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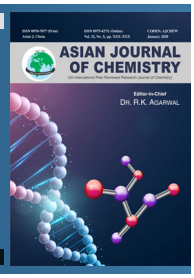

Cost Effective and Natural Plant Based Coagulant for Removal of Chloride from Potable Water

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In present study, water quality was assessed by collecting ten water samples in and around Tiruppur city of India. The physico-chemical characterisation of the water samples were analyzed using standard protocols. The samples with higher chloride content (3106 mg/L) was found in Ganapathy Palayam sample, the value was higher than the BIS prescribed limit. The sample was subjected to treatment with various dosages of the phyto coagulating agent *Tamarindus indica* L. seed powder and its polysaccharide. The maximum 51 % of chloride reduction was obtained with 0.3 g of seed polysaccharide, and it was taken as optimum dosage. The raw seed removed 47 % of chloride by the dosage 0.4 g. The seed powder was characterized by GC-MS and FT-IR analysis. The GC-MS chromatogram showed the presence of various phytocompounds such as lupanine, cyclopropane octanoic acid, ascorbic acid, octadecanoic acid in the plants. The functional groups found in the seed powder were characterized by FTIR analysis. The evaluated results confirmed the contamination of potable water in Tiruppur city by the dyeing industries located near the water sources. The present work concluded that tamarind seed coagulants are efficient, eco-friendly, low-cost and easily available material, which could be used for the treatment of potable water.

Keywords: Potable water, Tamarind seed, Polysaccharide, Contamination, Chloride.

INTRODUCTION

Water is one of the most indispensable and valuable natural resource, and it is a fundamental need for all living organisms to maintain their life cycle. Water is used for numerous purposes, as well as many industrial applications and its development. Contaminated drinking water, along with poor cleanliness and unhygiene, approximately 10 % of diseases world wide including 4 billion cases of diarrhoea and 1.8 million deaths occurs annually [1,2]. Particularly, children and elder people are suffering from chronic diseases due to contaminated water usage. One-sixth of the world's population suffers from the water scarcity [3]. Environmental pollution is a worldwide issue, mainly due to industrialization and urbanization, and it affects the human health, plants, animals and properties also. Larger volume of untreated industrial effluents that were introduced into open lands lead to water and land pollution. Several physical and chemical methods are available for the treatment of potable water [4]. But, these methods are of higher cost, not recommended for rural area and produce solid waste. The disposal of solid wastes also needs further treatment for its disposal. Hence, eco-friendly and low-cost phytocoagulant *Tamarindus indica* L. was selected and used for water treatment.

Tamarindus indica L. tree belongs to Fabaceae family. India and Thailand are the major producer and consumer, and generating 3,00,000 and 1,40,000 tons of tamarind fruit annually. It is one of the most significant edible fruit used as a flavouring agent in cooking, juices, preparation of beverages, human nutrition and medicinal value. The ancient tribal people prepare decoction by using the tamarind plant parts and used for medi-

cation. Tamarind seed contain various phytocompounds including 2-hydroxy-3′,4′-dihydroxy acetophenol, methyl-3,4-dihydroxybenzoate, *etc*. [5]. *Tamarindus indica* L. seed consists of fatty acid, palmitic acid, linoleic acid, eicosanoic acid and oleic acid. The seed has the property of wound healing, anti-diabetic, antimicrobial, antihelminthes infection, analgesics and antipyretic activity. Polysaccharides are structurally varied groups of biological macromolecules and long chains of monosaccharides which are the energy storage house occuring in nature [6]. *Tamarindus indica* L. seed polysaccharide isolated from seed kernel powder, reported the presence of carbohydrate, mucilage and reducing sugar. *Tamarindus indica* L. polysaccharide is composed of some monosaccharide residues such as (1→4) β-D-glucan backbone, D-xylopyranose and β-D galactopyranosyl, (1→4) β-D-xylopyranose [6]. *Tamarindus indica* L. seed polysaccharide is used in the preparation of eye drops to increase the effective time period due to presence of its mucoadhesive properties. In present investigation, an attempt is made to treat the potable water collected from Tiruppur city of Tamil Nadu state, India by using raw seed, as well as isolated polysaccharide from *Tamarindus indica* L. seed.

EXPERIMENTAL

Collection of drinking water samples: Drinking water samples were collected from ten sampling sites nearby the industrial area of Tiruppur city (11º 6′38.5020″ N and 77º 20′ 52.9620″ E) (Table-1).

TABLE-1
COLLECTION OF WATER SAMPLES FROM DIFFERENT SAMPLING SITES OF TIRUPPUR CITY, INDIA

Sample code	Sample source	Sampling sites
S1	Bore well	Bhavani
S2	Bore well	Cauvery
S3	Bore well	Muthali palayam
S4	Bore well	Vijayapuram
S5	Bore well	Vannanthurai puthur
S6	Bore well	Ganapathi palayam
S7	Bore well	Sivagiri
S8	Bore well	Aththikadavu
S9	Bore well	Ottapalayam
S10	Bore well	Chennimalai

Physico-chemical characteristics of drinking water samples: The physico-chemical characteristics of collected potable water samples, such as pH, total solids, total dissolved solids, total suspended solids, total hardness, alkalinity, acidity, chloride, sulphate, phosphate, silicate, calcium, magnesium, nitrate and fluoride were analyzed as per the standard method [7].

Isolation of *Tamarindus indica* L. polysaccharide: *Tamarindus indica* L. seed was purchased from the local market and washed carefully with tap water and finally with sterile distilled water. It was then soaked with distilled water overnight. The water was discarded and the seeds were shadow dried to remove the outer cover, and crushed in order to make it as powder. The particle size with 0.21 mm was used for the treatment of potable water. Now, *Tamarindus indica* L. seed powder was boiled for 1 h and kept aside for 2 h for the release of mucilage into water. The solution was filtered by muslin cloth and the supernatant was poured into twice the volume of absolute ethanol with continuous stirring. The precipitate was dried at 40 ºC in hot air oven. The resultant dried material was crushed into fine powder and kept in an air tight closed container for further analysis

Removal of chloride using *Tamarindus indica* L. seed powder from drinking water (raw seed and polysaccharide): Four sets of 5 conical flasks were used and to each flask 100 mL of water sample (S6) was dispensed. To the first two sets of flasks, 0.1 g, 0.2 g, 0.3 g, 0.4 g and 0.5 g of powdered *Tamarindus indica* L. seeds were added. In this, first set was kept in static condition and another second set was kept under agitation condition. Likewise, to the remaining third and fourth set of flasks 0.1 g, 0.2 g, 0.3 g, 0.4 g and 0.5 g of polysaccharide powder was added. Third set was kept in static condition and fourth set was kept for agitation. All sets were left for various time intervals such as 0.5, 1, 1.5, 2 and 2.5 h for the removal of chloride (with and without agitation or static condition). After the treatment, treated sets were filtered using Whatman No. 1 filter paper. The filtrate was subjected to chloride analysis for every 30 min.

GC-MS analysis: Gas chromatography-mass spectroscopy analysis (Agilent) was used to analyze the seed extract of *T. indica* L. seed and its polysaccharide using methanolic extract.

RESULTS AND DISCUSSION

Physico-chemical characterization of drinking water: The physico-chemical parameters were analyzed for all the collected ten drinking water samples and the obtained values are shown in Table-2. Each parameter for all the samples was found within the standard permissible limit, except for sample S6 collected from Ganapathi Palayam. The amount of chloride observed in S6 sample was 3.106 mg/L, which exceeded the BIS standard limit. The reason could be the contamination of industrial water, sewage, dissolution of chloride from rock and leaching of solid waste during rainfall.

Removal of chloride from drinking water with agitation: The highest amount of chloride *i.e*. 46 % of chloride was removed when the sample water was treated with 0.2 g of seed powder at 2.5 h detention time (Table-3). The results obtained for the removal of chloride did not follow the regular pattern and did not obey the rules of adsorption (Fig. 1). The results were random, which clearly suggested that the removal of chloride by *Tamarindus indica* L. seed powder has not been attributed by adsorption process.

Removal of chloride from drinking water without agitation: In static treatment, the removal process was increased gradually with time and dosage. Among the overall treatment, 0.4 g treatment exposed highest removal of chloride. About 47 % of chloride removal has been observed at 0.4 g dosage of seed powder after the time period of 2 h (Table-4). Beyond this dosage, no significant reduction of chloride was observed, which could be the optimum dosage for the removal of chloride from drinking water (Fig. 2). The results clearly proved the coagulant property of *Tamarindus indica* L. seed powder. Rayappan *et al*. [8] also reported the fluoride removal ability of *Strychnous potatorum* seeds as natural coagulant.

TABLE-2
PHYSICO-CHEMICAL CHARACTERIZATION OF POTABLE WATER SAMPLES

Parameters (mg/L)	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	BIS
pH	6.3	6.7	7.3	7.4	7	7.7	7	7	7	7.1	6.5-6.8
TS	430	370	460	890	970	1996	730	90	660	300	–
TDS	90	120	450	660	960	1920	610	80	560	200	2000
TSS	340	250	10	230	10	76	120	10	100	100	–
Alkalinity	420	120	360	180	200	245	320	180	200	370	250
Acidity	220	145	385	360	375	110	245	160	254	240	–
TH	194	74	188	365	235	600	263	60	242	256	600
Ca	94	36	110	265	145	250	168	98	180	158	250
Mg	100	38	78	100	90	96	95	38	62	98	100
Cl	74	64	114	826	212	3106	324	132	169	159	200
Fl	0.20	0.19	0.19	0.20	0.19	0.18	0.02	0.18	0.19	0.20	1.5
Phosphate	0.60	0.57	2.31	2.22	1.19	1.33	0.88	0.98	0.90	1.15	0.1
Silicate	0.21	0.61	0.63	1.75	0.25	150	0.85	1.25	0.57	1.3	200
Sulphate	5.33	1.66	8.09	16.3	20.5	210	9.78	2.30	11.05	6.51	200
Nitrate	3.16	6.35	5.76	13.4	12.1	15.2	9.51	4.51	7.91	6.72	45

All parameters are expressed in mg/L except pH

TABLE-3
EFFECT OF *Tamarindus indica* L SEED POWDER ON THE REMOVAL OF CHLORIDE FROM DRINKING WATER WITH AGITATION

Dosage (g)	Removal percentage of chloride at different time interval				
	0.5 h	1.0 h	1.5 h	2.0 h	2.5 h
0.1	36	38	35	37	42
0.2	40	43	45	43	46
0.3	38	40	41	44	40
0.4	36	45	38	47	43
0.5	40	42	44	47	48

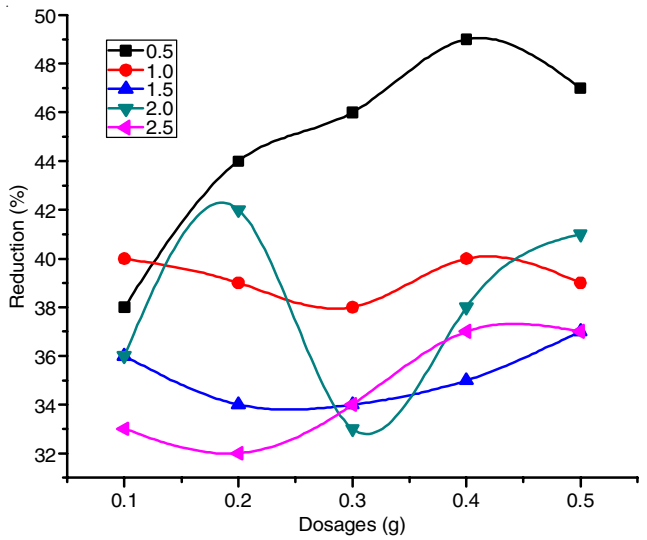

Fig. 1. Graphical representation on effect of *Tamarindus indica* L seed powder on the removal of chloride from drinking water with agitation

TABLE-4
EFFECT OF *Tamarindus indica* L SEED POWDER ON THE REMOVAL OF CHLORIDE FROM DRINKING WATER WITHOUT AGITATION

Dosage (g)	Removal percentage of chloride at different time interval				
	0.5 h	1.0 h	1.5 h	2.0 h	2.5 h
0.1	28	31	35	38	43
0.2	34	39	44	45	46
0.3	39	41	45	46	45
0.4	43	45	45	48	48
0.5	43	46	45	48	47

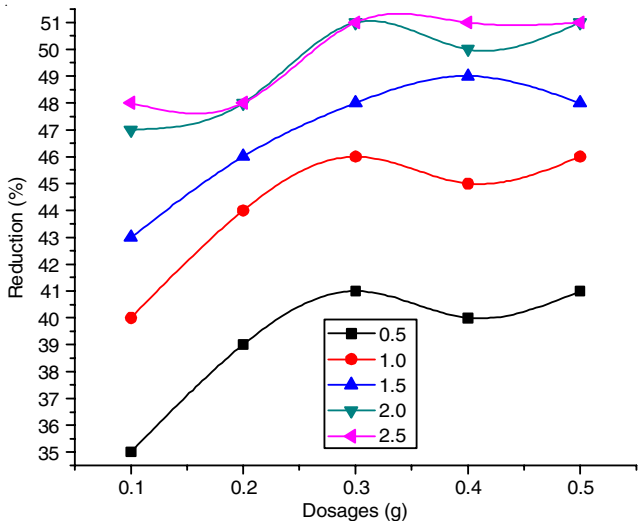

Fig. 2. Graphical representation on effect of *Tamarindus indica* L seed powder on the removal of chloride from drinking water without agitation

Removal of chloride from drinking water with agitation using *Tamarindus indica* L. seed polyaccharide: Isolated polysaccharide from *Tamarindus indica* L. seed was used for the removal of chloride from S6 sample. The polysaccharide was added to the water sample in various dosages and appropriate time duration was assigned for the treatment. The percentage removal of chloride from the sample is shown in Table-5. Similar random pattern regarding the removal of chloride had been followed using polysaccharide also. This also again proved that the removal mechanism has not involved in adsorption.

TABLE-5
EFFECT OF *Tamarindus indica* L SEED POLYSACCHARIDE ON THE REMOVAL OF CHLORIDE FROM DRINKING WATER WITH AGITATION

Dosage (g)	Removal percentage of chloride at different time interval				
	0.5 h	1.0 h	1.5 h	2.0 h	2.5 h
0.1	38	40	36	36	33
0.2	44	39	34	42	32
0.3	46	38	34	33	34
0.4	49	40	35	38	37
0.5	47	39	37	41	37

Removal of chloride from drinking water without agitation using *Tamarindus indica* L. seed polyaccharide: When the dosage of polysaccharide increased, the removal was also increased up to 0.3 g. Around 51 % of chloride removal had taken place when water samples were treated with 0.3 g of polysaccharide (Table-6). With further increase or decrease in the dosage of polysaccharide, no significant reduction of chloride removal was observed (Fig. 3). Hence, 0.3 g dosage can be confirmed as the optimum dosage for chloride removal from the drinking water sample (S6) without agitation.

TABLE-6
EFFECT OF *Tamarindus indica* L SEED POLYSACCHARIDE ON THE REMOVAL OF CHLORIDE FROM DRINKING WATER WITHOUT AGITATION

Dosage (g)	Removal percentage of chloride at different time interval				
	0.5 h	1.0 h	1.5 h	2.0 h	2.5 h
0.1	35	40	43	47	48
0.2	39	44	46	48	48
0.3	41	46	48	51	51
0.4	41	45	49	50	51
0.5	41	46	48	51	51

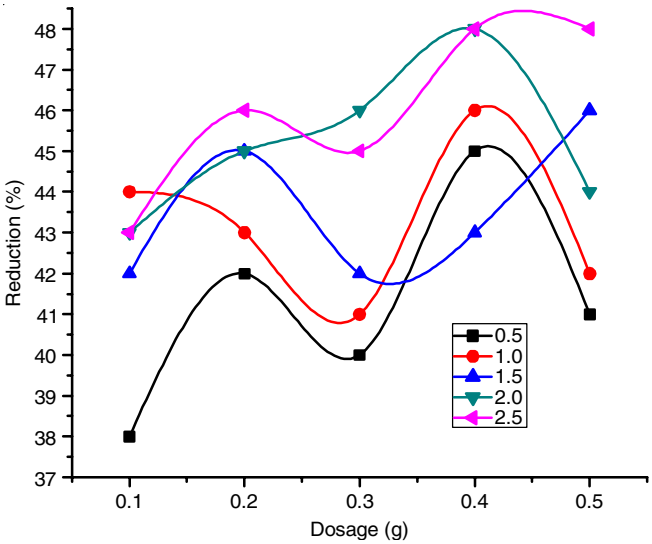

Fig. 3. Effect of *Tamarindus indica* L seed polysaccharide on the removal of chloride from drinking water without agitation

The mechanism involved for the reduction of chloride concentration was coagulation, which was achieved due to the presence of galactan and galactomannan polysaccharide in seeds, followed by the coagulant nature of seeds. *T. indica* polysaccharide hydrolyzates showed the presence of galacturonic acid and glucouronic acid in seed, while the mucilage contains only glucouronic acid. The cationic nature of polysaccharide have been bound with chloride anion, further neutralized and produced the flocculation followed by coagulation process.

GC-MS analysis of methanolic extract of *Tamarindus indica* L. seed powder: GC-MS chromatogram (Fig. 4) of methanolic extract of *Tamarindus indica* L. seed powder showed 16 peaks indicating the presence of phytocompounds including 4-hydroxy-3-methyl butan-2-one 7-benzyl-2,6-7*H*-purine; octahydro-1-nitroso-1*H*-azonine; 2,3-dihydro-3,5- dihydroxy-6-methyl-4*H*-pyran-4-one; lupanine; 7,14-methano-4*H*,6*H*-dipyrido; *E*,*E*-2,4-dodecadienal; 2-dodecylcyclobutanone; 3-O-methyl-d-glucose; 9,9-imethoxybicyclo[3.3.1]nona-2,4-dione; 2′-hexyl-1,1′-bicyclopropyl]-2-octanoic acid methyl ester; L-(+)-ascorbic acid 2,6-dihexadecanoate; 2-[2-[(2-ethylcyclopropyl)methyl]cyclopropyl]methyl]cyclopropane-octanoic acid methyl ester; oxacycloheptadec-8-en-2-one; 9-octadecenal, (*Z*)-olealdehyde and octadecanoic acid. The analyzed chromatogram is well in agreement with Tsuda *et al.* [5].

GC-MS analysis of methanolic extract of *Tamarindus indica* L. polysaccharide: The GC-MS chromatogram (Fig. 5)

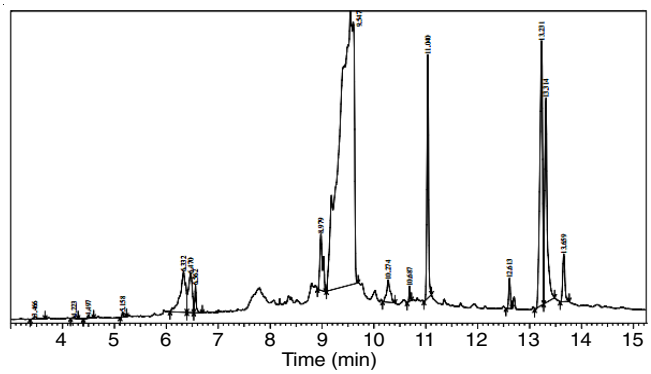

Fig. 4. GC-MS chromatogram of methanolic extracted *Tamarindus indica* L seed powder

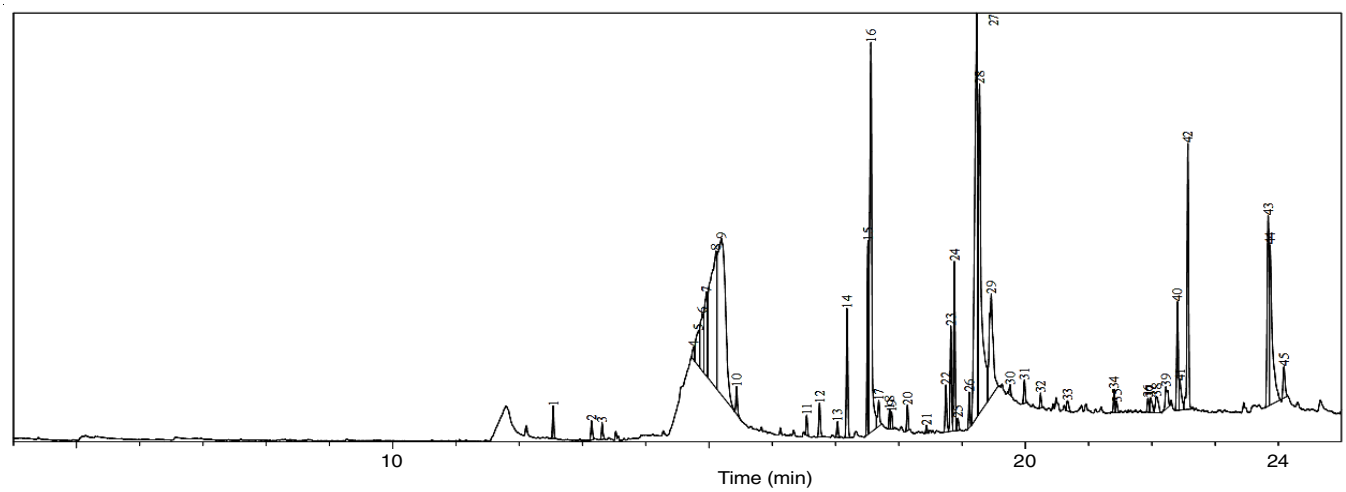

Fig. 5. GC-MS chromatogram of methanolic extracted *Tamarindus indica* L seed polysaccharide

of methanolic extract of *Tamarindus indica* L. seed polysaccharide showed the presence of various compounds *viz.* 2,4-*bis*(1,1-dimethyl)phenol, dodecanoic acid, cyclopropanebutanoic acid, α-D-mannofuranose, 1-O-[9-borabicyclo[3.3.1]non-9-yl]-2,3: 5,6-di-*o*-isopropylidene, dedecan-2-one, methyl stearate, (*Z*,*Z*)-9,12-octadecadienoic acid, oleic acid, linolen saeure-SN-glyceryl ester-2,3-diacetate, cyclopentylpropionic acid, 2-dimethylaminoethyl ester, dodecan-2-one, 1,2-benzenedicarboxylic acid, methyl-12-oxo-acetate-9-enoate, *n*-hexadecanoic acid and chrysene.

FTIR analysis of *Tamarindus indica* L. seed powder before and after treatment: In FTIR analysis, an intense and strong band was observed at 1668 cm^{-1}, which confirmed the presence of alkenes with C=C stretching bond. The peaks at 2934 and 2836 cm^{-1} indicate the presence of carboxylic acid with O-H stretching. Raw seeds showed the presence of alkenes, amide, alcohol, phenol and carboxyl groups (Fig. 6). Treated *Tamarindus indica* L. seed powder also showed similar peaks like raw seed powder.

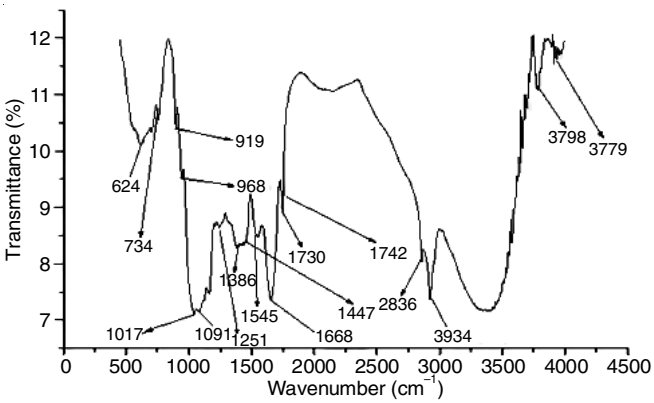

Fig. 6. FTIR spectrum of raw *Tamarindus indica* seed

FTIR analysis of *Tamarindus indica* L. seed polysaccharide before and after treatment: The FT-IR analysis of *Tamarindus indica* L. seed polysaccharide before the treatment of chloride removal from drinking water revealed the presence of six clear peaks of alcohol and phenol group with O-H stretching, aldehyde with C-H stretching, of alkenes compounds with C=O, aliphatic amine group, amine groups with C-N stretching, alkynes group C-H bending (Fig. 7). Similar spectrum was also observed after the chloride removal using *Tamarindus indica* L. seed polysaccharide. Thus, it is established that functional groups present in the *Tamarindus indica* L. seed polysaccharide remained intact even after use.

Conclusion

An effective, eco-friendly and alternative method for the removal of chloride ions from *Tamarindus indica* L. seed is reported. The maximum removal of chloride (51 %) was achieved with 0.3 g dosage of *Tamarindus indica* seed polysaccharide as natural coagulant. Due to the low cost operations and abundant availability of *Tamarindus indica* seed polysaccharide are highly effective in the removal of chloride from the water samples.

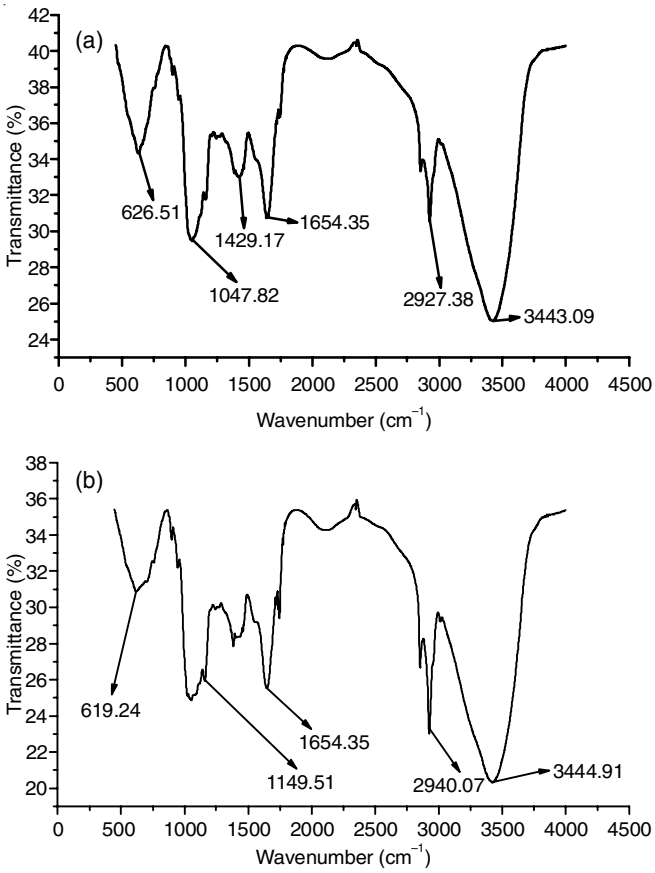

Fig. 7. FTIR spectrum of *Tamarindus indica* L seed polysaccharide before (a) and after (b) treatment

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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