Flyash: an Effective Method for Treatment of Wastewater

Neetu Dabi and Neha Patwa
Department of Chemistry, JIET Group of Institutions,
NH 62, Pali Road, Jodhpur, Rajasthan, India

Abstract—**Fly ash is a by-product of residual of all coal combustion in thermal power plants which has been regarded as problematic solid waste all over the world. The furnaces in which coal combustion takes place are used to generate steam for production of electricity. The resulting material is a siliceous as consisting of oxides of silica, aluminium and iron and contains <10% calcium oxide. Fly ash has been regarded as a problematic solid waste all over the world. Effluents generated in dye houses of the textile industry contain considerable amounts of unexhausted (about 20 - 40%) of input dye in addition to other impurities like salt, surfactant, and heavy metals. But the discharge of such coloured dye effluents is aesthetically objectionable. Coloured effluents also interfere with the transmission of sunlight, and upset the biological metabolism processes, which causes the direct destruction of aquatic communities present in ecosystems. Presently, several technologies have been developed such as filtration, chemical precipitation, advanced oxidation, reverse osmosis or adsorption. Adsorption is the most popular method for wastewater treatment due to its easy and inexpensive operation. Utilization of industrial solid wastes for the treatment of wastewater from another industry could be helpful not only to environment in solving the solid waste disposal problem, but also to the economy. Fly ash is used as an adsorbent for the removal of pollutant from waste water which meets the dual goals of disposal and treatment. Increased industrial activities have resulted in the generation of large amounts of wastewater polluted with heavy metals. Adsorption is recognized as an effective and economic method for low concentration heavy metal wastewater treatment. Fly ash with specific surface area of 6177.15cm2/gm is used as a clarifier to the waste water. This paper reviews a number of investigations where coal ashes have been studied for the removal of organic matter (COD), colour, organic compounds such as phenol and heavy metals. Different modes of operation and activation methods to improve the adsorption capacity are the future scope for the research.**

Keywords*— *Flyash; Wastewater treatment; Adsorbent.

I. INTRODUCTION

Wastewater coming out of household and industries has become a huge problem for our environment and it also adversely affects human beings. Heavy metals from industrial processes are also among the most important pollutants in source and treated water, and are becoming a severe public health problem. Although a lot of investigations have been done in employing fly ash as adsorbent, those researches show adsorption behavior of fly ash varies with the source of fly ash and its properties. Although fly ash presents low adsorption capacity and to enhance the adsorption capacity, it is necessary to modify the properties of fly ash.

Flyash, also known as flue-ash, is one of the residues generated in combustion. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. Fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters. The fine powder does resemble Portland cement but it is chemically different. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably. Fly ash is a heterogeneous material consists of SiO_2, Al_2O_3, Fe_2O_3 and CaO. Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm.

Fly Ash is an industrial by-product from Thermal Power Plants (TPPs), with current annual generation of approximately 112 million tones. Cement and Concrete Industry accounts for 50% Fly Ash utilization, the total utilization of which at present stands at 30MT (28%). The other areas of application are Low lying area fill (17%), Roads & Embankments (15%), Dyke Raising (4%), Brick manufacturing (2%) and other new areas for safe disposal of fly ash is in paint industry, agriculture etc as a source of air pollution constitutes fly ash.

The fine particles of fly ash reach the pulmonary region of the lungs and remain there for long periods of time; they behave like cumulative poisons. The submicron particles enter deeper into the lungs and are deposited on the alveolar walls where the metals could be transferred to the blood plasma across the cell membrane. The residual particles being silica (40–73%) cause silicosis. According to the hazardous waste management and handling rule of 1989, fly ash is considered as non-hazardous.

Adsorption, which is a surface phenomenon, that depends on the higher specific surface area, narrow particle size distribution and the porosity of an adsorbent were also investigated for the fly ash observed that the larger the specific surface area, the higher the carbon content and the finer the particle size of the fly ash the greater its adsorption capacity will be.

Wastewater can be treated by different methods like screening, sedimentation, filtration, aeration, Aerated lagoon, Trickling filters, pond stabilization. But all these methods are quite expensive, require large land area, complex technology, require high energy input etc. But using fly ash for the wastewater treatment is quite an effective method.

In this paper number of investigations are reviewed where coal ashes have been studied for the removal of organic matter (COD), colour, organic compounds such as phenol and heavy metals. Activated carbon is the commonly used adsorbent, the major drawback being the high cost. Different modes of operation and activation methods to improve the adsorption capacity are the future scope for the research.

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II. FLY ASH UTILIZATION

Fly ash utilization programmes can be viewed from two angles, i.e. mitigating environmental effects and addressing disposal problems (low value–high volume utilization). Following are some of the potential areas of use of fly ash: -

1) Development of Fly Ash Based Polymer Composites as Wood
2) Fly Ash Based Cement
3) Role of bio-amelioration of FA on soil
4) Fly ash bricks
5) Fly Ash in Road Construction
6) Fly Ash in Wastewater Treatment

III. MATERIALS AND METHODS OF WASTEWATER TREATMENT

Dinesh Mohan et. al., investigated low cost adsorbent for the replacement of existing expensive methods for wastewater treatment. The prepared adsorbent was characterized and used for the removal of dyes from wastewater. He studied the effect of different temperatures, particle sizes, pH's, and adsorbent doses and found that adsorption increases with increasing temperature, thereby indicating that the process is endothermic in nature. The removal of each dye was found to be inversely proportional to the size of the fly ash particles. Thermodynamic parameters such as the free energies, enthalpies, and entropies of adsorption of the dye−fly ash systems were also evaluated. In comparison to other low-cost adsorbents, the sorption capacity of flyash is found to be comparable to that of other commercially available adsorbents used for the removal of cationic dyes from wastewater[1].

V K Singh et. al., used flyash obtained from a thermal power plant, for the removal of malathion from aqueous solutions. The removal of malathion increased by increasing the temperature indicating endothermic nature of removal process. The fly ash exhibited first order rate kinetics and followed both Langmuir and Freundlich isotherm models. Endothermic nature of adsorption process was further supported from increasing values of Langmuir and Freundlich constants with increase in temperature. A comparison of the adsorption capacity of fly ash with other adsorbents shows that fly ash can be used for the removal of malathion from aqueous solutions[2].

Investigating the utilization of fly ash as a low-cost adsorbent to remove copper ions from aqueous solutions such as wastewater was carried out by J. Luo et. al. The results from sorption process showed that the maximum adsorption rate was obtained at 50 mg/L when different dosage of fly ash was added into the solution, and it could be concluded that decreasing the initial concentration of copper ion is beneficial to the adsorption ability of fly ash. With the increase of pH value, the removal rate increased. When pH was 6, the removal rate reached the maximum of 99.60%. When initial copper content was 50 mg/L, pH value was 6, the adsorption capacity of fly ash sample reached 0.98 mg/mg. The main removal mechanisms were assumed to be the adsorption at the surface of the fly ash together with the precipitation from the solution[3].

Release of Phosphorus (P) to surface waters leads to serious pollution. The development of technology for Phosphorus removal offers the opportunity for abatement of environmental hazards and recycling. In order to determine the phosphate removal capacity of fly ash and the effect of adsorbent quantity (5 and 10g per 100mL), temperature (28 and 50°C), retention time (5 and 30 min) on P removal, A K Sinha et. al., carried out sorption studies using phosphate solutions containing 20, 50, 100, 150 and 200 mg/L P. The results showed that the flyash was able to remove even 100% of 20 mg/L at 10g adsorbent with 30 min retention time at 28°C. The P removal capacity decreased with increase in P concentration, the removal was 86.51% at 200 mg/L P. The adsorbent quantity significantly influenced the P removal; the average removal was 94.81% at 5g and 97.5% at 10g. The Langmuir adsorption maximum was the highest for 5g fly ash-30 min equilibrium at 28°C (40.98 mg/kg)[4].

Safaa M. Ragheb also studied use of fly ash as potential adsorbent for removal of phosphate, heavy metals and organic pollutants in wastewater treatment. Batch adsorption experiments were performed in order to evaluate phosphate removal efficiency of slag and fly ash. The sorption process was relatively fast and equilibrium has been reached at 30 min contact time and the maximum removal percentage was achieved at an adsorbent loading weight of 0.5 gm/100 ml. Phosphate removal ratio using slag and fly ash was 93% and 95%, respectively, under the batch test conditions. The achieved phosphate removal efficiency was 96.15% and 96.9% using slag and fly ash respectively.

The effect of both adsorptions on the sorption kinetics of phosphate ion was studied at pH of 7 for fly ash and 5 for slag, 3 mg/l initial phosphate ion concentration. The sorbent dose was varied between 0.1 and 3 mg/l. This result is expected because the increase of adsorbent dose leads to a greater surface area. When the adsorbent concentration was increased from 0.1 to 0.4 g/100 ml, the percentage of phosphate ion adsorption increased from 83% and 98% to 100% and 98.8%. At a higher dosage, the equilibrium uptake of phosphate ions did not increase significantly with increasing fly ash and slag dosage. Such behavior is expected due to the saturation level attained during an adsorption process. This finding agrees with Koumanova et al., [5]. For subsequent studies, a dose of 0.4 g/100 ml of fly ash and slag was selected. The effect of fly ash on the removal of COD, BOD5, Ammonia, Nitrate phosphate, TDS, TS, Chloride and Sulfate show that, 28.5%, 39.2% of COD was removed, 42.65%, 17.8% of BOD5 was removed, 26.05%, 12.6% of ammonia was removed, 53.1%, 15.6% of Nitrate was removed, 96.15%, 96.9% of phosphate was removed, 19.35%, 36.9% of TDS was removed, 30.15%, 25.3% of chloride was removed, 17.2%, 39.7% of Sulfate was removed and 63.35%, 66.6% of oil and grease was removed[6].

Barbora Mikendova et. al., also investigated sorptive properties of three different types of fly ash and one fly ash type treated with a 1M, 3M, and 6M solution of NaOH to remove phosphates (P) from water. The results showed that the fly ash containing the highest initial CaO concentration sorbed the greatest amount of phosphorus. The treatment of fly ash with NaOH solutions did not significantly enhanced the sorption capacity of fly ash[7].

Yuruma used flyash for the removal of Boron from water with fly ash, zeolite, and demineralized lignite with different capacities. 94% boron was removed using fly ash. Batch experiments were conducted to test the removal capacity, to obtain adsorption isotherms, thermodynamic and kinetic parameters. Boron removal by all adsorbents was affected by pH of solution; maximum adsorption was achieved at pH 10[8].

Retention of fluoride ion in dynamic experiments on columns packed with fly ash was studied by R Piekos and S Paslawska at 20 ºC with a series of aqueous solutions containing 1, 5, 10, 20, 50, and 100 mg F^-/L. The flow rate through a 450-g bed was ≤ 2 mL/hr. At the lowest F^- concentration (1 mg/L), the F^- level in the effluent initially increased and then gradually decreased down to 0 mg/L after 120 hours. With higher F- concentrations in the feed solutions, the F^- concentration in the effluent steadily decreased reaching 0 mg/L after 120 - 168 hours. We conclude that coal fly ash is an effective sorbent for F^- ions, especially at high concentrations in water[9].

A S Jadhav and M V Jadhav used Maize husk fly ash (MH fly ash) as an adsorbent for removing fluoride from water. The equilibrium was attained in 120 minutes. Maximum removal efficiency was obtained at pH value of 2, optimum adsorbent dose was found to be 2.0 g/50 mL, optimum stirring rate was obtained at 250 rpm. Maximum fluoride removal was observed to be 86% at optimum conditions[10].

Satya Vani Yadla et. al., threw light that when the body is exposed to lead by being inhaled, swallowed, or in a small number of cases, absorbed through the skin, it can act as a poison. So the studied, the removal of lead (II) ions from aqueous solution by using fly ash. For this purpose, various factors affecting the removal of heavy metal ions, such as treatment time with the solution, initial pH with the solution and adsorbent size were investigated. They found that metal ion removal capacities of fly ash increased with increasing pH, and pH 6 was found to be the optimal pH value for maximum metal removal capacity. Lead ion adsorption and equilibrium could be achieved within one hour of time is 90.37. Maximum capacity of lead removal could be achieved at 52µm[11].

Shefali Saxena et. al., used Fly-ash (FA) collected from coal fired power station (Kota Thermal Power Station) and impregnated it with lime slurry, activated thermally and used as a low cost adsorption catalyst (LSFA) for defluoridating contaminated water. Results showed that activated fly-ash due to increased crystallinity property and increased Si-O-Ca phases possesses more activity over surface to act as a suitable adsorbent to remediate fluoride from drinking water. The application of fly-ash and Kota stone (lime) slurry in synthesis of a low cost adsorbent finds a noble way to utilize these abundant waste materials whose indiscriminate disposal pose a threat to the environment[12].

CONCLUSION

Based upon the results of this research, the following conclusions can be drawn:

1. Fly ash is found to be an effective method for the removal of various materials that are harmful to our environment and human beings.

2. Fly-ash can be collected from various thermal power stations and can be used as effective adsorbents as compared to costlier conventional methods and powdered activated carbon for the treatment of wastewater.

3. The results of all research show that the removal efficiency will remain high at lower initial concentration and then increases as the initial concentration is further increased.

4. The results of the tests using real wastewater showed that fly ash was effective in the simultaneous removal of organic matter (COD), colour, organic compounds such as phenol and heavy metals industrial wastewater.

5. The low cost adsorbent may also lead to less environmental problems. Improvement in plant economics may also be expected.

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