsorption isotherm and kinetics of methylene blue on activated carbon prepared from coconut husk were determined from batch test [51]. The effects of contact time (1-30 h), initial dye concentration (50-500 mg L\(^{-1}\)) and solution temperature (30 – 50 °C) were investigated. The equilibrium data were best represented by Langmuir isotherm model, showing maximum monolayer adsorption capacity of 434.78 mg g\(^{-1}\). The kinetics was found to follow pseudo-second order kinetic model.

Extracted babassu coconut (\textit{orbignya speciosa}) mesocarp (BCM) was examined as sorbent for the removal of various dyes, blue remazol R106 (BR 160), Rubi S2G (R S2G), red remazol 5R (RR 5), violet remazol 5R (VR 5) and indanthrene olive green 10G (OG 10G) dye solutions [52]. The maximum adsorption was found at pH 1.0 for all dyes. The ability of babassu coconut mesocarp to adsorb dyes was in the order: R S2G > VR 5 > BR 160 > 10 G > RR 5.

Coconut copra meal, a waste product of coconut oil production, was investigated as a sorbent for cadmium removal from aqueous solution [53]. The adsorption capacity of copra meal for cadmium ions was calculated to be 4.99 mg g\(^{-1}\) at 299 K. Adsorption of Crystal Violet, a basic dye, onto phosphoric and sulphuric acid activated carbons (PAAC and SAAC), prepared from male flowers of coconut tree has been investigated [54]. The adsorption capacities of both the carbons were found to be 60.42 and 85.84 mg g\(^{-1}\) for
PAAC and SAAC, respectively. Besides these, several other researchers investigated the potential of coconut waste as adsorbent for the removal of different pollutants [55-58].

Peanut hull was converted into an adsorbent by Namasivayam and Periasamy [59] by treating it with concentrated sulfuric acid, followed by its carbonization in air and further treating with 1 % (w/v) sodium bicarbonate solution overnight. The treated material was used as an adsorbent for the removal of Hg(II) ions from aqueous solutions and the adsorption was found to conform to both Freundlich and Langmuir isotherms. Charmarthy et al. [60], also prepared an adsorbent from peanut shell by thermal treatment in presence of phosphoric acid or citric acid and used it for the adsorption of Cd(II), Cu(II), Ni(II), Pb(II) and Zn(II). Their study showed that phosphoric acid - modified shells adsorbed metal ions in larger amounts compared to citric acid - modified shells.

Groundnut shell was used as an adsorbent by chemical activation with ZnCl₂ under optimized conditions and its comparative characterization was conducted with commercially available powdered activated carbon (CPAC) for its physical, chemical and adsorption properties [61]. Both the carbons were used for the removal of malachite green dye from aqueous solution and the effect of various operating variables, viz. adsorbent dose (0.1 – 1.0 g L⁻¹), contact time (5 - 120 min.), and adsorbate concentrations (100 - 200 mg L⁻¹) were examined for the removal of dye. The experimental results indicate that at a dose 0.5 g L⁻¹ and initial concentration of 100 mg L⁻¹, GSPAC showed 94.5% removal of the dye in 30 min., equilibrium time, while CPAC removed 96% of the dye in 15 min.
Adsorption of neutral red (NR) onto peanut husk in aqueous solutions was investigated at 295K [62]. Experiments were carried out as a function of pH, adsorbent dosage, contact time and initial dye concentration. The adsorption capacity of peanut husk for the removal of NR was found to be 37.5 mg g\(^{-1}\) at 295 K. The adsorption kinetic data followed pseudo - first - order and pseudo - second - order kinetic models. The intra-particle diffusion model was also used to explain the adsorption process at the two-step stage. Besides, several other researchers also investigated the potential of peanut or groundnut waste for the removal of different pollutants from water [63-67].

### 2.2.3 Adsorbents from peels of different agricultural waste

Sivaraj et al. [68], studied the effectiveness of orange peel in adsorbing acid violet 17 dye from aqueous solutions as a function of agitation time, adsorbent dosage, initial dye concentration and pH. The adsorption capacity was 19.88 mg g\(^{-1}\) at initial pH 6.3. Adsorption was found to increase with increasing pH. Furthermore, maximum desorption (60%) of dye was achieved in water medium at pH 10.0.

Orange peel waste was also examined by Namasivayam et al. [69], for the removal of congo red, procion orange and rhodamine B dyes. Acidic pH was found to be favourable for the adsorption of these three dyes. Arami et al. [70], also studied the use of orange peel as low-cost adsorbent for the removal of textile dyes from aqueous solutions. Direct red 23 and direct red 80 were used as model compounds. The adsorption capacity was found to be 10.72 and 21.05 mg g\(^{-1}\) for the two studied dyes at initial pH 2.
Banana peel, a commonly produced fruit waste, was examined as adsorbent for the removal of Cd(II) from environmental and industrial wastewater by Memon et al., [71]. An adsorption capacity of 35.52 mg g\(^{-1}\) was reported for Cd(II). They are also used the same adsorbent for Cr(VI) removal and reported an adsorption capacity of 131.56 mg g\(^{-1}\) in case of Cr(VI) [72]. Banana peel showed high adsorption capacity for phenolic compounds (689 mg g\(^{-1}\)), exhibiting that banana peel could be employed as a promising adsorbent for phenolic compounds adsorption. Low - cost banana and orange peels were used as adsorbents for the adsorption of dyes from aqueous solutions by Annadurai et al., [73]. The adsorption capacities for both peels decreased in the following order: methyl orange > methylene blue > rhodamine B > congo red > methyl violet > amido black 10 B. Based on the adsorption capacity, it was concluded that banana peels were more effective than orange peels for dyes removal.

Thermally treated Water Melon Peels (TWMP) have been utilized for the removal of methyl parathion (MP) pesticide from water by Memon et al. [74]. Maximum adsorption (99 ± 1 %) was achieved for 0.38 – 3.80 × 10\(^{-4}\) mol dm\(^{-3}\) of MP solution, using 0.1 g of adsorbent in 20 ml of solution for 60 min., agitation time at pH 6. Activated carbons prepared from waste cassava peel (an agricultural waste from the food processing industry) employing physical and chemical methods have been investigated for their efficiency in the removal of dyes and metal ions from aqueous solutions [75]. The adsorbent was found to be effective for model pollutants removal from water. The ability of pomela peel to remove Cd(II) from aqueous solution was investigated by Saikaew et al., [76].
The potential of garlic peel to remove methylene blue from aqueous solution was evaluated in a batch process [77]. Experiments were carried out as function of contact time, initial concentration (25 - 200 mg L\(^{-1}\)), pH (4 - 12) and temperature (303, 313 and 323 K). The maximum monolayer adsorption capacities were found to be 82.64, 123.45 and 142.86 mg g\(^{-1}\) of 303, 313 and 323 K, respectively. Besides, various other peels from different sources have been explored as adsorbents for the removal of pollutants [78-86].

2.2.4 Adsorbents from shells of different agricultural waste

Shells of various agricultural products have also been investigated as adsorbents by different researchers for the removal of toxic pollutants from water. Bael fruit shell was used to prepare activated carbon and used as an efficient low-cost adsorbent to remove was found at pH 2.0 in an equilibrium time of 240 min., the Langmuir monolayer sorption capacity was found to be 17.27 mg g\(^{-1}\) [87].

Carbonaceous adsorbents namely activated (AC - PW) and non - activated (C - PW) were prepared from brazilian pine - fruit - shell (*Araucaria angustifolia*) and tested as adsorbents for the removal of procion red MX 3B dye (PR - 3B) from aqueous effluents [88]. The activation process increased the specific surface area, average porous volume, and average porous diameter of the adsorbent AC - PW, when compared with C - PW. The effect of shaking time, adsorbent dosage and pH on adsorption capacity were studied. PR - 3B uptake was favorable at pH 2.0 - 3.0 for C - PW and 2.0 - 7.0 for AC - PW. The contact time required to obtain the equilibrium using C - PW and AC - PW as adsorbents was 6 and 4 hours at 298 K, respectively.
2.2.5 Adsorbents from seed, seed coat, stem and stalk of different agricultural products

Many researchers also examined the stability of seed, seed coat, stem and stalk of various agricultural products as inexpensive adsorbents for the removal of toxic pollutants from water.

The feasibility of papaya seeds (PS) for the methylene blue adsorption has been investigated [89]. Batch adsorption studies were conducted to study the effects of contact time, initial concentration (50 - 360 mg L\(^{-1}\)), pH (3 - 10) and adsorbent dose (0.05 - 1.00 g) on the removal of methylene blue (MB) at 30 °C. The data fitted well with the Langmuir model with a maximum adsorption capacity of 555.55 mg g\(^{-1}\). The pseudo-second-order kinetics fitted well for the adsorption of MB by PS with good correlation.

Tamarind seeds were used as adsorbent after activation for the removal of Cr(VI) from aqueous solution [90]. The tamarind seeds were activated by treating with concentrated sulphuric acid (98% w/w) at 150 °C. The adsorption of Cr(VI) was found to be maximum at low initial pH in the range of 1 - 3. The maximum adsorption capacity of 29.7 mg g\(^{-1}\) was observed at an equilibrium pH ranging from 1.12 to 1.46. The adsorption process followed second-order kinetics. The regenerated activated tamarind seeds showed more than 95% Cr(VI) removal to that obtained using the fresh activated tamarind seeds. Guava and mango seeds have also been used as adsorbents for the removal of dyes and phenols from aqueous solutions [91-93].
The potential of palm seed coat for the adsorption of o-cresol was tested by
Rengaraj et al. [94] and an adsorption capacity of 19.58 mg g\(^{-1}\) was observed with film
diffusion as the rate limiting step during the process. Rubber seed coat was used as
activated carbon for the removal of phenols using batch and column operations [95].

Activated carbon prepared from rubber (Hevea brasiliensis) seed coat was used to
remove the basic blue 3 (BB 3) from aqueous solutions [96]. Batch adsorption studies
were conducted to evaluate the effect of contact time, and initial concentration
(50-500 mg L\(^{-1}\)) on the removal of BB 3. The monolayer adsorption capacity was
observed as 227.27 mg g\(^{-1}\) at 30 °C. The adsorption kinetics was well described by the
pseudo - second - order kinetic model.

Pineapple stem waste, an agricultural waste, was investigated as low-cost
adsorbent to remove methylene blue from aqueous solutions [97]. The monolayer
adsorption capacity of 119.05 mg g\(^{-1}\) was reported in this study. Grape stalks waste,
generated in the wine production process, have been used as an adsorbent for the removal
of copper and nickel ions from aqueous solutions by Villaescusa et al. [98]. Maximum
uptake of \(1.59 \times 10^{-4}\) mol of copper and \(1.81 \times 10^{-4}\) mol of nickel per gram of dry
sorbent was reported.

Sunflower stalks as adsorbents were used for the removal of two basic dyes
(methylene blue and basic red 9) and two direct dyes (congo red and direct blue 71) from
aqueous solutions by Sun and Xu [99]. The maximum adsorption of two basic dyes on
sunflower stalks was found to be 205 and 317 mg g\(^{-1}\) for methylene blue and basic red 9, respectively. They also reported relatively lower adsorption for two direct dyes on sunflower stalks. The removal of metal ions such as copper, cadmium, zinc and chromium ions from aqueous solutions has also been studied using sunflower stalks as adsorbents [100].

2.3 Industrial and municipal wastes as low-cost adsorbents

Widespread industrial activities generate huge amount of solid waste materials as by-products. Some of these materials are being put to use while others find no proper utilization and are dumped elsewhere. The industrial waste material is available almost free of cost and causes major disposal problem. If the solid wastes could be used as low-cost adsorbents, it will provide a two-fold advantage to environment pollution. Firstly, the volume of waste materials could be partly reduced and secondly the low-cost adsorbent if developed can reduce the pollution of wastewaters of a reasonable cost. In view of the low-cost of such adsorbents, it would not be necessary to regenerate the spent materials. Thus, a number of industrial wastes have been investigated with or without treatment as a adsorbents for the removal of pollutants from wastewaters.

2.3.1 Fly ash

The major solid waste by products of thermal power plants based on coal burning is fly ash. The high percentage of silica and alumina in fly ash make it a good candidate for utilization as an inexpensive adsorbent for bulk use. Panday et al. [101], used fly ash without any pretreatment for the removal of Cu\(^{2+}\) and found that the adsorption data confirms to Langmuir model. Sen and Arnab [102] investigated the potential fly ash for
Hg(II) removal and an adsorption capacity of 2.82 mg g$^{-1}$ was reported by them. The removal of lead and copper from aqueous solution by fly ash was investigated under various experimental conditions, e.g., contact time, pH and temperature [103]. The level of uptake to Pb$^{2+}$ and Cu$^{2+}$ by the fly ash generally increased, but not in a progressive number, at higher pH values. The effect of temperature on the uptake of Pb$^{2+}$ and Cu$^{2+}$ revealed that the adsorption was enhanced on lowering the temperature.

The use of fly ash for phenol removal was replaced by Khanna and Malhotra [104]. The kinetics and mechanism of phenol removal were investigated. They also provided useful data for the design of phenol, fly ash adsorption systems. Fly ash was also used by Haribabu et al. [105], for the removal of phenol and chlorophenols and the process was found to be endothermic and followed first-order kinetics.

Fly ash also studied by Viraraghavan and Ramakrishna [106] for the removal of cationic and anionic dyes. The process was found to follow first-order kinetics and the isotherms conformed both Freundlich and Langmuir model. Few other researchers also examined the use of fly ash for dye removal [107, 108].

Chemically modified fly ash was investigated for the removal of fluoride from drinking water by Goswami Das [109]. It was reported by them that the potential of the modified fly ash bed was satisfactory for fluoride removal. The effectiveness of fly ash in removing phosphate from aqueous solution and its related removal mechanism was studied by Lu et al. [110]. Results showed that the removal of phosphate fly ash was rapid and the removal percentage of phosphate in the first 5 min., reached 68 – 96 % of
the maximum removal of fly ash. The removal processes of phosphate by fly ash included fast kinetics and high removal representing precipitation, then a slower and longer removal due to adsorption.

2.3.2 Steel industry waste

The steel industry also produces a number of wastes in large quantities such as blast furnace slag, dust and sludge etc., and these have been investigated as adsorbents. Dimitrova [111] investigated ungranulated blast furnace slag for the removal of Cu$^{2+}$, Ni$^{2+}$ and Zn$^{2+}$ ions from water and reported that slag alkalizing activity creates conditions for adsorption through hydroxo complex formation and colloidal particles of silica acid. Slag columns were utilized by the same research [112] for lead removal and Kanel et al. [113], used blast furnace slag for As(III) remediation. The maximum As(III) adsorption by slag was reported as 1.40 mg As(III)g$^{-1}$ at 1 mg L$^{-1}$ As(III) initial concentration, several other researchers also tested the potential of slag for different metal ions removal [114-116].

Slag has also been used for the removal of dyes [117, 118]. The utilization of treated basic oxygen furnace slag (BOF slag) was successfully carried out to remove three synthetic textile dyes reactive blue 19 (RB 19), reactive black 5 (RB 5) and reactive red 120 (RR 120) from aqueous solutions by Xue et al. [119]. In the batch system, the maximum dye uptaken on acid - treated BOF, slag adsorbent was observed at pH 2.0, and the maximum RB 5, RB 19 and RR 120 uptake capacities (at 500 mg L$^{-1}$ dye concentration) were 76, 60 and 55 mg g$^{-1}$, respectively. Adsorption kinetic process followed first - order kinetic model.
2.3.3 Aluminium industry waste

Red mud was also used for the removal of fluoride from aqueous solution by Cengeloglu et al. [120]. They used both the original and activated red mud forms in batch mode and found that the adsorption capacity of activated form for fluoride was higher than that of original form. They further reported that the maximum fluoride removal occurred at pH 5.5.

Fly ash and red mud have been employed as adsorbents for the removal of methylene blue dye from aqueous solutions by Wang et al. [121]. It was found that fly ash generally showed higher adsorption capacity than red mud. The adsorption capacities are $1.4 \times 10^{-5}$ and $7.8 \times 10^{-6}$ mol g$^{-1}$ for raw fly ash and red mud, respectively. Namasivayam and Arasi [122] investigated the adsorption potential of red mud for congo red dye removal from aqueous solution. The removal capacity of the red mud for the dye was 4.05 mg g$^{-1}$. Wang et al. [123], have discussed the novel applications of red mud as a coagulant, adsorbent and a catalyst for environmentally benign processors in their comprehensive review.

2.3.4 Fertilizer industry waste

Fertilizer industry also produces a number of by-products in large quantities, which create serious disposal problems and degrade the surroundings environment. Fe(III) / Cr(III) hydroxide, a waste material from the fertilizer industry has been used by Namasivayam and Ranganathan [124] for the adsorption of Cr(VI) from aqueous solution. The adsorption data fitted with both Freundlich and Langmuir models.
The waste carbon slurry, another fertilizer industry waste, was tested to remove Cu$^{2+}$, Cr$^{6+}$, Hg$^{2+}$ and Pb$^{2+}$ from aqueous solutions by Srinivastava et al. [125] and it showed excellent adsorption capacities for the studied metal ions. Carbon slurry waste has also been investigated for the removal of dyes, phenols, anions, pesticides, etc. from water [126-129] are found to be promising adsorbent.

2.3.5 Leather industry waste

The feasibility of leather industry solid waste was evaluated as an adsorbent for removal of Cr(VI) and As(V) from aqueous media [130]. The high amounts of Cr(VI) - 133 mg g$^{-1}$ and As(V) - 26 mg g$^{-1}$ adsorbed demonstrated the great potential for using this solid waste from the leather industry as a low - cost alternative to the traditionally used adsorbent materials. Sekaran et al. [131], used buffing dust was found to be 6.24 mg g$^{-1}$ at pH 3.5 and 30 °C for acid brown dye. The removal of methylene blue from aqueous solutions by adsorption on tanned solid wastes was studied by Tahiri et al. [132]. The maximum adsorption capacity was found to be 84 mg of methylene blue for each gram of buffing dust.

2.3.6 Paper industry wastes

Paper mill sludge was also investigated for the removal of orange G dye (an anionic dye) from aqueous solutions. The adsorption capacity of paper mill sludge adsorbent for orange G dye was found to be 62.3 mg g$^{-1}$ at 25 °C.

Shimada et al. [133], used waste newspaper as raw material for the production of activated carbon. The developed adsorbent showed good sorption capacity as evident by iodine (1310 mg g$^{-1}$) and methylene blue numbers (326 mg g$^{-1}$).
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