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A Comparative Study on Optimization of Coagulant dose in Treating Godavari water with Different Coagulants

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ABSTRACT

Kakinada town in coastal Andhra Pradesh with a population of about 18,000 in 1870 has grown to about 300,000 by 1991 and at present according to census 2011 of about 5,43,000, is expected to touch 1,000,000 by 2040. In this project the municipal water supply system of Kakinada is studied with special reference to chemical treatment of raw water supply from a surface water source from Samalkot near Kakinada. The main objective of this project is to optimize coagulant dose by using chemicals like alum, copperas and compare with natural coagulants/aids like Nirmali seed extract, Moringa oleifera seed powder in the treatment of Godavari water, which may help in minimizing the negative impacts of excess usage of chemicals on the Environment. The usage of natural coagulants not only reduces cost of chemicals but also reduces the potentiality of exposure of individuals to these dangerous chemicals if used in excess. Environmentally the chemical coagulants pose the exposure of dangerous ions like Al^{3+} and Iron causing diseases like Dementia or Alzheimer's disease in humans consuming this water containing more quantities of these ions. The improper disposal of the sludge containing more concentration of these ions into the Environment also results in Bio-magnification in Ecosystem.

Key words: ***Bio-magnification, Chemical Coagulants, Natural coagulants, Godavari water, Water treatment.***

I.INTRODUCTION

Water is the most important natural resource which forms an essential nutrient for the survival of life on the earth. Man can survive for 5 weeks without food but for less than five days without water. It is the only inorganic fluid in this universe and has a relative density of unity. Water is essential for digestion, dissolving nutrients and distributing them to cells, regulating the body temperature, removing the wastes in the body through tears, perspiration, urine and faeces and for lubricating the joints. Public water or drinking water must be palatable and wholesome. It must be attractive to senses of sight, taste and smell and must be hygienically safe. Man needs water for domestic purposes such as cooking, cleaning utensils, gardening, washing clothes and above all for drinking. He also needs it for commercial, industrial and recreational purposes. The water used by him should be of good quality. Polluted water is one which is unsuitable for its intended use. Urbanization and industrialization have directly or indirectly polluted most of the water sources on a global scale. The impurities in water are to be removed to such an extent, so that it is not harmful to public health. The concentrations of different substances are expressed in mg/l or ppm. The term 'wholesome water' or 'potable water' is used to

indicate quality of water that is not unsafe. The water collected directly from the source may not be safe for drinking because of physical, chemical and biological impurities. The municipal water works must deliver to the consumer the water that is: 1) hygienically safe, 2) aesthetically attractive and palatable, and (3) economically satisfactory for its intended use. Diseases like typhoid, cholera, dysentery etc. are water borne diseases. The principal aim of the purification works is to supply clean and bacteria free water.

The common components of water purification works are: 1) Filtration plants to remove objectionable color, turbidity, bacteria and other harmful organisms, (ii) Deferrization and demanganization plants to remove excessive amounts of iron and manganese, and (iii) Softening plants to remove excessive amounts of scale forming, soap consuming ingredients like calcium and magnesium ions.

Impurities in water are classified into three heads:

1. Suspended impurities.
2. Dissolved impurities.
3. Colloidal impurities.

Suspended impurities are those which normally remain in suspension. They are microscopic and make water turbid. Dissolved impurities are not visible, but they are large since water is good solvent. They cause bad taste, hardness and alkalinity. Sometimes, they are harmful. Colloidal impurities are electrically charged. Due to this, the colloidal particles, usually very small in size, remain in constant motion and do not settle. The purpose of water treatment is to remove all those impurities which are objectionable either from taste and odor point of view or from public health point of view.

The treatment of Surface water from rivers, lakes, ponds etc., includes the following procedures as shown on the following Flow chart.

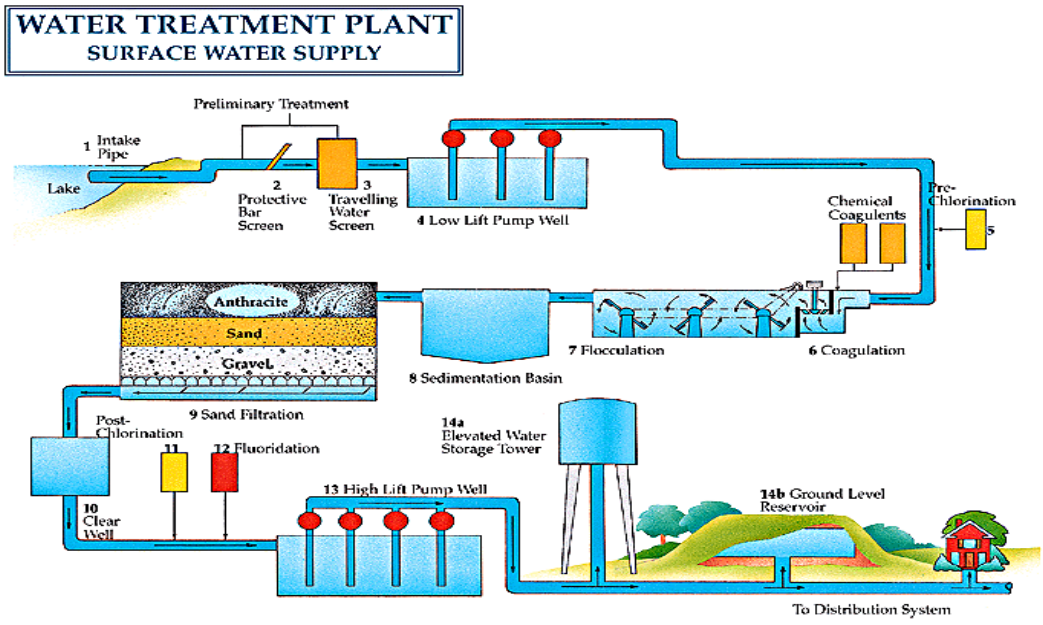

Fig 1: Flowchart for the treatment of surface water sources

II. PRESENT STUDY

The present study is based mainly on **Coagulation and Flocculation processes** of treatment which forms the basis for chemical treatment in municipal water supply system. Hydrolyzing coagulants (such as aluminum and iron salts) have been used for centuries in water purification. Theories as to the nature of the interaction with various colloidal impurities have changed over the years from the early concept of simple enmeshment by the gelatinous hydroxides to invocation of the Schulze-Hardy rule, followed by emphasis upon the properties of hydrolysis products, and finally, specific chemical interactions and various absorption model. The hydrolysis of polyvalent metal ions in aqueous solution has been studied in detail by many investigators, with considerable attention devoted to those ions of interest in coagulation. Most of the natural polymers and their derivatives used as coagulant aids are based on a polysaccharide skeleton and have anionic properties derived from the presence of carboxyl groups. The molecular weight of these materials may be up to 10^5. Not much is known about the flocculating properties of protienaceous substances such as gelatins and glues, and these have not yet found any significant use in water treatment. A larger number of synthetic polyelectrolytes are commercially available, ranging in molecular weight from 10^4 to 10^7. The exact formulation of any of these products is a matter of commercially secrecy. One advantage that natural polymers have is that they are nontoxic.

The engineering management of coagulation by the use of synthetic and natural polyelectrolyte is the most important development in the clarification of drinking waters. However, the usage of natural polyelectrolyte was known to ancient Indians as far back as 4000 years. In Sanskrit literature (about 2000 B.C.), use of many plant substances, notably Nirmali seed (Strychonos potatorum), is mentioned as a means of clarifying water. In a similar manner Moringa oleifera seed is a native tree of the sub-Himalayan parts of Northwest India, Pakistan and Afghanistan. Moringa oleifera is a perfect example of a so called “Multipurpose tree”. Earlier studies have found Moringa to be non-toxic and recommended it for use as a coagulant in developing countries. The use of Moringa has an added advantage over the chemical treatment of water because it is biological and has been reported as edible.

A paste made from Nirmali seed precipitates suspended siliceous impurities in raw water. Subbaramaiah and Sanjiv Rao found from electrophoretic measurements that the paste carried a weak negative charge. These authors studied the action of strychrine and albumin on synthetic turbid water and concluded that coagulation of turbidity by the paste is due to the presence of these two ingredients. Sen and Bulusu showed the extract of Nirmali seed to the effective as coagulant and coagulant aid it producing well defined flocs with rapid setting characteristics for all pH values for naturally occurring turbid water.

The pilot plant studies carried out by Bulusu and Sharma conclusively proved the efficiency of Nirmali seed extract as an aid to alum. Dhekane and others found out the optimum pH and dose of Nirmali seed and concluded that this can be used mainly as coagulant. They showed the nontoxicity of the extract and tried its chloroderivatives in the removal of bacteria. Rao and Sastry also concluded it to be a coagulant aid in turbidity and color removal.. Most of the above workers have studied the use of Nirmali seed extract either as coagulant or coagulant aid but none of them mentioned about mechanism of removal.

Results of full scale treatment trials using M.oleifera as the sole coagulant are presented. The study was conducted in February 1994 at the Thyolo treatment works in southern Malawi under the auspices of the

Ministry of Water Works Department. The works comprises flocculator-clarifiers, rapid gravity filters followed by chlorination. Imported alum and soda ash are the coagulants normally used on the works. When replaced by M.oleifera seed solution comparable treatment performance was achieved. This is the first time that any naturally derived material has been successfully used as a primary coagulant on such a scale (works flow 60 m3/hour) with the treated water entering supply. Inlet turbidities during the trials ranged between 270 and 380 NTU. Finished water turbidity was consistently below 4 NTU.

According to Suleyman et.all. hardness removal efficiency of Moringa oleifera was found to increase with increasing dosage. *M.oleifera* seeds act as a natural absorbents and anti microbial agent. Its seed contain 1% active polyelectrolyte's that neutralize the negative charged colloid in the dirty water. This protein can therefore be non toxic natural polypeptide forced sedimentation of mineral particles and organics in the purification of drinking water. M. oleifera seeds are also acting as antimicrobial agent against variety range of bacteria and fungi. The seed contain number of benzyl isothiocyanate and benzyl glucosinolate which act as antibiotic. It is believed that the seed is an organic natural polymer. The active ingredients are dimeric proteins. The protein powder is stable and totally soluble in water. The coagulation mechanism of the M. Oleifera coagulant protein has been explained in different ways. It has been described as adsorption and charge neutralization and interparticle bridging. Flocculation by inter-particle bridging is mainly characteristic of high molecular weight polyelectrolytes. Due to the small size of the *M. oleifera* coagulant protein, abridging effect may not be considered as the likely coagulation mechanism. *Moringa* seeds possess antimicrobial properties reported that a recombinant protein in the seed is able to flocculate gram-positive and gram-negative bacterial cells. In this case, microorganisms can be removed by settling in the same manner as the removal of colloids in properly coagulated and flocculated water. On the other hand, the seeds may also act directly upon microorganisms and result in growth inhibition. Antimicrobial peptides are thought to act by disrupting the cell membrane or by inhibiting essential enzymes reported that Moringa seeds could inhibit the replication of bacteriophages.

III.MATERIALS AND METHODS

3.1 1% Alum Solution

1.0000 gm of Alum powder was taken in 10 ml of distilled water and is dissolved in it. This volume is made up to 100 ml in a volumetric flask and stored. 1 ml of this solution contains 10 mg/l of alum in it.

Fig 2: Alum Solid

Fig 3: Alum Solution

3.2 1% Ferric Chloride Solution

1.000gms of Ferric chloride is weighed and is taken in 10ml of distilled water and is dissolved in it. The volume is made up to 100ml in a volumetric flask and stored. 1ml of this solution contains 10mg/l of ferric chloride in it.

Fig 4: Ferric Chloride powder

Fig 5: Ferric Chloride Solution

3.3 1% Nirmali Seed Extract

1.0000 gm of Nirmali seed powder is taken in 10 ml of distilled water and blended for 10 min at high speed. This volume is made up to 100 ml and 0.5 ml of HCl is added to preserve against bacterial decomposition. The extract is ready for use and is stored in refrigerator. Alternatively the seeds are rubbed over wet hard surface to give a wet paste of the seed which is similarly weighed and solution is prepared by taking 1 gm of it and dissolving in 10 ml of distilled water and finally the volume is made upto100 ml and stored in the refrigerator.

Fig 6: Nirmali Seeds

Fig 7: Nirmali Seed Extract

3.4 Preparation of Moringa Oleifera Seed Extract

Initially Moringa seeds are taken out from the green pods. These seeds are shelled and powdered. The powdered Moringa is then sieved through 0.8 mm sieve. 1.0000 gm of Moringa seed powder is taken in 10 ml of distilled water and blended for 10 min at high speed. This volume is made up to 100 ml and 0.5 ml of HCl is added to preserve against bacterial decomposition. The extract is ready for use and is stored in refrigerator.

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Fig 8: Moringa oleifera seeds

Fig 9: Moringa oleifera powdered form

IV.ANALYSES

4.1 Analyses of Various Parameters in the Water Samples

S.No	Parameter	Sample I	Sample II	Sample III
1.	pH	7.5	7.6	6.8
2.	Turbidity (NTU)	13.5	50	80
3.	Conductivity (micromhos/cm)	533	545	550
4.	Iron (mg/l)	0.06	0.061	0.06
5.	Nitrate (mg/l)	1.5	1.48	1.5
6.	Sulphate (mg/l)	11	12	11.5
7.	Fluoride (mg/l)	0	0	0
8.	Calcium (mg/l)	4.02	4.15	4.02
9.	Hardness as $CaCO_3$ (mg/l)	180	190	185
10.	Alkalinity as $CaCO_3$ (mg/l)	80	90	85

Table 1: Analysis of Parameters in Water Samples

The analysis of water samples collected from Sambamurty reservoir from Samalkot (SS tank) is taken as raw water sample I, Godavari river water is taken as sample II, and recycled water as sample III, is carried on at Victoria Water Works, Kakinada.

4.2 Comparison of Action of Various Coagulants in Removing Turbidity from Water Sample II

Initially the removal of turbidity by using 1% alum solution is studied in all the Godavari river water sample (Sample II) by Jar test and the observations with optimum doses are noted and in a similar way doses of Nirmali seed extract, combination of Nirmali seed extract and Alum, Copperas and Moringa oleifera solutions are observed and noted as shown below.

S.No	Coagulant used	Optimum Dosage of coagulant(mg/l)	Original turbidity (NTU)	Residual Turbidity (NTU)	pH
1	Alum	30	50	3.05	7.5
2	Nirmali seed extract	30	50	5.5	7.3
3	Alum + Nirmali seed extract	15 + 15	50	3.5	7.5
4	Copperas	25	50	5.2	7.5
5	Moringa oleifera	25	50	5	7.2

Table 2: Optimum Coagulant dose of various Coagulants

V. RESULTS AND DISCUSSIONS

5.1 Efficiency of Alum as a Coagulant in Water Treatment

Initially the removal of turbidity by using 1% alum solution is studied in water sample II by Jar test and the observations are plotted as shown in the following graph below.

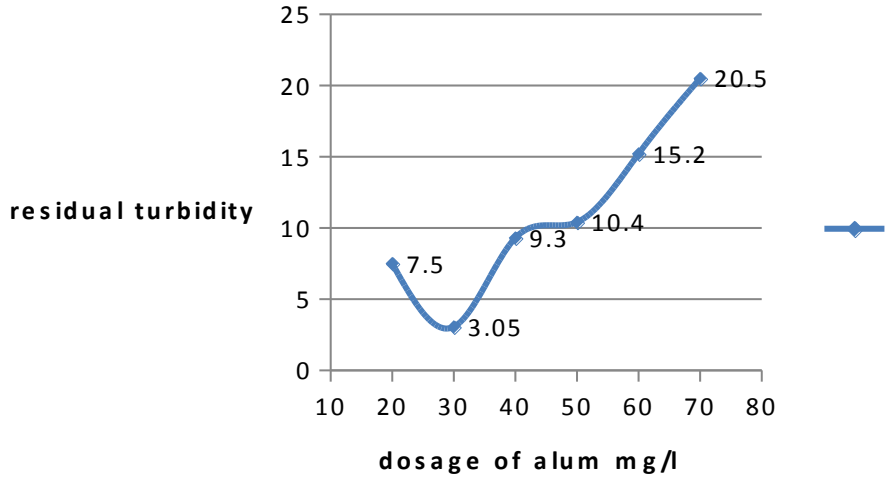

Fig1: Graph of optimum dose of Alum in Water Treatment

5.2 Efficiency of Nirmali Seed Extract as a Coagulant

Nirmali seed extract is taken in the similar manner as alum solution and its efficiency is observed in the Water sample II and results are plotted as follows.

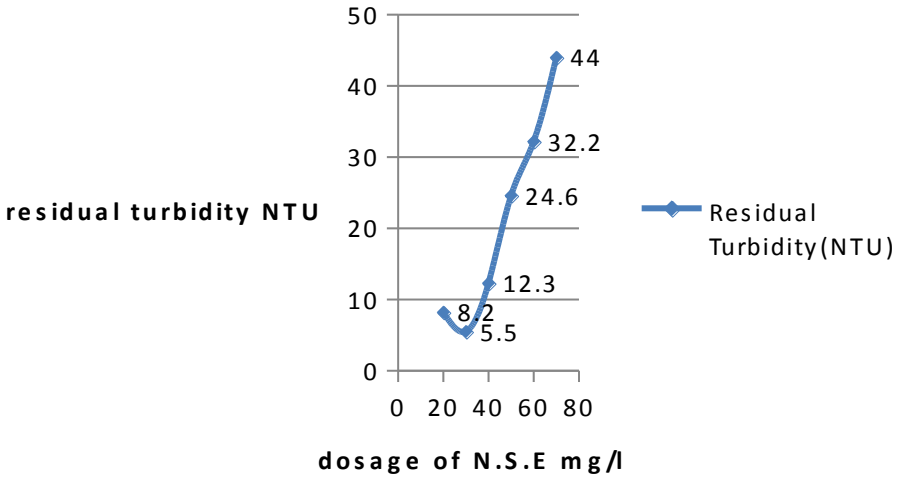

Fig 2: Graph of Efficiency of Nirmali Seed Extract as a Coagulant

The graph reveals that the water sample II with original turbidity of 50 NTU is flocculated with effective dose of 30 mg/l. To be effective in destabilization a polymer molecule must contain chemical groups which can interact with sites on the surface of the particle when a polymer molecule comes into contact with a colloidal particle, some of these groups adsorb at the particle surface, leaving the remainder of the molecule extending out in solution. If a second particle with some vacant adsorption site contacts these extended segments, attachment can occur. If a second particle is not available, in time, the extended segments may eventually adsorb on other sites on the original particle so that polymer is no longer capable of serving as a bridge. Dosages of polymer

which are sufficiently large to saturate the colloidal surface produce restabilized colloids since no sites are available for the formation of inter particle bridges. The experimental results are in accordance with the above statements.

5.3 Use of Nirmali Seed Extract as Coagulant Aid

Although it is often possible to obtain satisfactory flocculation by the use of a single coagulating agent, there are many waters which require more complex treatment. It is for this latter purpose that a number of materials not considered effective coagulants have been found useful in aiding the coagulating agent to perform its function. In this work its usefulness is already studied in turbidity and bacterial removal from the Godavari water. Now to study its potentialities as coagulant aid canal water having original turbidity of 50 NTU, Jar tests are conducted with different dosages of alum alone and with 15mg/l, 20mg/l, 25mg.l, and 30mg/l of Nirmali seed extract. The results show that by using 15 mg/l of Nirmali seed extract about 55% saving in alum can be achieved. The flocs are tougher, bigger and readily settleable. The results are plotted as follows:

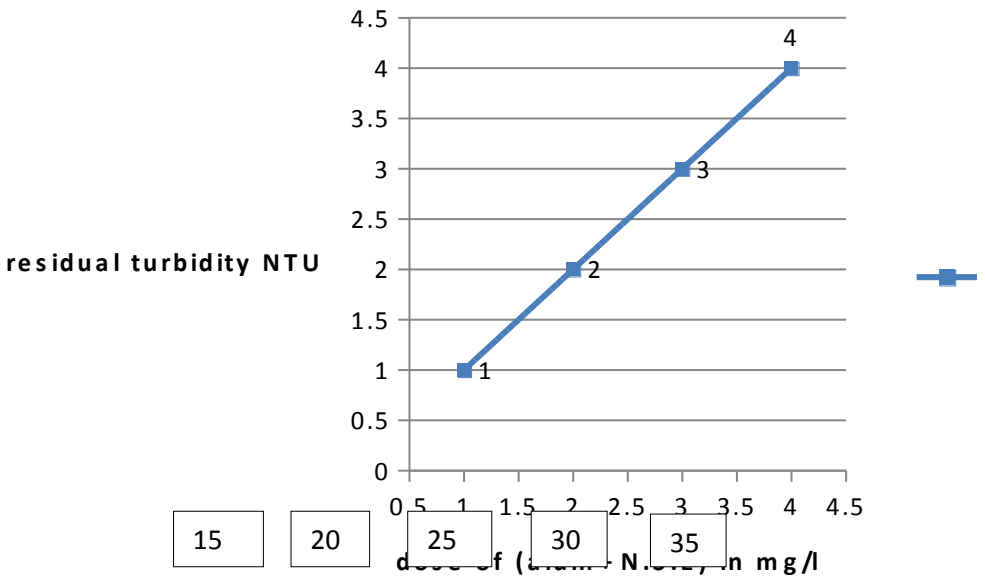

Fig: 3 Graph of Use of Nirmali Seed Extract as Coagulant Aid

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5.4 Efficiency of Copperas as a Coagulant

Copperas used as a coagulant is analyzed by taking 1% solution of ferrous sulphate and the different doses of the solution is added to water of 50 NTU and the following observations are plotted as:

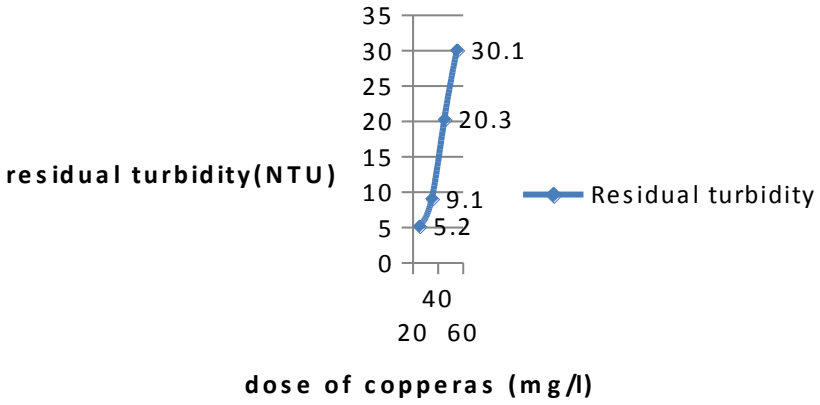

Fig : 4 Graph of Efficiency of Copperas as a Coagulant

5.5 Effect of Moringa Olifera Seed Extract as a Coagulant

Moringa oleifera seed extract is taken in the similar manner as alum solution and its efficiency is observed in the Water sample II. The observations are plotted as follows:

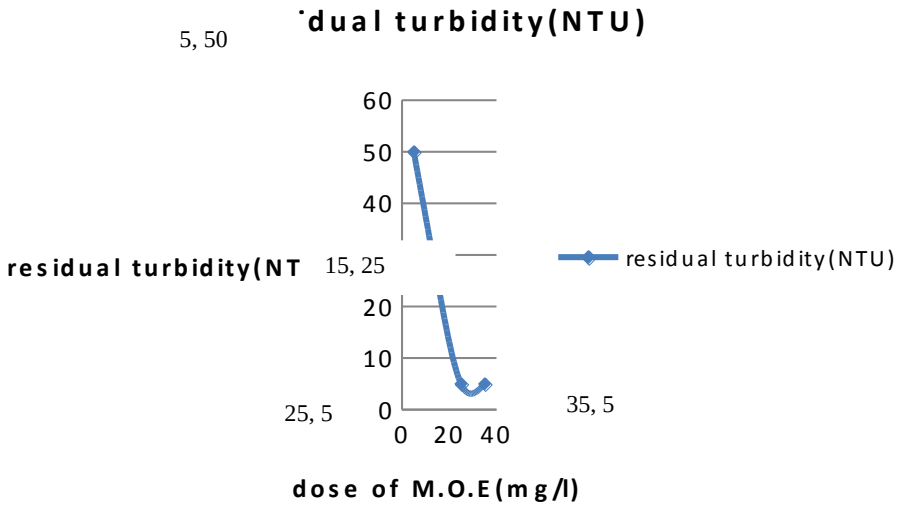

Fig: 5 Graph of Effect of Moringa Oleifera Seed Extract as a Coagulant

VI. CONCLUSIONS

1. Victoria Water Works is designed for a flow of 45,000 m^3/day. Total annual expenditure for Operations and Maintenance is Rs. 8.74 crore/year at the rate of Rs.5.32/m^3 of water treated. Out of Rs.8.74 crore annual expenditure, expenditure towards chemicals is Rs. 1.19 crore/year of which Alum alone costs Rs.1.02 crore/year. The cost of Alum can be reduced to Rs. 0.51 crore/year if Nirmali seeds are used as Coagulant aid, as the consumption of Alum is reduced to by 50-55% by weight (Kg/year). The remaining expenditure of Rs.7.5 crore/year is mainly towards power consumption (Rs.5.27 crore) and salaries to employees at Rs.2.03 crore, and Rs.0.2 crore is towards replacement of sand, maintenance and repairs of equipment like clarifiers, flash mixers.

2. The decrease in the consumption of Alum is beneficial in the following aspects – (a) it reduces the chances of occurrence of Alzheimer's disease in humans caused by increase in accumulation of Al^{+++} in dissolved form in treated water, (b) Reduction in expenses of water treatment and it reduces the consumption of the natural resources.

3. In the treatment of municipal water supply large quantity of the Nirmali seed extract is required. The requirement can be met by planting and growing Nirmali seeds in the surrounding areas of the Victoria Water Works, Kakinada. The climatic conditions of the Kakinada, which are tropical, are suitable for the growth and existence of these trees.

4. The taste of water treated by Nirmali seed extract is more aesthetically acceptable than the usage of Alum as coagulant.

5. The rate of Nirmali seeds is Rs. 180/Kg. It is one time expenditure as compared to running expenditure every year. At the same time it will reduce the serious environmental hazards like accumulation toxic Al^{3+} ions or Bio-magnification of Al^{3+} ions in human body.

6. The use of other coagulants like Copperas (Ferrous Sulphate) is studied and found that the consumption of the coagulant for similar levels of turbidity (50 NTU) is found to be 25 mg/l, with increasing efficiency at a range of pH 8 and above. But the cost of Copperas is in the range of Rs. 50 to Rs. 70 per Kg, which is highly expensive as compared to the cost of Alum at the rate of Rs. 8 to Rs. 9 per Kg. The usage of Copperas increases the expenditure upto 5 times as compared to Alum. So, usage of Copperas is not suitable in the similar conditions.

7. Moringa derived coagulants offer several advantages over conventional coagulants such as aluminium sulphate:

- Activity is maintained over a wide range of influent pH values – no pH correction required
- Natural alkalinity of the raw water is unchanged following coagulation – no addition of alkali is required
- Sludge production is greatly reduced and is essentially organic in nature with no aluminium residuals.

8. The cost of Moringa Oleifera seeds ranges from Rs.800 to Rs.1000 per Kg; although it is costly it has a wide range of Coagulant efficiency. As an added benefit, it will reduce the serious environmental hazards like accumulation of toxic Al^{3+} ions or Bio-magnification of Al^{3+} ions in human body.

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