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DEVELOPMENT OF FILTRATION/ ADSORPTION MEDIA FOR REMOVAL OF BACTERIA AND TURBIDITY FROM WATER

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ABSTRACT

A downflow column test (5 cm bed depth and 5 min bed contact time), employing tap water spiked with *Escherichia coli* (ca. 50 CFU/mL) and with or without natural turbidity (50 NTU), was used to screen filtration/adsorption media, prepared from locally available materials (bituminous coal, lignite, manganese ore and iron ore, both raw as well as pretreated/impregnated with alum, ferric hydroxide, lime or manganese dioxide), in terms of their capacity to remove bacteria and turbidity from water. Based on bacteria removal and turbidity data, ferric hydroxide impregnated lignite (Fe-lignite) and alum pretreated or lime impregnated manganese ore (alum-Mn ore or lime-Mn ore) ranked top among the twenty media tested, showing 100% removal of *Escherichia coli* with effluent turbidity not exceeding 5 NTU. In terms of chemical characteristics that may affect the aesthetic quality of drinking water, both Fe-lignite and lime-Mn ore were acceptable; however, Fe-lignite showed the least change in the filtered water quality. Effects of pH (5 - 10), ionic strength (0.005-0.0125) and temperature (20 - 35°C) on *Escherichia coli* sorption by Fe-lignite were investigated in batch sorption tests. In column tests using canal water with 3 min contact time, Fe-lignite produced filtered water with 0 - 4 CFU/mL coliforms and turbidity not exceeding 5 NTU. Fe-lignite was found to be a potentially useful media for domestic water filters in rural areas of the developing countries.

KEYWORDS

Filtration/adsorption media; domestic water filter; bacteria and turbidity removal; *Escherichia coli*; coliforms; bituminous coal; lignite; manganese ore; iron ore.

INTRODUCTION

Providing safe drinking water in rural areas of the developing countries is a challenging task. The available drinking water treatment technology suitable for the developed countries and urban areas of the Third World is often inappropriate for villages and small communities in the developing countries because of limitations on funds and skilled manpower. There is a renewed interest in the development of simple low-cost drinking water treatment devices which show promise for application in households in small communities or villages in the developing countries. A limited number of point-of-use drinking water treatment devices (candle filter and ion exchange or ultraviolet water purifier) are available but are beyond the reach of the target population.

The present study was undertaken with the objective of developing filtration/adsorption media, using locally available materials for the removal of bacteria and turbidity from water, which may prove useful for domestic water filters.

EXPERIMENTAL

The media included bituminous coal from Giridih, lignite from Neyveli, and iron ore (haematite) and manganese ore (pyrolusite) from Sandur, both raw and pretreated/impregnated with either alum, ferric hydroxide, lime or manganese dioxide. All media were crushed to a geometric mean size of 0.388 mm before pretreatment/impregnation. For alum pretreatment, the method of Anderson *et al* (1980) for alum loading of cation exchange resin was used. Raw media (20 g) in 200 mL 1 M alum ($Al_2(SO_4)_3 \cdot 16 H_2O$) solution at pH 3.2 were agitated in an end-over-end shaker at 20 rpm for 7 d. For ferric hydroxide impregnation, the method of Anderson *et al* (1982) for coating magnetite with ferric hydroxide gel was employed. Raw media (20 g) were slurried in 100 mL distilled water to which 0.5 g of ferric chloride ($FeCl_3$) was added. Using 2 N sodium hydroxide, the pH of the slurry was then adjusted at 6 pH units/h to 11.5 and the final volume made up to 200 mL. The slurry was allowed to stand for 15 min. Lime impregnation was carried out using a method reported by Cullen and Siviour (1982). Raw media (20 g) in 100 mL lime slurry (100 g/L) were agitated in an end-over-end shaker at 20 rpm for 2 h. For manganese dioxide impregnation, the method adopted by Kirankumar (1984) was used. Raw media (24 g) were added to a solution of potassium permanganate (25.675 g in 325 mL distilled water) at 90°C in a water bath. The slurry was stirred for 10 min followed by slow addition of 300 mL 2 N hydrochloric acid in 10 min with constant stirring. Stirring was continued for another 10 min followed by washing off excess precipitate with distilled water and 0.05 M perchloric acid till the supernatant became clear. Following pretreatment/impregnation all media were washed several times with distilled water and desiccated.

The screening column test (30 min) was performed in a 10 mm ID glass column (5 cm bed depth and 5 min bed contact time) employing dechlorinated filter-sterilised tap water spiked with a logarithmic phase resting suspension of *Escherichia coli* (ca. 50 CFU/mL) and with or without natural clay turbidity (50 NTU). Influent and effluent samples were analysed for *Escherichia coli* (pour plate method - 35°C/24 h - Eosin Methylene Blue agar) and turbidity.

A batch sorption test to study the effects of pH, ionic strength and temperature on *Escherichia coli* sorption was carried out by contacting the media (0.2%) with a logarithmic phase resting suspension of *Escherichia coli* in 100 mL dechlorinated filter-sterilised tap water (ca. 50 CFU/mL) in 300 mL glass bottles in an end-over-end shaker at 20 rpm. Mineral acid or alkali was used for pH adjustment. Ionic strengths in the range 0.005 - 0.0125 were obtained by blending dechlorinated filter-sterilised tap water (ionic strength 0.0125) with filter-sterilised canal water (ionic strength 0.005). At the end of 15 min sorption time, bottles were removed from the shaker and following 1 min settling, the supernatant was assayed for unadsorbed *Escherichia coli*.

In desorption tests, the supernatant following a sorption test was replaced by dechlorinated filter-sterilised tap water. The media were further agitated for 15 min and following 1 min settling, the supernatant was assayed for desorbed *Escherichia coli*. Subsequently, the procedure was repeated by replacing the supernatant by 3% beef extract.

Column tests using Lower Ganga canal water were performed under conditions similar to those of the screening column test. However, bed contact times of 1, 2, 3, 4 and 5 min were employed.

RESULTS AND DISCUSSION

Screening column test data for the twenty media are presented in Table 1. Based on bacteria removal and turbidity data, ferric hydroxide impregnated lignite (Fe-lignite) and alum pretreated or lime impregnated manganese ore

(alum-Mn ore or *coli* with effluent bituminous coal

Media

Giridih bituminous	
Raw	Alum
Raw	Fe-Oxide
Raw	Lignite
Raw	Mn-Oxide
Lignite	
Raw	Alum
Raw	Fe-Oxide
Raw	Lignite
Raw	Mn-Oxide
Manganese ore	
Raw	Alum
Raw	Fe-Oxide
Raw	Lignite
Raw	Mn-Oxide
Sandur ore	
Raw	Alum
Raw	Fe-Oxide
Raw	Lignite
Raw	Mn-Oxide

Fe-lignite, alum-Mn ore terms of the chemical similar to the screening column test col parameters Table 2

TABLE

Parameter
pH
Conductivity (µS/cm)
Alkalinity (mg CaCO ₃ /L)
Hardness (mg CaCO ₃ /L)
Chloride (mg/L)
Sulphate (mg/L)
Aluminium (mg/L)
Iron (mg/L)
Manganese (mg/L)

NS = Not specified;

(alum-Mn ore or lime-Mn ore) ranked top, showing 100% removal of *Escherichia coli* with effluent turbidity not exceeding 5 NTU. Alum pretreated Giridih bituminous coal (alum-GBC) also appeared promising.

TABLE 1 Screening Column Test

Media	<i>Escherichia coli</i> Removal (%)			
	With Turbidity		Without Turbidity	
	15 min	30 min	15 min	30 min
<u>Giridih Bituminous Coal (GBC)</u>				
Raw GBC	50	46(10.0)	81	88
Alum-GBC	97	100(5.0)	100	100
Fe-GBC	97	89(12.0)	100	100
Lime-GBC	57	57(6.7)	100	79
MnO ₂ -GBC	69	48(11.0)	79	58
<u>Lignite</u>				
Raw lignite	70	80(6.0)	90	92
Alum-lignite	95	95(4.0)	100	100
Fe-lignite	100	100(5.0)	100	85
Lime-lignite	40	57(6.7)	98	92
MnO ₂ -lignite	92	90(8.9)	58	58
<u>Manganese Ore</u>				
Raw Mn ore	86	90(9.0)	37	41
Alum-Mn ore	100	100(5.0)	100	87
Fe-Mn ore	73	97(19.0)	55	60
Lime-Mn ore	100	100(3.7)	100	100
MnO ₂ -Mn ore	96	99(3.4)	71	38
<u>Iron Ore</u>				
Raw Fe ore	71	79(9.0)	33	29
Alum-Fe ore	93	100(4.5)	100	95
Fe-Fe ore	95	95(14.0)	39	37
Lime-Fe ore	90	88(5.0)	95	97
MnO ₂ -Fe ore	75	91(4.4)	95	96

Influent: pH 7.3 - 8.2; turbidity 50 NTU; *Escherichia coli* 37-51 CFU/mL. Effluent turbidity (NTU) values are shown in parentheses.

Fe-lignite, alum-Mn ore and lime-Mn ore were subjected to further screening in terms of the chemical characteristics of the filtered water. Using a procedure similar to the screening column test but without *Escherichia coli* or turbidity, column effluent collected during 30 min filter runs was analysed for relevant parameters (Table 2) according to Standard Methods (APHA, 1985). In general,

TABLE 2 Chemical Characteristics of Filtered Water

Parameter	Influent	Effluent		
		Fe-lignite	Alum-Mn ore	Lime-Mn ore
pH	7.9	7.6	6.6	8.4
Conductivity (mS/cm)	98.0	98.5	99.5	99.0
Alkalinity (mg CaCO ₃ /L)	475	475	100	525
Hardness (mg CaCO ₃ /L)	182	-	50	232
Chloride (mg Cl ⁻ /L)	15	30	-	-
Sulphate (mg SO ₄ ²⁻ /L)	32.9	-	285	-
Aluminium (mg Al/L)	ND	-	2.75	-
Iron (mg Fe/L)	0.01	0.11	-	-
Manganese (mg Mn/L)	ND	-	0.76	0.04

ND = not detected; - analysis not performed.

Fe-lignite showed the least change in chemical characteristics of the filtered water whereas for alum-Mn ore, increased sulphate concentration as well as high levels of aluminium and manganese were observed. From the viewpoint of aesthetic quality of the filtered water, both Fe-lignite and lime-Mn ore were acceptable. Since Fe-lignite showed the least change in the filtered water quality, it was carried through further tests.

Effects of pH (5 - 10), ionic strength (0.005 - 0.0125) and temperature (20 - 35°C) on Escherichia coli sorption by Fe-lignite were investigated in batch sorption tests (Table 3). Appreciable sorption was observed at pH values

TABLE 3 Effect of pH, Ionic Strength and Temperature on Sorption

pH	Ionic Strength	Temperature (°C)	<u>Escherichia coli</u> Sorption (%)
5.0			88
6.0			79
7.0	0.0125	20	96
8.0			94
10.0			94
	0.005		60
7.0	0.0075	22	69
	0.01		90
	0.0125		96
		20	98
8.5	0.0125	30	100
		35	100

Input Escherichia coli 46 - 52 CFU/mL; Fe-lignite 0.2%; sorption time 15 min.

both below and above the pH of zero point charge (pH_{zpc}) of Fe-lignite which is 6.7 (Prasad, 1986). This may be explained by assuming electrostatic interaction between bacterial and media surfaces at pH below pH_{zpc} because both surfaces had predominantly opposite charges. At pH above pH_{zpc} , sorption was presumably influenced by cations in water since both surfaces had predominantly like charges. This was also supported by sorption data employing distilled water, viz., 90% (pH 5.0 and 6.0), 80% (pH 7.0) and 70% (pH 8.0 and 10.0). Noticeable decreases in sorption at pH above pH_{zpc} suggested the influence of cations in sorption at such pH values. At pH 7.0, Escherichia coli sorption also increased with ionic strength, further supporting this. Temperature in the range, 20-35°C did not have any significant influence on Escherichia coli sorption.

In desorption tests following sorption, 16% and 54% (total 70%) of the sorbed Escherichia coli eluted in tap water and 3% beef extract, respectively.

Fe-lignite was subjected to further column tests using Lower Ganga canal water (pH 8.1; turbidity 40 NTU; coliforms (pour plate method - 35°C/24 h + Eosin Methylene Blue agar) 100 - 200 CFU/mL; heterotrophic plate count (pour plate method - 35°C/24 h - plate count agar) 700 - 1200 CFU/mL) using 1, 2, 3, 4 and 5 min bed contact times. No coliforms were detected in the effluent up to 30 min for bed contact times of 3 - 5 min and effluent turbidity remained in the range 3.5 - 5.0 NTU whereas the heterotrophic plate count varied in the range 90-350 CFU/mL.

Data on Lower Ganga canal water in the Fe-lignite intermittent column test (5 cm bed depth and 3 min bed contact time; 3 h rest between 30 min cycles) to simulate a domestic filter use pattern are presented in Table 4. Fe-lignite was capable of producing effluent with 98 - 100% removal of coliforms and turbidity not exceeding 5 NTU up to three 30 min cycles, the effluent coliform level being in the range 0 - 4 CFU/mL.

The results of the column tests indicated the capacity of Fe-lignite as a filtration/adsorption medium in substantially reducing coliform and plate count

Time (min)

2
15
30

Influent: ...
Effluent pH

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TABLE 4 Fe-Lignite Intermittent Column Test

Time (min)	Effluent Turbidity (NTU)				Coliform Removal (%)			
	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 1	Cycle 2	Cycle 3	Cycle 4
2	5	5	5	10	99	100	100	100
15	5	5	5	10	100	100	100	55
30	5	5	5	10	100	99	98	84

Influent: pH 8.5; turbidity 35 NTU; coliforms 140 - 200 CFU/mL.
Effluent pH 8.0 - 8.2.

bacteria as well as turbidity from raw surface water. A study is currently underway to assess the usefulness of incorporating silver into Fe-lignite in inactivating the sorbed bacteria and improving its performance.

SUMMARY AND CONCLUDING REMARKS

The present study indicated the potential of some filtration/adsorption media, prepared from locally available materials, in removing bacteria and turbidity from water. These included ferric hydroxide impregnated lignite and alum pretreated or lime impregnated manganese ore. Alum pretreated bituminous coal also appeared promising. Ferric hydroxide impregnated lignite showed the least change in chemical characteristics of the filtered water and was found capable of substantially reducing coliform and plate count bacteria as well as turbidity from raw surface water. It is likely that such media may prove useful for domestic water filters in rural areas of the developing countries.

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