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DISCOVERY

Removal of fluoride by using *Musa paradisiaca* fruit peel as natural coagulant

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In this work, treatment of synthetic fluoride containing solutions by using *Musa paradisiaca* fruit peel powder as natural coagulant by coagulation-flocculation process. This method has been studied in order to treat wastewater from various industries (Electroplating, Photovoltaic wafers, Mineral processing units and Electronic goods production industries) and ground water (where high amount of fluoride observed in ground & drinking water). Several working parameters, such as concentration of fluoride, dosage of coagulant, initial pH of the solution and contact time of the reaction were studied to achieve a higher removal capacity. Variable concentrations (1-4 mg/L) of fluoride solutions were prepared by mixing proper amount of sodium fluoride with demonized water. The varying initial pH of the solution (pH 3 to pH 11) was also studied to measure the removal efficiency of *Musa paradisiaca* fruit peel powder. Results obtained with synthetic solutions revealed that the most effective removal capacities of fluoride could be achieved at 1 gm of coagulant dosage at 4 mg/L initial fluoride concentration. The removal efficiency is decreased as increases the initial fluoride concentration of the solution at constant coagulant dosage. The obtained results were substituted with coagulation flocculation kinetic parameters, which available in literature to find out the order of the process. The results indicated that the removal of fluoride by *Musa paradisiaca* fruit peel powder follows zero order of reaction. In addition, the process was successfully applied to the treatment of electroplating industry wastewater, where an effective reduction of fluoride concentration under legal limits was obtained just after 50-60 minutes. The results of this study showed that the removal efficiency of fluoride with *Musa paradisiaca* fruit peel powder given an economical solution to remove fluoride from aqueous solution.

INTRODUCTION

The generation of drinking or water for use of other activities from generally crude water sources and industrial wastewater includes coagulant use at a coagulation/flocculation stage to expel turbidity, minerals and metals in the type of suspended and colloidal material. Numerous coagulants and flocculants are broadly utilized in various water treatment plants. These materials can be ordered into inorganic coagulants (for example aluminum and ferric salts) and engineered natural polymers (for example polyacryl amide subordinates also, polyethylene imine). Aluminum salts are low cost and are the most generally utilized coagulants in water and wastewater treatment everywhere throughout the world. With respect to the use of manufactured polymers, the nearness of remaining monomers is unfortunate as a result of their neurotoxicity and solid cancer-causing properties. In ongoing years there has been significant enthusiasm for the improvement of use of natural and eco friendly coagulants which can be delivered or extricated from microorganisms, animals or plant tissues. These coagulants ought to be biodegradable and are ventured to be ok for human wellbeing. Likewise, regular coagulants deliver promptly biodegradable and less voluminous slop that sums just 20– 30% that of alum treated partner [1-4].

The utilization of characteristic materials of plant cause to clear up turbid crude waters is anything but another thought. Characteristic coagulants have been utilized for residential family unit for a considerable length of time in conventional water treatment in tropical rustic zones. Nowadays, a few reports depict characteristic coagulants from Nirmali seed and maize mesquite bean and *Cactus latifaria, Cassia angustifolia* seed and diverse leguminose species. All things considered, the material which has as of late gotten the best level of consideration is the seed of *Moringa oleifera* indigenous to Sudan. The water concentrate of *M. oleifera* seeds looks at very positively with aluminum salt. There are several studies reported for the removal of fluoride from drinking and industrial waste water by using chemical coagulation and electro coagulation process by using different chemical salts and electrodes.

Hence, there is a need to search for the native materials which can be used for water purification as these can provide technology near to the point of use that can be adapted by communities. In these lines, the present study has been focused on reviewing natural coagulants for water treatment owing to the disadvantages of chemical coagulants. Taking all the factors discussed above into consideration the present investigation carried out with *Musa paradisiaca* fruit peel powder as natural plant based coagulant for the removal of fluoride from synthetic and industrial waste water.

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Plant-Based Coagulants (PBC)

The PBC are broadly used for the cleaning of tainted water that is in less urbanized, in light of how they is clearly less passing on cost treated coagulates when emerged from phony. PBC coagulants are required to treat water appearing at medium turbidity go (50– 500) NTU. It is unforeseen that a flat out decisive examination of existing PBC is so far nonexistent in this 21st century. The significance of PBC to normal system at long last respect a moment zone for analyst in sustaining the examination to discover essential assets. Among PCB depicted explicitly, Peanut Seeds, Peanut Seeds powder and Cactus. Anionic polyelectrolytes are polymers of aloe Vera whose particles get clouded in water by through cover molecule cross. The seed expels contains – COOH and – OH groups that are equipped expansion the coagulation competency since lipids, sugars and alkaloids. Galactomannani and galactanii are blend of polysaccharide division that are expelled from Strychnospotatorum seeds which is skilled in decreasing turbidity up to 80%. In all viewpoints, the galactomannans are set up 1,4-related β-dmannopyranosyli residuum character end α-d-galactopyranosyl units related with 0– 6 point of some mannerresidue. Shelled nut Seeds , Peanut Seeds powder and its related coagulation process yet not been investigated, the closeness of boundless extent of – OH packs along chains of galactomannan and galactan gives unfortunately in any case plentiful adsorption that as time goes on lead to the past coagulant interparticle interfacing influence more research ought to be conceivable in this edges [5].

Cost of Plant-Based Coagulants

It has been explained in past bits that usage of plant based coagulants gives organic focal points and distinctive lab-scale considers have demonstrated that they are in assurance practical for little scale POU use. Notwithstanding, concerning commercialization, specifically it will dependably be set up in a general sense on whether the scale-up framework can continue proportional treatment execution at in every way that really matters undefined (or decreased) cost with the ordinary coagulants when separated and set up compound coagulants. There are a few portrayed reports that give the expenses of foul materials of the coagulants at any rate encourage associations with the degree coagulant types, Processing stages and costs in various geographical locales are an exceptionally puzzled undertaking given the specific trade rates, augmentation factor and fluctuating exactnesses of the costing respects. All things considered, the expenses imparted here ought to be treated as a sign as opposed to outright attributes. A concentrated review drove uncovers that costing examination of Peanut Seeds, Peanut Seeds powder has been given need over other ordinary coagulants and this is clear given the particularly advanced great states of the plant [5].

Aims & Objectives

The essential purpose of the present examination was to evaluate the coagulation furthest reaches of picked plant based coagulant *Musa paradisiaca* fruit peel powder natural products for the expulsion of fluoride in coagulation process. In order to achieve these going with targets are set and are inspected.

1. Affirmation of effects of different exploratory parameters like, contact time, introductory particle fixation, coagulant measurement and pH of the arrangement on coagulation and flocculation framework
2. Affirmation of coagulation active parameters, using model conditions available recorded as a hard copy on coagulation process.
3. Evaluation of fluoride ejection limit of *Musa paradisiaca* fruit peel powder natural products from industrial waste water.

MATERIALS & METHODS

Selection of coagulant for the removal of fluoride

The high measures of industrial effluents being discharged into a couple of water resources, with no pre treatment involve high union of fluoride [6]. Oftentimes in wealth of toxin center can't be cleared by direct fundamental treatment and can't be removed 100 % by other straightforwardness methodologies. This abnormal state of poisons departure can much of the time be cultivated by compound coagulation process in a manner of speaking. Along these lines, colossal quantities of the experts gave a record of electro-coagulative removal of chromium from different modern wastewaters [7 - 11] and expulsion of fluoride by salts of Al, Fe, Mg from drinking water [12-13]. These engineered mixes used in coagulation studies may achieve their destinations yet the examinations surmised that the usage of invention coagulants may changes the other water quality parameters. A couple of examinations induced that the excess proportion of Al salt satisfactorily ousting fluoride from drinking water yet it is changes the idea of water by extending electro conductivity and saltiness of the treated water [14-16]. As shown by WHO, high electro conductivity and saltiness containing water does not suits for drinking and other use. A couple of techniques have been represented to keep up a vital separation from the manufactured precipitation. A less data is available on usage of humble, ease, convincing and characteristic coagulants, for the removal of fluoride from watery arrangements. The advantages of the typical coagulants over the engineered and electro coagulants are according to the accompanying.

- Eco things got from plants and endless sources, adding to a viable and moderate water treatment.
- Plant based coagulants decay the volume of ooze and don't alter the pH of the water under treatment process.
- Non noxious and non ruinous eco things, accordingly contributes for long time systems for upkeeps of kinds of instruments utilized for treatment. Application on a broad pH expands (4 to 9), without modification of the spouting's pH.
- These plant based eco well disposed coagulants amazingly diminish the usage of acidic and stomach settling agent administrators realizing colossal saving of manufactured mixes.
- The effluents conductivity remains unaltered. This is imperative if there ought to be an event of osmosis process and in case of close circuit waters.

The material made consequently to remove fluoride from modern waste to made wastewater, biomass and diverse suspended solids. In this examination use of *Musa paradisiaca* fruit peel powder for expulsion of fluoride from industrial wastewater.

Musa paradisiaca

Kingdom : Plantae – Plants
Subkingdom : Tracheobionta – Vascular plants
Superdivision : Spermatophyta – Seed plants
Division : Magnoliophyta – Flowering plants
Class : Liliopsida – Monocotyledons
Subclass : Zingiberidae
Order : Zingiberales
Family : Musaceae – Banana family
Genus : *Musa* L. – banana
Species : Paradisiaca

Figure 1 *Musa paradisiaca,* plantation, fruits, dried peel and powdered peel

Musa paradisiaca, is a worldwide cultivating crop which produce a fruit generally called banana. Bananas are a popular fruit consumed worldwide with a yearly production of over 145 million tonnes in 2011. Once the peel is removed, the fruit can be eaten raw or cooked and the peel is generally discarded. Because of this removal of the banana peel, there is a significant amount of organic waste being generated. Banana peels are used as feedstock as they have some nutritional value. Banana peels are widely used for that purpose on small farms in regions where bananas are grown. There are some concerns over the impact of tannins contained in the peels on animals that consume them. The specific nutrition contained in peel depends on the stage of maturity and the cultivar; for example plantain peels contain less fibre than dessert banana peels, and lignin content increases with ripening (from 7 to 15 % dry matter). On average, banana peels contain 6-9 % dry matter of protein and 20-30 % fibre (measured as NDF). Green plantain peels contain 40 % starch that is transformed into sugars after ripening. Green banana peels contain much less starch (about 15 %) when green while ripe banana peels contain up to 30 % free sugars. Banana peels (Fig-1) are also used for water purification, to produce ethanol, cellulase, laccase and in composting. The literature survey reveals that starch is a good adsorbent for removal of fluoride. The starch, lignin and protein content in banana peel is more when compare to other coagulants studied previously. These bio molecules may help in removal of fluoride from water.

Preparation of Coagulant

The *Musa paradisiaca* peel, collected from juice centre located at local market of Hyderabad and washed with tap water followed by double distilled water to avoid the dust and soil particles. The cleaned peels were allowed to dry under sunlight for 12 days and cut into small pieces and ground into fine powder using domestic grinder. The powder was sieved to get uniform size of 250 mic and stored in glass bottle until it is used as coagulant.

Experimental Method

Preparation of fluoride standard curve

Into a series of 50 mL stand flask different fluoride solutions were taken and to this solution 5 mL of SPADNS reagent was added and the final volume was made up to the mark using distilled water. The Optical Density (O.D.) values were taken at 570 nm using spectrophotometer [17-25].

Determination of Optimum Coagulant Dosage

Affirmation of perfect coagulant estimation Jar test is commonly used strategy for surveying and propelling coagulation-flocculation process. This examination involves bunch tests including quick mixing (to dissipate coagulant bit) and moderate mixing (to enhance floc course of action and sedimentation for instance settling of surrounded floc). In the present examination all preliminaries were performed by using jar apparatus with aqueous solution of fluoride and particular constant amount of coagulant, are incorporated into a movement of 6 containers arranged on jar apparatus. The fluoride solutions are mixed rapidly for 20 minutes at standard 100 rpm speed sought after by 30 minutes moderate blending at standard 40 rpm speed for the game plan of flocs. Finally the flocs were allowed to consent to 40 minutes before pulling back the samples for examination [26-27]. In the present investigation all analyses were performed by utilizing jar apparatus with 4 mg/L fluoride concentration and diverse dose of coagulant (0.2, 0.5, 1.0, 1.5, 2.0 and 3.0 gm) are included into a progression of 6 containers situated on jar apparatus. The solutions are mixed quickly for 20 min. at standard 100 rpm speed pursued by 30 min. moderate blending at standard 40 rpm speed for the arrangement of flocs. At long last the flocs were permitted to make due with 40 min. before pulling back the samples for investigation. The last fluoride fixation after adsorption was straightforwardly estimated with spectrometer by utilizing SPADNS. To gauge the rate expulsion of fluoride from aqueous solutions the following formula has used.

$$\% \, Removal \, of \, Fluoride = \frac{C_{initial} - C_{final}}{C_{initial}} \, X \, 100$$

Effect of Initial Fluoride Concentration

To find the effect of fluoride concentration on coagulant, the tests are finished by taking different concentrations of fluoride solutions (reaching out from 1 mg/L- 8 mg/L) into a series of estimating jars arranged on jar apparatus. To the every single jar 1.0 gm of constant proportion of coagulant is incorporated. By then the tests are mixed rapidly for 20 min. at standard 100 rpm speed sought after by 30 min. moderate mixing at standard 40 rpm speed for the improvement of flocs. Finally the flocs were allowed to make due with 40 min. beforehand pulling back the samples for examination.

Effect of pH on Coagulation Process

To check the ideal pH for the evacuation of fluoride the tests were completed at various pH esteems. In this examination the coagulation were analyzed at the following pH esteems for example 3, 4, 5, 6, 7, 9, 10 and 11. The examinations are done by taking steady and constant measure of fluoride and coagulant dose i.e. 4 mg/L of fluoride and 1.0 gm of coagulant in all measuring jars and then the samples are mixed quickly for 20 minutes at standard 100 rpm speed pursued by 30 minutes slow mixing at standard 40 rpm speed for the development of flocs. At long last the flocs were permitted to make due with 40 minutes before pulling back the samples for examination.

All the receptive and chemical substances utilized in this examination were analytical grade and double distilled water used to be utilized in every one of the tests to prepare working standards. As a prudent exercise standard systems were pursued for test managing and arrangement [28]. All cleaned glassware drenched in 10% HNO_3 in a solitary day for fluoride evaluation and washed with distilled and deionized water before they had been utilized. The evaluation of the samples were done rapidly after arrangement and put away in a fridge for further investigation.

Coag-Flocculation Kinetics and Functional Parameters Response

Coag-flocculation is a center cleansing procedure, which finds wide scope of utilization in water and waste water treatment industries. Adroitly, Coagflocculation is the way toward adding substances to aqueous solution to make suspended particles to tie together (coagulate) and accordingly collecting into noticeable flocs (flocculation) that settle out of the water. This is accomplished when the balanced out particles are helped to beat their frightful powers to shape masses of flocs [29-32]. Among the elements that influence the procedure are crude effluent quality, temperature, pH, and so on [33]. Specifically, coag-flocculation related to other treatment forms is viewed as a reasonable choice for the treatment of aqueous solution. Coag-flocculation can be accomplished by any of the normal coagulants, for example, alum, lime and so forth. The Coag-flocculation practices of these normal mixes have been very much examined with practically no consideration given to the Coag-flocculation possibilities of bio and plant based. To this end, a center is thus given to the examination on chose plant based coagulants, as a potential wellspring of Coag-flocculation subsidiary for the evacuation of fluoride.

Theoretical Principles and Model Development for coagulation kinetics [34-36]

For a uniformly composed coag-flocculation phase with negligible influence of external forces

$$\mu_i = G_i = \left[\frac{dG}{dn_i}\right] P.T.n = a\ constant \ldots\ldots\ldots 1$$

Thus

$$d\mu_i = 0 \ldots\ldots\ldots 2$$

For each of the species *I* present

G is the total Gibbs free energy

n_i is the number of moles of component (i), for dilute solutions

$$\mu_i \approx \mu_i + RT \ln C_i \ldots\ldots\ldots 3$$

A Shift from the equilibrium generates diffusional process represented by

$$f_d = \frac{d_\mu}{d_x} \ldots\ldots\ldots 4$$

Recall K_B = R/N such that for sing N, K_B = R. Hence

$$\mu_i \approx \mu_i^0 + K_B T \ln C_i \ldots\ldots\ldots 5$$

Where KB is Boltzmann Constant

μ_i is Chemical Potential

R is Universal gas Constant

C_i is Concentration

N is Avogadro's Constant

x is diffusion distance

Combining equation 4 and 5 yield

$$f_d = \frac{d}{dx}(\mu_i^0 + K_B T \ln C_i \ldots\ldots\ldots 6$$

$$f_d = \frac{K_B}{C_i}\frac{dC_i}{dx} \ldots\ldots\ldots 7$$

The viscous drag force on the particles due to surrounding fluid is

$$f_d = BU_d \ldots\ldots\ldots 8 \text{ and}$$

$$J_i = CU_d \ldots\ldots\ldots 9$$

Where B is friction factor

U_d is terminal diffusing velocity

J_i is flux of diffusing material

f_d is drag force

From Fick's law

$$D' = \frac{-J}{(^{d_c}/_{d_x})} \ldots\ldots\ldots 10$$

Where D' is diffusion co-efficient. Combining equations 8, 9 & 10 yield

$$D' = \frac{-f_d}{B}\frac{c}{(^{d_c}/_{d_x})} \ldots\ldots\ldots 11$$

Comparing equations 7 and 11 generate Einstein's equation

$$D' = \frac{k_B T}{B} \ldots\ldots\ldots 12$$

For similar phase, the rate of successful collisions between particles of sizes *I* and *j* to form particle of size *k* is

$N_{i\,j} = \varepsilon_p\, \beta\,(i,j) n_i n_j$ ……….13

Where $N_{i\,j}$ is the rate of collision between particles of size I and j (mass concentration/time)

ε_p is collision efficiency

$\beta\,(i,j)$ is collision factor between particles of size *I* and *j*.

$n_i n_j$ is particle concentration for particles of size *I* and *j* respectively.

Assuming mono disperse, no break up and bi particle collision, the general model peri kinetic coag – flocculation is given as

$$\frac{dn_k}{d_t} = \frac{1}{2}\sum_{i+j=k} \beta\,(i,j) n_i n_j - \sum_{i=1}^{\infty} \beta\,(i,k) n_i n_k \text{ ……….14}$$

Where $\frac{dn_k}{d_t}$ is the rate of change of concentration of particle size k (concentration/time)

β is function of coag- flocculation transport mechanism. The appropriate value of β for Brownian transport is given by

$$\beta_{BR} = \frac{8}{3}\,\varepsilon_p\,\frac{k_B T}{n} \text{ ……….15}$$

Where K_B is Boltzmann's constant (J/K)

T is Absolute temperature (k)

The generic aggregation rate of particles (during coagulation/ flocculation) can be derived by the combination of equation 2 and 3 to yield

$$-\frac{dN_t}{d_t} = KN_t^{\propto} \text{ ……….16}$$

Where Nt is total particle concentration at time t

K is the α^{th} order coag – flocculation constant

A is the order of coag – flocculation process.

And $K = \frac{1}{2}\,\beta_{BR}$ ……….17

Where β_{BR} is collision factor for Brownian transport, also

$\beta_{BR} = \varepsilon_p K_R$ ……….18

Combining equations 4. 5 and 6 produce

$$-\frac{dN_t}{d_t} = \frac{1}{2}\beta_{BR} N_t^{\propto} \text{ ……….19}$$

$$= \frac{1}{2}\varepsilon_p K_R N_t^{\propto} \text{ ……….20}$$

Where K_R is the Von Smoluchowski rate constant for rapid coagulation. However

$K_R = 8\pi\, R\, D^{'}$ ……….21

$R_p = 2a$ ……….22

Where $D^{'}$ is particle diffusion coefficient

A is particle radius.

From Einstein's equation

$D^{'} = {}^{K_B T}/_{B}$ ……….23

From stroke's equation

$B = 6\pi n a$ ……….24

Where B is the friction factor and n is viscosity of the fluid.

Combining equation 21 to 24 gives

$$-\frac{dN_t}{d_t} = \frac{4}{3}\,\varepsilon_p\,\frac{K_B T}{n}\,N_t^{\propto} \text{ ……….25}$$

Comparing equations 16 and 25

$$K = \frac{4}{3}\,\varepsilon_p\,\frac{K_B T}{n} \text{ ……….26}$$

For peri kinetic aggregation, α theoretically equals 2 as would shown below

From Fick's law

$$J_f = D^{'}\, 4\pi\, R_p^2\, \frac{dN_t}{d_R} \text{ ……….27}$$

Integrating equation 27 at initial conditions $N_t = 0$, R = 2a

$\frac{J_f}{D^{'}4\pi}\int_0^{R_p}\frac{\delta R_p}{R_p^2} = \int_{N_0}^{N_t}\delta N_t$ ……….28. There fore

$J_f = 8\pi D^{'}\, a N_0$ ……….29

$$= \frac{1}{2}\,K_R\,N_0 \text{ ……….30}$$

For central particle of same size undergoing Brownian motion, the initial rate of rapid coag – flocculation is

$-\frac{dN_t}{d_t} = J_f\,\varepsilon_p\,N_0$ ……….31

$$\frac{1}{2} = K_R\,\varepsilon_p\,N_0^2$$

$$= \frac{4}{3}\,\varepsilon_p\,\frac{K_B T}{n}\,N_0^2 \text{ ……….32}$$

$$= \frac{4}{3}\,\varepsilon_p\,\frac{K_B T}{n}\,N_t^2 at\ t > 0$$

Hence, from equation 32, α =2. However in real practice, empirical evidences shows that in general $1 \le \alpha \le 2$. Based on this, what is required to evaluate 'K' is to determine the line of better fit between α = 1 and 2, while the experimental data are fitted into linearised form of equation. Hence for α = 1, equivalence of equation 16, yields

$$\frac{dN}{dt} = -kN \text{ ……….33}$$

Integrating within the limits produces

$\int_{N_0}^{N}\frac{dN}{dt} = -\int_0^t K dt$ ……….34. Hence

$\ln(\frac{1}{N}) = k_t - \ln N_0$ ……….35.

Plot ln (1/N) vs t gives a slop of K and intercept of (-ln N_0).

For α = 2, equivalence of equation 16 yields

$$\frac{dN}{dt} = -kN^2 \text{ ……….36}$$

$$\int_{N_0}^{N}\frac{dN}{dt} = -k\int_0^t dt \text{ ……….37}$$

$$\frac{1}{N} = k_t + \frac{1}{N_0} \text{ ……….38}$$

Plot ln (1/N) vs t gives a slop of K and intercept of $1/N_0$

For the evaluation of coagulation period ($\tau_{1/2}$), from equation 38

$$N = \frac{N_0}{1 + N_0 k_t} \dots\dots\dots 39$$

$$= \frac{N_0}{1 + \frac{t}{(1/N_0 K)}} \dots\dots\dots 40$$

Where

$$\tau = \left(1/_{N_0} K\right)$$

$$N = \frac{N_0}{1 + (t/\tau)} \dots\dots\dots 41$$

When t = τ the equation 41 becomes

$$N = \frac{N_0}{2} \dots\dots\dots 42$$

Therefore as N0 → 0.5 ; $\tau = \tau_{1/2}$

$$\tau_{1/2} = \frac{1}{0.5\, N_0 K} \dots\dots\dots 43$$ for second order and

$$\tau_{1/2} = \frac{\ln 2}{K} \dots\dots\dots 44$$ for first order

RESULTS

Determination of optimum coagulant dosage

The effect of coagulant dosage was investigated on coagulation of fluoride by *Musa paradisica* peel powder and results were presented in Fig-2. From the figure it is observed that the percentage removal of fluoride is increased with increase in coagulant dosage. This phenomenon is observed only to certain level. There is no significant removal of fluoride is observed in samples treated with > 0.4 g coagulant dosage [37 -39].

Effect of Initial Fluoride concentration on coagulation process

To find out the effect of initial fluoride ion concentration on coagulation process by *Musa paradisica* peel powder is done by taking different initial fluoride concentrations (1 to 8 mg/L) with optimum coagulant dosage. The experimental results were shown in Fig-3. From the figure it is observed that, with increase in concentration the removal rate also increased at these particular conditions. This can be explained by the theory of dilute solution. In dilute solutions formation of diffused layers on the vicinity of coagulation causes a slow reaction rate but in concentrated solution the diffused layer has no effect on the rate of diffusion or migration towards the ion surface [40 - 43].

Effect of pH

The effect of pH on coagulation of fluoride was studied by taking different pH solution maintained in the range of pH 3 to pH 11. The experimental results were shown in Fig-4. From the figure it is observed that the pH of the solution during coagulation effects chemistry of the coagulant. The best coagulation and uptake capacity of coagulant occurred at pH 3. At pH of higher than optimum pH, the charges produced from *Musa paradisica* peel powder for bridging and entrapping the microflocs to form larger flocs was very low. Thus adsorption on the surfaces of flocs formed was very less [44 – 47].

Efficiency (%) versus time (T) plots

The effect of contact time on removal of fluoride by *Musa paradisica* peel powder was shown in Fig-5. From the figure it is observed that the percentage removal of fluoride is increase with increase in contact time at all coagulant dosage. The same experiment conducted at a constant coagulant dosage by varying intital fluoride concentration from 1 -4 mg/L and the results were shown in Fig-6.

From the figure it is observed that the percentage removal of fluoride is increase with increase in contact time at all different intial fluoride concentrations. Further it is concluded that the percentage removal is high at higer concentrations compare to lower fluoride concentrations. A better efficiency was observed at coagulant dosage 0.4 - 0.8 g. Note that starting from *t*=5 min, there is virtually no variation in E (%) values at 0.4 g with the least E>70%, it confirms the effectiveness of *Musa paradisica* peel powder to remove fluoride from the aqueous solution.

Coagulation Kinetics

First Order Kinetic Model

The plot *log (a-x)* versus *time* representing the first order kinetic model for removal of fluoride by *Musa paradisica* peel powder at different coagulant dosage and at different initial fluoride concentrations, are shown in Fig-7 & 8.

From these figures it is observed that the lines were deviated from the linearity. The first order rate constant k_1 and concentration of metal C were calculated from slope and intercept of the plot. The correlation coefficient (R^2) values are in between 0.386 to 0.654 at different coagulant dosage and 0.417 to 0.648 at different initial fluoride concentrations, proving that the removal fluoride from aqueous solution using *Musa paradisica* peel powder by coagulation method is not applicable to first order kinetic model. The calculated constant values for first order kinetic model were shown in table-1 & 2.

The plot $1/N_t$ versus time, shows a linear relationship if the removal of fluoride using *Musa paradisica* peel powder by coagulation method. The second order kinetic models for present investigations (different coagulant dosage and different fluoride concentrations) were shown in Fig-9 & 10. From the figure it is observed that the removal process shown linearity at lower fluoride concentration and at higher coagulant dosage compared to higher concentration and lower coagulant dosage respectively.

The R^2 values of second order kinetic models at higher coagulant dosage and lower intial concentrations were compared with correlation values of first order kinetic model, which indicates that coagulative removal of fluoride by *Musa paradisica* peel powder is approximately fit into second order kinetic model. The second order rate constant K_2 and $1/N_o$ values were determined from the slope and intercept of the plot.

DISCUSSION

Coagulants are fabricated manufactured substances that water needs to help the procedure of precipitation of little scale particles that can't settle with no different substances. Reliably, mechanical treatment utilized inorganic coagulants, for example, alum, PAC, ferric chloride, ferric sulfate and cation polymer in their waste water treatment. Inorganic coagulants are more overwhelming than characteristic coagulants, in any case in high portions, they may cause enlivens that are hard to treat. This reason settles on common coagulant as a choice to supplant inorganic one. Plant seeds are ordinarily utilized as would be expected coagulants crude material.

Protein rich seeds and vegetative parts can be utilized as coagulant in light of the manner in which that the seeds protein content that goes about as a polyelectrolyte.

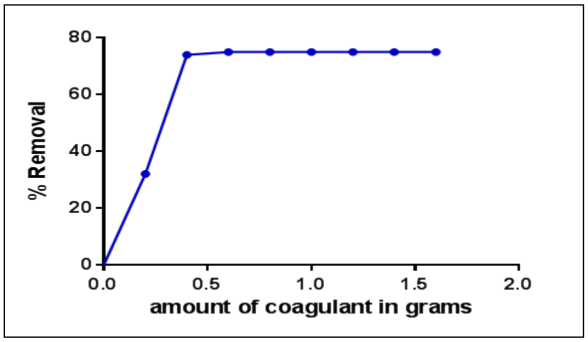

Figure 2 Effect of *Musa paradisica* peel powder dosage on fluoride removal

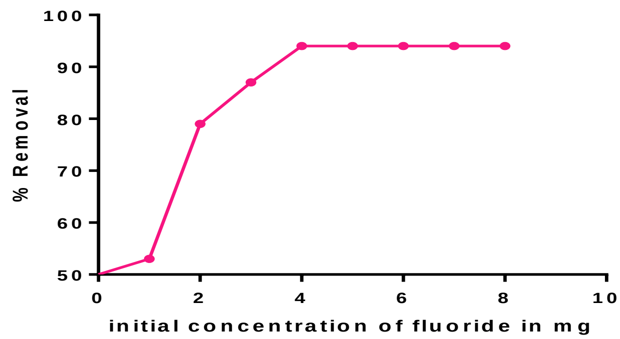

Figure 3 Effect of initial fluoride concentration on coagulation process using *Musa paradisica* peel powder

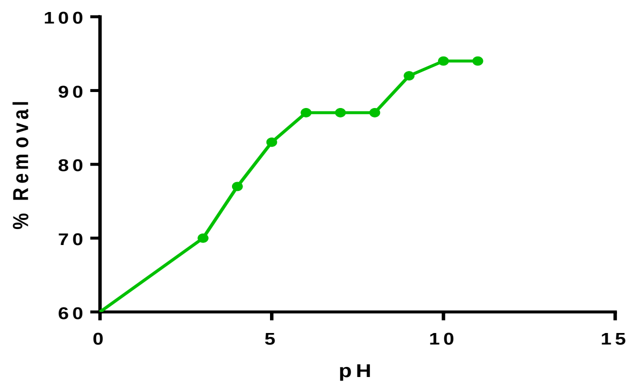

Figure 4 Effect of pH on fluoride removal using *Musa paradisica* peel powder

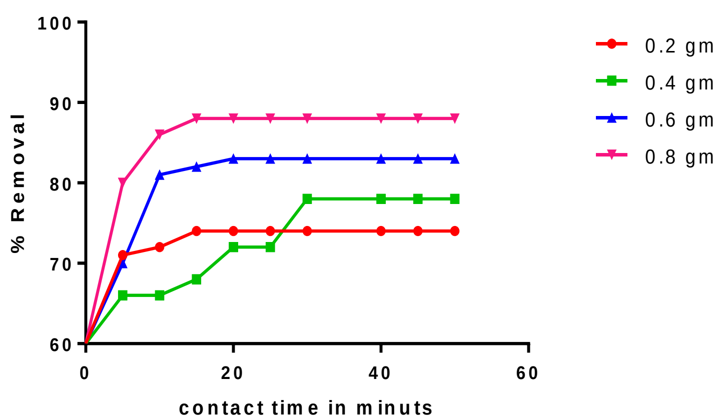

Figure 5 Effect of contact time on fluoride removal at different *Musa paradisica* peel powder dosage

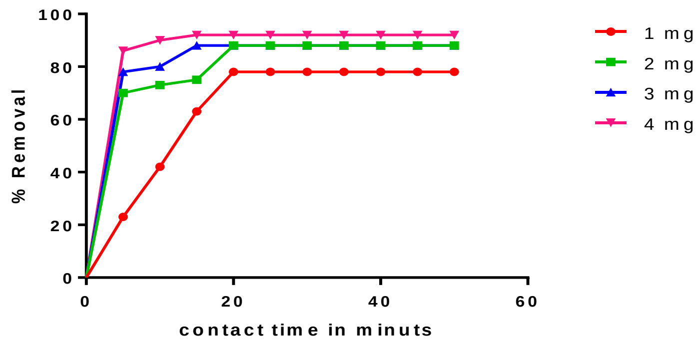

Figure 6 Effect of Contact time at different fluoride concentrations on % removal

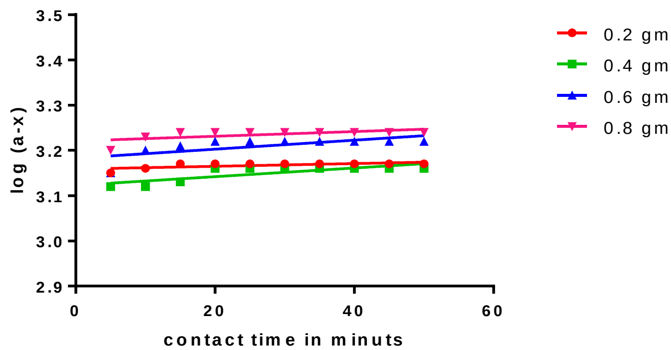

Figure 7 First order reaction for fluoride concentration at different coagulant dosage

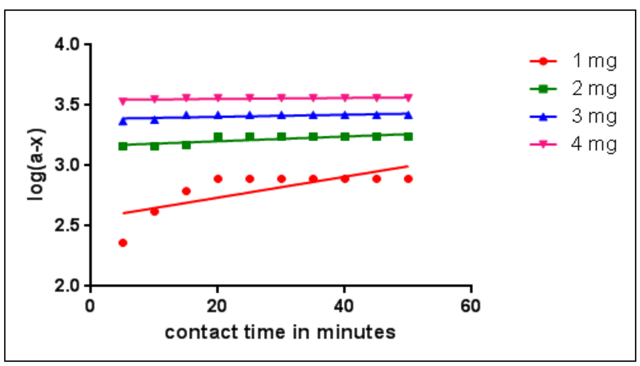

Figure 8 First order reaction for removal of fluoride at different fluoride concentrations Second Order Kinetic Model

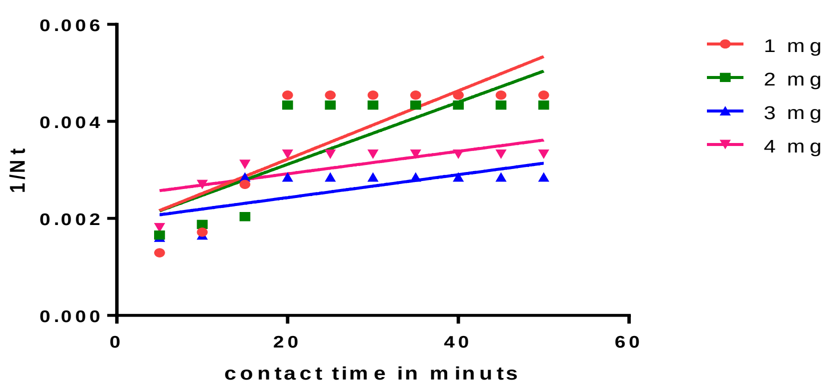

Figure 10 The second order kinetic model for fluoride removal at different fluoride concentration

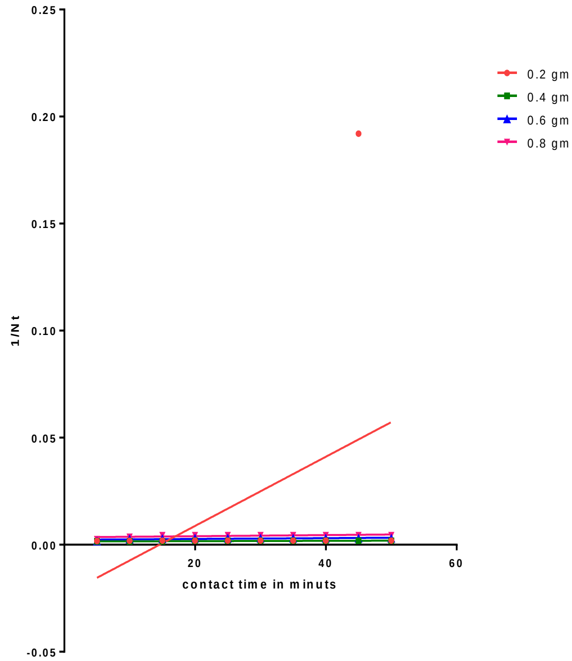

Figure 9 Second order kinetic model for removal of fluoride different coagulant dosage

Table 1 Coag-floculation functional parameters for varying dosage at constant fluoride concentration

Parameter	0.2 gm/L	0.4 gm/L	0.6 gm/L	0.8 gm/L
	First Order Kinetic Model			
R^2	0.461	0.654	0.463	0.386
K	3.03 x10^4	9.57 x10^4	9.93 x10^4	5.21 x10^4
β_{BR}	6.06 x10^4	19.14 x10^4	19.86 x10^4	10.42 x10^4
ε_p	30.82 x10^{21}	97.35 x10^{21}	101 x10^{21}	53.00 x10^{21}
$\tau_{1/2}$	2310	729.62	700.14	1332
	Second order Kinetic Model			
R^2	0.165	0.654	0.477	0.437
K	1.615 x 10^3	1.835 x 10^2	1.296 x 10^2	1.780 x 10^2
β_{BR}	3.23 x 10^3	3.67 x 10^2	2.592 x 10^2	3.56 x 10^2
ε_p	16.43 x10^{20}	18.66 x10^{19}	13.18 x10^{19}	18.10 x10^{19}
$\tau_{1/2}$	430.52	37.77	53.73	38.94

Table 2 Coag-floculation functional parameters for varying fluoride concentration at constant dosage of coagulant

Parameter	1mg/L	2mg/L	3mg/L	4mg/L
	First Order Kinetic Model			
R^2	0.549	0.648	0.490	0.417
K	8.66 x 10^3	1.97 x 10^3	8.84 x 10^4	4.12 x 10^4
β_{BR}	17.32 x 10^3	3.94 x 10^3	17.68 x 10^4	8.24 x 10^4
ε_p	88.10 x10^{20}	20.04 x10^{20}	89.93 x10^{21}	41.91 x10^{21}
$\tau_{1/2}$	80.59	364.81	866.4	1732
	Second order Kinetic Model			
R^2	0.655	0.651	0.487	0.505
K	4.75 x 10^2	4.31 x 10^2	1.59 x 10^2	1.56 x 10^2
β_{BR}	9.5 x 10^2	8.62 x 10^2	3.18 x 10^2	3.12 x 10^2
ε_p	48.32 x10^{19}	43.84 x10^{19}	16.17 x10^{19}	15.86 x10^{19}
$\tau_{1/2}$	14.59	16.08	43.59	44.43

Table 3 Removal efficiency of fluoride from Electro plating industrial wastewater with chemical coagulants

S.No	Name of the Coagulant	Coagulant dosage (mg)	Initial Fluoride Concentration (mg/L)	Residual Fluoride (mg/L)	Fluoride removal (%)
1	$AlCl_3$	100	4.4	3	31.8
2	$MgCl_2$	100	4.4	2.70	38.6
3	$FeCl_3$	100	4.4	3.35	23.8
4	*Musa paradisica* peel powder	100	4.4	2.55	42.0

As indicated by Dobrynin & Michael (2005), [48] polyelectrolytes are polymers that pass on positive or negative charges of ionized floc arrangement. In a polar dissolvable, for example, water, the gathering may seclude, leaving the charge on its polymer chain and discharging the restricting atom in arrangement. The expansion of a polyelectrolyte focus will result in reduced colloidal relentlessness and will diminish the dismissing power between particles to help the precipitation system. Coagulation is the making of fine particles that occurs because of its belongings. Compound responses are regularly separated. They have diverse side responses with different substances in the wastewater. Coagulation changes with different parts like pH, temperature and segment. The four fundamental systems related with this methodology are twofold layer pressure, charge balance, clear flocculation and adsorption. This system isn't possible in many creating nations in perspective of high settled capital and separation of produced/concoction coagulants. There are unbelievable courses of action of issues creating in perspective of the utilization of fabricated/manufactured or compound coagulants. Alum treated water contain leftover aluminum that prompts real restorative issues, for example, the progress of Alzheimer's sullying (AD) and feeble dementia. Moreover, utilizing of inorganic coagulants traps the managing and safe exchange endeavors. Because of these drawbacks of synthetic coagulants, normal bio and plant based coagulants are taking lift from condition's perspective. In addition, plant based coagulants produces biodegradable and least volume slop 20-30% that of substance coagulant. Bio based or plant based coagulants have been utilized for family unit for a broad time allotment in standard water treatment in tropical commonplace districts.

Because of the absence of legitimate water treatment procedures and systems in these country and immature networks, the best impel elective is to utilize clear and unassumingly fiscally insightful reason for use (POU) advances, for example, coagulation. Coagulation is an essential procedure in the treatment of both surface water and mechanical wastewater. Its application wires takeoff of isolated substance species and turbidity from water by techniques for advancement of typical concoction based coagulants, unequivocally, alum ($AlCl_3$), ferric chloride ($FeCl_3$) and poly aluminum chloride (PAC). While the plentifulness of these designed manufactured synthetic compounds as coagulants is particularly seen, there are, in any case, loads related with utilization of these coagulants, for example, inadequacy in low-temperature water, sensibly high anchoring costs, negative consequences for human flourishing, period of expansive slime volumes and the way in which that they in a general sense affect pH of treated water. There is in like way solid affirmation partner aluminum-based coagulants to the improvement of Alzheimer's sickness in individuals. It is from now on beguiling to override these substance coagulants with plant based coagulants to check the as of late referenced shortcomings.

Merits of Plant-Based Coagulants

The urgent great states of utilizing customary plant-based coagulants as POU water treatment material are undeniable; they are financially astute, impossible to make treated water with mind boggling pH and fundamentally biodegradable. These central focuses are particularly created if the plant from which his coagulant is expelled is indigenous to a country compose. In the season of biological change, usage of earth's standard assets and sweeping common corruption, utilization of these coagulants is an indispensable exertion according to the overall down to business improvement works out. Utilization of plant-based coagulants for turbid water treatment and deadly poison clearing comes back to more than several many years sooner and so far, organic masters have could perceive a few plant types thus. While it is authentic that the coagulants are gathered as basic adjacent POU advancement, there have in like way been diverse examinations centered around their utilization for treatment of present day wastewaters. The instruments related with various trademark coagulants are fluctuated as well. It is central for tremendous take holders to absolutely comprehend the nuances included while pondering the coagulants for ordinary, nuclear family or mechanical water treatment. To address this, this paper given a reasonable response for fluoride ejection and the trademark coagulant sources, strategies and instruments included with the target that normal managers can tailor its utilization for a horde of water contaminants for expressly fluoride departure. To give a progressively associated with talk, normal coagulants got from non-plant sources, for example, chitosan (completely produced using exoskeleton of shellfish) and isinglass (passed on from fish swim bladders) are restricted from this diagram. This evading depends upon practicability, since non plant sources are less arranged to have the potential for tremendous scale manufacturing emerged from plant sources. It is shocking to see that a complete fundamental examination of accessible plant-based coagulants is still non-existent given the centrality of supportable natural progression in the 21st century and ideally this survey can give a prompt stage to trademark pros to fabricate their examination on these customary materials.

Natural Plant-Based Coagulants and Coagulation Mechanisms

Polymeric coagulants can be cationic, anionic or non-ionic, in which the previous two are generally speaking named as polyelectrolytes. Different examinations concerning ordinary coagulants suggested them as 'polyelectrolytes' paying little respect to the manner in which that a broad bundle of these examinations did not by any stretch of the creative energy direct in-depth made portrayal to pick their ionic movement. Everything considered, this term ought to be utilized watchfully, and be related soon after ionic improvement is embarked to be open in the coagulant. Commonplace coagulants are generally either polysaccharides or proteins. If all else fails, regardless of the manner in which that polymers set apart as non-ionic are less absent of charged relationship, as there might be connection between the polymer and a dissolvable inside an answer space as the polymer may contain for the most part charged social events including – OH along its chain. It is basic to absolutely comprehend the critical coagulation instruments related with these essential coagulants so full scale exchange the running with bits. The closeness of foundation electrolytes in watery medium can enable the coagulating impact of polymeric coagulants since there is lesser electrostatic awfulness between particles. However many plant-based coagulants have been spoken to, just four sorts are regularly outstanding inside standard researchers, to be unequivocal, Nirmali seeds (Strychnos potatorum), Moringaoleifera, Tannin and Cactus. Discernment of their utilization can be understands it. Social affair of Particulates in an answer can happen through four fantastic coagulation structures: (a) twofold layer weight; (b) clear flocculation; (c) adsorption and charge balance; and (d) adsorption and cover iota navigate. The closeness of salts [or fitting coagulants] can cause load of the twofold layer which destabilizes the particulates. Range flocculation happens when a coagulant encapsulates suspended particulates in a delicate colloidal floc. Adsorption and charge balance recommend the sorption of two particulates with oppositely charged particles while cover molecule navigate happens when a coagulant gives a polymeric chain which sorbs particulates. Polymeric coagulants are for the most part connected with systems (c) and (d) as their since quite a while earlier binded structures (particularly polymers with high atomic weights) astoundingly increment the measure of void adsorption territories. It gives that these two instruments give basic checks to the internal undertakings of plant based coagulants too and they are the purpose of intermingling of exchange the running with bits. The proximity of foundation electrolytes in watery medium can enable the coagulating impact of polymeric coagulants since there is lesser electrostatic horrendousness between particles. In any case, many plant-based coagulants have been spoken to, just four sorts are commonly well-known inside set up researchers, to be express, Nirmali seeds (Strychnos potatorum), Moringa oleifera, Tannin and Cactus, Peanuts, Aloe vera, mung Bean.

Application

The developed method was applied for electroplating industry wastewater (which has 4.40 mg/L fluoride) was treated with 0.1 g of *Musa paradisica* peel powder and removal efficiency was found to be promising when compared with chemical coagulants like $AlCl_3$, $MgCl_2$ and $FeCl_3$. Results were shown in table-3.

REFERENCES

1. Haydar S and Aziz J. A., Coagulation flocculation studies of tannery wastewater using combination of alum with cationic and anionic polymers., J. Haz. mat., 168(2- 3), 1035-1040, (2009).
2. Gayatri S. L., Vinay B.M., Ranade V.V., Industrial wastewater treatment - Removal of acid from wastewater, J. Environ. Res. Develop., 8(3A), 697-704, (2014).
3. Jonnalagadda S.B., Srinivasu N. and Pare B., Water treatment and industrial bleaching: Scope of chlorine dioxide, J. Environ. Res. Develop., 8(4), 956-963, (2014).
4. Shah Parin D. and Kavathia S., Development and application of hybrid materials in coagulation and flocculation of wastewater, J. Environ. Res. Develop., 9(4), 1218-1224, (2015).
5. Subramani T, Kathirvel C , Harris Mohamed H , Mohamed Nowfis M, Niyasdeen A. Plant Based Coagulant For Waste Water Treatment. International Journal of Emerging Trends & Technology in Computer Science. (2018) 7(2), 177-185.
6. Manjusha A, Gandhi N, Sirisha D. Removal of Chromium (VI) from Paint Manufacturing Industry Wastewater by using Papaya Peel Powder, Inter. J. Pharma World Res. 3 (2012) 1 – 9.
7. Rezaee A, Hossini H, Masoumbeigi H, Darvishi Cheshmeh R. Simultaneous Removal of Hexavalent Chromium and Nitrate from Wastewater using Electrocoagulation Method. Inter. J. Envir. Sci. Develop. 2 (2011) 1 – 5.
8. Sadeghi S. Moghadaam M.R, Arami M. Performance of polyaluminum chloride on removal of hexavalant chromium from synthetic wastewater. 3rd inter. Confer. Envi. Plann. Mange. 26th November (2013).
9. Feng Ting L.I, Xia L.I, Zhang B.R, Ouyang Q.H. Removal of heavy metals in effluents by adsorption and coagulation. Chinese Chem. Let. 15 (2004) 83 – 86.
10. Beyazit N. Copper (II), Chromium (VI), and Nickel (II) removal from metal platting effluent by electro-coagulation, Inter. J. Electro Chem. Sci. 9 (2014) 4315 – 4330.
11. Kashefi asl M, Moshtaghi M, Hassani A.H. Efficiency evaluation of electro coagulation process for removal of chromium (Heavy metal) from municipal and industrial wastewater. Indian. J. Sci. Res. 7 (2014) 1258 – 1268.
12. Amuda O.S, Amoo I.A, Ipinmoroti K.O, Ajayi O.O. Coagulation/flocculation process in the removal of trace metals present in industrial wastewater. J. Appl. Sci. Enviro. Mang. 10 (2006) 159 – 162.
13. Zhu J, Zhao H, Ni J. Fluoride distribution in electro coagulation defluoridation process, Sep. Puri. Tech. 56 (2007) 184 – 191.
14. Gang W.X, JQu H, R.P. Liu, H.C. Lan, Effect of aluminium fluoride complexation on fluoride removal by coagulation. Collodes and Surfaces – A, Phys. Eng. Asp. 395 (2012) 88 – 93.
15. Gumbo F.J, Mkongo G. Water defluoridation for rural fluoride affected communities in Tanzania. 1st International workshop on fluorosis prevention and defluoridation of water. Auckland (1995) 109 – 114.
16. Dahi E. Development of the contact precipitation method for appropriate defluoridation of water. 2nd international workshop on fluorosis prevention and defluoridation of water, Denmark (2000) 128 – 137.
17. Gandhi N, Sirisha D and K.B. Chandra sekhar and Smita Asthana. Removal of fluoride from water and waste water by using low cost adsorbents. International Journal of Chem Tech Research, (2012) Vol. 4(4); pp 1646-1653.
18. Gandhi N, Sirisha D, Smita Asthana and Manjusha A. Adsorption studies of fluoride on multani matti and red soil. Research Journal of Chemical Sciences, (2012) Vol. 2(10); pp 1-4.
19. Gandhi N, Sirisha D and K.B. Chandra sekhar. Phytoremediation of Chromium and Fluoride in Industrial wastewater by using aquatic plant *Ipomea aquatica*. South pacific journal of Pharma and Bio Sciences, (2013) Vol. 1(1), 001-004.
20. Gandhi N, Sirisha D and K.B. Chandra sekhar. Adsorption of Fluoride from aqueous solution by using chalk powder. World Journal of Pharmacy and Pharmaceutical Sciences, (2013)Vol. 2(5), 3897-3914.
21. Gandhi N, Sirisha D and Sarita P. Selection of Coagulants for Controlling Fluoride in Water Samples of Nalgonda District, Telangana, India. Continental Journal of Applied Sciences. (2015) 10(2): 26-34.
22. Gandhi N, Sirisha D, Smita Asthana. Phytoremediation of Fluoride (F^-) from water using germinated seeds. International journal of advanced Research in Engineering and Applied Sciences. (2016) Vol. 5 (7), 16 – 28.
23. Gandhi N, Sirisha D and K.B. Chandra sekhar. Adsorption of Fluoride (F^-) from Aqueous Solution by using Pineapple (*Ananas comosus*) and Orange (*Citrus sinensis*) peel Powders. International Journal of Environmental Bioremediation and Biodegradation. (2016) Vol. 4(2), 55 – 67.
24. Gandhi N, Sirisha D and K.B. Chandra sekhar. Adsorption of Fluoride (F^-) from Aqueous Solution by using Horse gram (*Macrotyloma uniflorum*) seed Powder. . N. Gandhi, D. Sirisha and K.B. Chandra Sekhar. International Journal of Engineering and Technical Research. (2016) Vol. 5 (3), 54 – 62.
25. Gandhi N, Sirisha D and K.B. Chandra sekhar. Adsorption of Fluoride (F-) from Aqueous Solution by using Ragi (*Eleusine coracana*) seed Powder. Journal of Chemical and Pharmaceutical Research. (2016) Vol. 8 (7), 127 – 141.
26. Haydar S, Aziz A.J. Coagulation and Flocculation Studies of Tannery Wastewater using Combination of Alum with Cationic and Anionic Polymers, J. Hazar. Mater. 168 (2009)
27. Hanif A.M., Nadeem R., Zafar N.M., Bhatti N.H., R. Nawaz, Physico Chemical Treatment of Textile Wastewater using Natural Coagulant Cassia fistula (golden Shower) Pod Biomass. J. Chem. Soci. Pakistan, 30 (2008) 385 – 393.
28. American Public Health Association (APHA), (1998); Standard methods for the exmination of water and waste water; 20th edition, Washington.
29. Ma J.J, Li G, G.R. Chen, G.O. Xu, G.Q. Cai, Enhanced coagulation of surface waters with high organic content by permanganate perooxidation. Water science and Technology: Water Supply, 1 (2001) 51-61.
30. Diterlizzi S.D., Introduction to Coagulation and Flocculation of Waste water, Environmental System Project, U.S.A, (1994) 1-4.
31. Edzwald J.K., Coagulation – sedimentation filtration process for removing organic substances in drinking and waste water. Noyes Data Corporation, Park Bridge, New Jersey, (1987) 26-27.
32. Meila C.R. Coagulation in waste water treatment: The scientific basis

of flocculation (NATO Advanced study Inst. Series E,Appl.Sc.No 27), In : Sijtholf and Noordhoff, Alpenan den Rijn, (1978) 219-268.
33. Jin Y., Use of high Resolution Photographic Technique for studying Coagulation/flocculation in water treatment, M.Sc thesis, University of Saskatchewan, Saskatoon, Canada. (2005)
34. Ugonabo V.I, Menkiti, M.C. Osoka, E.C, Atuanya, C.U and Onukwuli, O.D. Kinetic Modeling and Functional Parameters Evaluation of Mass Transfer Rate on Bio Coagulant Interface in Pharmaceutical Industry Effluent. International Journal of Basic & Applied Sciences, (2013) 13(3), 33-47.
35. Ugonabo V.I, Menkiti M.C, Onukwuli O.D. Kinetics and coagulation performance of snail shell biomass in pharmaceutical Effluent. IOSR Journal of Engineering, (2012) 2(7), 38-49.
36. Ugonabo V.I, Menkiti M.C, Onukwuli O.D. Coagulation Kinetics and Performance Evaluation of Corchorus Olitorus Seed in Pharmaceutical Effluent. International Journal of Multidisciplinary Sciences and Engineering, (2012) 3 (7), 20-32.
37. Sadasivan pillai P, Hari Kumar, Jasseela C, Megha T. Defluoridation of water using biosorbents, water quality division, Centre for water resources development and management, Kozhikode, India, Natural Sci. 4 (2012) 245 – 251.
38. Krishnaveni V, Ravidhranath K. Removal of Chromium (VI) from polluted waters using powders of leaves or their ashes of some herbal plants. J. Exper. Sci. 3 (2012) 01 – 09.
39. Derived from FAOSTAT, Food and Agriculture Organization of the United Nations. The data for bananas and plantains for 2011 were combined as the two are distinguished by some countries but combined under bananas by others.
40. Babatunde G.M, Availability of banana and plantain products for animal feeding In D Machin, S. Nyvold: roots, tuber, plantains and bananas in animal feeding. Proceeding of FAO expert consultation held in CIAT, Colombia, FAO, animal production and health paper 95, FAO, Rome, (1992).
41. Emaga T.H, J. Bindelle, R. Agaeesens, A. Bulden, B. Wathelel, M. Paquot, Ripening influences banana and plantain peels composition and energy content. Trop. Anim. Healt. Prod. 43 (2011) 171 – 177.
42. Onwuka C.F.I, P.O. Adetiloye, C.A. Afolami, Use of house hold wastes and crop residues in small ruminant feeding in Nigeria. Small rumin. Res. 24 (1997) 233 – 237.
43. Chaparadza A, J.M. Hossenlopp, Adsorption kinetics, isotherms and thermodynamics of atrazine removal using banana peel based sorbent, Water Sci. Tech. 65 (2012) 940 – 947.
44. Oberi H.S, P.V. Vadlani, L. Saida, S. Bansal, J.D. Hughes, Ethanol production from banana peel using statistically optimized simultaneous saccharification and fermentation process. Waste management. 31 (2011) 1576 – 1584.
45. Sun H.V, L. Juanhu, P. Zhao, M. Peng. Novel substrates for cellulose production under solid state fermentation, Applied Biochem. Biotech. 165 (2011) 204 – 210.
46. Vivekanand V, P. Dwivedi, N. Pareek, R.P. Sing, A potential substarte for laccase production by Aspergillus fumingatus vkj2.4.5 in solid state fermentation, African J. Biotech. 10 (2011) 1788 – 1799.
47. Kalemelawa F, E. Nishihara, T. Endo, Z. Ahmad, R. Yeasmin, M.M. Tenywa, S. Yamamoto, An evaluation of aerobic and anaerobic composition of banana peel treated with different inoculums for soil nutrient replenishment. Biores. Tech. 126 (2012) 375 – 382.
48. Dobrynin, A. V., & Rubinstein, M. (2005). Theory of polyelectrolytes in solutions and at surfaces. Progress in Polymer Science (Oxford), 30(11), 1049-1118.

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