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Experimental Analysis of Ionic Iron Compounds on Post-Coagulation Floc Settlement under the Presence of Magnetic Field in Fly-Ash Media

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Abstract- The most abundant and one of the most precious resources (fresh water) for the Survival of life is on the verge of depletion. Hence various treatment processes to treat wastewater have and are being researched. Speaking about waste, another recent waste comes into the picture which is available in abundance and easily accessible commonly known as Flyash. Multiple research have been done in order to utilize the components of fly ash for removal of heavy metal like Arsenic, Cadmium, and Nickle etc. for the past years. This paper is based on the idea of utilization of the magnetic property of the Nano iron particles (Fe2+ & Fe3+) present in the fly ash as Fe2O3, as well as the adsorption capacity of the carbon particles present in the fly ash.

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Experimental Analysis of Ionic Iron Compounds on Post-Coagulation Floc Settlement under the Presence of Magnetic Field in Fly-Ash Media

Abhishek Singh [α], Rajlakshmi Barman [σ], Dr. T S Anantha Singh [ρ] & Dr. Anurag Kandya [ω]

Abstract- The most abundant and one of the most precious resources (fresh water) for the Survival of life is on the verge of depletion. Hence various treatment processes to treat wastewater have and are being researched. Speaking about waste, another recent waste comes into the picture which is available in abundance and easily accessible commonly known as Flyash. Multiple research have been done in order to utilize the components of fly ash for removal of heavy metal like Arsenic, Cadmium, and Nickle etc. for the past years. This paper is based on the idea of utilization of the magnetic property of the Nano iron particles (Fe2+ & Fe3+) present in the fly ash as Fe2O3, as well as the adsorption capacity of the carbon particles present in the fly ash.

Magnetic field induced treatment process with flyash as a media lead to a decrease in the settlement time of the floc produced after media mix to 35 seconds in 1000ml of Wastewater sample with a fly ash concentration of 12 g/l. Turbidity removal was 95% at variable settlement time. Usually prologed settlement time lead to better result for turbidity removal due to carbon adsorption. The raw water used for the experiment was obtained from multiple educational institutions in Ahmedabad & Gandhinagar regions, having various organic and inorganic concentrations in raw form. This raw sewage water initially having an over range turbidity (>2000NTU) which was reduced to a limit of 50 to 100 NTU on introducing flyash into the medium which acted as a natural coagulative.

During the Cogulative process the Ion's Fe2+ & Fe3+ gets confined with floc particles and these floc's with ionic iron settles at a faster rate in the presence of established magnetic field. Atomic spectrometric test for Fe+ ions gave results with slight decrease in the Fe+ concentration in the treated water in comparison to initial concentration in raw water. The complete treatment process initialized by the adopted singular treatment method(Magnetic Filteration) lead to a significant reduction in time span of the whole process as compared with the standard Multi-tier process for the treatment of sewage water at the Wastewater teatment plant.

Index Terms: atomic absorption spectroscopy, fly-ash, turbidity, magnetic filtration.

I. Introduction

Fly ash is one of the most abundant & easily accesible waste product, produced by the geothermal power plants powering a country. It has been used to treat different concentration of metals in the water, conditioning of the wastewater sludge etc. for the past years. One of the most impressive property of fly ash is its adsorption and coagulation tendency due to high carbon, alumina and silica content. In general a fly ash sample will be having silica content as 44% by weight and alumina content as 20-25% by weight. [1] Fly ash and wastewater both contain certain pollutant level, especially heavy metals depending upon their characteristics and wastewater in addition may contain high concentration of pathogenic microorganisms which may produce foul and pungent smell. Keeping the environmental concern in mind the leachate from these waste product should not contaminate ground water, for survival of surrounding ecosystem.

The Nano Fe+ present in the fly ash would react to the magnetic field produced from the magnet which would lead to a faster rate of settlement. The adsorption property of fly ash will create flocks in water having high concentration of organic and inorganic waste due to Si and Al concentration. Fly ash exhibits strong ability to fix Cd, Cr, Cu, Ni and Zn. The three major heavy metal fixation mechanism are sorption, hydroxide and silicate precipitation. [1]

The fly ash compromising of approx. 25% Si and between 10 to 15% alumina in various samples tested for concentrations, with Ca and Fe concentration varying over a tenfold range. [2] Magnetic field has been adopted for treatment of metallic/ magnetic contents within various oil purification process and industries refining oil from heavy machineries. The utilization of the magnetic filtration with the help of fly ash having materials with magnetic properties in treatment of high sludge concentration wastewater for better economic and feasible treatment were never studied. The complete treatment process worked on basis on two fundamental principle of magnetic loading and gravitational loading settlement of solid matter with variables as time and solids concentration.

Fly ash is a residue predicted to increase significantly in the coming years. Only a small percentage of fly ash is used in concrete production, road base construction, soil amendment and zeolite synthesis; the large majority is still discharged into ash ponds, lagoons or landfills [3]. In terms of chemical composition, fly ash consists of more than 70% silicon,

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aluminum and iron oxides (SiO2 + Al2O3 + Fe2O3). In recent years, other possible applications to pozzolans have been proposed, including wastewater treatment [4]. Many studies have shown that pozzolanic material can act as an adsorption substrate for phosphate, heavy metals and organic pollutants, indicating a potential application as a low cost adsorbent for wastewater treatment [5, 6, 7].

Scanning electron microscopy of fly ashes from different conditions were done and it was verified to the forms that the material particle can acquire. Spherical particles made up most of fly ash which are vitreous and transparent indicating the complete melting of the silicate minerals. These spheres could be of shapes such as hollow, solid or filled with other smaller spheres, amorphous particles or crystals [8]. Magnetic technology is a method for the magnetization of matters by the magnetic field. It is widely used for wastewater treatment. In recent years, the effects of magnetic technology on activated sludge process have been studied [9].

Furthermore, the removal of particles from solution with the use of magnetic fields is more selective and efficient (and often much faster) than centrifugation or filtration [10, 11]. Lately there has been an increase of interest to use magnetic materials based on iron oxide (fly-ash) for magnetic filtration for organic, arsenic & phosphorous removal.

II. Materials & Method

a) Fly ash

Fly ash type of class F was obtained from Gandhinagar thermal power plant for this study. The wastewater samples were collected from multiple universities to simulated a general undiluted random characteristic of water sample. Ideology behind using the Flyash as a medium is due to high concentration of Carbon, Alumina and silica presence which over the due course of study gave the characteristics of coagulative and adsorptive tendencies.

b) Alum stock solution

Aluminium Sulphate (Alum) Al2(SO4)3 used in this study was supplied by SDFCL(S Define chem. Ltd) Mumbai, India. A 2% solution of alum in distilled water was made (2 g of alum in 100mL of distilled water). The alum was entirely soluble at this concentration. The chemical leaves no residual color, offers very good turbidity removal. Further laboratory grade coagulant Potash Alum (Dodecahydrate) $KAl(SO_4)_2.12H_2O$ was used to get boundary range data for comparision purpose.

c) Coagulation

Coagulation was conducted using jar method with 2 different coagulant and at different dosages. The coagulants used are

- Aluminium Sulphate (Alum) - Al2(SO4)3
- Fly ash (class F) – Composition of Si compounds + Al_2O_3 + Fe_2O_3 + C compounds

d) Magnetic Field Intensity

Due to presence of magnetic compounds in nano/ionic form in the Fly ash the experiment was conducted with and without the presence of a small magnetic field induced due to combination of permanent magnets. Gauss meter was used to check for the intensities of the different magnets used and their effect over the range to which settlement was happening. The permanent magnet used had their magnetic field intensities in uT (micro tesla).

Description of which is mentioned in Table 1 below:

Table 1: Magnetic intensity of permanent magnets used in the experiment

S. No.	Type of Magnet	Magnetic Intensity (uT)
1	Permanent Type 1	6.48*
2	Permanent Type 2	3.45*

**Magnetic field mentioned is the MAX obtained due to variation of magnetic intensity with time & temperature.*

The experiment revolved around the theory based that Permanent magnets of different intensity such as 6.48uT and 3.45uT (taken in this study) will be used to increase the rate of solid (floc) settlement in wastewater with Fly ash media as a cogulant and magnetic field as motivating force for faster settlement.

e) Magnetic Filteration

For initating the magnetic filteration process class F fly ash in required dosage is needed, different dosages will help optimize the weight by volume dosage for multiple variable of wastewater for potability/ natural discharge. The fly ash concentration were taken on random basis of concentration in 1000ml of wastewater samples. The range varied from 1gm/l to 16gm/l.

The process for addition of dosage was done in 2 simultaneous process 1. Under the effect of magnetic field and 2. Under general gravitational forces. Both done such that the effect of Magnetic field intensity could be compared to general gravity settlement of the flock particles. The floc formation occurred naturally due to presence of Al_2O_3 and fine Carbon particles present in the Fly ash. As per previous studies undertaken by various researchers it has been proven that the Fly ash particles are of spherical shape with nano porous surface. As the particles interacts with the colloidal impurities present in the water they start making flocs and these flocs settle down under the forces taken in this comparision study.

Addition of Fly ash dosage in adequate amount will lead to the flock formation in highly turbid water and after wards the nano Fe+ particles present in the mix will be trapped in between the flocs which will start to settle under the gravitational loading/magnetic field intensity releasing water and concentrating sludge at the bottom of the tank/storage unit.

f) Atomic Adsorption Spectroscopy

Considering the ionic property of the nano iron particles present in the Flyash Samples. The concentration of Fe+ ions (Fe2+ & Fe3+) was checked before and after the treatment process. The sample analysis of the Raw water and the treated water was done through Atomic Adsorption Spectroscopy (AAS).

The data obtained as such is given below in Table 2:

Table 2: Fe+ concentration in water sample Pre & Post treatment process involving Magnetic Filtration

Type of water	$_{Fe}^{+}$ Concentration(mg/l)
Raw sewage water	3.556
Treated water	3.515

The data above validates that no extra Fe+ ion addition took place on adding Fly ash as a coagulant and that all the Fe+ionic compounds produced on adding Flyash for treating Wastewater is recovered as Sludge enriched with multiple minerals and organic compounds. This Data predicts the fesibility of using Fly ash as an coagulant for domestic water with high organic content and turbidity.

III. Experimental Data & Results

Table 3: Data related to experimental reading in lab scaled study under influence of magnetic field. (Except column 6)

Fly ash Dosage (gm)	Water Recovery Volume(ml)*	Organic Sludge Mix Recovered (ml)*	Ph Range	Turbidity (NTU)**	Gravitational Settlement Time (mins)	Magnetic Field Settlement Time (mins)	BOD5 (Ppm)
1	360	640	8.05	33	62	38	6.28
2	380	620	8.03	186	47	30	5.42
4	400	600	8.13	476	53	10	5
6	430	570	8.14	690	10	4	3.8
8	420	580	8.04	974	3	2	1.4
10	450	550	8.08	957	2	1	0.7
12	410	590	7.75	979	1	0.83	0.6
14	440	560	7.95	980	1.01	0.76	0.2
16	432	569	7.90	995	0.98	0.84	0.18

**Data pertain to ml recovered per 1000 ml sample taken for study*

***Rise of Turbidity is due to Fine carbon and silica particles present in the Flyash and not due to initial organic and inorganic compounds.*

Tolerance Limits for Inland Surface Waters Subjected to pollution (IS: 2296-1982) [12]
Tolerance Limits, Class C (Clause 3.3)

Table 4: Tolerance limits for Inland Surface Water Discharge Conforming to IS CODE: 2296-1982

Charasteristic	Tolerance limit
BOD (5Days @ 20°C)	3 mg/l
Ph Value	6.5-8.5
Turbidity	No tolerance Limits
Iron	50 mg/l
Total Dissolved Solids	1500 mg/l

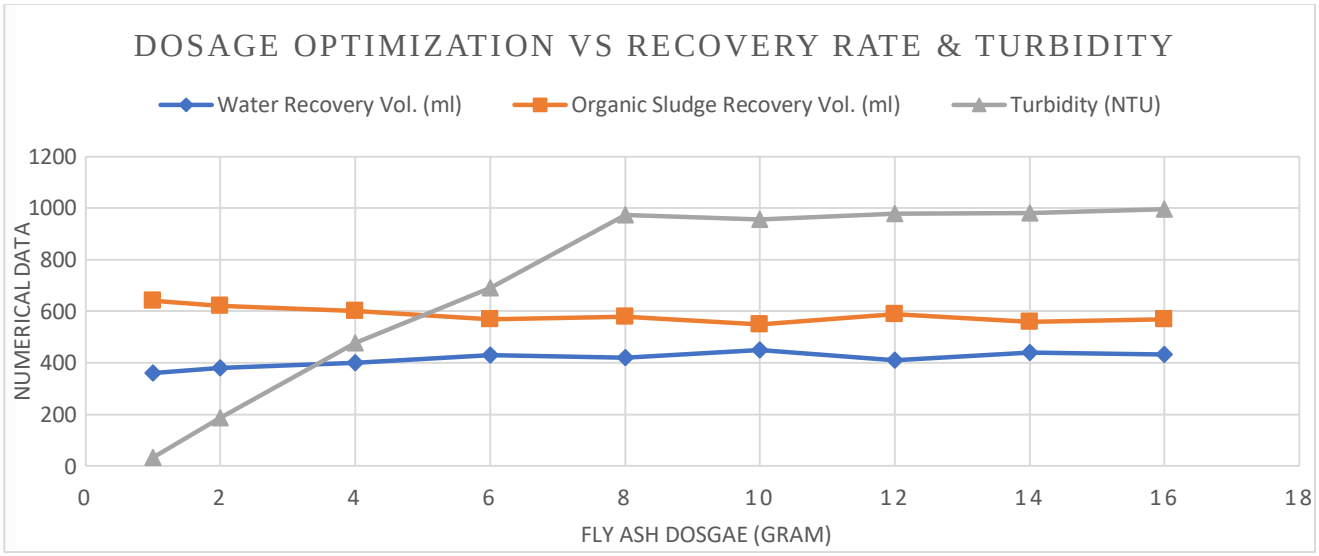

Figure 1: Data representation of multiple dosage of fly ash on Water recovery, Sludge recovery and Turbidity(NTU) variation

Analysis of above data keeping the tolerance criteria as presented in Table 4 above gave the conculsion that the range of Total solids was well within the premissable range of 1500 mg/l. The turbidity as a variable had no impact on the tolerance limit but increase in turbidity at higher dosage was an intermediate result of higher concentration of Carbon and silica particles present within the Flyash. Due to ionic seperation of compounds present in Fly ash and their coherence with the water molecules they stay in collidal state for a certain period of time. Leaving the Water to look like Greying white resembling texture like that in a river in plains.

Recovery of sludge was almost linear and spontaneous as compared with standard treatment process. With average Organic sludge volume of 586.5 ml per 1000ml of sample taken for study, representing heavy concentration of organic and inorganic pollutants in wastewater sample taken for study.

Turbidity on the contrary follows a linear scale from dosage 1mg to 8mg and then tends to remain constant around a range of 900 NTU. The high data value of turbidity is only due to the fine carbon compounds and silica compounds and not any organic or inorganic collidal suspension. The water on the text of touching gave a sandy smooth sensation same as that of sea waves on shores or a river in alluvial plain.

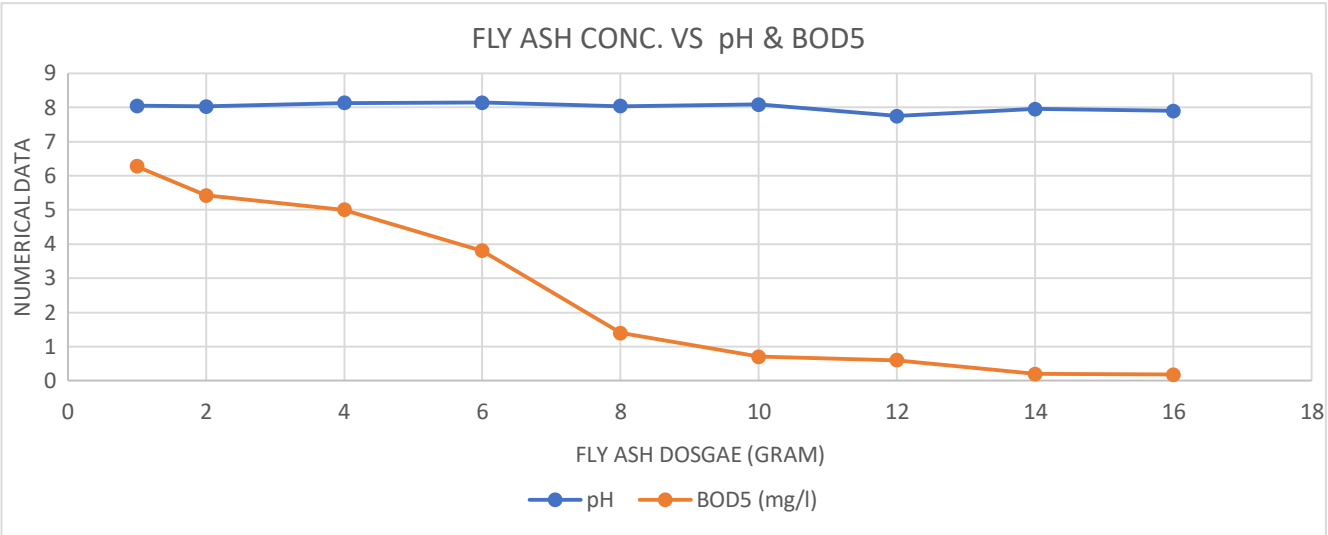

Figure 2: Variation of pH and BOD5 on subsequent dosage of Flyash as an coagulant.

The concentration of Fly ash which varied accordingly to optimize the dosage for getting the max treatment effciency lead to the observation and pattern, that though having multiple compounds present within the molecular & physical structure it kept the pH of the waste water within a constant zone ranging from 8.5-7.5. This range so obtained collided within the tolerance limit range for discharge of treated water in Inland Surface water bodies as presented in Table 4 above.

As per the nature of decrease of BOD5 value a significant decrease of 96%, than that of actual value obtained from the Raw water sample can be seen. Trending value of BOD5 predicted that over high dosgae of fly ash i.e. 14 gm and 16 gm, BOD5 value decreased below the tolerable limit of 5mg/l, which is for inland surface discharge of water. Hence proving that using Flyash will lead to effective decrease in BOD5 value even at lower dosage varing in a range of 6.5 – 0.15 mg/l.

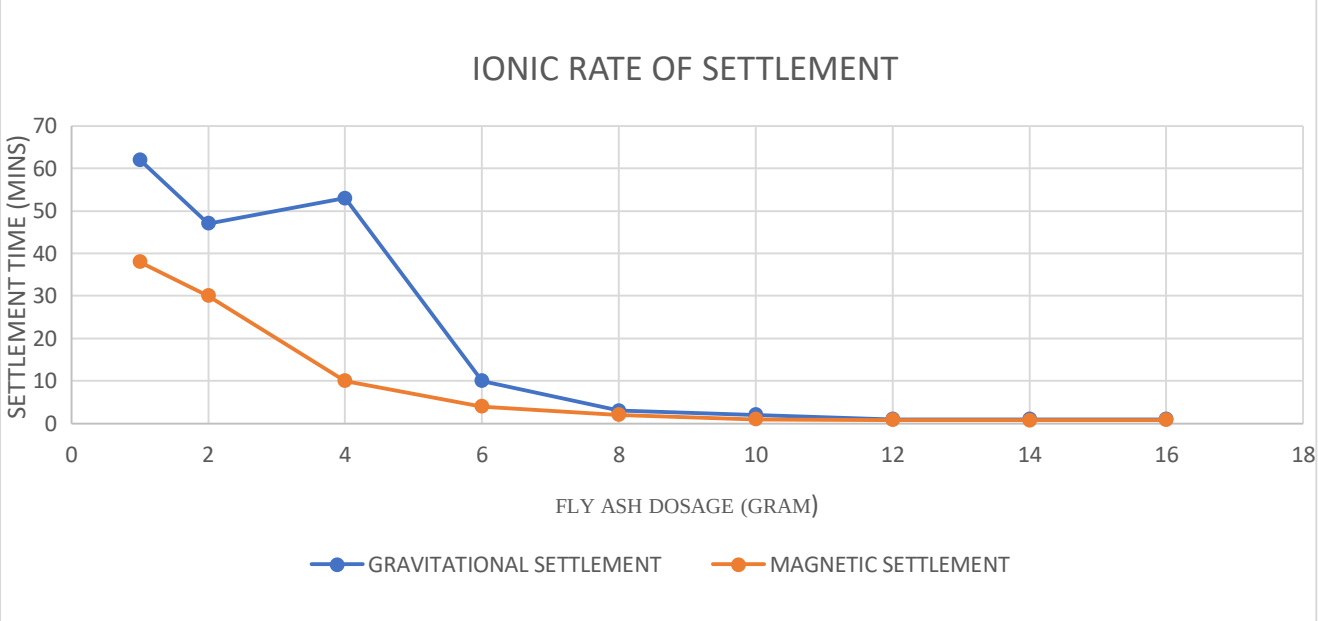

Figure 3: Rate of settlement post cogulation under ionic Fe+ floc formation, in effect og gravitational and magnetic field

The settlement rate in presence of magnetic filed intensity of 6.48uT and 3.45uT based on the assumption that Fe+ ions will be entrapped between the colloidal flocs formed will be attracted towards the source of magnets spinning at the bottom of the container, presnting a faster settlement rate than that merely due to gravitational settlement. The combinataion of strong and relatively weak magnet sufficed the expreiment as continious flucuation lead to rapid change on field intensity and which lead to faster rate of settlement in the flocs carrying Fe+ions post coagulation with Fly ash. Though a general idea based on the above representation of data predicts that at higher dosage of Fly ash, settlement rate didn't varied by much due to high weight to volume ratio of the sample. But in the intial range of data significant variation is to be seen under the magnetic field intensity, making the rate of settlement 3 times faster at different concentrations.

Table 5: Data obtained based on Alum Coagulation under different dosage at 27°C

Concentration(mg/l)	pH	Turbidity(NTU)	Time (mins)
60	7.52	147	30
120	7.50	129	30
240	7.49	76.8	30

As per the representation of data in Table 5 above, the time variation could not be determined to exact minutes and had an average duration of 30 mins due to molecular interation and slow rate of settlement of the colloidal impurities, with significant reduction in turbidity due to ionic Al3+ presence and neutralization of negative charges. The vartion of pH also remained negligible and presented a good output in terms of treatment process. In comparision to Magnetic Filtration with Fe+ ions entrapped withinn the flocs and their settlement under magnetic field intensity of above mentioned units. This process looks uneconomical and more time taking in comparision to the adopted magnetic filteration process, with Fe+ ionic floc settlement rate.

IV. Conclusion

As the assumption was produced and validated with the experimentational analysis that on addition of Flyash as a media for treatment of Watewater for Inland Surface Discharge, the Fe+ ions played a significant role in rate of settlement under the infulence of magnetic field intensity. Optimum dosage for the study was >=12 grams, because of multiple variable stayed within the tolerance limit parameter and even though the turbidity increased the nature of colloidal suspension was that of muddy water with no toxicity above tolerance limit. Also, the reduction of multiple variables as such BOD5 range(6.5 -0.15 ppm), pH (8.5 -7.5) and Sludge Volume(Total solids) (500 -700 ml per 1000ml sample taken) was seen and represented under observation in the result section. The research/study presented the utilization of Fly ash(Class F) a waste product of thermal power plant to be an effective treatment material for Coagulation and Magnetic Filtration in areas having high domestic wastewater characteristic of organic nature.

As compared with traditional Coagulant i.e. Aluminium Sulphate (Alum) - Al2(SO4)3, Fly ash presented a more economical and benificial use, most abundant use of which could be adopted in rural sector producing heavy organic loading in the raw sewage discharge, and heavy contaminants of biodegradable nature. The process of magnetic filteration will treat the wastewater for permissable discharge parameters for release in Inland surface water bodies and further study on the dried sludge obtained from the treatment could be studied to check for its applicabilty as local fertilizer.

- *Data Availability*

All data, models, and code generated or used during the study appear in the submitted article.

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