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Testing the Efficiency of Acacia Bark (Galool-Asal) as Disinfectant for Polluted Waters

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ABSTRACT

Acacia bark efficiency for disinfecting polluted water for the purpose of using it for drinking purposes was tested. Five polluted water samples were collected from different locations in Jordan, namely, King Abdullah Canal, an Agricultural pond in the Jordan Valley, Yajouz wells, Hazeir spring, and Wadi-Seer spring. Different volumes of the water samples were treated with 10 g of the shredded acacia bark (obtained from Somalia) for different retention times. The volumes used were 1 L, 2.5 L, and 5 L and the detention times were 2, 4, and 24 hours. The samples were tested for total coliform, *E. coli*, electrical conductivity, pH, total dissolved solids, turbidity and color before and after treatment with the acacia bark. Results revealed that the optimum conditions for disinfection were: 1 L polluted water treated with 10 g acacia bark for 24 hours. Log removals of about 2.5 for *E. coli* were obtained under these conditions. Higher removals could be achieved by using larger amounts of the acacia bark, but the chemical water quality regarding turbidity and color will not be suitable for drinking purposes and levels of tannic acids present in the acacia bark might reach toxic levels. Toxic levels will not be reached if 1 glass of water/kg body weight every 4 - 5 hours daily is consumed.

KEYWORDS

Acacia Bark; Water Disinfection; Disinfection Efficiency; *E. coli*; Polluted Water; Drinking Water Availability

1. Introduction

The Acacia tree is indigenous to the Nile area, Ethiopia, East Africa, Angola, Mozambique, South Africa, Arabia, Iran, Afghanistan, and India. It grows to about seventy feet with hard, woody, rusty-brown colored bark and feathery leaves. It produces small, bright yellow flower heads and pods up to six inches long [1].

The *Acacia* genus of *Leguminosae* family includes more than 1200 species of flowering trees and shrubs. Many of them are used medicinally for their soothing properties [1].

In the Sudan and other Arab countries, the fruit of *Acacia nilotica* is widely used as a traditional medicinal remedy. Water, ethanol, n-hexane and chloroform extracts were prepared from dried powdered fruit and tested for *in-vitro* antimicrobial activity against human pathogenic bacteria and *Candida albicans*. The extracts had a varying degree of antimicrobial activity. Extracts in water and ethanol were generally more active than those in n-hexane and chloroform. The extracts were more effective against Gram-positive *cocci* than Gram-negative bacilli. Antifungal activity against *Candida albicans* was found in the n-hexane extracts only. The results indicate that the therapeutic value of *A. nilotica* extracts as potential antimicrobial agents, which are water-soluble [2].

The antimicrobial activities of chloroform, methanol and aqueous extracts of *acacia plicosepalus* leaves and stem are reported by Elegami *et al*. [3]. In particular, the leaf methanol extract showed the highest level of activity against the tested standard microorganisms and was effective also against a range of gram-positive and gram-negative clinical isolates bacteria from Sudanese patients [3].

Decoctions made from the powdered leaves, stems, and pods are taken for shigelloses, malaria, dysentery, and diarrhea. The brew is both antimicrobial and anti-inflammatory [3].

Almas *et al*. [4], compared the antimicrobial effect of aqueous extract of seven different types of chewing sticks found in Pakistan and other Asian countries, among which, he found that there was antimicrobial effect on *Streptococcus fecalis* at 50% concentration of *Acacia Arabic*.

Acacia Bark is the dried bark of *Acacia arabica*, well known in Arabic as Ummu-Ghilan, and also the dried bark of *Acacia decurrens*, known as (*Leguminosae*.). The bark is obtained from wild or cultivated trees not less than seven years old, and after being dried, it is kept for one year before being used medicinally [5].

The bark of *A. arabica* is hard and woody, rusty brown and tending to divide into several layers. The outer surface of older pieces is covered with thick blackish perineum, rugged and fissured. The inner surface is red, longitudinally striated and fibrous, taste, astringent and mucilaginous [6]. The bark has many medical uses such as it is used for treatment of different diseases such as diarrheas, asthma, bronchitis, diabetes, dysentery, and skin diseases. It is believed that the Acacia bark owes its medicinal properties to the high percentage of tannin it contains, which is about 24 to 42 percent [7], it also contains, mucilage, flavonoids and terpenoids [7]. It is used as a stringent in diarrheas, being usually employed in the form of a decoction, the British Pharmacopoeia preparation being 6 parts in 100, administered in doses of 1/2 to 2 fluid ounces. The decoction can be applied to inflamed tissue and burns to promote rapid healing and the knitting together of the tissues [8].

In this work, the efficiency of Acacia bark in treating polluted water for the purpose of rendering it suitable for drinking purposes was tested. Polluted water samples from five locations namely; King Abdullah Canal (surface water resource), an agricultural pond in the Jordan valley (irrigation water), Yajouz ground water wells, Hazeir well (shallow ground water subject to surface contamination), and Wadi-Seer spring (subject to surface contamination) were treated with the Acacia bark at different concentrations and at different retention times. Three different concentrations at three different detention times were tried. The samples were analyzed for electrical conductivity, total dissolved solids, turbidity, color, pH, total coliform count, and *Escherichia coli*. The results were compared with those of the raw water samples and changes were reported. The suitability of water for drinking purposes was determined based on the comparison with the WHO guidelines (WHO, 1998) [9] and the Jordanian Standards for Drinking Water No. 286/2010 [10] for the examined parameters.

2. Methodology

2.1. Acacia Bark

Acacia bark obtained from acacia bark trees in Somalia was provided by the Center of Environmental Health Activities (CEHA/WHO).

2.2. Water Samples Collection

The samples from the following locations were collected:

1) King Abdullah Canal in Deir Alla/Jordan Valley (surface water source);

2) Agricultural pond on a farm in the Jordan Valley (irrigation water);

3) Yajouz untreated ground water wells;

4) Untreated groundwater sample from Hazeir-well/ Salt (shallow ground water subject to surface contamination);

5) Wadi-Seer spring untreated water (subject to surface contamination).

2.3. Disinfection Method

10 g of the shredded acacia bark was stirred with the measured water sample (1 L, 2.5 L, and 5 L) and was kept for the appropriate detention time (2, 4, and 24 hours). The sample was then filtered through a piece of cotton cloth and the different above mentioned parameters were then measured. The raw water samples (control samples) were also filtered through a cotton cloth before analysis.

2.4. Methods of Analysis

Analyses of electrical conductivity, total dissolved solids, color, turbidity, total coliform, and *E. coli*. were carried out in duplicate according to "Standard Methods for the Examination of Water and Wastewater, 1998" [11].Tests, method name, and method number are given in **Table 1**.

Summary of the results of analysis of the raw water samplers are given in **Table 2**.

2.5. Toxicity

Toxicity was evaluated based on the fact that 10 g of acacia bark was soaked in 1 L raw water for 24 hours at room temperature. The resulting solution is then filtered. A person can consume up to 500 mL/kg body weight without reaching toxic levels. This value has been estimated based on the assumption that 40% of acacia bark is tannic acid, and all of the tannic acid is extracted by the water [7]. The toxic level of tannic acid was taken from "The Material Safety Data Sheet" which indicates that the oral LD_{50} in rats is 2.3 g/kg [12].

3. Results and Discussion

Summary of the results of analysis of the five raw water samples is given in **Table 2**. *E. coli* is used as an indicator for fecal contamination as recommended by WHO and the Jordanian standards for drinking water.

Table 1. Chemical and biological methods used for water analysis[*].

	Conc. Unit	Method No.	Test Method
A. Chemical Analysis			
Electrical Conductivity, EC.	µs/cm	2510 B	Conductivity Meter
Turbidity	NTU	2130 B	Nephelometric Method
Color	Unit	2120 C	Spectrophotometric Method
pH	pH-value	4500-H^+ B	pH Meter
Total Dissolved Solids, TDS	mg/l	2540 C	Gravimetric
B. Biological Analysis			
E. coli	MPN/100 ml	9223 B	Enzyme Substrate Test
Total Coliform	MPN/100 ml	9221 B	Multiple Tubes

[*]Analysis according to Standard Methods for Examination Water & Wastewater, 20th Edition, 1998.

Table 2. Summary of the results analysis of raw water samples.

	Total Coliform (MPN/100 ml)	Echerichia Coli (MPN/100 ml)	Electrical conductivity (µs/cm)	Total dissolved Solids (mg/l)	Turbidity (NTU)	Color (Unit)	pH-Value
King Abdullah Canal	9070	1750	860	560	12	107	8.2
Agricultural Pond	1040	310	1408	916	8	63	7.98
Yajouz	261	13.5	663	425	1	1	7.22
Hazeer	1080	170	811	528/	1	1	7.32
Wadi-Seer	2410	1046	744	476	1	1	7.12

Average results of total coliform and *Escherichia coli* for the different water samples are shown in **Tables 3-7**. The tables show total coliform and average *Escherichia coli* log removals. The log removal is calculated as the difference between log count for the raw water sample and log the average count for the acacia bark treated samples at different concentrations and at different retention times. **Figures 1-5** represent histograms showing log removals of *E. coli* for the different samples at different concentrations and different retention times. Average range of logs was calculated according to "Standard methods for Water and Wastewater Analysis" [11].

Tables 3-7 give a summary of the percentage change in the average of each tested parameter (electrical conductivity, pH, turbidity, total dissolved solids, and color) for each Acacia bark treated sample as compared to the raw water sample.

As shown from **Tables 3-7**, the microbiological results indicate that the highest log removal was obtained for the water samples treated with the Acacia bark when the sample volume was 1 L after 24 hours (except in case of the agricultural pond where the removal was highest after 4 hours. *E. coli*. Log removals were: 2.44, 1.47, 2.23, 1.3, and 2.521 for King Abdulla canal, agricultural pond, Hazeir, Yajooz, and Wadi-Seer respectively. According to WHO guidelines for drinking water and the Jordanian Standards No. 286/2010, the drinking water should be free of total coliform and of *Eschericia coli*.

The chemical analyses indicate a large increase in all parameters measured for all treated samples at different concentrations and different retention times, and the values are highly exceeding the limits suggested by WHO guidelines and the Jordanian standards.

Therefore, the treated samples are not suitable for drinking purposes from both microbiological as well as chemical points of view.

Escherichia coli removal was complete for samples that originally contain 135 - 170 MPN/100 mL, and log removal was more than 2 for samples originally containing 1050 MPN/100 mL. Increasing the concentration of acacia bark by using 20 g instead of 10 g for 1 L water sample for Hazeir raw water containing 816 MPN/100 mL, total coliform and 166 MPN/100mL *E. coli* resulted in 2.91 log removals of total coliform and 2.22 log removal of *E. coli* (complete removal) after 24 hours detention time.

It has been noticed that when the turbidity of the raw water is low, better disinfection results were obtained.

The raw water quality for King Abdulla Canal and the agricultural pond was inadequate for drinking purposes from biological as well as chemical points of view. Yajouz, Hazeir and Wadi-Seer waters were adequate from chemical points of view, but inadequate from biological point of view. Although acacia bark is not expected to improve the water quality from the chemical point, it can treat it biologically. Thus no improvement of chemical

Table 3. **Results of total coliforms & echerchia coli in sample taken from king abdulla canal.**

Sample Type	Sample Size	Retention Time (Hour)	Sample No.	Total Coliforms		*E. coli*		Turbidity		Color	
				Total Coliforms (MPN/100)	Log Removal (Average)	*E coli* (MPN/100)	Log Removal (average)	Turbidity (NTU)	Average	Color (Unit)	Average
Raw Sample				9070		1750		12		107	
Treated Samples with 10 g Galool-Asal	1 L	2	1	687	0.769	172	0.831	57	58	533	545
			2	2400		344		58		557	
		4	1	665	0.771	218	0.929	85	84	733	700
			2	2410		194		82		667	+3
		24	1	830	1.097	4.10	2.44	668	673	5800	5934
			2	620		8.60		679		6067	
	2.5 L	2	1	2410	0.576	1730	0.005	48	48	473	462
			2	2410		1730		47		450	
		4	1	2410	0.576	2410	0.306	76	76	700	684
			2	2410		317		75		667	
		24	1	2410	0.576	162	0.475	268	267	2400	2350
			2	2410		1010		266		2300	
	5 L	2	1	2410	0.576	2410	−0.073	40	39	393	383
			2	2410		1730		38		373	
		4	1	2410	0.843	1730	0.262	61	60	533	533
			2	195		183		58		533	
		24	1	2410	0.576	437	0.090	248	250	2367	2350
			2	2410		2410		252		2333	

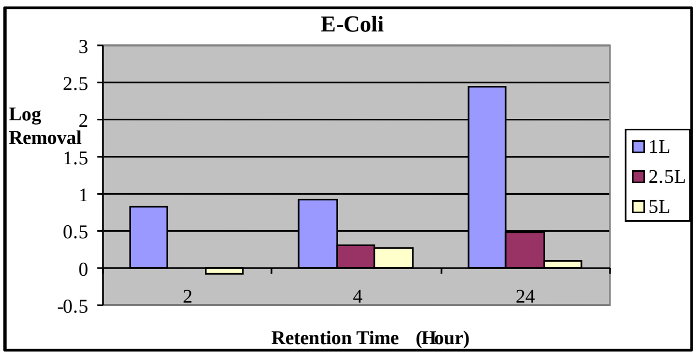

Figure 1. **Log removal of *E. coli* at different acacia concentrations and at different detention times for King Abdullah Canal Water (average range of logs: 0.2).**

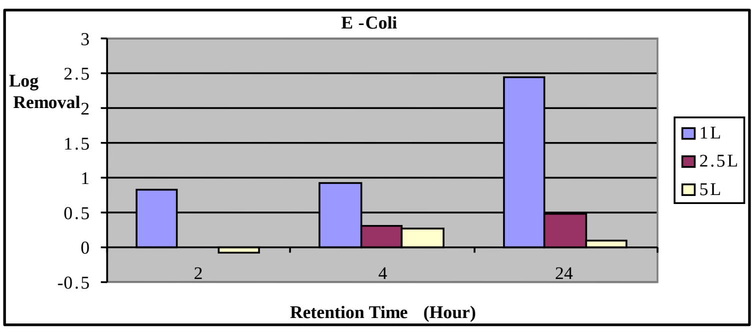

Figure 2. **Log removal of *E. coli* at different acacia concentrations and at different detention times for Agricultural Pond Water (average range of logs = 0.17).**

Table 4. **Result of total coliforms & *Escherichia coli* in sample taken from agricultural pond.**

Sample Type	Sample Size	Retention Time (Hour)	Sample No.	Total Coliforms		*E. coli*		Turbidity		Color	
				Total Coliforms (MPN/100)	Log Removal (Average)	*E. coli* (MPN/100) (Average)	Log Removal (Average)	Turbidity (NTU)	Average	Color (Unit)	Average
Raw Sample				1040		310		8		63	
Treated Samples with 10 g Galool-Asal	1 L	2	1	980	0.052	18.7	1.302	47	48	447	454
			2	866		12.2		48		460	
		4	1	550	0.247	510	1.472	83	84	733	717
			2	629		15.8		85		700	
		24	1	2410	−0.099	40.4	1.102	464	459	4467	4234
			2	201		860		454		4000	
	2.5 L	2	1	2410	−0.365	337	−0.028	46	46	433	433
			2	2410		325		46		433	
		4	1	2410	−0.365	2410	−0.891	74	74	667	667
			2	2410		2410		74		667	
		24	1	2410	−0.365	337	−0.028	268	268	2567	2567
			2	2410		325		267		2567	
	5 L	2	1	2410	−0.365	50.4	0.897	34	34	333	328
			2	2410		28.2		33		323	
		4	1	2410	−0.365	167	0.446	49	49	4566	4600
			2	2410		55.2		49		4633	
		24	1	2410	−0.365	2410	−0.891	464	459	2267	2234
			2	2410		2410		454		2200	

Table 5. **Result of total coliforms & *Escherichia coli* in sample taken from Yajooz.**

Sample Type	Sample Size	Retention Time (Hour)	Sample No.	Total Coliforms		*E. coli*		Turbidity		Color	
				Total Coliforms (MPN/100)	Log Removal (Average)	*E. coli* (MPN/100) (Average)	Log Removal	Turbidity (NTU)	Average	Color (Color Unit)	Average
Raw Sample				260		13.5		1		1	
Treated Samples with 10 g Galool-Asal	1 L	2	1	2410	−0.965	23.7	−0.318	39	39	383	380
			2	2410		32.5		38		377	
		4	1	691	−0.513	12.5	−0.028	43	43	417	414
			2	1010		16.3		43		410	
		24	1	2410	−0.965	00	1.130	171	172	157	159
			2	2410		00		172		160	
	2.5 L	2	1	2410	−0.965	2410	−2.190	31	31	300	300
			2	2410		1770		30		300	
		4	1	2410	−0.965	1980	−2.138	35	36	333	337
			2	2410		1730		36		340	
		24	1	2410	−0.965	726	−1.546	101	103	1270	1285
			2	2410		224		105		1300	
	5 L	2	1	2410	−0.965	1980	−2.138	14	14	133	135
			2	2410		1730		14		137	
		4	1	2410	−0.965	1290	−2.000	18	18	167	164
			2	2410		2410		17		160	
		24	1	2410	−0.965	649	−1.734	103	100	900	917
			2	2410		816		97		933	

Table 6. **Results of total coliforms & *Escherichia coli* in water samples taken from hazeir.**

Sample Type	Sample Size	Retention Time (Hour)	Sample No.	Total Coliforms		*E. coli*		Turbidity		Color	
				Total Coliforms (MPN/100)	Log Removal (Average)	*E. coli* (MPN/100)	Log Removal (Average)	Turbidity (NTU)	Average	Color (Color Unit)	Average
Raw Sample				1080		170		1		1	
Treated Samples with 10 g Galool-Asal	1 L	2	1	218	0.183	43	0.388	44	44	337	337
			2	1200		96		44		337	
		4	1	250	0.754	26	0.878	96	98	773	777
			2	131		19		99		780	
		24	1	122	0.949	00	2.230	261	262	4333	4333
			2	121		00		263		4333	
	2.5 L	2	1	2410	−0.349	1730	−1.038	29	29	257	254
			2	2410		1980		29		250	
		4	1	2410	−0.349	1730	−0.984	51	51	400	397
			2	2410		1550		50		393	
		24	2	2410	−0.349	2410	−1.086	180	179	1667	1650
			2	2410		1730		178		1633	
	5 L	2	1	2410	−0.349	2410	−0.927	21	21	173	173
			2	2410		461		21		173	
		4	1	2410	−0.349	1110	−0.893	35	34	267	267
			2	2410		1550		33		267	
		24	1	2410	−0.349	816	−0.874	175	174	1500	1450
			2	2410		1730		173		1400	

Table 7. **Results of total coliforms & *Escherichia coli* in water samples taken from wadi-seer.**

Sample Type	Sample Size	Retention Time (Hour)	Sample No.	Total Coliforms		*E. coli*		Turbidity		Color	
				Total Coliforms (MPN/100)	Log Removal (Average)	*E. coli* (MPN/100)	Log Removal (Average)	Turbidity (NTU)	Average	Color (Color Unit)	Average
Raw Sample				2410		1050		1		1	
Treated Samples with 10 g Galool-Asal	1 L	2	1	2400	0.002	225	0.663	27	28	425	425
			2	2400		230		28		425	
		4	1	2400	0.002	36.0	1.028	54	53	750	743
			2	2400		160		51		735	
		24	1	2400	0.002	630	2.521	197	198	2750	2825
			2	2400		00		198		2900	
	2.5 L	2	1	2400	−0.266	308	0.435	21	21	255	263
			2	6490		460		20		270	
		2	1	96.0	0.736	57.0	0.780	26	26	330	340
			2	790		290		25		350	
		24	1	2400	−0.535	630	2.521	130	136	2250	2300
			2	14100		0		141		2350	
	5 L	2	1	5330	−0.314	237	0.761	4.30	4.3	45	53
			2	4610		126		4.30		60	
		4	1	144	0.457	139	0.958	15.6	17	200	205
			2	1540		91.6		15.6		210	
		24	1	2400	−0.475	261	0.056	86	87	1300	1325
			2	12000		1580		87		1350	

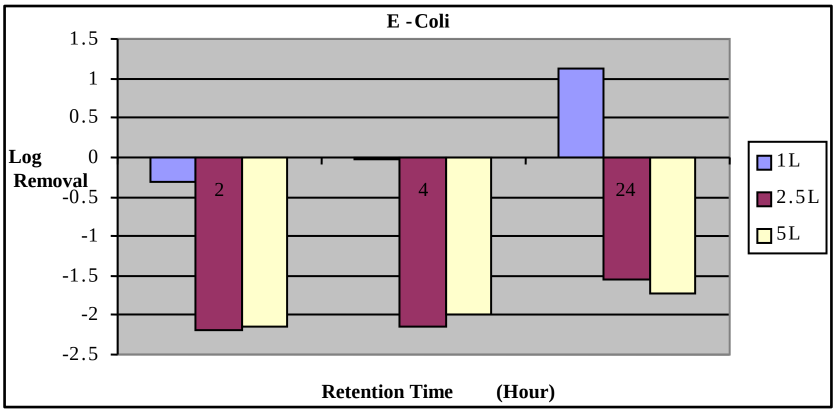

Figure 3. Log removal of ***E. coli*** at different acaia concentrations and at different detention times for Yajouz Water (average range of logs = 0.08).

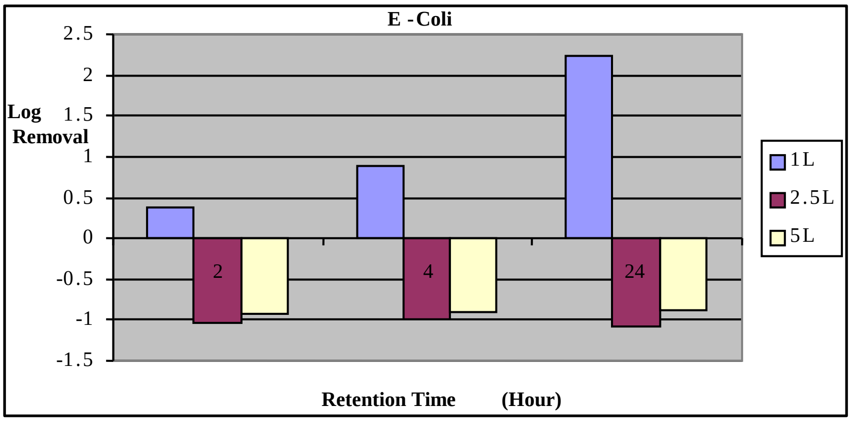

Figure 4. Log removal of ***E. coli*** at different acaia concentrations and at different detention times for Hazeir Water (average range of logs = 0.11).

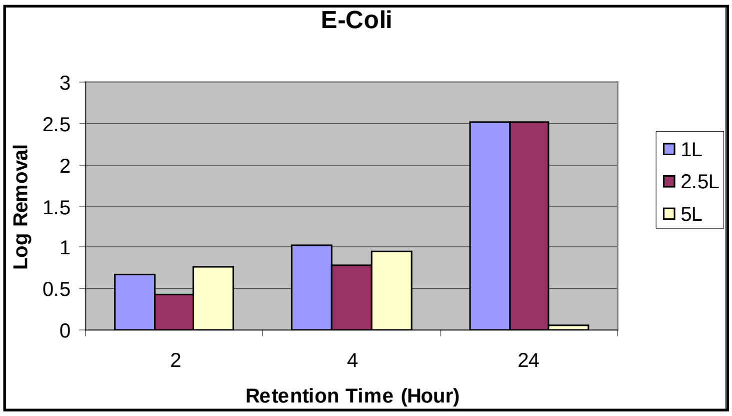

Figure 5. Log removal of ***E. coli*** at different acaia concentrations and at different detention times for Wadi -Seer Water (average range of logs = 0.45).

quality parameters is expected. On the contrary an increase in turbidity, and color has been observed for all water samples after treatment with acacia bark at all concentrations and at all detention times and for all water qualities. In case better water quality water is not available, the water can be disinfected to a certain extent using acacia bark.

Good disinfection could be achieved when high concentration of acacia bark (10 g/L) is used and for long detention times (24 hours). Such long detention times resulted in improving the microbiological quality of the water, but the color and turbidity will deteriorate.

As for toxicity of acacia bark constituents, although tannic acid is not considered to be toxic, it is believed that it is responsible for decrease in feed intake, growth rate, feed efficiency, net metobalizable energy, protein digestibility and most of all iron absorption [13]. So it is recommended that the intake should not exceed 50 mL/kg body weight, five times a day, every 4 - 5 hours. This timing was based on the elimination rate of ellagic acid (one component of tannic acid) [14], which was estimated as four times the time required for half tannic acid to be eliminated (t½), to insure that no tannic acid accumulation occurs.

4. Conclusions

1) Acacia bark has shown anti microbial activity and is capable of reducing the total coliform count and the *Escherichia coli* in polluted water samples.

2) The concentration and detention time used are important factors in the degree of removal. 10 g of the Acacia bark in 1 L water sample is capable of removing more than 2 logs of *Escherichia coli* in samples treated with Acacia bark after 24 hours detention time.

3) Color, turbidity, and total dissolved solids increase upon treatment with Acacia bark. Higher concentrations of Acacia bark could not be used to get better results in microbiological disinfection due to the increase in color and turbidity. The water will not be complying with WHO guidelines from color and turbidity points of view although its microbiological quality has improved.

4) The bacteriological quality of some water samples deteriorated after addition of acacia bark as compared to raw water quality. The reason behind that might be due to the fact that at low acacia concentrations, no disinfection is taking place and the bacteria will grow and reproduce in the water which is originally polluted. This happens if the raw water is left untreated for the same period of time.

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