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Potential of Natural Adsorbents in treating Industrial Effluents in Ludhiana- A review

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Abstract—*Industrial effluents have always one of the prior concerns in developing nations because growth has to be achieved along with sustainability and the hesitation of industries to set up ETPs incurring high costs and the lesser centralized facilities available make the situation more alarming. Ludhiana, an industrial city in the state of Punjab has numerous textile, electroplating and steel industries which are operating under partial or no treatment that is contaminating the drinking water resources. Further, it is affecting the ground quality which leads to toxic contamination on the agricultural lands ultimately making the pollutants enter the food chain. The problem is aggravated by the improper CETPs installed as per the requirement. So, the need for an eco-friendly and economical treatment option brought down the usage of natural materials in line and adsorption is one such technique which serves the purpose. The paper reviewed the applicability of adsorption technique using natural adsorbents like activated carbon from sawdust and agricultural waste, rice husk ash and fly ash on the industrial effluent for reducingthe concentration of colour, COD and heavy metals like lead, copper, cadmium and chromium. Sawdust showed the best results in removal of all the parameters reducing the concentration by around 90%. Agricultural waste also showed significant removal rates and can be selected as an option as otherwise it is generally disposed of by open combustion leading to contamination of air. Overall, adsorption was observed as a better technique which if extended to adsorption modelling and adsorption columns can bring about desirable results at low cost and without causing any harm.*

Keywords*: Industrial effluent, heavy metals, adsorption, natural adsorbents, fly ash, rice husk ask, saw dust.*

1. INTRODUCTION

Water is the prime requirement of life and extremely crucial for the survival of all living organisms. It is a fact that only 0.02% of the total available water in the form of oceans, rivers, lakes and streams is fit for human consumption. [1]. The growing ecosystem degradation around the world particularly of water is more damaging to the vast population of poor in the developing countries who depend solely on ecosystem services, and are sometimes the principal factor causing poverty and social conflict [2].With the Indian Government making an all-out effort to increase Foreign direct investment [3], huge investments can be expected in manufacturing chemicals, pesticides, textiles and every imaginable product; increase in waste output and spread of toxic hotspots across the country.

It has been estimated that about 13468 MLD of wastewater is generated by industries of which only 60% is treated [4]. Further, as per CPCB, in case of small scale industries that may not afford cost of waste water treatment plant, Common Effluent Treatment Plants (CETP) has been set-up for cluster of small scale industries [5]. The treatment methods adapted in these plants are dissolved air floatation, dual media filter, activated carbon filter, sand filtration and tank stabilization, flash mixer, clari-flocculator, secondary clarifiers and Sludge drying beds, etc. Moreover, the proper treatment cost excluding the capital and other expenses as per CPCB estimates to around 73.22 INR per kilo litre water (as shown in Table 1) while the extent of treatment and the functioning of ETPs is always uncertain [6]. And if the overheads for the capital and other annual costs are accounted, then the treatment cost reaches a much higher limit.

Table 1: Economics of different levels of treatment using conventional measures

Particulars	Primary treatment system	Primary + ultra-filtration system	Primary + ultra-filtration system + reverse osmosis
Capital cost (Rs lakhs)	30.0	90.64	145
Annualized capital cost @ 15% p.a. interest and depreciation	5.79	18.06	29.69
Operation and maintenance cost (lakhs/annum)	5.88	7.04	12.63
Annual burden (annualized cost + O&M cost) Rs lakhs	11.85	27.1	42.5
Treatment cost Rs/kl (without interest and depreciation)	34.08	52.40	73.22

Ludhiana, an industrial hub in the state of Punjab has around 40,000 small, medium and large industrial units [7]. Most of the industrial hubs are linked with textile and electroplating industry which contributes a lot towardscolour and heavy metal concentration in the effluent stream. The industrial cluster of Ludhiana has been identified as one of the most critically polluted clusters by the Ministry of Environment, Forests and Climate Change [8]. Moreover, there is no separate centralized facility here for the effluent treatment except from a few ETPs. So there is dire need of decentralized facilities which can help in easy installation and keeping the ground water sources as well as the land pollution free.Further, as per CPCB reports, if there is practically not cent percent treatment at decentralized levels and there is some lack at the private and government ends, some natural, economical and effective technology can always prove to be a better alternative. Adsorption using natural adsorbents is one such technology.

This paper analyses in detail the studies conducted earlier on the role of various adsorbents natural and artificial namely rice huskash blended with monomers, activated carbon from agricultural wastes and saw dust and fly ash in treating industrial effluent especially for the removal of colour, COD and heavy metals.

2. ADSORPTION

2.1 Introduction

Over the last few years, investigations have been undertaken by various researchers all over the world for treatment of waste water using adsorption process. The adsorption process is utilized as a stage of integrated chemical-physical-biological process for the treatment of wastewater [9,10], or simultaneously with a biological process [11]. The process of adsorption is a surface phenomenon which involves separation of a substance from one phase accompanied by its accumulation or concentration at the surface of another substance. Adsorption is a mass transfer process which involves the accumulation of substances at the interface of two phases, such as, liquid–liquid, gas–liquid, gas–solid or liquid–solid interface. The substance being adsorbed is the adsorbate and the adsorbing material is termed the adsorbent. The properties of adsorbates and adsorbents are quite specific and depend upon their constituents. The constituents of adsorbents are mainly responsible for the removal of any particular pollutants from wastewater [12].

2.2 Removal Mechanism

Generally, there are two basic removal mechanism theories proposed which are based on physical and chemical forces.

Physical adsorption is a process in which binding of adsorbate on the adsorbent surface is caused by Vander Waal forces of attraction. The electronic structure of the atom or molecule is hardly disturbed upon physical adsorption. Vander Waal forces originate from the interactions between induced, permanent or transient electric dipoles. Physical adsorption can only be observed in the environment of low temperature and under appropriate conditions, gas phase molecules can form multilayer adsorption. Commercial adsorbents utilize physical adsorption for its surface binding [13]. Physical adsorption is accompanied by a decrease in free energy and entropy of the adsorption system and, thereby, this process is exothermic.

Chemical adsorption, however involves a chemical reaction between the adsorbent and the adsorbate. The strong interaction between the adsorbate and the substrate surface creates new types of electronic bonds i.e., covalent and ionic [13]. Chemical adsorption is also referred as activated adsorption. The adsorbate can form a monolayer. It is utilized in catalytic operations. Under favourableconditions, both processes can occur simultaneously or alternatively.

The selection of an adsorbent is the most vital step in effluent treatments and there are certain basic properties which regulate the selection of a particular adsorbent. Its hydrophobic/hydrophilic nature, its surface area, nature of functional groups present, adsorption capacity (i.e. an idea about the number of active sites available), the adsorbent life (number of adsorption-desorption cycles for which the adsorbent can be used significantly), chemical and thermal stability, hardness and mechanical strength to prevent crushing and erosion to lower physical losses, ease of regeneration and economic viability [14].

2.3 Colour removal

Textile industry being a major consumer of dyes- natural or synthetic provide a long lasting colour to water which hinders the degradation process and make it difficult to discard aerobically [15] and in turn making it carcinogenic [16]. Dyes are generally cationic in nature and hence the natural adsorbents which possess anionic functional groups are observed to show better removal of colour from the effluent. There have been numerous studies on the use of activated carbon from agricultural waste and saw dust which have shown a great removal [17-22]. Other studies on different adsorbents like rice husk ash [23] and fly ash [24] along with the removal efficiency achieved for colour have been tabulated in Table 2. The adsorbent Activated Carbon from sawdust is observed to show the maximum removal of colour of around 98.44% which is quite effective. Such removal can be linked to high number of active sites available

Table 2: Removal efficiency for colour by different adsorbents

Adsorbent	Efficiency
Fly ash	53%
Rice Husk Ash	87.95%
Activated Carbon from sawdust	98.44%
Activated Carbon from agricultural waste	94.64%

on the surface of the adsorbent and strong forces of attraction between the adsorbent and adsorbate.

2.4 COD removal

Industries use a large amount of organic dyes and other chemicals which contribute a lot towards the oxygen demand. Such effluents cannot be disposed directly over any surface body because it may have toxic effects on the aquatic life. The removal rate for different adsorbents for COD have been listed in Table 3.

The max. removal is shown by rice husk ash followed by activated carbon from sawdust which also shows a considerable removal of COD. The removal efficiency again depends on the surface characteristics of the adsorbent. However, there is considerable effect of initial concentrations and the temperature and pH kinetics, which needs prior optimization while finally coming up with the max removal rate.

Table 3: Removal efficiency for colour by different adsorbents

Adsorbent	Efficiency
Fly ash	51%
Rice Husk Ash	92.5%
Activated Carbon from sawdust	80%
Activated Carbon from agricultural waste	65.72%

2.5 Heavy metal removal

Electroplating industries operating in Ludhiana city have a major role in the ground water contamination by disposing off effluents containing high concentrations of heavy metals into surface water bodies or sewerage systems which carry it to the STPS that are not designed to treat them. So ultimately they land up somewhere they addto the nuisance potential of the area. Further, the treatment units required for the heavy metal removal such as ultra and nano filtration techniques or the other electro-chemical processes involved are quite costly. So adsorption again serves as a good alternative.

The removal of heavy metals using adsorption technique is mostly linked with the chemical adsorption theory (though a very little amount is removed by physical vanderwaal's forces). The nature of functional groups on the surface of adsorbent has a major role to play in the removal mechanism as the anionic groups such as carboxyl (COO^-), amines (NH_2^-) lead to chemical attraction between the cationic heavy metals and them. Such attractions are again highly influenced by temperature conditions and the isotherms- Langmuir and Freundlich are developed for attaining the equilibrium conditions and developing adsorption columns treatment units.Table 4 gives the removal efficiencies for the heavy metals as per the literature study [25-33]. Maximum removal was attained by activated carbon from saw dust.

Table 4: Removal efficiencies in percentage of heavy metals by different adsorbents

Adsorbent	Lead (Pb)	Copper (Cu)	Cadmium (Cd)	Chromium (Cr)
Fly ash	76.06	98.54	73.54	95%
Rice Husk Ash	87.17	98.17	67.92	79%
Activated Carbon from sawdust	98.6	97	95.1	81%
Activated Carbon from agricultural waste	80%	90%	100%	99.99%

3. CONCLUSION

The analysis of the literature and previous studies suggest that adsorption is a much efficient technique both in case of removal percentage as well as economic feasibility. And if that done with natural adsorbents further enhance the environmental stability, as the waste product from one process (such as agricultural waste, fly ash or saw dust) is used a treatment material for another waste. Ludhiana being a major industrial city can definitely undertake adsorption models as the treatment option with natural adsorbents especially the activated carbon from sawdust which showed the maximum removal around 90% for almost all the parameters thus serving as the best adsorbent amongst the options considered. The second most efficient adsorbent was the activated carbon from the agricultural waste which can serve as a good option for disposing the agricultural waste which otherwise is generally burnt leading to air pollution.

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