Chapter – 2
REVIEW OF LITERATURE
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2.1 STATUS OF WATER POLLUTION IN DEVELOPED COUNTRIES

Before the year of 1800, all the rivers in Western Europe were comparatively free from pollution. Circumstances changed very quickly with the passage of time and the problem of water pollution in the acute form as it exists today began in the early nineteenth century, with the coming of the Industrial Revolution and the phenomenal growth of population.

United Kingdom which was the fore-runner of the industrial development was also the first to be subjected to the adverse consequence of pollution hazards. Now this country is facing a serious problem of water pollution particularly in areas like Lancashire, Midland, Yorkshire and London which were thickly populated.

Farr (1852)\textsuperscript{137} held the opinion that river water pollution was largely responsible for the dwindling of the fish industry in the Mercy and Irwell rivers and the outbreaks of water borne diseases in the United Kingdom specially the cholera epidemic of 1846-49. His views were
supported by other workers after the cholera epidemic in 1854, 1866 and 1872. At last, the government decided that something ought to be done to combat the steadily increasing menace due to river pollution and hence two Royal Commissions were appointed to study and report on the problem, one in 1865 and the second in 1868. According to the reports submitted by the Royal Commission, the government of U.K. imposed two acts, the public Health Act of 1875 and the prevention of pollution of River Water Act of 1876.

Similarly, in the rivers of the United States of America, the Industrial Revolution was also taking its toll of the environment, though later then that of the experience in England. Fuller and McClintock, 1926 have reported that the Chicago River was covered with such thick scum, that people were able to walk on it safely.

With the expansion of the chemical and pharmaceutical industries since World War II, the production of toxic compound like pesticides and other byproducts has greatly risen. There has also been a growing use of radio isotopes and many nuclear reactors have been constructed since World War II for power and peace purposes and these activities resulted in the discharge of radio active and other toxic wastes to fresh water courses. This is a public health hazard of growing importance (Camp, 1963).

Between 1950-60 WHO also earned out several investigations covering urgent water pollution problem in various European countries and
put forth legal, technical and administrate measures to overcome this menace. This work has been well documented in WHO, Public Health Paper news on aspect of Water Pollution Control in 1962 and has been further explored by a WHO expert committee in 1965 (WHO, 1966).

2.2 WATER POLLUTION IN DEVELOPING COUNTRIES

The WHO Expert Committee (1968) focused the occurrence of widespread and serious water pollution in developing countries. According to the report, this problem was mainly due to the tremendous growth of towns and industries and a greater increase in irrigation with a corresponding rise in demand of water. Some of these countries like Japan and Bulgaria are provided with piped water supply, both urban and rural while in other situation, piped water supply is only in towns. All the towns having a piped supply do not necessarily have a sewage system. Countries like Japan have implemented compulsory measures regarding sewage treatment, while in others (Rio-de- Janeiro and Sao-Paul city) there are no such restrictions at all. Only a few areas like Guatemala are free from the pollution of surface water but others like Romania and Iraq are grossly polluted by oil.

2.3 STATUS OF WATER POLLUTION IN INDIA:

It is paradox that a river which is a part of cultural heritage of India is being put to ecological assault by the some people who worship it. A vast segment of Indian masses still regard the Ganga water to be "purest
form of liquid" in the world with a capacity to cure a wide range of human ailments. Even some of the highly educated and knowledgeable people believe that the Ganga is unpollutable. This type of blind faith is mainly responsible for greater and more severe ecological abuse of the Ganga ecosystem.

Any undesirable change in the physico-chemical characteristics of water brings about water pollution. There have been alround industrialization and urbanisation activities during last few decades. The waste water generated from industries and cities increased gradually and in most of the cases it is being discharged to river bodies untreated. The regenerating capacity of rivers has been also adversely affected due to flow of waste water in greater quantities from all the cities situated on their banks. Ultimately we are ourselves victim of such indiscriminate disposal of waste water and other pollutant to fresh water bodies.

George et al.\textsuperscript{149} (1966), Verma and Dalela\textsuperscript{150} (1975), Ajmal et al.\textsuperscript{151} (1985) have studied pollution load in Kali Nadi and found that, the pollution load that river receives, is mainly due to the effluents discharged from distilleries, industries, sugar mills and khandsari sugar units apart from domestic sewage. Water quality of sewage drains entering Yamuna at Agra has been studied by Sharma \textit{et al.}\textsuperscript{152} (1981). Someshekhar\textsuperscript{153} (1984) has also analysed physico-chemical characteristics of Cauvery river water in Karnataka. Ajmal and Razi-Ud-Din\textsuperscript{154} (1988) have noticed deterioration in the quality of Hindan River at Jaipur, Maheshpur and Yitawi. River Ganga

2.4 PARAMETERS OF POLLUTION:

The accurate measurement of specific pollutants is essential for solving the problem of water pollutions. Parameters of pollution vary in different water quality situations and change from time to time. The detection and identification of particular pollutants, followed by the application of quantitative methods to determine the extent of pollution, constitutes an important feature of a water body survey.

The WHO expert committee in 1965, while describing the various parameters for assessing the water quality and effluents said that "No single measurement is sufficient because quality can be compared in many ways and each may need to be assessed separately." There are, however, a few fundamental measurements that apply to most kinds of water which are taken into account when devising and implementing only pollution control strategy. These are physical pollutants e.g. colour and odour or chemical pollutants e.g. pH, dissolved oxygen, biologically oxidizable organic matter, salinity etc. or biological pollutants e.g. bacteria or viruses. Other tests which are done under special circumstances are for hardness, nitrates, sulphates, phosphates and concentration of toxic material being discharged into a water body.
The occurrence of toxic metals like Cd, Cr, Ni, Pb, As, Hg and Cu in drinking water supplies has created concern about their health effect on humans because of their non biodegradability and consequence persistence. This is further magnified by the tendency of some metals notably Hg and Cd to become concentrated in chains through bioaccumulation. The environmental risk posed by metals passing into the aquatic system can be divided into hazards pertaining to terrestrial organisms utilizing the aquatic system and also those relating to the components of the aquatic ecosystem itself. The degree or intensity, the geographical extent, and the duration of harmful effects caused by metal concentration can be related to the characteristics of the pollutants source and the intrinsic properties of the receiving environment.

A classification proposed by Wood, 1974 however, divided the gross effects of the potentially hazardous elements of the periodic table into categories of non critical, very toxic and relatively accessible and toxic but very insoluble. The relevant elements in each of these groups are listed in table (2.1)

2.5 SOURCES OF METALS INTO AQUATIC ENVIRONMENT

Chalmers, 1982 has divided the sources of metals that enter the water environment into two main categories:

(i) Those that originate from human activities known as anthropogenic
(ii) Those that originate from natural origin known as non-anthropogenic

Anthropogenic has recently defined as referring to the environmental alterations resulting from the presence of activity of human (Parker\textsuperscript{162}, 1984). Eventually the metals in the water systems from natural sources may be defined as non anthropogenic.

Non-anthropogenic sources include the run off arising from the geo-chemical background concentrations due to sources in the lithosphere. The important sources of metal, organic and dyes pollution involve domestic sewage, industrial water, geological weathering, mining effluents, atmospheric sources and urban storm run-off. Metal containing industrial effluents constitute a major source of metallic pollution of the hydrosphere.

2.5.1 TOTAL ENVIRONMENTAL INPUTS:

Over the last century, there has been a sharp increase in environmental concentration by many heavy metals. It has been staled that between 80,000 and 250,000 tonnes/year of copper reaches the world's environment due to natural weathering process only (Demayo \textit{et al.}, 1982).\textsuperscript{163} This non-anthropogenic source is between 40-67\% of the total copper entering the global environment.
Table (2.1)

Classification of Selected Metals and Associated Ligands.

<table>
<thead>
<tr>
<th>Hard acceptor/Acid</th>
<th>Intermediate</th>
<th>Soft acceptor/Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>K⁺, Na⁺, Be⁺, Mg²⁺, Mn²⁺, Al³⁺, As³⁺, Co³⁺, Cr³⁺</td>
<td>Co²⁺, Cu²⁺, Ni²⁺, Pb²⁺, Zn²⁺</td>
<td>Ag⁺, Au⁺, Cu⁺, Cd²⁺</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hard donor/Base</th>
<th>Intermediate</th>
<th>Soft donor/Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O, OH⁻, F⁻, Cl⁻, O²⁻</td>
<td>Br⁻, NO²⁻, SO³⁻</td>
<td>SH⁻, RS⁻, CN⁻, SCN⁻</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class A Metals</th>
<th>Border line</th>
<th>Class B Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>K⁺, Na⁺, Ba²⁺, Be²⁺, Ca²⁺</td>
<td>Cd²⁺, Co²⁺, Cr²⁺, Cu²⁺, Mn²⁺, Ni²⁺, Pb²⁺, Zn²⁺</td>
<td>Ag⁺, Cu⁺, Hg²⁺, Pb(IV)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Essential Animals</th>
<th>Possibly beneficial</th>
<th>No apparent metabolic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co, Cr, Cu, Fe, Mn, Mo, Ni, Zn</td>
<td>As, Ba</td>
<td>Bi, Cd, Hg, Pb</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plants</th>
<th>Non Critical</th>
<th>Toxic/Accessible</th>
<th>Toxic/Insoluble</th>
</tr>
</thead>
<tbody>
<tr>
<td>B, Cu, Fe, Mn, Mo, Se Zn</td>
<td>Al, Ca, Fe, K, Mg, Na</td>
<td>Ag, As, Be, Bi, Cd, Co, Cu. Ni, Pb, Zn, Sb</td>
<td>Ba</td>
</tr>
</tbody>
</table>

Wealliering phenomena also accounts for a significant proportion of lead released to the global environment to the tune of 21,000 - 180,000 tonnes/year (Demayo, et al, 1982)\textsuperscript{163}. However, it must be emphasized here that anthropogenic emissions to the atmosphere from antiknock agents present in internal combustion engine fuel can contribute 3,33,000 tonnes/year.

2.5.2 OCCURRENCE IN THE LITHOSPHERE:

The abundance of any element within earth's crust or lithosphere is related to its use by human and is usually quoted on a percentage by weight basis. Oxygen is the most abundant element in lithosphere. Thus the order of abundances of heavy metals in the lithosphere (Taylor, 1964)\textsuperscript{164} is reported as:

\text{Al > Fe > Mn > V > Cr > Ni > Zn > Cu > Co > Pb > Be > Sn > Mo > Tl > Sb > Cd > Bi > Hg > Ag > Se > Te.}

The pollutants present in domestic waste water will be derived from all discharges from residential areas and includes service industries such as automobile repair shops and restaurants. Zinc is the most abundant metal present in human faeces and occurs at concentrations of approximately 250 mg/kg dry solids (Spector, 1956)\textsuperscript{165}.

It is a fact that mundane daily domestic tasks such as taking a bath, brushing teeth and washing hair contribute a significant proportion of
metals and organic pollutants discharged to sewers in residential areas (Atkins and Hawley, 1978)\textsuperscript{166}.

The catastrophic episodes of metal poisonings have been reported by Goldwater\textsuperscript{167} 1971; Bakir \textit{et al.}\textsuperscript{168} 1973; Kobayashi\textsuperscript{169} 1971; Derban\textsuperscript{170} 1974; Train\textsuperscript{171} 1979 and Fujuki\textsuperscript{172} 1972.

Kopp and Kroner\textsuperscript{173} (1967) studied the naturally occurring metal content in rivers of the United States. Similarly, concentrations of heavy metals in rivers of other western European countries and USA were reported by Smith, Nicholson and Moore\textsuperscript{174} 1971; Preston\textsuperscript{175} 1973; Mart \textit{et al.}\textsuperscript{176} 1985; Dissanayake \textit{et al.}\textsuperscript{177} 1983; Kubota \textit{et al.}\textsuperscript{178} 1974; Walker \textit{et al.}\textsuperscript{179} 1973; Nriagu \textit{et al.}\textsuperscript{180} 1982. Similarly, other studies on concentrations of toxic metals in rivers of developing countries like Pakistan, Uganda, Sudan, Egypt, Nigeria, and Israel were reported by Tariq and Ahmed\textsuperscript{181} (1985); Bugenyi\textsuperscript{182} (1982); Hassan \textit{et al.}\textsuperscript{183} (1984); Saad \textit{et al.}\textsuperscript{184} (1981); Ajayi and Osibanjo\textsuperscript{185} (1981); Kronfeld and Navrot\textsuperscript{186} (1975); Fujiwara\textsuperscript{187} (1985); Matsunga \textit{et al.}\textsuperscript{188} (1975).

Various aspects of physico-chemical characteristics of river water were discussed by Alexander \textit{et al.}\textsuperscript{189} (1935); Abdin,\textsuperscript{190} 1948; Oliff,\textsuperscript{191-193} 1960, 63; Shane \textit{et al.},\textsuperscript{194} 1971; Jones & Fredlee,\textsuperscript{195} 1982 and Brooker,\textsuperscript{196} 1984. Effects of different pollutants: on river water have been studied by Curtis\textsuperscript{197} (1970); Becker,\textsuperscript{198} 1973; McCrow,\textsuperscript{199} 1974 and Martin \textit{et al.}\textsuperscript{200} 1982.
River water in India have also been analysed for physico-chemical characteristics by several workers. River Godavari and Bhadra river of Mysore state were analysed by Ganpati & Chacko\textsuperscript{201} (1951). Gomati river at Lucknow (Bhaskaran \textit{et al.} 1963)\textsuperscript{202}, river Yamuna at Delhi (Mathur,\textsuperscript{203} 1965; Ajmal \textit{et al.} 1985; Chaturvedi,\textsuperscript{204} 1985); Kali Nadi (Ajmal & Khan, 1985; Kudesia \textit{et al.}\textsuperscript{205} 1985). The Periyar river (Paul \textit{et al.},\textsuperscript{206} 1976); Godavari river (Mitra,\textsuperscript{207} 1982), Damodar river (De,\textsuperscript{208} 1985); Ganga river (Bilgrami & Datta Munshi,\textsuperscript{209} 1985; Sikandar, 1986; Tiwari,\textsuperscript{210} 1983; Agarwal \textit{et al.},\textsuperscript{211} 1976) The Ami river at Gorakhpur by Srivastava and Singh (1995)\textsuperscript{212}.

A number of investigators abroad have analysed and discussed various aspects of bacteriological characteristics of river water. Such some workers are as Drabkova,\textsuperscript{213} 1965; Geldreich,\textsuperscript{214-216} 1970, 1972, 1974, Sundarlin \textit{et al.},\textsuperscript{217} 1974; Langowska,\textsuperscript{218} 1982. Indicator bacteria were discussed by Smith \textit{et al.},\textsuperscript{219} 1971; Carney \textit{et al.},\textsuperscript{220} 1975; Ca belli \textit{et al.},\textsuperscript{221} 1979 and Kalina,\textsuperscript{222} 1980. Various aspects of bacterial pollution have also been reported by Wheatland \textit{et al.},\textsuperscript{223} 1959; Desmet,\textsuperscript{224} 1972; Stuart \textit{et al.},\textsuperscript{225} 1984; Volterra & Laura \textit{et al.},\textsuperscript{226} 1985. Various aspects of coliform, faecal coliform and faecal streptococci were reported by Jones,\textsuperscript{227} 1971. Edward \textit{et al.},\textsuperscript{228} 1972; Bell \textit{et al.},\textsuperscript{229} 1978; Mancini,\textsuperscript{230} 1978 and Fleischer \textit{et al.},\textsuperscript{231} 1980.

Several workers, such as, Mathur,\textsuperscript{232} 1966; Agrawal \textit{et al.}, 1976; Ramaraao \textit{et al.},\textsuperscript{233} 1978; Singh,\textsuperscript{234} 1986; Bilgrami \textit{et al.}, 1985, have reported
various aspects of bacteriological characteristics of river water in India. At Varanasi, the Ganga river water qualities with special reference to bacteriological pollution were investigated by Tripaihi (1982)\textsuperscript{235} and Dwivedi (1991)\textsuperscript{236}.

Different methods \textit{viz.} precipitation, coagulation, ion exchange, sedimentation, floatation, etc have been used for the purification treatment of water and wastewater. However, the adsorption process was found to be better in virtue of less investment, simple design and easy operation, no effect by toxic substances and superior removal of organic waste constitutes as compared to the conventional Biological Treatment Processes. The use of activated carbon as an adsorbent in the treatment of wastewaters rich in certain dyes is still popular, but its manufacturing and regeneration costs are, high.

The adsorption of Disperse Blue 7 on activated carbon was carried out by McKay and Sweeney\textsuperscript{237}. The initial rate of its removal was found to be dependent on surface mass transfer coefficient. McKay\textsuperscript{238} used activated carbon for the removal of Victoria Blue under the effects of contact time, agitation rate, initial dye concentration and carbon particle size. McKay\textsuperscript{239-240} carried out batch and column studies on the adsorption of several dyes \textit{i.e.}, Telon Blue, Chlorantine Fast Orange, Victoria Blue, Cibaset Turquoise Blue and Deorlene Yellow on activated carbon from their aqueous solutions. As a result of exhaustive studies on the removal of Telon Blue, Deorlene Yellow by activated carbon McKay developed a two -
resistance model based on film diffusion and homogeneous solid phase diffusion. Kulkarni et al. used the activated carbon for the removal of Astrazone Blue and suggested a complex formation mechanism at the solid solution interface for metals, organic pollutants, odour control and dyes. Activated carbon was satisfactorily used for the removal of Omega Chrome Red ME from its aqueous solution by Gupta and coworkers.

It was observed that the uptake was highly dependent on retention time, initial dye concentration and pH of the medium. Apart from this, the activated carbon has also been successfully used as an adsorbent in the treatment of wastewater containing cadmium, mercury, cobalt, chromium, other metals, organic pollutants, odour control and dyes.

Besides activated carbon a large number of cheap and unconventional adsorbents were also employed in the removal of various types of dyes. Poots and co-workers have reported peat and wood as potential adsorbents for the removal of acid dye (Telon Blue). They found that for the removal of basic dye (Astrazone Blue) spruce wood was an excellent adsorbent. As a result of the mass transfer studies at different agitation rates, initial dye concentrations, temperatures and adsorbent particle sizes, McKay et al. have proposed a three step model for the adsorption of Astrazone Blue on silica. Banergee carried out the adsorption and desorption studies of Crystal Violet and Malachite Green on and from synthetic zeolite 3A and AW 500 and found that crystal violet was...
more extensively adsorbed than Malachite Green. The sorption studies of
Orange II and Naphthol Blue Black on HCl treated alumina were made by
Mundhara and co-workers\textsuperscript{77}. The adsorption was found to be pH dependent
and associated with low values of heat of adsorption. Ramteke and co-
workers\textsuperscript{258} removed Malachite Green more than 90% from wastewater by
using pyrolytic char as an adsorbent. Manjunath and Mehrotra\textsuperscript{259} observed
90\% removal of Procion Brill Red H -7B by alum. Charred plant material
was used by Perineau \textit{et al.}\textsuperscript{260} for the removal of Acid Blue-80 (AB-80) and
Basic Red-22 (BR-22) from wastewater. L-shaped adsorption isotherm was
found to fit in these studies showing monolayer adsorption of dye
molecules. The treatment of highly coloured waters by a magnetic gel was
done by Anderson and co-workers\textsuperscript{261}. Singh \textit{et al.}\textsuperscript{88} reported that up to 95\%
of Congo Red can be removed from wastewater by Wollastonite at pH 3.0.
The studies showed that the adsorbent can be regenerated and the dye can be
recovered. McKay \textit{et al.}\textsuperscript{262,263} showed that fuller's earth is more effective
than fired clay for the removal of Astrazine Blue and Telon Blue under
various parameters like agitation rate, adsorbent mass, initial dye
concentration and temperature. The kinetics of adsorption study showed
that the rate of adsorption was totally controlled by boundary layer film
diffusion. A kinetic model was developed to explain the external mass
transfer. Royer and others\textsuperscript{264} carried out batch and continuous studies for the
removal of bleached Kraft effluents by a white-rot fungus. In batch
experiments, it was found that the mean colour removal was 300 colour
units (CU) g\textsuperscript{-1} mycelium h\textsuperscript{-1} from original liquor containing 700CU. The
vegetable part of carbonized wool waste was employed as an adsorbent in the removal of a basic dye, Maxilon Red from aqueous solutions by Mulmary and co-workers\textsuperscript{265} where a maximum (~ 98\%) dye removal was possible in continuous mode of operation.

A comparative study for colour removal from pulp and bleach plant effluent using fly ash, lime and high molecular weight amine (Kemamine T, 1902 D) as adsorbent was carried out by Gupta and Bhattacharya\textsuperscript{73}. Although the colour removal by Kemamine T was very high, it was costlier than the treatment with fly ash, which gave a 94\% removal. Beyond 90\% colour removal the process needs a large amount of lime, which puts a barrier in its use, since large scale equipment would be costly. Pandit and Mayadeo\textsuperscript{266} showed that metal oxide could be used to decolourize dye wastewaters, containing moderate concentrations. Mckay \textit{et al.}\textsuperscript{267} found that the bentonite clay was better than several low cost materials \textit{e.g.}, teak wood, bark, rice husk, coal, hair and cotton waste for the removal of Sandolan Rhodine, Sandolan Blue, Safranine, Methylene Blue, Congo Red, Solar Blue, Foron Brill Red and Foron Blue. In comparison to other dyes, basic dyes, \textit{i.e.}, Safranine and Methylene Blue were adsorbed to a greater extent on above adsorbents. Karthikeyn\textsuperscript{268} used the red soil (R.S.), fly ash (F.A.), ground nut shell powder (G.N.S.P.), bauxite (B.T.) for the treatment of water containing a basic dye (safranine) and a direct dye (Congo Red) separately. The efficiencies of the adsorbents used were found in the order of BT > RS > FA > GNSP > and RS > BT > GNSP > FA for Congo Red and Safranine respectively. Panswad and Wongchaisuwan\textsuperscript{269}
reported that for the removal of a reactive dye, hydrated magnesium carbonate was superior to quick lime and alum. This may be probably due to synthetic adsorbing capacity of flocculates, Mg(OH)$_2$ and CaCO$_3$. Fly ash and ash obtained by the incineration of used tea dust or leaves were employed by Balasubramanian and Murlishankar$^{270}$ as decolourising agents for dye effluents mainly containing a reactive dye (red dye). They reported that fly ash is better adsorbent in comparison to activated carbon in that case. McKay and co-workers$^{271}$ used fuller's earth and fired clay for the treatment of Astrozone Blue and Telon Blue. The rate parameter, K, characteristic of the rate of intraparticle transport was correlated with a number of system variables namely initial dye concentration, adsorbent mass and particle size. Khare and co-workers$^{272}$ employed fly ash for the removal of Victoria Blue at different pH and initial concentrations. They observed that with diffusion controlled nature, the process followed first order rate expression. Maximum removal (96%) was noted at pH 8.0 and low desorption of the dye from adsorbent surface indicated the possibility of chemisorption. Various chrome dyes such as Met Omega Chrome Orange GL, Omega Chrome Red ME and Omega Chrome Fast Blue B were removed from their aqueous solutions by Gupta et al.$^{72,85,273,274}$ using china clay, fly ash, coal and wollastonite as an adsorbent. More effective results were obtained on using coal and fly ash in comparison to china clay and wollastonite.

Allen and co-workers$^{275}$ have reported the adsorption of basic dyes on peat from single and multi component systems. They have applied
Freundlich, Langmuir and Redlich-Peterson isotherm equations. The adsorption of Basic Yellow 21 from aqueous solutions on peat has been examined by Allen et al.\textsuperscript{276}. The process was found diffusion controlled and the diffusion rate parameter, $K$ was correlated with possible system variables. Prasad and Rajamme have reported the treatment of weaving factory effluent using cheap adsorbents.

McKay and co-workers\textsuperscript{277} carried out the adsorption kinetic study of four dyes, \textit{viz.} Basic Blue-69, Basic Red-22, Acid Blue-25 and Acid Red-114 using bagasse pith as an adsorbent. They have considered the effect of agitation, initial dye concentration, temperature, pith mass and pith particle size. A model was developed determine the external mass transfer coefficient and its correlation with the above variables. Gupta and co-workers\textsuperscript{278} carried out the removal of a chrome dye Met Omega Chrome Orange-GL from water by fly ash. A 98.45\% removal was achieved in 110 minutes of equilibrium at 10 mg \textsuperscript{-1} concentration, 30°C temperature and 3.0 pH. Correlations between intraparticle diffusion, rate constant and studied parameters were developed.

Gupta \textit{et al.}\textsuperscript{279} investigated the removal of Omega Chrome Red ME from aqueous solutions by adsorption on a homogeneous mixture of fly ash and coal in different proportions under varying conditions of adsorbate concentration, particle size of adsorbent, temperature and medium used. Gupta and co-workers\textsuperscript{280} found that wollastonite, a mineral found in plenty in India can be used as a potential substitute for activated carbon to treat
textile effluents rich in Omega Chrome Red ME. Geundi\textsuperscript{281} studied the adsorption of Astrazone Blue, Maxilon Red, Telon Blue and Erionyl Red on to maize cob. High adsorptive capacities were observed in case of Astrazone Blue and Maxilon Red. He found that the rate of agitation in the maize cob mass increases the rate of dye adsorption. Langmuir isotherm was found to fit the adsorption data. A generalized empirical model was proposed for the kinetics at different initial concentrations. Red mud was used as an adsorbent for treating dyeing industry waste water rich in reactive dyes\textsuperscript{282}. Effect of red mud does and the presence of lime was also studied. Certain low cost materials like fly ash, coal, wollastonite and china clay were applied in the treatment of hazardous dye house wastewaters rich in Omega Chrome Fast Blue. The uptake of dye follows the order: fly ash > coal > wollastonite > china clay-B\textsuperscript{283}.

Li and Zhao\textsuperscript{284} reported the treatment of printing and dyeing wastewater rich in medium, disperse and cationic dyes by dust and ash. They have observed that both the dust and ash are effective to treat the above effluents. Ahmed and Ram\textsuperscript{285} performed the kinetics of removal of Basic Blue-3 from textile effluent using silica as an adsorbent. The adsorption was found to follow a first order kinetics. Parameters investigated were concentration, temperature and pH of dye solution and presence of electrolytes and surfactants.

Treatment of effluents of carpet and metallic industries rich in certain chrome dyes and heavy metals has been carried out by Singh and co-
workers using wollastonite as an adsorbent. The dynamics of adsorbates transport from bulk to solid phase has been studied in light of their adsorption on the outer surface as well as diffusion within the pores of wollastonite. The adsorption data fit to the Langmuir's isotherm model. Recently, Gupta et al. have assessed the ability of china clay to remove a popular chrome dye, Omega Chrome Red ME for aqueous solution. A maximum removal of 81.08% was noted at 10ms l initial dye concentration, 2.0 pH and 303 K temperature. The process was found to be of first order. Intraparticle diffusion and mass transfer coefficient have been determined at different temperatures to explain the results. Heat of adsorption has been found to decrease with the increase of surface loading.

Mall and coworkers employed boiler bottom ash for the removal of basic dyes (methylene blue and malachite green) at different pH and initial concentrations. Sakaran et al. found that buffing dust generated from leather industry can be considered as a source for obtaining activated carbon for removal of dye from wastewater. The adsorption capacity of buffing dust based activated carbon was 6.24 mgg⁻¹ at pH 3.5, temp 30° for the dye concentration of 125 mg l⁻¹ and carbonization temperature of 900° C.

According to Nag, acid hydrolysed charred sawdust was found to be an effective adsorbent of dyes (Menthyl Orange, menthyl red and menthyl violet), toxic salts and oil from water. The absorbency of dyes on to sawdust and also on to charred waste from oxalic acid plant has been
compared. The possibility of using sawdust as an adsorbent in decolouring waste water in a fixed-bed as well as batchwise was studied\textsuperscript{292}. The results showed that the best operating conditions were obtained at an intermediate feed velocity of 0.12 cm sec\textsuperscript{-1}, a particle diameter of 0.018 cm and a bed height of 10 cm. Deo and Ali\textsuperscript{293} used common low cost material, paddy straw as an adsorbent in the removal of methylene blue from aqueous solutions. The paddy straw was found to be an efficient binder of the dye from its dilute aqueous solutions and was capable of removing 95\% of the dye. The potential of the chrome sludge, a waste product from the electroplating industries, to remove colour from aqueous solutions, had better affinity for acidic than basic dyes. Equilibrium data can be fitted onto the Langmuir isotherm with maximum sorption of 30-60 mg g\textsuperscript{-1} for the range of acid dyes studied. Nassar \textit{et al.}\textsuperscript{294} have used palm fruit bunches as adsorbent for the removal of basic dyes (basic red 18) over range of initial dye concentrations with adsorbent particle sizes varying in the range of 106-300 μm.

Bousher and co-workers\textsuperscript{295} have reported the adsorption of coloured organic matter onto low cost waste materials. The results showed that all adsorbents would physically adsorb constituents in a reversible manner; some constituents were more readily adsorbed than others. Thermodynamical data from this study were used to predict the relative distribution of three constituents on the surface of different adsorbents. Cascade sequences of four biologically aerated filters were used to examine the treatment of a simulated textile waste\textsuperscript{296}. The dye component of the
synthetic wastewater was Maxilon Red BL-N, which was added at 25 and 50 mg L. A high colour removal (99%) was achieved at both the concentration tested with the first reactor removing the majority (96%). McKay et al.\textsuperscript{297} carried out the adsorption of four dyes onto bagasse pith. The equilibrium saturation adsorption capacities were 21.7, 22.9, 155.4 and 76.6 mg g\textsuperscript{-1} for Telon Blue ANL (acid blue 25), Erionyl Red BLN (basic red 22), respectively. Isotherms were also measured at different temperatures and from the data; the enthalpies of adsorption were determined.

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