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Study on Removal Efficiency of Blended Coagulants on Different Types of Wastewater

S. Sivaranjani*† and A. Rakshit**

*Soil and Water Conservation, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, RGSC BHU, Mirzapur-231001, U.P., India

**Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, Banaras Hindu University, Varanasi-221005, U.P., India

†Corresponding author: S. Sivaranjani

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ABSTRACT

The conventional methods of water treatment involve various water clarification processes which include coagulation, flocculation, sedimentation and disinfection. Coagulation is a critical step in water treatment because it involves removing the colloidal particles as well as pathogens that are often attached to the particles. These methods are often not suitable because of the high cost and low availability of chemical coagulants and disinfectants. Synthetic coagulants are not always available at a reasonable price and can leave undesirable residues in treated water. In the present study, the removal efficiency of *Moringa oleifera* and alum were compared using different types of wastewater. The efficacy of two coagulants has been tested based on some critical parameters including dosages of coagulant, pH, EC, TDS, hardness, DO and COD of turbid water and change in values of these parameters in finished water. These coagulants obviously possessed positive coagulation abilities. There are about nine treatments with one control been used for the study. From the observed results, the blended coagulant MO: $(Al_2(SO_4)_3$ treatments T7(25:25) and T8(50:50) dosage ratio gives better removal efficiencies with respect to pH, EC, TDS, hardness, DO, COD, Na and K, and appears to be suitable for treatment of wastewater, when compared with other dosages.

INTRODUCTION

Water is one of the fundamental requirements of life and any undesired addition of chemical substances leads to its contamination and makes it unfit for human utility. Many industrial and power plants use rivers, streams and lakes to dispose off the wastes which can have a disastrous effect on the life in an aquatic ecosystem (Maitera et al. 2011). Exposure to those in drinking water has a number of adverse effects on human health, including neuro, gastrointestinal, skin and skeletal disorders, that is a significant cause of morbidity in a number of regions of the world. Mainly, the ground water is polluted due to industrial effluents and municipal waste in water bodies. The conventional methods of water treatment involve various water clarification processes which include coagulation, flocculation, sedimentation and disinfection. These methods are often not suitable because of the high cost and low availability of chemical coagulants and disinfectants. Synthetic coagulants are not always available at a reasonable price and can leave undesirable residues in treated water.

To overcome chemical coagulant problems it is necessary to increase the use of natural coagulants for drinking water treatment. Naturally occurring coagulants are usually presumed safe for human health. Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from microorganisms, animals or plants. In the recent years, the use of various natural products has been widely investigated as an alternative to the current expensive methods of water treatment. Some of the natural products can be effectively used as a low cost absorbent (Shaikh & Bhosle 2011). More so, the dosages and techniques involved are too cumbersome for use in most rural areas (Aho & Lagasi 2012).

For this reason, the use of coagulants of plant origin is an option for the clarification of turbid waters, especially in rural areas and small communities of developing countries (Broin et al. 2002). One of these alternatives is *Moringa oleifera* seeds. The *Moringa oleifera* seed has been found to have antibacterial activity. The seeds also act as a natural absorbent and an antimicrobial agent (Madsen et al. 1987).

It is a native tree of the sub-Himalayan parts of northwest India, Pakistan and Afghanistan. *Moringa oleifera* is the most widely cultivated species of a monogeneric family, the Moringaceae, that is, native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan. It is already an important crop in India, Ethiopia, Philippines and Sudan, and is being grown in west, east and south Africa, tropical Asia, Latin America, the Caribbean, Florida and the Pacific Islands. Almost every part of the plant (leaves, flowers, seeds, roots and bark) is used as food or for medicinal and therapeutic purposes, especially in developing countries (Jed 2005). *Moringa oleifera* seeds are also used as a primary coagulant in drinking water clarification and wastewater treatment due to the presence of a water-soluble cationic coagulant protein able to reduce turbidity of the treated water. *Moringa oleifera* is a perfect example of a so called "multipurpose tree". *Moringa oleifera* is a small, fast growing, drought "deciduous" tree that ranges in height from 5- 12 m with an open, umbrella shaped trunk, which when fully grown is straight with corky and whitish bark (Jed 2005). The evergreen foliage has leaflets 1-2 cm in diameter, and the flowers are white or cream coloured. The fruits are initially light green, slim and tender, eventually becoming dark green, firm and upto 120 cm long. *Moringa oleifera* can easily be planted by transplanting or by seed. The seed can be sown either directly or in containers with no seed treatment necessary. The plants raised from 1 mere beat, pods from the second year. Thereafter, it grows with maximum production of 4 to 5 years. *Moringa oleifera* is a natural coagulant, whose seeds are cationic proteins, responsible for coagulation/flocculation of impurities (Ndabigengesere et al. 1995, Okuda et al. 2001).

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. The hardness removal efficiency of *Moringa oleifera* was found to increase with increasing dosage (Suleyman et al. 1994). *M. oleifera* seed has also been found to have antibacterial activity. The reduction in the bacterial count is similar to that of alum. However, the bacteria count in the sludge reduced significantly with increased *M. oleifera* coagulant dosage unlike alum where the bacterial count in the sludge remained fairly constant with increased dosage (Broin et al. 2002). This may be an indication of bactericidal activity of *M. oleifera*, although further investigation is required to verify the mechanism of the action. The ability of a recombinant *M. oleifera* protein to decrease the viability of Gram-negative or Gram-positive bacterial cells and to mediate the aggregation of negatively charged particles in suspension, such as bacterial cells, clay or silicate microspheres (Suarez et al. 2003). The seed contain a number of benzyl isothiocyanate and benzyl glucosinolate, which act as antibiotic (Eilert et al. 1981). 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 *Moringa oleifera* coagulant protein has been explained in different ways. It has been described as adsorption and charge neutralization and inter particle bridging. Flocculation by inter-particle bridging is mainly characteristic of high molecular weight polyelectrolyte. Due to the small size of the *Moringa oleifera* coagulant protein, a bridging effect may not be considered as the likely coagulation mechanism (Suleyman et al. 1994). *Moringa oleifera* seeds which 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, that are thought to act by disrupting the cell membrane or by inhibiting essential enzymes, reported that *Moringa* seeds could inhibit the replication of bacteriophages. The use of natural materials of plant origin to clarify turbid water is not a new idea (Bina 1991, Folkard & Sutherland 2001). At 95.0% confidence level, there was a significant difference among all the treatments at the varying loading dose concentrations on the pH (Amagloh & Benang 2009). The treatments gave a range of 7.2 to 7.9 pH which falls within the reduced as the concentrations of the dosing solutions were increased. The reverse was observed with the Moringa treatment. Among all the plant materials that have been tested over the years, powder processed from the seeds from *Moringa oleifera* has shown to be one of the most effective as a primary coagulant for water treatment and can be compared to that of alum, a conventional chemical coagulant (Kumar Sudhir et al. 2010). It was inferred and confirmed from the reports that the powder has antimicrobial properties.

Moringa seed contains 1% active polyelectrolytes that neutralize the negative charged colloid in the dirty water (Ndabigengesere et al. 1995, Ndabigengesere & Narasiah 1998, Oloduro & Aderiye 2007). This protein can therefore be a non toxic, natural polypeptide for sedimentation of mineral particles and organics in the purification of drinking water. *Moringa oleifera* seeds are also acting as an antimicrobial agent against a varied range of bacteria and fungi (Anwar et al. 2007). The objective of this study is to characterize different wastewater of varied sources and to study the effect of *Moringa oleifera* as single or in combination with synthetic inorganic coagulant for treatment of wastewater collected from different sources (Lowel 2001).

MATERIALS AND METHODS

Collection and processing of *Moringa oleifera* and alum: *Moringa oleifera* seeds were collected from farms in Kovilpatti, Tamilnadu. The dried seeds were collected from the trees, hulls and wings from the kernels were removed by hand. The kernel was ground into medium fine powder with a domestic food blender. Fig. 1 shows *Moringa oleifera* and its dry powder. The analytical grade of chemical coagulant alum was taken in the laboratory, Department of Chemistry, BHU, Varanasi.

Collection of different wastewater: There are three different types of wastewater used for the study, i.e., sewage wastewater (W1), saree dyeing wastewater (W2) and carpet dyeing wastewater (W3). The first sewage wastewater was collected from the gully place, which is situated near the Ravidas Gate, Banaras Hindu University, Varanasi. And the second one, saree dyeing wastewater was collected from the dyeing units of Varanasi and the carpet dyeing wastewater collected from Badohi, Varanasi. About fifteen litres of sample from each were collected and used for further analysis.

Physicochemical analysis of wastewater: The wastewater was analysed in terms of pH, EC, TDS, DO, COD, hardness, Na and K. The standard analytical procedure has been used for analysing the different physiochemical characteristics of water.

Experimental Details

Factors: 2

A. Treatments with synthetic and natural coagulant

- T0 = Control
- T1 = Treatment with *Moringa oleifera* 50mg/L
- T2 = Treatment with *Moringa oleifera* 100mg/L
- T3 = Treatment with *Moringa oleifera* 150m/L
- T4 = Treatment with Alum 50mg/L
- T5 = Treatment with Alum 100mg/L
- T6 = Treatment with Alum 150mg/L
- T7 = Treatment Combination of M.o + Alum 50mg/L
- T8 = Treatment Comination of M.o + Alum 100mg/L
- T9 = Treatment Combination of M.o + Alum 150mg/L

B. Varied wastewater source

- Sewage water (W1)
- Saree Dyeing wastewater (W2)
- Carpet Dyeing wastewater (W3)

Replication: Three

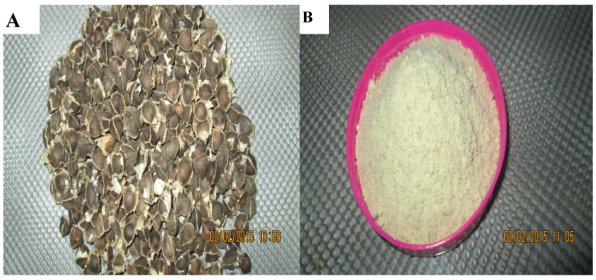

Fig. 1: *Moringa oleifera* and its dry powder.

RESULTS AND DISCUSSION

An initial experiment was carried out to determine the preliminary characteristics of different type of wastewater for examining the effectiveness of *Moringa oleifera* and alum as a coagulant. The initial and after treatment values has been given in Table 1, 2 and 3.

Effect of *Moringa oleifera* and alum on pH: Coagulants in general bring a change in pH towards alkaline side. The addition of coagulant has made a drastic change in OH^- concentration in sewage wastewater as compared to saree dyeing wastewater and carpet dyeing wastewater. For sewage wastewater and saree dyeing wastewater, the effect was more pronounced with treatment T1 whereas for carpet dyeing wastewater effect was more in T3 treatment (Fig. 2). In the figure, x-axis represents the different types of treatments and y-axis the pH values; the changes in pH values of different type of wastewater due to different types of treatment are represented in the bar diagrams. Low pH indicates increasing acidity, while a high pH indicates increasing alkalinity.

Effect of *Moringa oleifera* and alum on EC: For sewage wastewater, the effect was more pronounced with treatment T4 and T7 (with removal efficiency of about 56% and 55% respectively) , for saree dyeing wastewater it does not show that much change in the conductivity, whereas for carpet dyeing wastewater, the effect was more in T3 (removal efficiency 29%) and T5 (removal efficiency 28%) treatment. The effect has been shown in the Fig. 3. In the figure, x-axis represents the different types of treatments and y-axis the electrical conductivity values; the changes in EC values of different type of wastewater due to different types of treatment are represented in the bar diagrams. There was no alteration in the conductivity after the treatment in W2 and W3, whereas, in sewage wastewater there were changes in conductivity after the treatment. In primary axis the EC for sewage and saree dyeing wastewater are given, while due to lower EC values for carpet dyeing wastewater, it is given in the secondary axis.

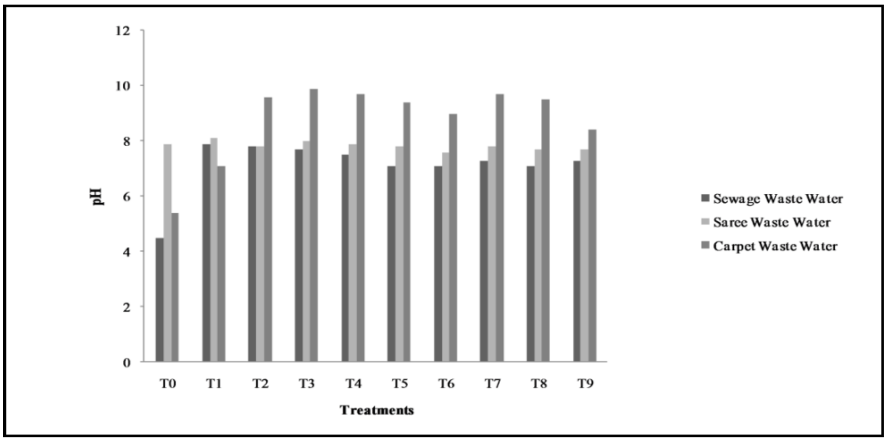

Fig. 2: pH vs. treatments (W1 = Sewage Waste Water, W2 = Saree Industry Waste Water and W3 = Carpet Industry Waste Water, T0 = Sample before treatment, T1 = Treatment with Moringaoleifera 50mg/L, T2 = Treatment with Moringaoleifera 100mg/L, T3 = Treatment with Moringaoleifera 150m/L, T4 = Treatment with Alum 50mg/L, T5 = Treatment with Alum 100mg/L, T6 = Treatment with Alum 150mg/L , T7 = Treatment Combination of M.o + Alum 50mg/L, T8 = Treatment Comination of M.o + Alum 100mg/L, T9 = Treatment Combination of M.o + Alum 150mg/L.)

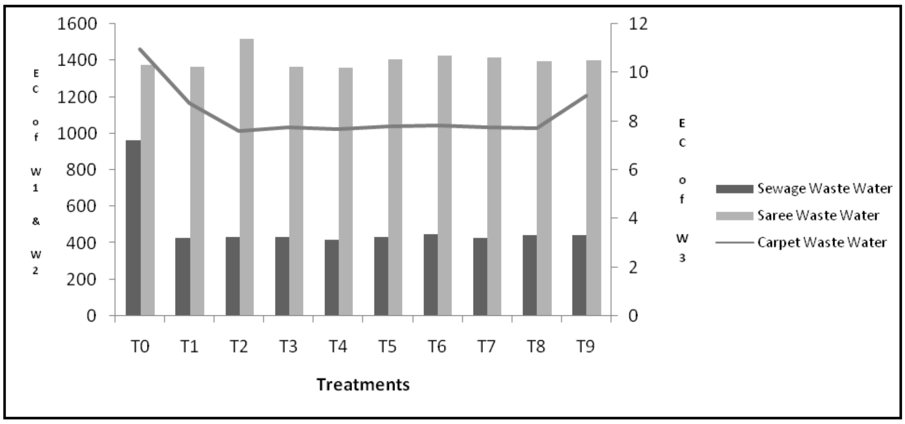

Fig. 3: EC vs. treatments (captions as in Fig. 2).

Effect of *Moringa oleifera* and alum on TDS: In the sewage wastewater the effect was observed more in treatments T4 and T7 (with removal efficiency of about 56% and 55% respectively), whereas, in saree dyeing wastewater the effect was reversed, and in carpet dyeing wastewater the effect was observed more in the T2 and T4 (both have removal efficiency of about 30%) (Fig. 4). In the figure, x-axis represents the different types of treatments and y-axis the TDS values; the changes in TDS values of different type of wastewater due to different types of treatment are represented in the bar diagrams. In primary axis, the TDS for sewage and saree dyeing wastewater are given, while due to lower TDS values for carpet dyeing wastewater, it is given in the secondary axis.

Effect of *Moringa oleifera* and alum on hardness: The sample wastewaters collected from different sources are hard initially, but the hardness reduced after the treatment with the coagulants. In sewage wastewater, more hardness reduction has been observed in the treatments T1 and T4 (with removal efficiency of about 55% & 50% respectively), whereas, in saree dyeing wastewater the reduction has been observed in the T5 and T9 treatments (removal efficiency of about 33% & 25% respectively) and in carpet dyeing wastewater the reduction has been observed in T6, T7 and T9 (with removal efficiency of about 48%) (Fig. 5). In the figure, x-axis represents the different types of treatments and y-axis the hardness values, the changes in hardness values of different type of wastewater due to different types of treatment are represented in the bar diagrams.

Effect of *Moringa oleifera* and alum on DO: In the sample sewage wastewater, the effect has been observed in the T5 and T6 treatments, whereas in saree dyeing wastewater the

Table 1: Physiochemical values of sewage wastewater before and after treatment (values in mg/L except pH and EC).

Parameters	Sewage wastewater (W1)									
	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
pH	4.5	7.93	7.8	7.7	7.53	7.13	7.13	7.3	7.1	7.3
EC	961.5	430.5	431	434	417.5	435.5	449.5	427.5	444.5	442.5
TDS	640.16	286.71	287.04	289.04	278.05	290.04	299.36	284.71	296.03	294.70
Hardness	22.5	10.04	10.68	10.56	11.2	10.82	10.44	10.52	10.72	10.64
DO	3.5	6.1	6.65	6.55	6.8	8	8.2	7.5	7.6	7.75
COD	238.4	236.8	255.2	234.4	241.28	228.8	233.6	236.8	248.8	223.2
Na	365.66	265.95	270.35	278.56	354.65	408.45	457.35	313.1	345	391.15
K	48.33	23	24.35	27.35	54.75	74.50	90.60	38.8	50.35	67.80

Table 2: Physiochemical values of saree dyeing wastewater before and after treatment (values in mg/L except pH and EC).

Parameters	Saree dyeing wastewater (W2)									
	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
pH	7.3	8.1	7.83	8.0	7.90	7.80	7.60	7.80	7.70	7.73
EC	1378	1363.5	1516.5	1364.5	1361	1407	1426	1415	1394.33	1403
TDS	923.48	913.54	1016.05	1140.76	911.87	942.69	955.42	948.05	934.31	939.86
Hardness	328.33	258	278	257	237	217	248	273	246	243
DO	3.2	10.73	10.73	11	11.90	11.23	11.83	12.23	12.43	11.35
COD	259.2	134.4	127.2	112	127.2	107.42	105.6	117.6	117.6	108.8
Na	404.3	405.25	414.85	410.35	423.7	435.75	451.60	423.15	427.15	433.30
K	4.5	4.7	4.93	5.13	7.83	11.73	7.40	7.13	8.23	9.93

Table 3: Physiochemical values of carpet dyeing wastewater before and after treatment (values in mg/L except pH and EC).

Parameters	Carpet dyeing wastewater (W3)									
	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
pH	5.4	7.13	9.60	9.93	9.73	9.40	9.03	9.70	9.53	8.40
EC	1096	875	758	772	766	779	782	774	771	906
TDS	729	582	507	514	510	518	520	515	513	602
Hardness	119	72	62	62	59	62	61	61	59	61
DO	2.53	2.75	3.20	3.50	3.33	3.20	4.05	3.75	3.50	4.05
COD	278.40	228	218.60	215.20	130.40	135.21	134.40	122.40	132.80	98.40
Na	1557	1286	1102.33	1111	1175.33	1229.33	1267	1148.33	1186.33	1366.33
K	341.25	285.6	20.77	26.32	51.07	108.40	137.85	43.93	72.65	93.45

effect has been observed in the T7 and T8. And in carpet dyeing wastewater the effect was more observed in the T6 and T9. This shows a significant increase in the dissolved oxygen content of the water after treatment with the coagulants (Fig. 6). In the figure, x-axis represents the different types of treatment and y-axis the DO values; the changes in DO values of different type of wastewater due to different types of treatment are represented in the bar diagrams.

Effect of *Moringa oleifera* and alum on COD: After treatment with the different coagulants, there was a little/small decrease in the COD. In the sewage wastewater, a little reduction in COD has been observed in the T5 and T9 (with removal efficiency of about 4% and 6% respectively), whereas in saree dyeing wastewater the reduction has been observed in T3, T7 and T8 (with removal efficiency of about 56% and 54% respectively). And in the carpet dyeing wastewater the reduction observed in the treatments T5 and T9 (with removal efficiency of about 51% and 64%) (Fig. 7). In the figure, x-axis represents the different types of treatment and y-axis the COD values; the changes in COD values of different type of wastewater due to different types of treatment are represented in the bar diagrams.

Effect of *Moringa oleifera* and alum on Na: The sewage wastewater shows reduction in the treatments T1 and T2, and increase in concentration of sodium with the other treatments. Whereas, in saree dyeing wastewater, the reduction

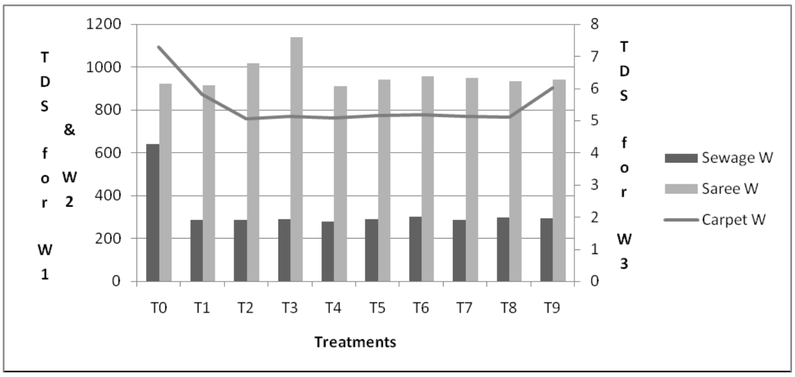

Fig. 4: TDS vs. treatments (captions as in Fig. 2).

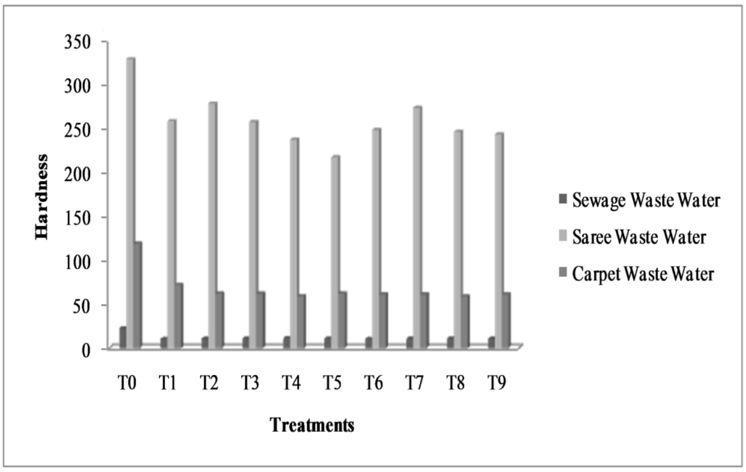

Fig. 5: Hardness vs. treatments (captions as in Fig. 2).

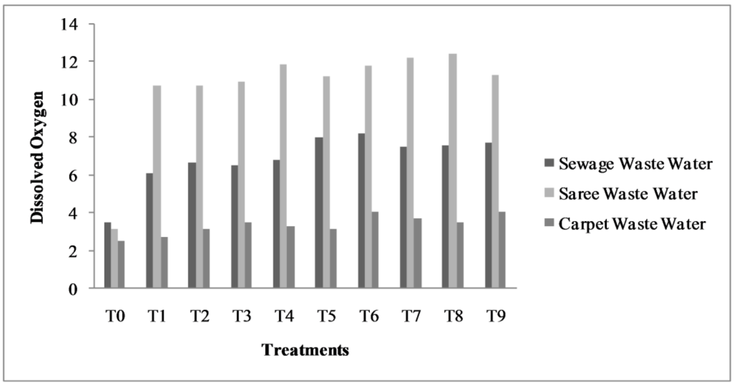

Fig. 6: Dissolved oxygen vs. treatments (captions as in Fig. 2).

was observed in the treatments T1 and T3. In carpet dyeing wastewater the reduction observed in the T2 and T3 treatments (Fig. 8). In the figure, x-axis represents the different types of treatment and y-axis the Na values; the changes in Na values of different type of wastewater due to different types of treatment are represented in the bar diagrams.

Effect of *Moringa oleifera* and alum on K: In the sewage wastewater, the initial level of potassium has been decreased

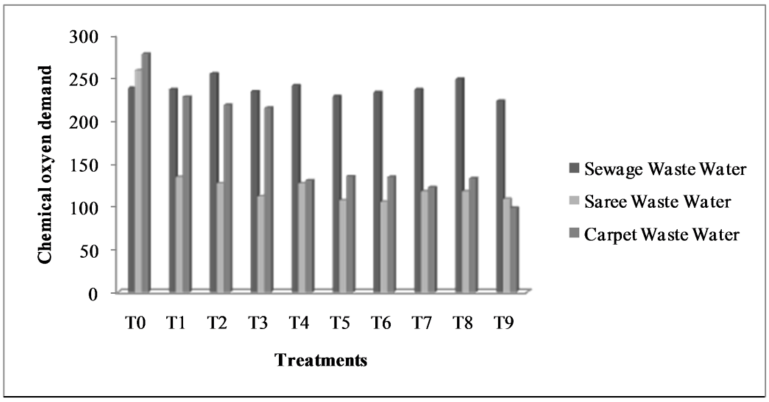

Fig. 7: COD vs. treatments (captions as in Fig. 2).

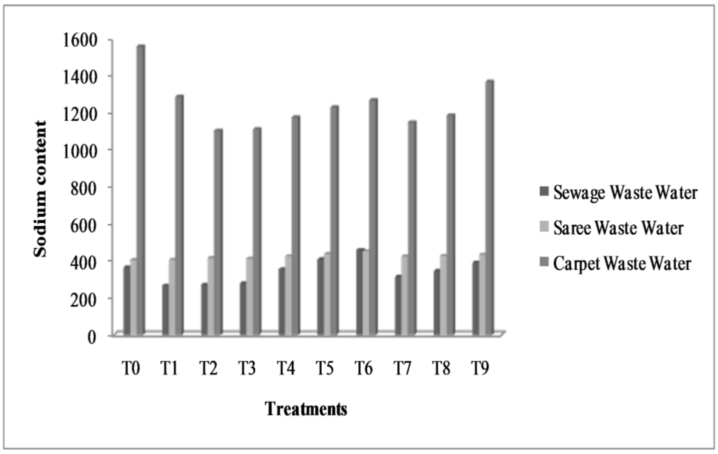

Fig. 8: Sodium content vs. treatments (captions as in Fig. 2).

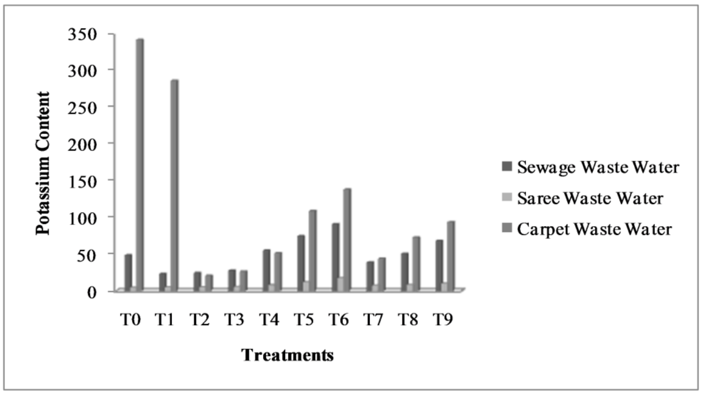

Fig. 9: Potassium content vs. treatments (captions as in Fig. 2).

after the treatment with natural coagulant, whereas after treatment with chemical coagulant and in combination it shows increase in the concentration. In the saree dyeing wastewater, increase in potassium content with increasing the concentration of the coagulant, and in carpet dyeing wastewater the reduction in potassium content with increasing the concentration (Fig. 9). In the figure, x-axis represents the different types of treatment and y-axis the K values; the changes in K values of different type of wastewater due to different types of treatment are represented in the bar diagrams.

CONCLUSIONS

The wastewater collected from the different type of sources in Varanasi was examined for the various parameters. The feasibility in the treatment of different wastewater using natural coagulant *Moringa oleifera* and chemical coagulant alum has been taken for the investigation. The overall efficiency of the blended coagulants in treating varied wastewater showed different trends. In sewage wastewater and carpet dyeing wastewater the effect was more pronounced in T7 (25mg/L M.o + 25mg/L alum) whereas, in saree dyeing wastewater, the significant effect was observed in T8 (50mg/L M.o + 50m/L alum). In conclusion, using this natural coagulant in combination with synthetic alum results in considerable savings in chemicals, sludge handling cost and can address this sensitive issue in a sustainable approach.

REFERENCES

Aho, I.M. and Lagasi, J.E. 2012. A new water treatment system using *Moringa oleifera* seed. American Journal of Scientific and Industrial Research, 3(6): 487-492.

Amagloh, F.K. and Benang, A. 2009. Effectiveness of *Moringa oleifera* seed as coagulant for water purification. African Journal of Agricultural Research, 4: 119-123.

Anwar, F., Latif, S., Ashraf, M. and Gilani, A.H. 2007. *Moringa oleifera*: a food plant with multiple medicinal uses. Phytotheraphy Research, 21: 17-25.

Broin, B.M., Santaella, S.C., Cuine, C.S., Kokou, K.K., Peltier, P.G. and Joet, T. 2002. Flocculent activity of a recombinant protein from Moringa oleifera Lam. seeds. Applied Microbiology and Biotechnology, 60(1): 114-119.

Bina, 1991. Investigation into the use of natural plant coagulants in the removal of bacteria and bacteriophage from turbid waters. PhD Thesis, University of New Castle Upon Tyne.

Eilert, U., Wolters, B. and Nahrstedt 1981. The antibiotic principle of seeds of *Moringa oleifera* and *Moringa stenopetala*. Planta medica, 42(05): 55-61.

Folkard, G. and Sutherland, T. 2001. The use of *Moringa oleifera* as a natural coagulant for water and wastewater treatment. Department of Engineering, University of Leicester, UK.

Jed, W.F. 2005. *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic and prophylactic properties. Trees for Life Journal, 1-15.

Kumar Sudhir, P., Mishra, Debasis, Ghosh, Gautam and Panda, Chandra S. 2010. Medicinal uses and pharmacological properties of *Moringa oleifera.* International Journal of Phytomedicine, 2: 210-216.

Lowel, J.F. 2001. Introduction to Moringa Family. Church World Service, Dakar Senegal.

Maitera, O.N., Barminas, J.T. and Shinggu, D.Y. 2011. An evaluation of the physical parameters of river Gongola in Adamawa State Nigeria. Advance Applied Science Research, 2(6): 62-69.

Madsen, M., Schlundt, J. and Omer, E.F. 1987. Effect of water coagulation by seeds of *Moringa oleifera* on bacterial concentration. Journal of Tropical Medicine Hydrology, 1: 90-109.

Ndabigengesere, A., Narasiah, K.S. and Talbot, B.G. 1995. Active agents and mechanisms of coagulation of turbid water using *Moringa oleifera*. Water Research, 29(2): 703-710.

Ndabigengesere, A. and Narasiah, K.S. 1998. Quality of water treated by coagulation using *Moringa oleifera* seeds. Water Research, 32: 781-791.

Oloduro, A.O. and Aderiye, B.I. 2007. Efficacy of *Moringa oleifera* seed extract on the microflora of surface and underground water. Journal of Plant Sciences, 2: 453-458.

Okuda, T., Baes, A.U., Nishitimas, W. and Okada, M. 2001. Isolation and characterization of coagulant extracted from *Moringa oleifera* seed by salt solution. Water Resources, 35(2): 405-410.

Shaikh, P.R. and Bhosle, 2011. Occurrence of chromium metal in Siddheshwar Reservoir at Hingoli India. Advances in Applied Science Research, 2(1): 214-220.

Suleyman, A., Muyibi, and Lilian, M. 1994. *Moringa oleifera* seeds for softening hard water. Water Research, 29(4): 1099-1105.

Suarez, M., Entenza, J.M., Doerries, C., Meyer, E., Bourguin, L., Sutherland, J., Manson, I., Moreillon, P. and Mennod, N. 2003. Expression of a plant-derived peptide harbouring water-cleaning and antimicrobial activities. Biotechnol. Bioeng., 81(1): 13-20.