Coagulation Performance Evaluation of Papaya Seed for Purification of River Water

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Abstract: - **Access to safe water is a serious issue affecting people of all ages for those living in remote communities and far flung areas where availability of improved water resources is limited; it is a great challenge to impart quality of water in significant ways. Point use of treatment is now common in India. It is a water treatment method used to treat small amount of drinking water for use in home, using indigenous resources. Turbidity and Hardness are the major problems in domestic water. Coagulation is a process used to neutralize the negative charge of dissolved materials in water with the help of some chemicals like alum for their removal; some of the commonly used natural coagulants are Cowpea, Peanuts, Moringa Olifera, and Beans etc. This study is carried out to investigate the effectiveness of powder extracted from matured dried Carica Papaya seed as active coagulant in water, which is readily available and commonly recognizable in most urban and rural communities. It was aimed at identifying papaya seed as a possible replacement for alum and other synthetic materials in treating water. Laboratory scale studies using Jar test experiments were performed on medium turbid water to determine the effect of dosage, stirring time and speed on coagulation. Results obtained showed that at dosage of 0.6g/L stirring time of 30 minutes and mixing speed of 80rpm, optimum removal of water quality parameters were obtained. 89.14% turbidity removal efficiency was obtained from this study and total dissolved solids removal efficiency of papaya seed obtained from this study was 90.29%. Papaya seed exhibited high efficiency in removing Total Suspended Solids, Alkalinity, Total Hardness, Dissolved Oxygen etc.**

Key Words: **Alum, Coagulation, Papain, Papaya seed, Sieve analysis**

I. INTRODUCTION

Water is used for variety of purpose like drinking, washing, bathing, recreation as well as numerous other varied industrial applications. World Health Organization (WHO),report that wholesome of water means absence of suspended solids, inorganic solids and pathogens. Water covers 71% of earth surface, on earth,96.5% of planet water is found in ocean,1.7% in ground water,1.7% in glaciers and icecap in Antarctica and Greenland, a small fraction in various other water bodies, and precipitation only 2.5% of earth water is fresh water and 98.8% of that water is in ice and ground water, less than 0.3% of all fresh water is in river, lakes and the atmosphere, and an even small amount of earth's fresh water contained within biological bodies and manufactured products. Safe water is essential for human and other forms of life even though it provides no calories or organic nutrients .Access to safe water is improved over last decades in almost every part of the world, but approximately one billion people still lack to safe water and over 2.5 billion lack accesses to safe sanitation. Increasing amount of discharged sewage progressing urbanization, the use of chemicals in agriculture and industry as well as anthropogenic activities all affects quality of waters. The final effect of water degradation is the limits to the use of drinking water reservoirs [2].

Water quality is of concern to everyone. Quality is the acceptability of the water for uses like drinking, cooking, bathing, and laundering. Most municipally treated water is safe and generally of good quality. Water from private or community wells can be contaminated. Contaminated water may have off-tastes, odors, or visible particles [3].The conventional method of water purification using aluminium sulphate (alum) and calcium hypochlorite puts pressure on the nation's over-burdened financial resources since they are imported thereby making treated water very expensive in most developing countries and beyond the reach of most rural folks. Hence, they resort to the sources like dams, dug outs, streams, rivers and lakes. Water from these sources is usually turbid and contaminated with microorganisms that cause many diseases [4].

In developing countries treatment plants are expensive, the ability to pay for service minimal and skills as well as services are scare. In order to alleviate the prevailing difficulties, approaches are focused on sustainable water treatment systems that are low cost, robust and require minimal operational skill. Coagulation and flocculation helps in removal of colloidal particles, available coagulants like aluminium sulphate and poly aluminium chloride. They are cheap, effective and easy to handle. Aluminium can be over dosed for efficient coagulation but overdose of aluminium salt increases the alum concentration and cause turbidity. Excess intake of aluminium causes Alzheimer's disease. Locally available materials can be exploited towards achieving sustainable safe portable water supply [1].

In India, people live in extreme poverty have been drinking highly turbid and microbiologically contaminated water as they lack knowledge of proper treated water,they do not afford to use high cost of treatment methods using chemical coagulants. There are few problems that cause large seasonal variations in raw water and increase its turbidity. Natural coagulants have been used for domestic purposes since traditional times in tropical rural areas. The main advantages of using natural plant based coagulants are cost effective, less production of pH and biodegradability. The naturally occurring coagulants are presumed safe for human health [1].

Kallada River is the study area which is flowing through Kollam district is one of the most important water source for domestic purpose, industrial use and water treatment plant, Punalur. Many industries are flourishing on the bank of Kallada River. Punalur Paper Mills was one of such industry operated near the bank of this river. The effluent discharged from the industry in to river is found to alter the physicochemical factors. The quality of water is changed due to various reasons. In congested areas the water supplies get polluted mainly by domestic and industrial wastes. Population growth, rapid industrial and technological developments, urbanization, periodic drought and even legal decisions are some of the reasons for the declining of water quality. Hence it is important to treat water from Kallada River before using it for domestic purpose.

Natural coagulants have been used in rural areas as effective coagulants. The naturally occurring coagulants are presumed safe for human health. The main objective of this study is to investigate the efficiency of Carica Papaya seeds, in coagulation of turbid water. The study also focused on the determination of optimum dosage and contact time for using papaya as a natural coagulant in house hold water treatment as well as community water treatment plants. The comparative efficiency studies of alum and papaya seed for water treatment was also studied. This will show the way to improve the quality of drinking water in the rural area. This material was selected for this study because papaya seed has high protein content and some authors have considered that the active coagulating agents in plant extract are proteins.

II. MATERIALS AND METHODS

2.1 Materials

Few materials were used in this study such as water and natural coagulant like Papaya seed. The detailed description of this coagulant is given below;

2.1.1 Carica Papaya

Papaya fruit contain large number of small black color seeds. The fruit as well as seeds contain large protein content and have medicinal values. Papaya seed have anti-inflammatory properties, wound healing properties, suitable for digestion, prevention of cancer and kidney disorders, provide heart health and its use increase immunity because it contains vitamin A & C. Papaya seed is a rich source of proteins. Seed work as a coagulant due to the presence of positively charged proteins which bind with negatively charged particles (silt, clay, bacteria and toxins etc),allowing the resulting flocs to settle and obtain clear water(adsorption & charge neutralization). Also papaya seed powder has ability to join with solids in water and settle to the bottom. Papain (Papaya proteinase) is the important protein present which contains 345 amino acid residues and consists of a single sequence of propeptide and mature peptide.

2.2 Methods

2.2.1 Collection of Water Sample

The raw water sample was collected from Kallada River, flowing through Punalur town, Kollam. The water was collected from the river by immersing a sterilized plastic container (container is washed with nitric acid) until it was full. The cap was inserted while it was still underway. The water was then treated using prepared coagulant.

2.2.2 Collection and Identification of Seed

Seed used in this study that is Carica papaya was collected from the market and nearby locations.

2.2.3 Preparation of Seed Powder

The fruits were sliced open using a clean knife. The seeds were washed severally with water. Then the seeds were dried under sunlight for a period of 7 days before crushing. The seed were made into fine powder using home grinder and powder was collected in sterile bottle with air tight cap. Then the seed powder was sieved and finer particles were then used as coagulant.

2.2.4 Collection of Alum Treated Water

The alum treated water sample was collected from Water Treatment Plant, situated in Punalur town, Kollam. The water was collected from the alum mixing tank by immersing a sterilized plastic container (container is washed with nitric acid) until it was full. The cap was inserted while it was still underway. The water was then used for water quality parameters testing.

2.2.5 Water Quality Tests

Water quality tests were conducted using standard methods in APHA 1998.

III. RESULTS AND DISCUSSION

3.1. Physico-chemical parameters of raw water

The physico-chemical properties of the raw water sample used in this study are presented in table 3.1.From table it is clear that turbidity, total suspended solids, total dissolved

solids and BOD value of raw water were much higher as compared to drinking water standards given by WHO and BIS. Hence need for treatment. However all other components are within the limits and safe without treatment.

3.2 Sieve Analysis Result

Table 3.2 show the readings obtained by conducting sieve test. From that value a particle size distribution curve is drawn and effective size of papaya seed powder was obtained. Figure 3.1 shows the particle size distribution curve. The effective size (D_{10}) of papaya seed powder obtained was 180µ.

3.3 Effect of Dosage on Coagulation

Table 3.3 shows the effect of papaya seed powder dosage on coagulation. The dosages were varied from 0.2g/L-1.2g/L dosage interval. At varying coagulant dosages, the effect on constituent parameters is shown below in Table 3.3.

3.3.1 pH:

At varying dosage no significant changes were observed on pH, for the water sample treated with Papaya seed as coagulant, however, there was a notable decrease in all other parameters of the water sample after treatment.

3.3.2 Turbidity:

The initial turbidity for the raw water sample taken was 35 NTU which was beyond the limits of BIS/WHO standards. It was observed after treatment the turbidity got reduced from 35 NTU to 4.4NTU for 0.6g/L dose respectively.The optimal dosage for specific water is defined as the dosage which gives the lowest turbidity in the treated water. The greatest decrease was seen at the dose of 0.6g/L of raw water which reduced the turbidity from 35 to 4.4. This value is below the WHO recommended level of 5NTU. Due to this treatment there was an improvement in the flock size and flock settled rapidly. This analysis shows that with increase in dose of coagulants the turbidity got reduced to an optimum extent.

3.3.3 TDS and TSS:

At this dosage the efficiency of the coagulant in removing TSS and TDS was also highest, reducing TSS from 860 to 25.4 and TDS from 1610 to 146 respectively. At this dosage all other parameters were reduced below the limits recommended by WHO and BIS. Fig 3.2 -3.6 shows the effect of dosage on water quality parameters.

3.3.4 Alkalinity:

Alkalinity during the research work was observed to be 98mg/L for raw water but after treatment with Carica Papaya seeds alkalinity got reduced to 13.4mg/L for 0.6g/L dose respectively [Table 3.3, Fig3.5]. The alkalinity present was within the range of BIS/WHO standards. It was observed the seeds had the natural buffering capacity. The flocks were light however it confined the reduction of alkalinity.

3.3.5 Hardness:

Hardness was 52mg/L for raw water after treatment with Carica Papaya the hardness got reduced to 15.3mg/L for 0.6g/L dose respectively. It was observed that hardness of water is decreased with increase in dose of coagulants used to an optimum extent.

3.3.6 Acidity:

Acidity of raw water was 24mg/L, after treatment with Carica Papaya the acidity got reduced to 13.6mg/L for 0.6g/L dose respectively. It was observed that papaya has an ability to reduce acidity of water to a value which is within the limit of BIS & WHO recommendations.

3.3.7 Dissolved Oxygen:

Dissolved oxygen value of raw water was 4.3mg/L which is increased to 7.48mg/L after treating with papaya. It was observed that DO value of water is increase with increase in dosage because the experiment was conducted in an open environment, there is a chance of adding atmospheric oxygen to water.

3.3.8 Biochemical oxygen demand

BOD of raw water was 2.4mg/L after treating with papaya the value become nil because papaya seed has an ability to remove organic matter from water and also increased DO value decreases BOD of water.

3.4 Effect of Stirring Time on coagulation at a constant coagulant dosage

Table 3.4 shows the results obtained when the effect of stirring time on coagulation was studied by varying the time at a constant coagulant dosage.

3.4.1 pH:

At varying time no significant changes were observed on pH, for the water sample treated with Papaya seed as coagulant, however, there was a notable decrease in all other parameters of the water sample after treatment.

3.4.2 Turbidity:

The initial turbidity for the raw water sample taken was 35 NTU which was beyond the limits of BIS/WHO standards. It was observed after treatment the turbidity got reduced from 35 NTU to 4.3NTU for 30 min respectively. This value is below the WHO recommended level of 5NTU. After 30 min there is an increase of turbidity was noted because increase in time decreases the stability of initially formed flocs.

3.4.3 TDS and TSS:

At this time the efficiency of the coagulant in removing TSS and TDS was also highest, reducing TSS from 860 to 28 and TDS from 1610 to 140 mg/L respectively. At

this time all other parameters were reduced below the limits recommended by WHO and BIS. Fig 3.7 -3.11 shows the effect of time on water quality parameters.

3.3.4 Alkalinity:

Alkalinity during the research work was observed to be 98mg/L for raw water but after treatment with Carica Papaya seeds alkalinity got reduced to 16 mg/L for 30 min stirring time respectively [Table 3.4, Fig3.10]. The alkalinity present was within the range of BIS/WHO standards. It was observed the seeds had the natural buffering capacity. The flocks were light however it confined the reduction of alkalinity.

3.4.5 Hardness:

Hardness was 52mg/L for raw water after treatment with Carica Papaya the hardness got reduced to 14.5 mg/L for 30 min stirring time respectively. It was observed that hardness of water is decreased with increase in stirring time of coagulation.

3.4.6 Acidity:

Acidity of raw water was 24mg/L, after treatment with Carica Papaya the acidity got reduced to 12.1mg/L for 30min stirring time respectively. It was observed that papaya has an ability to reduce acidity of water to a value which is within the limit of BIS & WHO recommendations.

3.4.7 Dissolved Oxygen:

Dissolved oxygen value of raw water was 4.3mg/L which is increased to 7.32 mg/L after treating with papaya. It was observed that DO value of water is increase with increase in time because the experiment was conducted in an open environment, there is a chance of adding atmospheric oxygen to water.

3.5 Effect of Mixing Speed on coagulation at a dosage of 0.6g/L

From Table 3.5, the effect of mixing speed on coagulation was observed to only have a moderate effect on the coagulation process.

3.5.1 pH:

At varying mixing speed no significant changes were observed on pH, for the water sample treated with Papaya seed as coagulant, however, there was a notable decrease in all other parameters of the water sample after treatment.

3.5.2 Turbidity:

The initial turbidity for the raw water sample taken was 35 NTU which was beyond the limits of BIS/WHO standards. It was observed after treatment the turbidity got reduced from 35 NTU to 4.9NTU at 80rpm speed respectively. This value is below the WHO recommended level of 5NTU. After experiment, it was clear from figure3.14; papaya seed has capacity to remove turbidity of raw water sample. After reaching an optimum turbidity reduction at a speed of 80rpm, its value gets increased due to the shearing of initial floc formation caused by increased speeds.

3.5.3 TDS and TSS:

At this speed the efficiency of the coagulant in removing TSS and TDS was also highest, reducing TSS from 860 to 60 and TDS from 1610 to 146 respectively. At this speed all other parameters were reduced below the limits recommended by WHO and BIS. Fig 3.12 -3.16 shows the effect of dosage on water quality parameters.

3.5.4 Alkalinity:

Alkalinity during the research work was observed to be 98mg/L for raw water but after treatment with Carica Papaya seeds alkalinity got reduced to 58 mg/L for 80rpm speed respectively [Table 3.5, Fig3.15]. The alkalinity present was within the range of BIS/WHO standards. It was observed the seeds had the natural buffering capacity. The flocks were light however it confined the reduction of alkalinity.

3.5.5 Hardness:

Hardness was 52mg/L for raw water after treatment with Carica Papaya the hardness got reduced to 35 mg/L at 80rpm speed respectively. It was observed that hardness of water is decreased with increase in mixing speed.

3.5.6 Acidity:

Acidity of raw water was 24mg/L, after treatment with Carica Papaya the acidity got reduced to 19mg/L at 80rpm speed respectively. But this value is slightly higher than the value recommended by BIS & WHO.

3.5.7 Dissolved Oxygen:

Dissolved oxygen value of raw water was 4.3mg/L which is increased to 7.4mg/L after treating with papaya. It was observed that DO value of water is increase with increase in dosage because the experiment was conducted in an open environment, there is a chance of adding atmospheric oxygen to water.

3.5.8 Biochemical oxygen demand

BOD of raw water was 2.4mg/L after treating with papaya the value become nil because papaya seed has an ability to remove organic matter from water and also increased DO value decreases BOD of water.At stirring time of 80rpm with lowest turbidity value of 4.9 and moderately least value of TSS & TDS were obtained. In the case of increased speed turbidity, TSS and TDS values were increased. It can therefore mean that the lower mixing speed may improve the removal of turbidity due to reduced shearing of the flocs during initial formation.

3.6 Comparison of efficiency of Alum & Papaya seed as a coagulant

Comparative study of efficiency of alum and papaya seed as coagulants are presented in Table 3.6.

From the table 3.6, it is clear that papaya seed is better than alum for reducing all physico-chemical parameters of water especially turbidity, EC, TSS and TDS. Aluminium sulphate (alum) has also been indicated to be a causative agent in neurological disease. There is a fear that ingestion of aluminium ions may include Alzheimer's disease. Also sludge produced is voluminous and non-biodegradable after treatment and therefore poses disposal problems leading to increase cost of treatment. The costs of these chemicals have been increasing at an alarming rate in developing countries. But use of papaya seed has no such problems and can be effectively use this seed for water treatment without any side effects and it is also economically feasible.Table 3.7 shows the efficiency of alum and papaya seed in reducing water quality parameters within limits.

From table 3.7, it is clear that papaya seed powder is more efficient than alum for reducing turbidity, TSS, TDS, and also DO value of water. Fig 3.17 shows the bar diagram for efficiency of alum and papaya seed powder in reducing water quality parameters.

There is no effect on pH by using alum or papaya seed as coagulant for water treatment. It is clearly seen that higher concentrations of papaya seed powder of 0.6g/L loading dose as coagulant gives better effect on turbidity compared with alum. This shows that papaya can be adopted for water treatment. This is likely to lead to cost reduction in the conventional water treatment using alum and no threat to human life in case of overdose. Papaya seed provide 90% reduction of turbidity as compared to alum because protein present in the seed is more efficient for charge neutralization and there by forming flocs and are settled to give better result.

IV. CONCLUSION

The present study which was carried on natural seeds i.e. Carica Papaya in treatment of River water that acts as natural coagulant. From the study an optimum dosage of 0.6g/L, optimum speed at 80rpm, and stirring time of 30 minutes were obtained respectively. The pH reading was almost similar before and after treatment. From the results obtained, Papaya seed has been found to be an efficient natural coagulant for river water treatment and also it is clear that papaya seed is better than alum for water treatment. From the observations taken it was also concluded that when natural coagulants were used as a coagulant aid, the dosage of alum can be reduced which can help to reduce the detrimental effects caused by chemical based coagulants. Natural coagulant is sustainable and suitable for economical way of water treatment process. Considering the fact that papaya seed can be locally produced, its use in water purification should be encouraged. This is likely to reduce the high cost of the current water treatment systems. The seed used has not giving any toxic effect. It is eco-friendly and provides cheaper method of water treatment. These seeds can be used in rural areas where no facilities are available for the water treatment; the sludge settled can be used as bio fertilizer advantage for rural villages. Papaya seed is high efficient to remove turbidity of water. This study revealed that papaya seed has the efficiency of being an alternative or a supplement to aluminium sulphate or other proprietary polyelectrolyte and can save cost. This study has also confirmed that the seeds are highly effective in removing suspended particles and dissolved particles from water with medium to high levels of turbidity. It can be concluded that purification of water with papaya seed extracts used as coagulant gives best results.

V. RECOMMENDATIONS

Based on the results obtained, the following recommendations were provided:

- It is recommended that more research should be conducted on highly turbid water by using papaya seed powder as coagulant.
- It is recommended that more natural sources should be investigated for potential coagulation abilities.
- There is a need to develop a localized water purification system so that rural villages can use plant and seed extracts to improve drinking water quality from shallow well and river.
- It is recommended that a combination treatment of alum and papaya seed in different proportions be investigated to establish their effectiveness in treating raw water.

ACKNOWLEDGEMENT

The authors will like to acknowledge UKF College of Engineering and Technology for the valuable support for the completion of present project.

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List of Table

Table 3.1 Initial parameter values of Kallada River Water

Parameter	Initial Result	WHO Standard	BIS Standard
pH	7.6	6.5-8.5	6.5-8.5
Electrical conductivity(µS/cm)	130	1400 Max	2000 Max
Turbidity(NTU)	35	5Max	5Max
Alkalinity(mg/L)	98	-	200
Acidity(mg/L)	24	-	15
Total hardness(mg/L)	52	500	200
Total suspended solids(mg/L)	860	-	-
Total dissolved solids(mg/L)	1610	500	500
Dissolved oxygen(mg/L)	4.3	-	4-6
Biochemical oxygen demand(mg/L)	2.4	6	2

Table 3.2 Sieve test results

Sieve size	Weight retained	Percentage weight retained	Cumulative percentage retained	Percentage finer
600µ	70.61	24.61	24.61	75.39
300µ	82.63	28.8	53.41	46.59
212µ	90.84	31.66	85.07	14.93
150µ	29.14	10.16	95.23	4.77
75µ	11.55	0.04	95.27	4.73
Pan	2.13	0.0072	95.28	4.72

Table 3.3 Effect of coagulant dosage result

Parameter / Dosage	0.2g/L	0.4g/L	0.6g/L	0.8g/L	1.0g/L	1.2g/L
pH	7.6	7.8	7.6	7.7	7.6	7.9
EC	61	53	48	72	81	89
Turbidity	6.8	5.1	4.4	6.6	6.9	7.2
Alkalinity	20.8	13	13.4	13.1	12	10
Acidity	19	15	13.6	12	13.4	13.8
Total hardness	21	21.3	15.3	18	21	23
Total suspended solids	38	31	25.4	26	37	41
Total dissolved solids	340	290	146	130	148	158
Dissolved oxygen	4.3	5.1	7.12	7.16	7.3	7.48
Biochemical oxygen demand	0.68	0.47	NIL	NIL	NIL	NIL

Table 3.4 Effect of stirring time on coagulation at coagulant dosage of 0.6g/L

Parameter / Time	15min	30min	45min	60min	75min
pH	7.4	7.5	7.6	7.6	7.5
EC	47	51	53	49	66
Turbidity	4.5	4.3	4.2	4.7	5.2
Alkalinity	17.3	16	18	17.2	18.2
Acidity	12.4	12.1	12.8	13	12.1
Total hardness	15.1	14.5	14.1	15.2	14.8
TSS	39	28	24	25	22
TDS	159	140	149	144	161
DO	4.5	7.1	7.2	7.4	7.32
BOD	1.1	NIL	NIL	NIL	NIL

Table 3.5 Effect of mixing speed on coagulation at dosage of 0.6g/L

Parameter /Speed	40rpm	60rpm	80rpm	100rpm	120rpm
pH	7.7	7.6	7.4	7.4	7.5
EC	68	56	51	68	61
Turbidity	6.1	5.4	4.9	6.2	5.9
Alkalinity	48	51	51	49	50
Acidity	19	18	19	17	16
Total hardness	38	41	35	32	28
TSS	78	61	60	68	71
TDS	141	149	146	240	386
DO	4.3	6.8	7.1	7.1	7.4
BOD	0.92	NIL	NIL	NIL	NIL

Table 3.6 Parameters of water after coagulation with Alum and Papaya seed powder

Parameter	**Alum coagulant**	**Papaya seed**	**BIS**
pH	7.1	7.2	6.5-8.5
EC	92	58	2000 Max
Turbidity	5.2	3.8	5Max
Alkalinity	12.4	12	200
Acidity	14	13.8	15
Total hardness	16	21	200
TSS	32	25	-
TDS	310	151	500
DO	6.85	7.3	4-6
BOD	NIL	NIL	NIL

Table 3.7 Efficiency of Alum and Papaya seed

Parameter	Initial Result	Alum	Papaya seed	Efficiency of Alum (%)	Efficiency of Papaya seed(%)
pH	7.6	7.1	7.2	6.58	5.26
EC	130	92	58	29.23	55.38
Turbidity	35	5.2	3.8	84.86	89.14
Alkalinity	98	12.4	12	87.35	87.75
Acidity	24	14	13.8	41.67	42.5
Total hardness	52	16	21	69.23	59.61
TSS	860	32	25	96.28	97.09
TDS	1610	310	151	78.01	90.29
DO	4.3	6.85	7.3	59.23	69.77
BOD	2.4	NIL	NIL	100	100

List of Figure

Fig 1.1 Kallada River

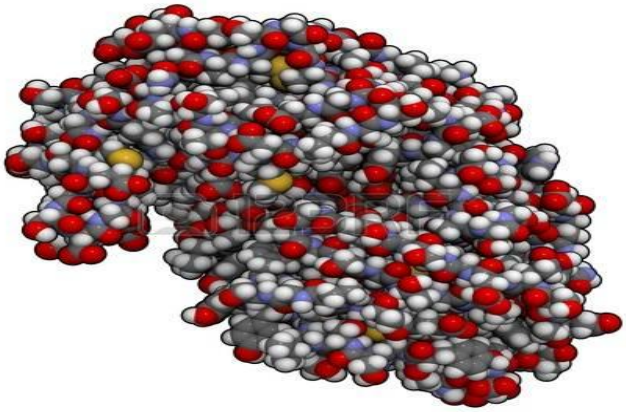

Fig 2.1 Papain structure

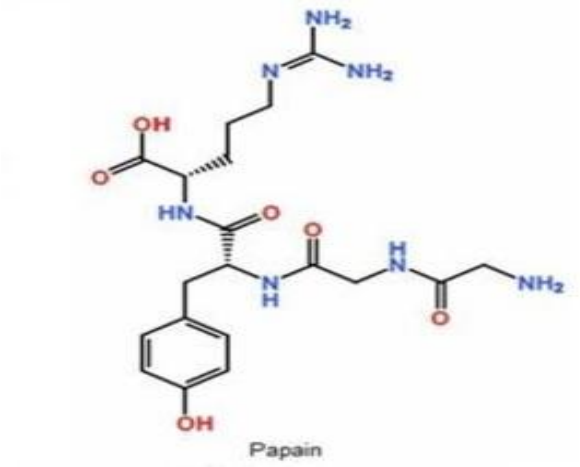

Fig 2.2 Papain skelton

Fig 2.3 Raw papaya seed

Fig 2.4 Dry papaya seed

Fig 2.5 Papaya seed powder

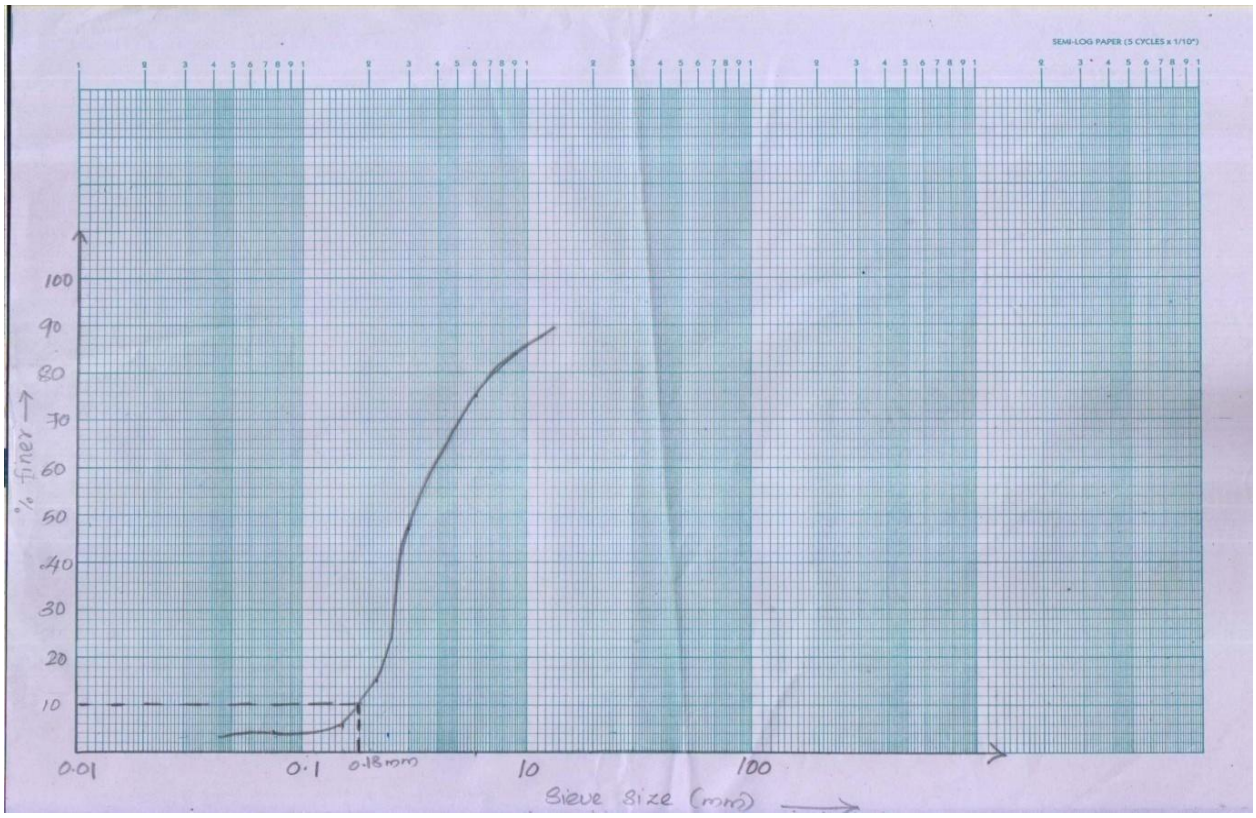

Fig 3.1 Particle size distribution curve

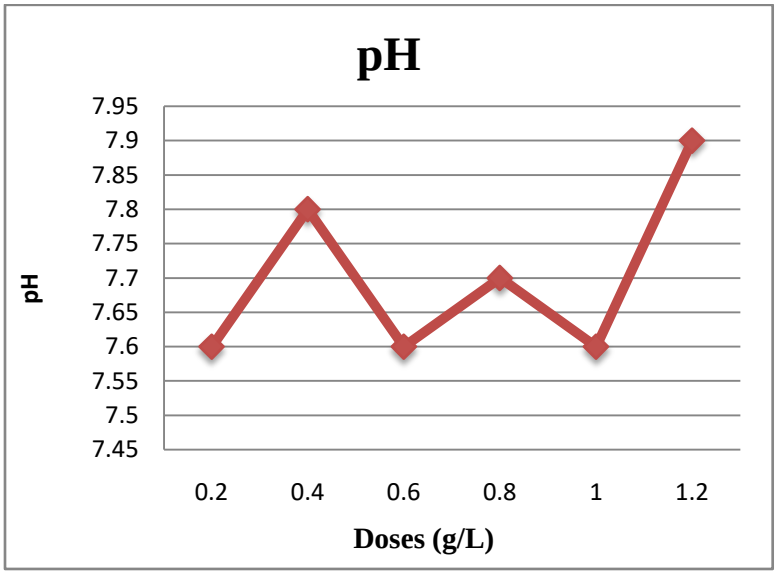

Fig 3.2 Effect of dosage on pH

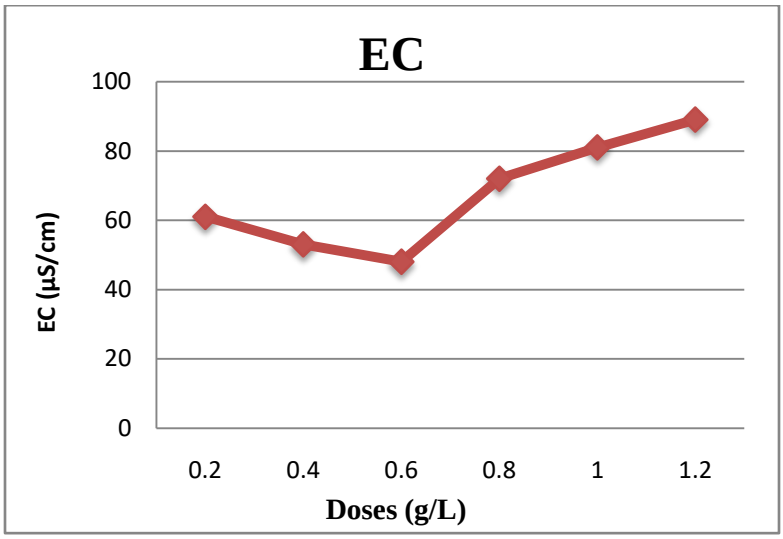

Fig 3.3 Effect of dosage on EC

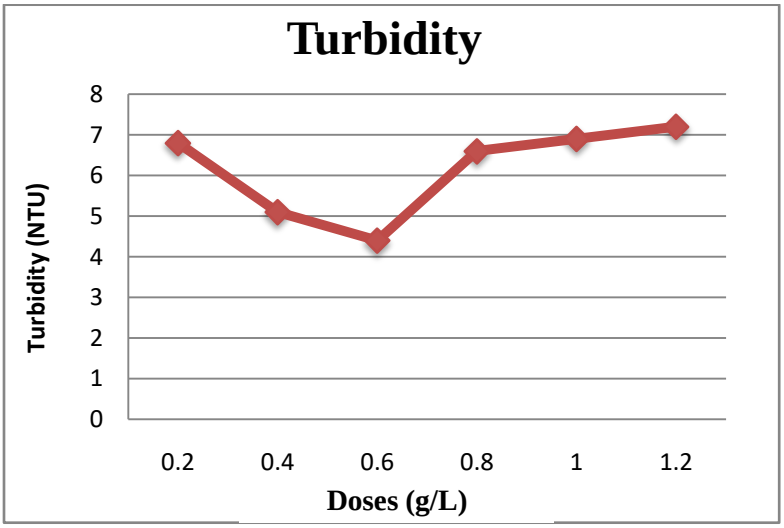

Fig 3.4 effect of dosage on Turbidity

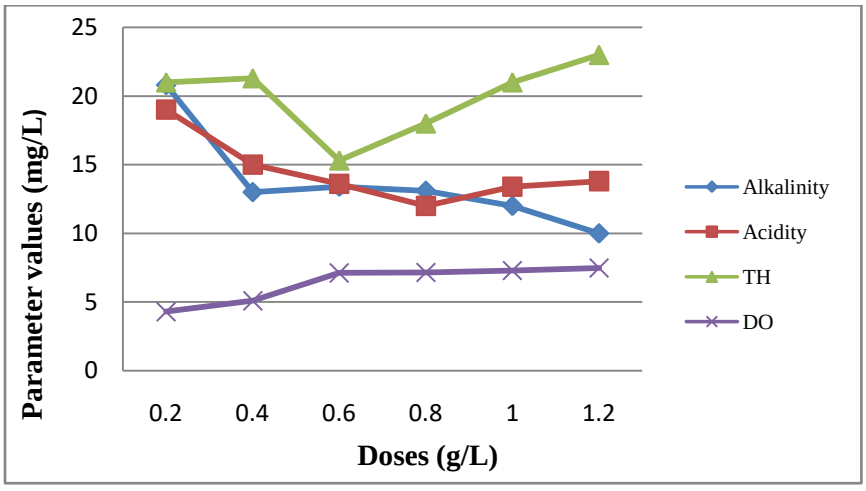

Fig 3.5 Effect of dosage on Alkalinity, Acidity, Total Hardness & DO

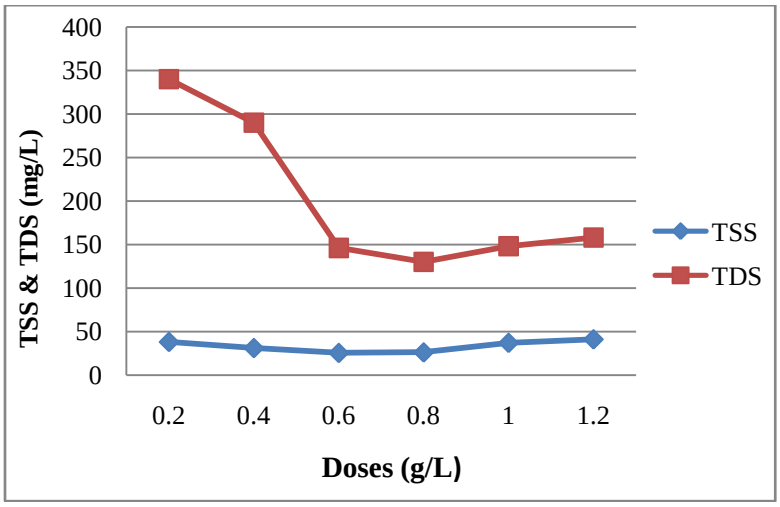

Fig 3.6 Effect of dosage on TSS & TDS

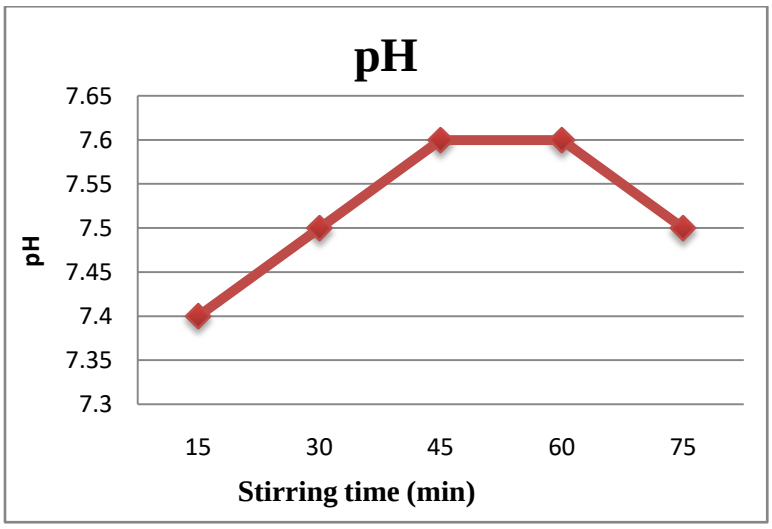

Fig 3.7 Effect of Stirring time on pH

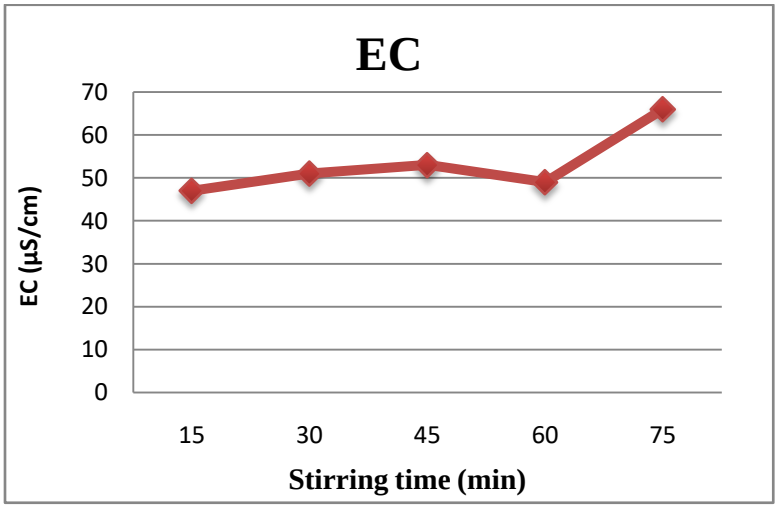

Fig 3.8 Effect of stirring time on EC

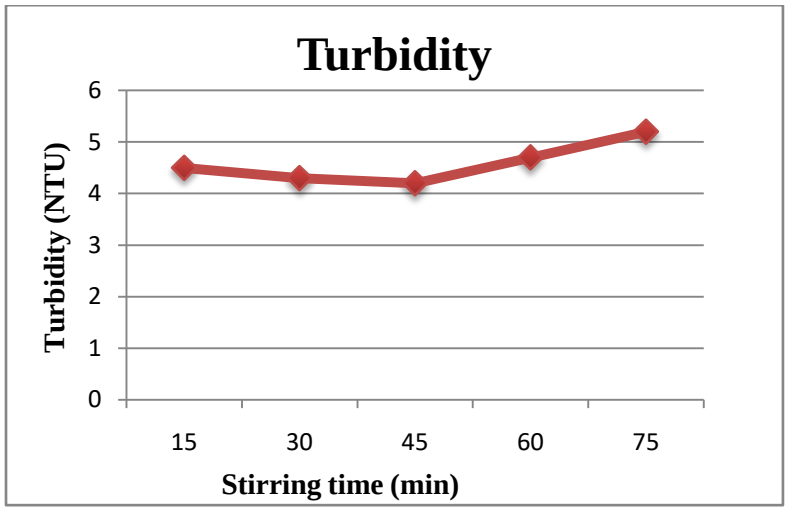

Fig 3.9 Effect of stirring time on turbidity

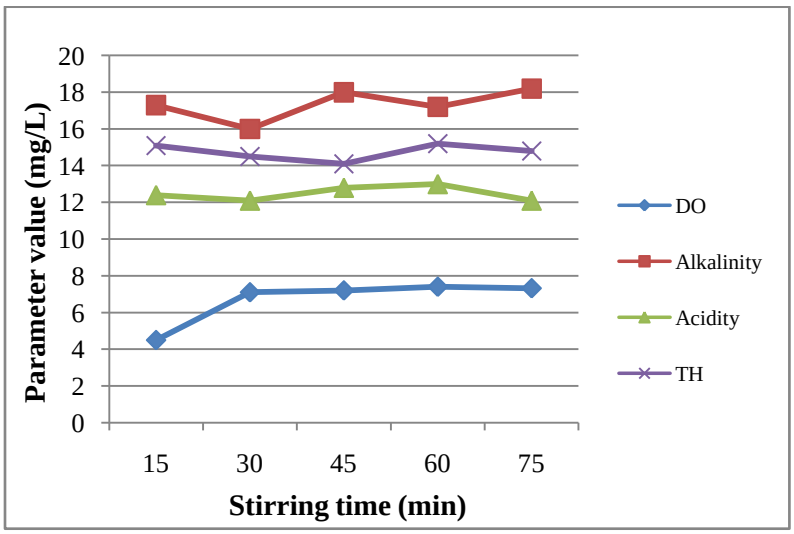

Fig 3.10 Effect of Stirring time on DO, Alkalinity, acidity & Total Hardness

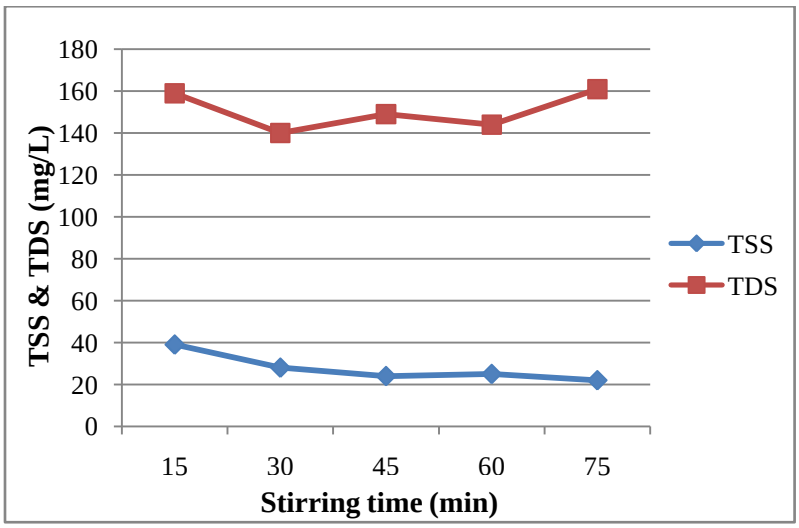

Fig 3.11 Effect of Stirring time on TSS &TDS

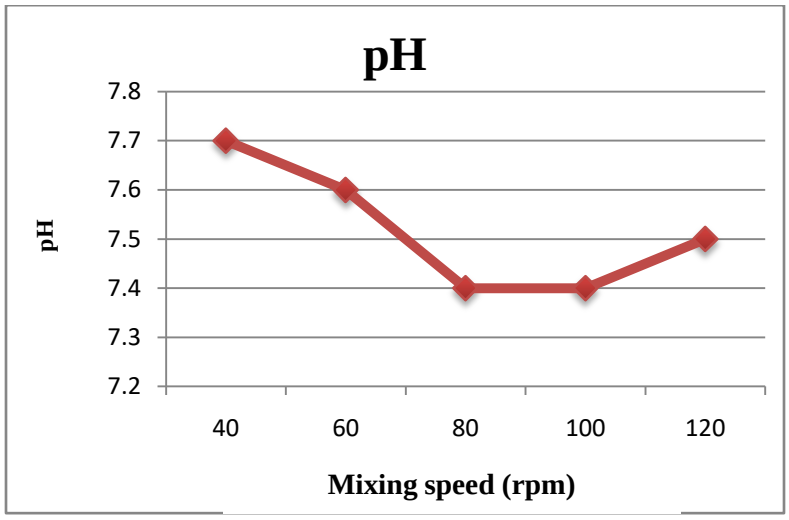

Fig 3.12 Effect of mixing speed on pH

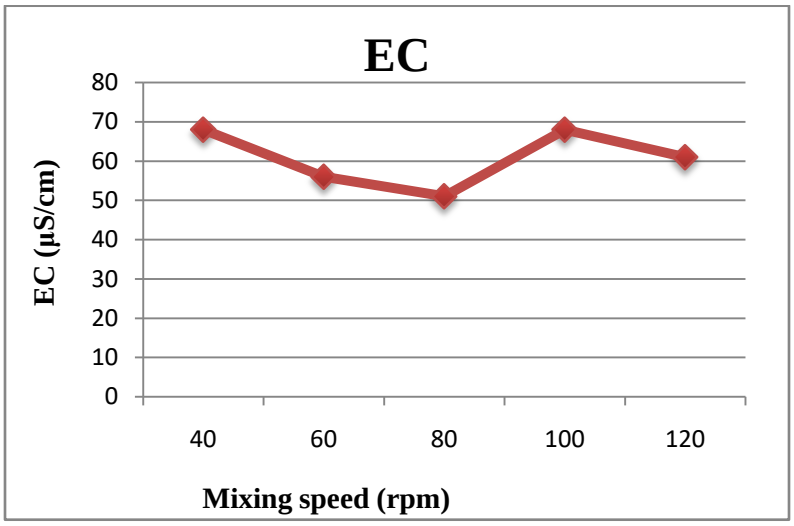

Fig 3.13 Effect of mixing speed on EC

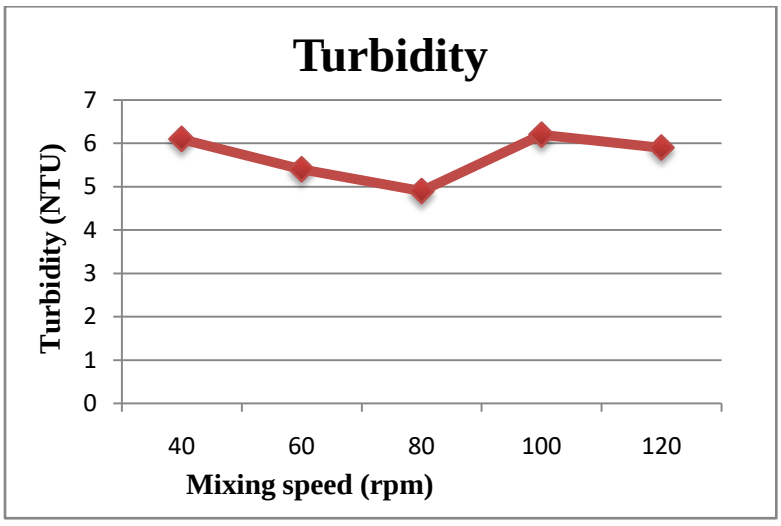

Fig 3.14 Effect of mixing speed on Turbidity

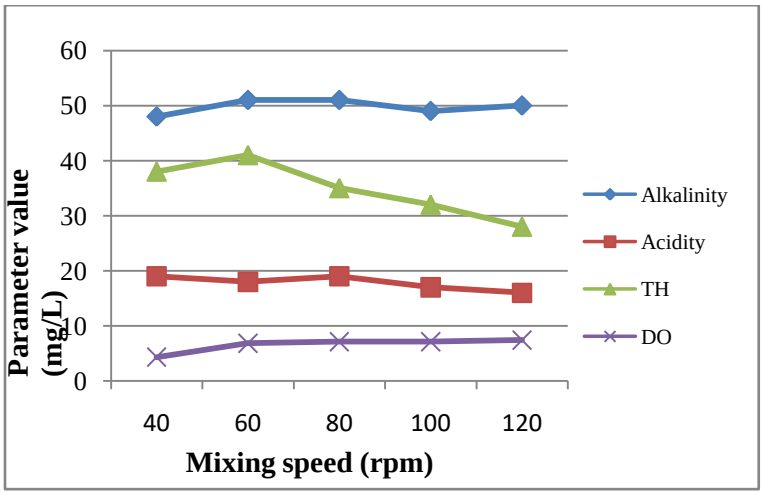

Fig 3.15 Effect of mixing speed on Alkalinity, Acidity, Total Hardness & DO

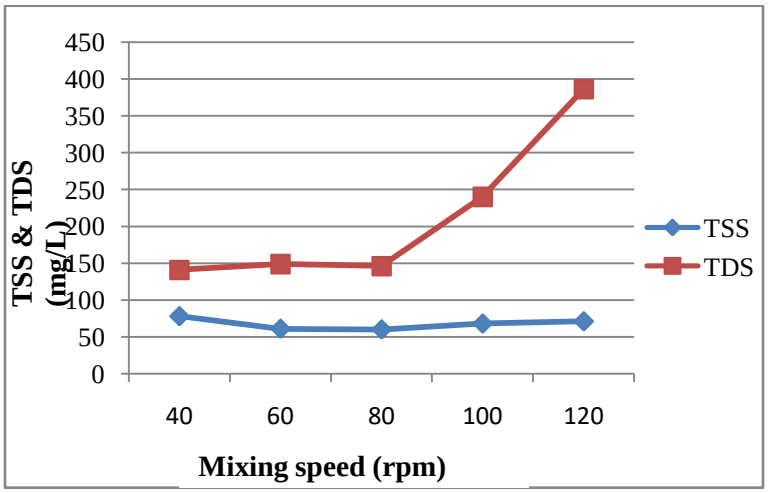

Fig 3.16 Effect of mixing speed on TSS & TDS

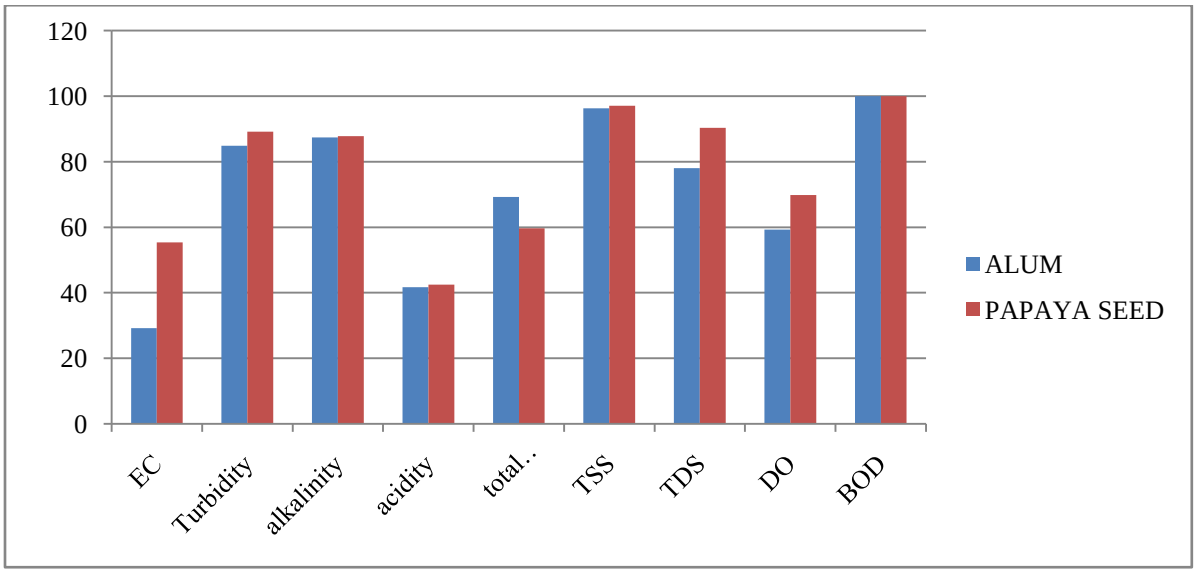

Fig 3.17 Efficiency of alum and papaya seed in reducing water quality parameters