Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 7, No. 1, p. 54-60, 2015
http://www.innspub.net

INNSPUB
RESEARCH PAPER

OPEN ACCESS

Utilization of *Moringa oleifera seeds* for treatment of canal and industrial waste water - an alternative sustainable solution for developing countries

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Article published on July 4, 2015

Key words: *Moringa oleifera*; Turbidity; Metals and environmental friendly.

Abstract

Moringa oleifera is low cost, easily available and environmentally friendly natural coagulant. This research project was initiated to investigate the performance of *Moringa oleifera* compared with that of aluminum sulfate $Al_2 (SO_4)_3$ and alum for treatment of canal water and industrial wastewater. The results of canal water with seed kernel and 0.15 g Alum was found to have maximum reduction in turbidity and microbial load. Treatment of arsenic samples (25, 50, 75. 100 ppb) the dose rate of 0.2 g of seed kernel with sieve size 125 µm was found efficient as compared to 250 and 500 µm sieve size. For industrial waste water samples maximum chromium removal was found with 0.05 seed kernel that is 718.9 mg/L to 53.85 mg/L which is 92.51 %. However other metal like Ni, Cu and Zn was also showed the best result with dose rate of 0.05 g for 100 mL wastewater. It is concluded from result that *M. oleifera* was not as effective as universal coagulant like alum, magnesium oxide, ferric oxide etc. that can be used for treatment of turbid waters in developing countries. The main reasons for using natural coagulants are low cost, easily available, having low health risk and environmental friendly.

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Introduction

In modern era there has been significant concern in developing countries about the usage of natural coagulants which can be produced or extracted from microorganisms, animal or plant tissues. The main reason is natural coagulants should be biodegradable and are assumed to be safe for human health. In addition, natural coagulants produce less voluminous sludge that amounts only 20– 30% that of alum treated counterpart (Narasiah *et al.,* 2002).

Moringa oleifera is one of the renowned natural coagulants that contain ability to removal many contaminants from water effluents (Bolto and Gregory, 2007). It grows throughout the tropics and almost every part of the plant is of value as food. Flowers, leaves, and roots are used for remedies for tumors whereas the seeds for abdominal tumors. Its bark regarded as anti-scorbic exudes a reddish gum with properties of tragacanth which is used for the treatment of diarrhea. Roots are bitter and act as a tonic to the body and lungs (Dixit and Ali, 2010). As a tropical multipurpose tree, *M. oleifera* is generally known as the miracle tree (Fuglie, 2001) because of its wide variety of benefits that cover from nutritional issues (Makkar and Becker, 1996). Moreover it is widely used in cosmetics (Armand *et al.,* 2003). With other properties, *M. oleifera seeds* also contain a coagulant protein that can be used either in drinking water clarification or wastewater treatment (Ndabigengeser and Narasiah, 1998). It is said to be one of the most effective natural coagulants and the investigation on these kinds of water treatment agents is growing nowadays (Sciban *et al*., 2009).

M. oleifera has received various levels of interest from a number of researchers (Muyibi and Evison, 1996; Jeyanthi *et al.,* 2004; Nkurunziza *et al.,* 2009) assessing the potential as a primarily natural coagulant. There is, however, limited published data to derive a direct comparison between the effectiveness of a biological coagulant (such as *M. oleifera*) against that of established chemical coagulants (such as alum and ferric).

Inorganic coagulants and/or polymers are typically used during the water treatment process to remove suspended solids, bacteria and viruses. There are currently two main chemicals used to aid coagulation in developed countries, these are aluminum sulfate $Al_2 (SO4)_3$ and ferric sulfate $Fe_2(SO4)_3$; termed alum and ferric respectively. Due to the limited availability and relative expense of these chemicals for the developing world, there is an urgent need to find alternative water purification solutions (coagulation aids) for rural villages (Pritchard *et al.,* 2010).

Previous research work has mainly focused on using *M. oleifera* as a co-coagulant together with alum. For example, when *M. oleifera* was added as a pre-treatment, Jahn (1986) showed turbidity levels of raw water to be reduced beyond the levels found when alum was used alone. In recent years there has been a focus on the use of appropriate, low-cost technology for the treatment of polluted water. One solution to these problems is utilization of naturally available treatment materials other than by use of chemical treatment materials which are quite costly. Natural coagulants are low cost, easily available, having low health risk and environmental friendly. The main objective of this research project was to investigate the direct performance of *M. oleifera* seed with different sieves sizes compared with that of alum and/or ferric in terms of physical and chemical parameters removal.

Materials and Methods

M. oleifera seeds were collected from Shadhara seed market, Lahore, Pakistan. The seed was washed thoroughly in distilled water then air dried ground to powder using an electrical blender, passes through sieve sizes i.e., 500, 250 and 125µm and stored for experiment.

Canal water treatment

Canal water was treated with *M. oleifera* seeds (whole seed with cover and seed kernel) by using different sieve sizes i.e., 500, 250 and 125µm and to optimize the process the experiments were done at different dose rate with the combination of alum and Aluminum Sulphate. Different doses of *M. oleifera* whole seed (125 µm) that is 0.05, 0.1, 0.15 and 2% solution were used. In next experiments 0.15 g of whole seed were used with different doses of alum and Aluminum Sulphate (Table 1). The same does rate were used for canal water treatment (Table 2) by using seed kernel (125 µm).

Reduction of arsenic from synthetic samples by M. oleifera seeds

M. oleifera seeds were used to treat arsenic synthetic samples(25, 50, 75 and 100 ppb) with different pore size(500,250 and 125µm) of whole seed, seed kernel, de-oiled whole seed and with different their amount and with different pH adjustment and observed the best sieve size and amount to reduce maximum amount of arsenic in aqueous solution.

Reduction of metal in industrial waste water

M. oleifera seeds sieve size and optimized does which gave maximum reduction of metal (whole seed with cover and seed kernel) were used on actual industrial waste water samples**.** Three industrial waste water tanneries, textile and electroplating were treated with *M. oleifera seeds* (Tables 4-6).

Analysis of water qualit

The changes in water quality were measured before and after treatment. Turbidity was measured by turbidity meter (LP2000-11 HANNA). pH of water was measured using digital pH meter (JENCO 6173). The other parameters like total hardness, Calcium, magnesium hardness, Chlorides, Sulphate, Bicarbonate, Sodium, Potassium, Microbial load, Total suspended solids, and Total dissolve solids were carried out by using standard methods of water and waste water, APHA 2005 (APHA, 2007) The concentration of arsenic and other metals were determined by Inductive couple plasma (PerkinElmer optimum-5300

Results and discussion

Natural coagulant *M. oleifera* seed was used to treat canal water and industrial waste water to exhibit its coagulating property as far as reduction of microbial load, turbidity and metals. Table 1 represents canal water treatment with *M. oleifera* whole seed with pore size(125µm) and with different milliliters of 2 % solution and with combination of chemical coagulants Alum and $Al_2(SO_4)_3$. It was observed that when 200 mL of canal water was treated with whole seed /seed kernel in amount 0.15 g with combination of 0.15 g of Alum, maximum reduction of turbidity and microbial load were observed and other parameters were within WHO permissible limit. However, the combination of 0.15g *M. oleifera* whole seed +0.15g Alum were also showed better performance in reduction of turbidity and microbial load in solution forms.

The result in Table 2 showed canal water treatment with seed kernel having sieve size 125 µm in 2% solution form, with combination of Alum and $Al_2(SO_4)_3$. Results of 0.15 seed kernel and 0.15 g Alum was found to have maximum reduction in turbidity and microbial load comparing all types of applications. But it was less than results of whole seed (125µm). Comparing the result of whole seed and seed kernel for canal treatment, seed kernel was better coagulant as far as turbidity and microbial load are concerned. There were not remarked change /reduction in other parameters of canal water but these were under WHO permissible level. Arsenic reduction was observed (Table 3) by using *M. oleifera seeds* with different pore size (500µm, 250µm, 125µm). To optimize process different does that is 0.05, 0.1 and 0.2 g of *M. oleifera* seed were used. The maximum reduction of Arsenic was found in case of 125 µm with 0.2 g of seed kernel that is 68 % as comparing to all sieve size i.e., 500µm, 250µm and125µm of whole seed and De-oiled whole seeds. It was concluded that 0.2 g of seed kernel with sieve size 125 µm without gave maximum reduction of arsenic in 200mL of synthetic sample.

Chromium reduction was done on different tannery sample with *M. oleifera* whole seed and seed kernel (0.05 g in 100 mL wastewater). The result in Table 4 revealed that *M. oleifera* has high metal sequestering property and both whole seed and seed kernel reduced remarkably metals from aqueous medium. However, seed kernel is even better than whole seed for coagulating metals. It reduces 718.9 mg/l to 53.85 mg/L that is 92.51 %.

Table 1. Treatment of canal water with whole seed (W.S) 200 mL of canal water.

Parameters	WHO Standards	Before	After 0.05 g (W.S)	After 0.1g (W.S)	After 0.15 g (W.S)	After 1 mL 2% solution (W.S)	After 2 mL 2% solution (W.S)	4mL2% solution (W.S)	0.15+ 0.05 Alum	0.15+ 0.05 $Al2(SO4)_3$	0.15+ 0.1 Alum	0.15+0.1 $Al_2(SO_4)_3$	0.15 +0.15 Alum	After 0.15+ 0.15 $Al2(SO4)_3$
PH	6.5-8.5	6.88	6.90	6.92	6.97	6.57	6.59	6.58	6.56	6.54	3.80	3.78	3.95	3.85
Conductivity	--	280	290	301	312	306	318	326	356	366	513	543	683	679
Turbidity	5	152	4.73	5.48	6.85	5.99	4.19	3.91	2.38	4.27	3.73	11.78	3.82	11.94
Colour Pt-Co/hazen	--	24	24	25	26	42	45	49	26	28	25	26	20	21
Total hardness	--	105	110	115	118	112	120	121	124	128	134	140	188	198
Calcium hardness	--	25	37	38	40	40	41	42	42	45	47	49	65	68
Magnesium Hardness	--	80	73	77	78	72	79	79	82	83	87	91	123	130
Cl^-	250	25	20	22	22	40	38	39	40	43	45	46	44	48
SO^-_4	200	35	31	33	35	42	48	50	48	49	44	46	48	51
HCO_3^-	--	155	149	148	150	153	158	160	230	233	221	225	230	234
Na^+	200	101	102	102	101	103	102	103	102	100	103	102	100	101
K^+	--	4	4	4	3	4	5	4	4	4	4	4	5	4
Ca^{++}	200	10.0	14.8	15.2	16	16	16.4	16.8	16.4	18.0	18.8	19.6	26.0	19.2
Mg^{++}	100	19.44	17.73	18.71	18.95	17.496	19.197	19.197	19.92	20.169	21.141	22.113	29.889	31.59
TSS	*N.D	1000	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
TDS	500	182	188	195	200	198	205	211	231	237	331	350	440	436
Microbial load	N.D	$4x10^2$ CFU	120	100	80	76	70	65	26	25	24	22	ND	N.D

*N.D= Not detected

Table 2. Canal water treatment with seed kernel (SK) 125µm for 200 mL of canal water.

Parameters	WHO standard	Before	After 0.05 g SK	0.1 g SK	0.15 g SK	1 mL 2% solution	2 mL2% solution	4mL2% solution	0.15+ 0.05 Alum	0.15+ 0.05 $Al_2(SO_4)_3$	0.15+0.1 Alum	0.15+0.1 $Al_2(SO_4)$	0.15+ 0.15 Alum	0.15+0.15 $Al_2(SO_4)_3$
PH	6.5-8.5	6.88	6.54	6.56	6.59	6.50	6.44	6.40	5.75	5.74	3.84	3.86	3.90	3.83
Conductivity	--	280	292	305	318	310	328	330	356	366	520	550	710	690
Turbidity	5	152	6.64	7.50	8.32	6.31	6.27	5.83	3.24	4.77	3.70	11.74	4.21	10.56
Colour pt-Co/hazen		24	23	25	27	44	49	50	25	28	27	29	22	24
Total hardness		105	110	115	118	112	120	121	124	128	134	140	188	198
Calcium hardness		25	37	38	40	40	41	42	42	45	47	49	65	68
Magnesium		80	73	77	78	71	79	79	82	83	87	91	123	130
Cl^-	250	25	20	22	22	40	38	39	40	43	45	46	44	48
SO^-_4	200	35	31	33	35	42	48	50	48	49	44	46	48	51
HCO_3^-	--	155	149	148	150	153	158	160	230	233	221	225	230	234
Na^+	200	101	102	102	101	103	102	101	102	102	102	101	102	103
K^+	--	4	4	4	3	4	5	4	4	4	4	4	5	4
Ca^{++}	200	10.0	14.8	15.2	16	16	16.4	16.8	16.4	18	18.8	19.6	26	27.2
Mg^{++}	100	19.44	17.73	18.71	18.9	17.253	19.197	19.197	19.926	20.169	21.141	22.113	29.88	31.59
TSS	*N.D	1000	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
TDS	500	180	188	197	206	200	211	214	229	235	335	356	457	445

Microbial load	N.D	4x10^2 CFU	89	81	78	60	55	47	24	23	10	4	N.D	N.D

*N.D= Not detected

Table 3. Arsenic reduction by *M. oleifera seeds* (different pore size 500, 250 and 125µm) in 200mL of sample.

Parameters	Whole seed (% reduction)				Seed kernel (% reduction)				Deoiled whole seed (% reduction)			
	100 ppb	75 ppb	50 ppb	25 ppb	100 ppb	75 ppb	50 ppb	25 ppb	100 ppb	75 ppb	50 ppb	25 ppb
500µm 0.05g	45	46	44	46	43	44	42	40	40	39	39	38
500µm 0.1 g	47	48	46	45	46	45	44	45	41	40	41	40
500µm 0.2g	48	48	45	47	47	46	47	45	43	44	42	43
250µm 0.05 g	51	50	49	51	49	48	49	48	45	44	46	45
250µm 0.1 g	52	53	51	52	50	49	49	48	47	45	46	47
250µm 0.2 g	54	54	55	53	53	52	51	52	49	47	48	48
125µm 0.05 g	62	59	60	61	51	49	50	51	49	48	46	49
125µm 0.1 g	65	63	62	62	55	54	56	55	49	50	51	52
125µm 0.2g	64	65	66	64	67	68	66	68	56	55	56	54

Table 4. Chromium reduction with *M. oleifera* whole (W.S) seed and (S.K) seed kernel (0.05 g for 100 ml sample).

Metals	Tannery sample (1)		Tannerysample (2)		Tannery sample (3)		Tannery sample (4)		Tannery sample (5)		Tannery sample (6)		Tannery sample (7)		Tannery sample (8)	
	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L
W.S 125µm	718.9	58.45	986.0	74.34	1171	107.5	30.47	3.06	57.29	5.21	3.31	1.09	2.92	0.65	3.38	0.97
S.K 125µm	718.9	53.85	986.0	69.15	1179	98.26	30.47	2.67	57.29	4.66	3.31	0.78	2.92	0.23	3.38	0.88

B= before treatment A=after treatment

Table 5. Cr, Ni and Zn reduction with *M. oleifera* whole seed and seed kernel (0.05 g for 100 mL sample).

Metals	Electroplating (1)		Electroplating (2)		Electroplating (3)		Electroplating (4)		Electroplating (5)		Electroplating (6)		Electroplating (7)		Electroplating (8)	
Metals	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L
Cr(WS)	84.61	7.34	572	40.12	2.48	0.54	11.8	1.74	22.6	2.09	239	19.1	196	14.6	175.	12.88
Cr (SK)	84.61	5.79	572	36.98	2.48	0.55	11.8	0.98	22.6	1.98	239	15.5	196	11.4	175	11.67
Ni (WS)	435.70	34.6	38.2	3.44	19.08	2.13	15.6	1.67	11.9	1.11	16.5	1.88	17.1	1.78	4.74	0.62
Ni(SK)	435.70	34.6	38.2	2.09	19.08	1.88	15.6	1.09	11.9	0.98	16.5	1.12	17.1	1.22	4.74	0.12
Zn(WS)	1.78	0.88	1.45	0.95	0.51	0.01	88.9	10.7	276	29.6	393.	31.8	412	39.6	19.0	2.01
Zn(SK)	1.78	0.26	1.45	0.22	0.51	*N.D	88.9	8.33	276	25.8	393.	9.79	412	38.4	19.0	1.05

B= before treatment, A=after treatment, WS=whole seed, SK=seed kernel, *N.D= Not detected

Table 6. Zinc and Copper reduction with *M. oleifera* Whole Seed and Seed Kernel 0.05 g for 100 mL sample).

Metals	Textile unit (1)		Textile unit (2)		Textile unit (3)		Textile unit (4)		Textile unit (5)		Textile unit (6)		Textile unit (7)	
	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L	B mg/L	A mg/L
Zn (WS 125um)	1.19	0.10	1.13	0.12	0.64	*N.D	0.53	N.D	0.38	N.D	0.28	N.D	0.18	N.D
Zn (SK 125um)	1.19	0.08	1.13	0.09	0.64	N.D	0.53	N.D	0.38	ND	0.28	N.D	0.18	N.D
Cu (WS 125um)	0.89	N.D	1.52	0.09	1.70	0.12	1.21	0.09	1.32	0.09	0.91	N.D	1.52	0.09

Cu (SK 125µm)	0.89	N.D	1.52	0.07	1.70	0.11	1.21	0.07	1.32	0.07	0.91	N.D	1.52	0.08

B= Before treatmentA=After treatment, *N.D= Not detected

The result in Table 5 showed comparative study of whole seed and seed kernel of *M. oleifera* (0.05 g for 100 mL of wastewater) for reduction of metals (chromium, nickel, zinc) from electroplating industrial waste water. It was seen that there is remarkable reduction of metals e.g., chromium metal reduced from 572.7 to 36.98 mg/L and nickel reduced from 435.70 to 34.68 mg/L and zinc from 1.78 to 0.26 mg /L. It is also observed that results of whole seed and seed kernel are very close but seed kernel has better coagulation power. It has been found that the active component of *M. oleifera* causing coagulation is a soluble protein that acts as a natural cationic polyelectrolyte during treatment and causes coagulation in turbid water (Barth, 1982).

The result in Table 6 showed comparative study of whole seed and seed kernel of *M. oleifera* (0.05 g for 100 mL of wastewater) for reduction of copper and zinc from textile industrial waste water. It was seen that metals are appreciably reduction e.g., zinc from 1.19 to 0.08 mg/L and copper from 1.52 to 0.07. It is also observed that results of whole seed and seed kernel are very close but seed kernel protein has better coagulation power. Comparing Table 4-6 *M. oleifera* seed kernel with pore size 125µm was found better coagulant for metals as compare to whole seed with wings. The result showed that *M. oleifera seeds* part has very good coagulating property to reduce microbial load, turbidity and different metals from aqueous medium up to 90 %. Moreover its use is simple and low cost purifications procedures as well as the use of the coagulant in combination with other coagulants and treatment processes needs to be adopted (Ghebremichael *et al.*, 2009).

Conclusion

It is concluded that *M. oleifera* along with alum and Aluminum Sulfate produce good result for the treatment of water. However the result of *M. oleifera* seed itself has better coagulating properties and this can be an alternative, sustainable solution for the treatment of polluted water of developing countries. Following conclusion can be drawn from the results,

- Comparing different pore sizes (500, 250,125µm) 125µm is better for coagulating properties.
- *M. oleifera* seed kernel (125µm) show better coagulating properties as compared to whole seed and whole seed for turbidity, metals (Ar, Zn, Cr, Ni and Cu) and microbial load.
- The optimized does of *M. oleifera* seed kernel (125µm) was 0.2 g per 200 ml of water treatment for turbidity and coliform.
- For Cr, Ni, Cu and Zn best does is 0.05 g for 100 mL wastewater.

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