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Water clarification using *Moringa oleifera* Lam. seed as a natural coagulant

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ABSTRACT

Moringa oleifera Lam. was evaluated as natural clarifier for water purification. Various water sources like bore water, river water and tap water from Tirupati, A. P., India were collected and tested for physical, chemical and microbiological parameters. Water is treated with alum and *Moringa oleifera* seed powder and compared for all parameters. Experiments were carried out at three turbidity levels <50, 50-150, >150 (NTU) and the pH range 6-8.5 to evaluate the efficacy of *M. oleifera* seed powder and alum in the laboratory. Extract of *M. oleifera* seed could improve the water quality by minimizing the significant decrease in turbidity levels and pH ranged between 7.5 and 8.5, electrical conductivity was in range of 240-380, overall alkalinity mean values ranged between 80-260 and hardness, 82-302. The *M. oleifera* seed powder has the dominant mechanism of turbidity removal and exhibited antibacterial effect. The incorporation of this powder in the water purification systems will help to improve natural quality of water, wherever necessary.

KEY WORDS: Alum, coagulation, *Moringa oleifera,* purity, water treatment

INTRODUCTION

Access to safe drinking water and adequate sanitation is crucial for human survival. Almost 70 percent of water available in the country is not potable causing numerous types of illnesses. Water obtained from deep aquifers may contain microorganisms at levels as high as 10CFU/ml. In many parts of the world, water from different sources like rivers, lakes, wells are being used which are highly turbid. The treatment processes cover three major operations: sedimentation, filtration and flocculation disinfection. The natural coagulants are focused as clarifying agents. *Moringa oleifera* belonging to the family Moringaceae have been shown to be one of the most effective primary coagulant for water treatment as compared to those of alum (conventional chemical coagulant). The powder from crushed moringa seed kernals work as natural flocculant and coagulant that aid in binding the solids in water and causing to sink to the bottom (Bina, 1991, Kaser *et al.,* 1990 and Sani,1990).

Aluminum is regarded as an important chemical contaminant used to reduce water turbidity in the countries where water is a major poisoning factor leading to many waterborne illnesses especially with reference to Sudan (Sani, 1990, Sutherland *et al.,* 1994). Hence, the present study has been taken up to standardize the method using 'Moringa seed powder' as a natural coagulant for water purification and analyse the physical, chemical, microbiological parameters of different types of water.

MATERIALS AND METHODS

Studies were carried out at nine locations in and around Tirupati, Chittoor district, Andhra Pradesh, India (Table 1) where turbidity of water has been clearly observed (Table 2 & Fig 1). The climate is usually warm during most of the periods in a year. The maximum temperature is around 45°C during April to May and minimum temperature around 25-28°C during December-January. Water samples were collected from different wells in bacteria free plastic cans by employing a purposive sample method for microbial analysis.

The selected water samples were tested for physico-chemical, microbiological parameters that were analysed as per standard methods by the American Public Health Association (1989) and assessed for the potability of water for drinking. All chemicals used were of analytical grade. At each sampled site an aliquot of 500ml of water was collected in a polyethylene bottle for the determination of physico-chemical and micro biological parameters. The physical parameters like colour, odour, pH, turbidity, electrical conductivity *etc*. Chemical parameters like alkalinity, total hardness *etc* and microbial activity of total coliform and *Escherisia coli* were analysed.

The pH was analyzed by electrode method, electrical conductivity was analysed by conductometry; turbidity was analyzed by Nephelometric method and optimum coagulant dose was analyzed by Jar test, Chemical parameters like alkalinity was analyzed by potentiometric titration method. Total hardness was analyzed by EDTA Titrimetric method and Microbiological parameters was tested for MPN ratio by multiple tube method. The standard values of different physico-chemical parameters used for the characterization of water quality (Table 3) for drinking are taken as standards for comparison

Dosage of *Moringa oleifera* seed powder and solution for the treatment of water as follows (Table 4). The seed powder is allowed to mature and to dry naturally to a brown colour on the tree prior to harvesting. After shelling the seeds they are crushed and sieved (using 0.8 mm mesh or similar). Seed powder was ground with small amount of clean water to make a paste. Approximately 50-150 mg of ground seed will be needed to treat a litre of water, depending on the quantity of suspended matter. The paste is diluted to required strength and the insoluble material filtered using muslin cloth or fine mesh till obtaining a milky white suspension, which is added to turbid water by continuously stirring for about 5 min (15-20 rotations/min.). Treated water should be covered and left to settle for at least one hour. The method selected has to be standardized and the dosage of the coagulant is used according to the raw water turbidity. The amount of seed required will vary depending on the raw water source and based on the raw water turbidity (Gate Tech. Info: 2000).

Post treatment analysis of water for physical, chemical and microbiological parameters

The samples treated with *M. oleifera* seed powder were analyzed for physical, chemical, microbiological parameters as per the methods described previously. The water samples were also treated with alum and were analyzed for the purpose of comparison. The data recorded was subjected to appropriate statistical analyses.

RESULTS AND DISCUSSION

The natural product that can replace the expensive aluminium sulphate is *M. oleifera* seed powder. For several years researchers have been examining the tree and found its seed to be suitable for water treatment. The tree has a lot of potential to replace aluminium and other chemicals used in water treatment, especially for the rural poor population whose economic livelihood would depend on this tree. Researchers picked up from the local people who used crushed moringa seed to cause sedimentation in their own water storage vessels in the home (Folkard *et al.* (1990).

The present investigation can replace Commercial Chemical Coagulants by natural coagulant as an alternative in water clarification by cost effective means, especially to the rural poor who cannot afford any water treatment chemicals, without affecting the health of their environment.

The results obtained from the prior and after treatment analysis for physico-chemical parameters of open well (OW), river water (RW) and borewell water (BW) samples collected from different villages in and around Tirupati is presented hereunder.

Physical characteristics

The water samples collected were analysed for the following parameters:

Odour and colour:

Prior to treatments all the selected samples exhibited slight to moderate odour. The dissolved organic materials or the inorganic salts, or the dissolved gases may impart tastes and odour to the water, which generally occur together. The mild odour of untreated samples became odourless upon treatment with coagulants (alum, moringa seed powder) for different water samples. Dissolved organic matter from decaying vegetation or some inorganic materials, such as coloured soils, etc., may impart colour to the water. The excessive growth of algae and aquatic micro-organisms may also sometimes impart colour to the water. The pale yellow untreated samples became colourless on treatment with moringa seed powder and alum. The water samples which were initially clear were not altered after treatment with coagulants.

pH of the pre-treated and treated samples:

From the tabulated results it was found that the pH which should be maintained in the clarified water is between 6.5-8.5 as per (IS 10500, 1994) the standards. The pre treatment mean pH values were 8.4, 8.2 and 7.88 in open well water, river water and bore well water, respectively. After treatment with *Moringa oleifera* (T2) and alum(T3) the mean pH values were 8.05 (T2) and 8.21(T3) in open well water, 7.98 (T2) and 7.55 (T3) in river water and 7.98 (T2) 7.55 (T3) in bore well water. Significant difference was observed in all the pre treated samples with that of the treated samples (Table 5). No significant difference was observed between the samples treated with plant extract and alum.

There is a reduction in pH of different types of water samples when the water samples were treated with moringa seed powder (Moramudali *et al.* (1999). There was no pH effect in treatment of water when the initial turbidity was lower than 50 NTU (Bawa *et al.,* 2001)

Turbidity of pre-treated and treated samples:

The turbidity depends upon the fineness and concentration of particles present in water. Although the clay or other inert suspended particles may not be harmful to health yet they are to be removed or reduced for aesthetic and psychological reasons. Since people don't like turbid water, the turbidity of untreated water must be measured and then reduced by treatment to permissible values so as to make it invisible to naked eye.

The mean turbidity values of pre treated samples (PT1) for open well was 77.7, river water was 200.1 and bore well water was 38.2. After treatment the values for Open well water was found to be 2.23 (sample treated with moringa seed powder), 1.81(sample treated with alum).The Pretreated samples were significantly different to that of the treated samples (0.05% level and 0.01% level) and no significant difference was observed between the PT2 & PT3 samples. Similar observations were also found in river water samples where the mean was found to be 1.9 (PT2) & 1.9 (PT), in bore well samples mean was found to be 2.30 (PT2) & 2.11(PT3).The vast decrease in turbidity levels after treating the different types of water samples with Moringa seed powder or alum proves that Moringa seed extract is an effective natural coagulant as against the chemical coagulant alum (Table 5)

Sani (1990) carried out jar test with moringa as primary coagulant using water from 4 sources (2 surface and 2 shallow wells) and observed the decrease in turbidity 100-800 NTU and 80-150 NTU, respectively to 92-99%. Sutherland *et al.,* (1994) reported the inlet turbidities of 270-380 NTU were consistently reduced to below 4 NTU in the finished water.

Electrical Conductivity:

Electrical conductivity of water samples is due to ionisation of dissolved inorganic solids and is used as a basic index in judging the suitability of water for potable properties. From the tabulated results, it is evident that the overall mean electrical conductivity of pre-treated water samples of OW was 274, for PT_2 192.3 and for PT_3 277.6 was observed. River water samples showed the mean as PT1 350.6,PT2363.3,PT3 357.6; whereas the mean values for Bore Well water samples showed as PT1 261,PT2 261.8,PT3 260.7 EC of water samples after treatment with Moringa seed powder or Alum was increased slightly and lies within the range of 250 to 380 (Table 6). So, moringa seed powder can also be as effectively used as Alum to increase the EC of water. Studies on Conductivity of different types of water sample showed that there is a rapid increase in conductivity of the samples when treated with Moringa seed powder (Moramudali *et al.,* 1999).

Chemical characteristics of water before and after treatment with Moringa seed powder and alum:

The chemical parameters like total alkalinity, hardness of different types of samples before and after treatment were studied and indicated in Table 6.

Total alkalinity of pre-treated and treated samples:

The overall mean alkalinity of OW for PT_1 was 180.63 for PT_2 143.91 and for PT_3 161.1. The values for River water are 275.3

for PT1,PT2 244.1 &PT3 260.21.Bore Well samples showed the mean as 122.0 PT1, 80.87 for PT2,93.56 for PT3. The overall significant reduction in alkalinity was observed in samples treated with Moringa seed powder and the significant reduction was similar to that of the samples treated with Alum. Similar observations were also reported by Sani (1990) who found that alkalinity reduction averaged only 30% in the coagulation of water using Moringa seed powder.

Hardness of pre-treated and treated samples:

Hardness of water is caused due to sulphates or chlorides of iron, manganese and aluminium. Water with 25 mg/lit calcium carbonate is considered soft while with 500 mg/lit $CaCO_3$ is termed as hard In some cases the hardness was very slightly reduced and in some cases it is not reduced. Most of the cases, no significant results were observed and the mean hardness after treatment ranged from 82 to 302 and so Moringa seed powder though not an effective reduction of hardness, but can be as equally used as alum to reduce the hardness of water. As a polyelectrolyte it may therefore be postulated that Moringa seed powder removes hardness in water through absorption and inter-particle bridging (Lamer and Healy, 1963). Sani (1990) reported that there is a significant difference and reduction in hardness between 60-70% from 180-300 mg/1.

Microbiological examination of water before and after treatment with Moringa seed powder and alum

The MPN ratio of different types of water samples, i.e., river water (RW), borewell water (BW) and open well water (OW) was tested before and after treatment with Moringa seed powder and alum (Table 7).

The mean water as it falls down through the atmosphere, collects bacteria and other types of parasitic organisms, such as viruses etc., from the dry dust or smog present in the air or the atmosphere. Since the initial rains wash away most of these dusts, they are likely to be highly contaminated with bacteria and other organisms. Some bacteria are the deadly foes of man and animals and may enter their tissues, causing serious water borne diseases, such as cholera, typhoid, infectious hepatitis, etc. Such harmful bacteria or organisms are known as pathogenic bacteria or pathogens. MPN represents the bacterial density which is most likely to be present.

The prevention of food adulteration act (1955) has laid specification for salmonella, coliforms, yeast and mold in addition to Bacillus vibrial and Clostridium specifications for microbiological quality laid by PFA is tabulated (Table 8).

Anti microbial activity of Moringa seeds were studied against *E. coli*, total coliforms which are indicative of faecally polluted water and disease causing organisms.

The number of *E. coli* in the water samples (pre-treated) ranged from (4 to 7) and after treatment with Alum or Moringa seed powder their number is completely reduced to zero. Jeyanthi *et al.* (2004) studied the quality evaluation of potable water on treatment with selected medicinal plant products. Treatment with *Moringa oleifera* seed powder shown to reduce bacterial total count to 100 cells/ml than that of untreated water sample (200×103cells/ml). This reflects the efficiency of *M. oleifera* seed powder in improving water quality. Higher variable counts indicate that the quantity of micro organisms is more and an identification of the types of organisms should be made to see if pathogenic organisms have multiplied in which case, consumption of such water would lead to significant health risks such as a water borne disease outbreak.

The method of sterilising the water also influences the microbial safety. The methods like disinfection with chemicals, ozonation, reverse osmosis, using ultraviolet radiation etc., are employed. A combination of methods yields a more purified product. But in case of Moringa seed powder and Alum it is clear that the effectiveness of these coagulants will help to yield more purified products. The results thus indicate that the methods of coagulation with Moringa employed were more appropriate.

Comparison of physico chemical characteristics with standards (BIS, IS10500 1994)

The physico-chemical characteristics of different types of water samples before and after treatment with Moringa seed powder and alum were studied and compared with that of standards (BIS, IS10500 1994).

The permissible range for pH as laid by BIS *HDL is 7.0-8.3 and # MPL is 8.5-9.0. The permissible range for pH as laid by IS 10500, 1994 is 6.5-8.5. Hence pH values of the tested samples were neutral and within the standard limits.

The maximum permissible limit by BIS is 8.5-9.0 indicates more alkalinity values. But none of the water samples tested were within this maximum permissible limit by BIS except OW3 (PT1) sample with mean value of 8.600, which indicates more alkaline condition when compared to other water samples.

For the water samples collected mean turbidity levels varies from 35.50 to 20.00 for all water samples. The samples after treatment with coagulant solutions are within the highest desirable limit as prescribed by BIS AND ISI 10500.

The total mean alkalinity values for all pre-treated samples vary from 110-293 as caco3.Samples after treatment with Moringa seed powder became low when compared to Alum.

Total Hardness was also within the desired levels prescribed by standards confirming the use of Moringa seed powder is working effectively as that of chemical coagulant Alum in purifying the water.

Overall acceptance of natural coagulant in treatment of water

The overall acceptance of natural coagulant, i.e., effectiveness of *Moringa oleifera* in water treatment systems were studied by many scientists and is given Table 9.The overall review of studies including the present study states that *Moringa oleifera* seed powder is a natural coagulant in efficiently removing the suspended impurities and also acting as a effective bactericidal agent. Thus the research in the area of incorporation of this powder in the water purification systems will help to improve naturally the quality of water wherever necessary. It is considered to offer significant advantages over proprietary chemical coagulants particularly for developing countries.

CONCLUSION

The results obtained after thorough analysis of physico-chemical and microbiological components in water samples from different areas revealed that certain parameters reduced when compared to the permissible limits. The seeds from *Moringa oleifera* have been shown to be one of the most effective as a primary coagulant for water treatment and can be compared to those as of alum (conventional chemical coagulant).

The values of pH, and the other chemical parameters seem to be influenced by the composition of the source of water from which it is derived, the composition of the ground water table, the chemicals used for disinfection and extent of pollution of the source. But most of the results indicate no significant difference in the values of the different parameters when treated with moringa and alum. The results of micribiological analysis revealed that the *M. oleifera* seeds in water purification gave good results by removing 90-99.9% of the bacteria as well as clearing the water solids.

Thus, it can be concluded that *M. oleifera* can form a good natural replacement coagulant for proprietary coagulants that meets the purity requirement of water in developing countries.

Table 1: Various types of water samples collected for analysis

Sample No.	Code	Type of water	Location	Habitation
1	OW_1	Open well	Near Z.P. School	Guttvaripalli (Rural area)
2	OW_2	Open well	Nearby E.B. Transformer	Chandragiri (Rural area)
3	OW_3	Open well	Nearby Ganesan	S.V. Nagar (urban area)
4	RW_1	River water	Kalyanidam Reservoir	Rangampet
5	RW_2	River water	Pipeline Nindra	Pitchatluru (Rural area)
6	RW_3	River water	Swarnamukhi	Near Kalahasti temple
7	BW_1	Bore water	Nearby Canal	Tirupati (Urban area)
8	BW_2	Bore water	Along Road side	Nennur (Rural area)
9	BW_3	Bore water	Nearby Shopping Complex Road side entrance	Tirthakatta Street (Urban area)

Table 2: Classification of the samples according to turbidity

Raw Water Turbidity [NTU]	No.	Collected water samples				
		O.W	No.	R.W	No.	B.W
		Mean		Mean		Mean
<50					3	1) 35.500 2) 38.00 3) 38.00
50-150	3	1) 57.80 2) 85.50 3) 90.01				
>150			3	1) 180.00 2) 200.50 3) 220.00		

NTU : Nephthelometric Turbidity Units ; O.W : Open Well water; R.W : River water; B.W : Borewell water

Table 3: Drinking Water Quality Standards

Parameters	WHO		ICMR		BIS	
	*HDL	#MPL	*HDL	#MPL	*HDL	#MPL
Total dissolved solids(mg/ml)	-	-	500	1500	500	2000
Flouride(mg.l)	1.50	-	1.00	1.50	0.6-1.2	-
Total Hardness as CaCo3(ppm)	200	600	300	600	200	600
Alkalinity as CaCo3(ppm)	-	120+	-	-	200	600
Salinity/chloride(ppm)	200	600	200	1000	250	1000
PH	7.0-8.5	6.5-9.5	7.0-8.5	6.5-9.2	7.0-3.3	8.5-9.0
Turbidity(NTU)	-	-	5.0	25.0	5.0	10.0
D.O(mg/Lit)	-	>6	3.0-6.0	-	-	-

*HDL-Highest Desirable Limit; #MPL- Maximum Permissible Limit; BIS - Bureau of Indian Standards; WHO- World Health Organisation; ICMR- Indian Council of Medical Research

Table 4: Optimum dosage used to test the Turbidity of water samples

Raw Water turbidity, (NTU)	Dosage Range (mg/l)
<50	10-50
50-150	30-100
>150	50-200

Table 5: Comparison of different types of water samples for their physical characteristics after treating with moringa seed powder and alum

Sl. No.	Water samples and treatment		pH Mean	Overall pH Mean			t- value	Turbidity mean	Overall turbidity Mean			t-value	EC Mean	Overall EC Mean			t-value
				PT_1	PT_2	PT_3			PT_1	PT_2	PT_3			PT_1	PT_2	PT_3	
1.	OW_1	PT_1 PT_2 PT_3	8.20 7.81 7.92	8.4	8.05	8.21	7.81^{**} (PT_1-PT_2) 6.31^{**} (PT_1-PT_3) 1.62^{NS} (PT_2-PT_3)	57.80 2.19 1.84	77.77	2.23	1.89	5894.33^{**} (PT_1-PT_2) 3380.12^{**} (PT_1-PT_3) 18.02^{**} (PT_2-PT_3)	280.00 284.22 281.41	274	192.3	277.6	8.40^{**} (PT_1-PT_2) 6.54^{**} (PT_1-PT_3) 5.12^{**} (PT_2-PT_3)
2.	OW_2	PT_1 PT_2 PT_3	8.40 8.06 8.27				11.82^{**} (PT_1-PT_2) 2.71^{*} (PT_1-PT_3) 3.71^{*} (PT_2-PT_3)	85.50 2.20 1.87				8508.33^{**} (PT_1-PT_2) 5518.79^{**} (PT_1-PT_3) 18.10^{**} (PT_2-PT_3)	265.00 272.10 270.64				29.01^{**} (PT_1-PT_2) 36.88^{**} (PT_1-PT_3) 5.03^{**} (PT_2-PT_3)
3.	OW_3	PT_1 PT_2 PT_3	8.60 8.31 8.45				9.03^{*} (PT_1-PT_2) 4.30^{*} (PT_1-PT_3) 2.95^{*} (PT_2-PT_3)	90.01 2.31 1.96				5154.90^{**} (PT_1-PT_2) 3253.03^{**} (PT_1-PT_3) 10.69^{**} (PT_2-PT_3)	277.00 280.68 280.76				12.39^{**} (PT_1-PT_2) 26.05^{**} (PT_1-PT_3) 0.22^{NS} (PT_2-PT_3)
4.	RW_1	PT_1 PT_2 PT_3	8.45 8.25 8.28	8.2	7.98	7.55	5.76^{**} (PT_1-PT_2) 2.87^{*} (PT_1-PT_3) 0.39^{NS} (PT_2-PT_3)	180.00 1.97 1.93	200.16	1.95	1.95	3443.37^{**} (PT_1-PT_2) 3439.40^{**} (PT_1-PT_3) 2.44^{*} (PT_2-PT_3)	350.00 380.50 361.34	350. 6	363.3	357.6	140.90^{**} (PT_1-PT_2) 74.07^{**} (PT_1-PT_3) 72.28^{**} (PT_2-PT_3)
5.	RW_2	PT_1 PT_2	8.20 7.99				4.66^{**} (PT_1-PT_2)	200.50 1.97				11679.9^{**} (PT_1-PT_2)	369.00 371.67				18.52^{**} (PT_1-PT_2)

		PT_3	8.02				2.42^{NS} (PT_1-PT_3) 0.34^{NS} (PT_2-T_3)	1.97				9660.64^{**} (PT_1-PT_3) 0.00^{NS} (PT_2-PT_3)	373.12				28.59^{**} (PT_1-PT_3) 7.12^{**} (PT_2-PT_3)
6.	RW_3	PT_1 PT_2 PT_3	8.00 7.69 7.76				3.29^{**} (PT_1-PT_2) 1.96^{NS} (PT_1-PT_3) 0.46^{NS} (PT_2-PT_3)	220.00 1.99 1.94				11441.70^{**} (PT_1-PT_2) 4712.78^{**} (PT_1-PT_3) 1.06^{NS} (PT_2-PT_3)	333.00 337.82 338.58				29.18^{**} (PT_1-PT_2) 28.23^{**} (PT_1-PT_3) 2.96^{*} (PT_2-PT_3)
7.	BW_1	PT_1 PT_2 PT_3	8.14 7.90 7.76	7.88	7.66	7.65	5.28^{**} (PT_1-PT_2) 3.14^{*} (PT_1-PT_3) 1.07^{NS} (PT_2-PT_3)	35.50 2.29 1.98	38.2	2.30	2.11	1743.02^{**} (PT_1-PT_2) 3556.09^{**} (PT_1-PT_3) 14.89^{**} (PT_2-PT_3)	256.00 256.14 257.17	261	261.8	260.7	1.437^{NS} (PT_1-PT_2) 10.31^{**} (PT_1-PT_3) 1.72^{**} (PT_2-PT_3)
8.	BW_2	PT_1 PT_2 PT_3	7.60 7.38 7.45				8.22^{*} (PT_1-PT_2) 4.56^{*} (PT_1-PT_3) 0.95^{NS} (PT_2-PT_3)	38.00 2.35 2.12				1290.69^{**} (PT_1-PT_2) 1183.84^{**} (PT_1-PT_3) 5.61^{**} (PT_2-PT_3)					9.27^{**} (PT_1-PT_2) 25.17^{**} (PT_1-PT_3) 11.79^{**} (PT_2-PT_3)
9.	BW_3	PT_1 PT_2 PT_3	7.90 7.69 7.72				2.21^{NS} (PT_1-PT_2) 5.72^{**} (PT_1-PT_3) 0.31^{NS} (PT_2-PT_3)	41.20 2.26 2.23				396.75^{**} (PT_1-PT_2) 1431.62^{**} (PT_1-PT_3) 0.327^{NS} (PT_2-PT_3)					2.33^{NS} (PT_1-PT_2) 35.75^{**} (PT_1-PT_3) 19.71^{**} (PT_2-PT_3)

* Indicates significant difference at 0.05 level,** Indicates significant difference at 0.01 level; NS Indicates no significant difference. OW - Open well water RW - River water BW - Bore well waterT_1 - Pre-treatment PT_2 - Treatment with Moringa seed powder PT_3 - Treatment with Alum

Table 6: Comparison of different types of water samples for their chemical characteristics after treating with Moringa seed powder and Alum

Sl. No.	Water samples and treatment		Alkalinity Mean	Overall Alkalinity Mean			t- value		Hardness mean	Overall Hardness Mean			t-value	
				PT_1	PT_2	PT_3				PT_1	PT_2	PT_3		
1.	OW_1	PT_1 PT_2 PT_3	162.50 116.66 147.60	180.63	143.91	161.1	(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	2.546^{NS} 12.60^{**} 1.715^{NS}	181.00 181.00 149.93	169.66	167.96	154.07	(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	0.00^{NS} 544.50^{**} 65.45^{**}
2.	OW_2	PT_1 PT_2 PT_3	188.00 155.12 160.96				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	3.275^{*} 3.581^{*} 0.465^{NS}	176.00 172.80 163.61				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	6.28^{**} 21.78^{**} 12.03^{**}
3.	OW_3	PT_1 PT_2 PT_3	191.40 159.94 175.00				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	3.089^{*} 6.248^{**} 1.432^{NS}	152.00 150.09 148.66				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	2.39^{NS} 12.29^{**} 1.68^{NS}
4.	RW_1	PT_1 PT_2 PT_3	262.00 235.93 251.10	275.3	244.1	260.21	(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	2.573^{NS} 2.834^{NS} 1.379^{NS}	250.00 249.09 248.74	278.0	277.19	277.1	(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	2.17^{NS} 1.94^{NS} 0.43^{NS}
5.	RW_2	PT_1 PT_2	271.00 239.11				(PT_1-PT_2)	3.221^{*} 2.564^{NS}	282.00 280.16				(PT_1-PT_2)	4.52^{*} 9.14^{**}

		PT_3	258.80				(PT_1-PT_3) (PT_1-PT_3)	1.793^{NS}	280.60				(PT_1-PT_3) (PT_1-PT_3)	1.00^{NS}
6.	RW_3	PT_1 PT_2 PT_3	293.00 257.33 270.33				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	3.083^{*} 4.686^{**} 1.071^{NS}	302.00 304.33 302.06				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	1.25^{NS} 0.14^{NS} 0.49^{NS}
7.	BW_1	PT_1 PT_2 PT_3	110.00 73.31 91.00	122.0	80.87	93.56	(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	3.708^{*} 5.758^{**} 1.696^{NS}	84.00 84.06 82.06	92.73	92.68	90.84	(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	0.16^{NS} 4.07^{*} 3.20^{*}
8.	BW_2	PT_1 PT_2 PT_3	144.00 95.31 120.33				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	4.133^{*} 43.484^{**} 2.122^{NS}	96.20 96.24 94.943				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	0.06^{NS} 20.10^{**} 2.05^{NS}
9.	BW_3	PT_1 PT_2 PT_3	112.00 74.00 69.36				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	3.193^{*} 1.774^{NS} 0.173^{NS}	98.00 97.74 95.53				(PT_1-PT_2) (PT_1-PT_3) (PT_1-PT_3)	0.61^{NS} 5.66^{**} 3.64^{*}

* Indicates significant difference at 0.05 level.** Indicates significant difference at 0.01 level. NSIndicates no significant difference.
OW - Open well water RW - River water BW - Bore well water ; PT_1 - Pre-treatment PT_2 - Treatment with Moringa seed powder PT_3 - Treatment with Alum

Table 7: Microbiological analysis (MPN/100 ml) of water samples

Microbiological analysis (MPN/100 ml)	**OW_1**	**OW_2**	**OW_3**	**RW_1**	**RW_2**	**RW_3**	**BW_1**	**BW_2**	**BW_3**
Total Coliforms									
PT_1	21	23	20	39	28	43	23	9	11
PT_2	Nil	4	Nil	7	Nil	7	4	Nil	Nil
PT_3	Nil	Nil	Nil	4	Nil	7	Nil	Nil	Nil
E.coli									
PT_1	7	4	7	21	4	21	4	Nil	9
PT_2	Nil	Nil	Nil	4	Nil	4	Nil	Nil	Nil
PT_3	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

MPN - Most Probable Number ; PT_1 - Pre-treatment; PT_2 - Treatment with Moringa seed powder; PT_3 - Treatment with Alum

Table 8: Mean Physico-chemical characteristics studied and compared with standards

S.NO	Type of water sample	Mean			BIS Std		IS 10500 1994	
		PT1	**PT2**	**PT3**	***HDL**	**#MPL**	***HDL**	**#MPL**
1	PH							
	0W	8.4	8.05	8.21	7.0-8.3	8.5-9.0	6.5	8.5
	RW	8.2	7.98	7.55				
	BW	7.88	7.66	7.65				
2	Turbidity							
	OW	77.71	2.23	1.8	5	10	5	10
	RW	200.16	1.95	1.95				
	BW	38.2	2.30	2.11				
3	EC							
	0W	274	192.3	277.6				
	RW	350.6	363.3	357.6				
	BW	261	261.8	260.7				
4	Alkalinity							
	OW	180.63	143.9	161.1	200	600	200	600
	RW	275.3	244.1	260.2				
	BW	122.0	80.87	93.56				
5	Hardness							
	OW		167.96	154.07	200	600	200	600
	RW	169.66	277.19	277.1				
	BW	278.0	92.68	90.84				
		92.73						

*HDL- Highest Desirable Limit; MPL -Maximum Permissible Limit. BIS- Bureau of Indian Standards

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