Treatment of Iron Pollution in the Waters of Bayelsa and Environs Using Innovative In-Country Technology

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Abstract

Brown discolouration of surfaces caused by water supply in most parts of Bayelsa State is attributed to the presence of iron (Fe) in the aquifer. Consequently, the colourless water pumped from source eventually turns brown on exposure to the atmosphere. The purpose of this study is to proffer solution to this menace. Hence, a treatment option using an in-country technology that focuses on the removal of causative iron metal specie from source was studied. The aim is to remove the metal from source and prevent the transformation to brown colour. The effect of a biogenic de-pollutant (BGD) formulated from locally sourced materials on the removal of Fe from water was investigated as a function of BGD concentration. Impact on three water quality parameters namely pH, electrical conductivity (EC) and total dissolved solid (TDS) were evaluated following standard procedures. Results showed that BGD could remove up to 471 mg Fe/L at concentration ≤ 10 mg BDG/L. Pearson correlation revealed strong and positive relationship between Fe removal efficiency and BGD concentration with correlation coefficient (r) of 0.922, significant at p = 0.028. Treatment did not negatively impact TDS, pH and EC values. Study revealed that BDG has a great potential to solving the Fe pollution menace in Bayelsa waters or any other place with similar issue. It is recommended that further studies be conducted, aimed at optimization of this innovative technology for field applications. Study is a contribution to sustainable development goal No.6 (Clean water and Sanitation).

Key words: *Iron Pollution, Water Treatment, In-Country Technology, Clean Water, Environment*

1. INTRODUCTION

A major challenge facing water resources in some parts of Niger Delta Region of Nigeria, Bayelsa State in particular, is the presence of iron (Fe) in the aquifer. In the absence of safe or functional public water supply system, residents are encumbered with random and unregulated treatment of raw water supplies from boreholes with prevailing Fe pollution. This exposes consumers to health risks. Surfaces are also strained from resultant colour transition when Fe converts from ferrous (Fe^{2+}) to ferric (Fe^{3+}) oxidation states. In addition to discolouration of surfaces, excess Fe in water can create blockages in units such as pipelines, causing rust and corrosion. Hence, it is very critical to remove Fe from water to make it suitable for drinking or industrial use. Chemical treatments including chlorination, catalytic filtration, chemical oxidation, phosphate treatment, use of water softeners, iron removal filters, distillation or reverse osmosis seem to be the predominant treatment processes for removal of Fe from water both within or outside Nigeria (Khadse et al., 2015; Abanda, 2021). The objective of this study is, therefore, to proffer a home grown, eco-friendly and cost-effective solution to this environmental menace. Hence, a treatment option using an incountry technology that focuses on the removal of causative iron metal specie (Fe^{2+}) at source, advancing green technologies in water treatment, is presented.

2. MATERIALS AND METHODS

2.1 Depollution of Iron Contaminated Water

The biogenic de-pollutant (BGD) investigated in this study was prepared from plant biomass as described in Adekunle (2010) and Adekunle et al. (2011) with slight modifications to transform it to technical grade product. Raw borehole water (RBW) sourced from Federal University Otuoke, Bayelsa State was used in this study. Increased pollution of 4867 mg Fe/L was achieved by spiking with a ferrous salt to give the polluted raw borehole water (PBHW). Samples of PBHW were subjected to treatment with BGD at constant volume to volume (v/v) ratio but at varied BGD concentrations of 5.0, 7.0, 8.0, 9.0 and 10.0 with units in mg/L. Reaction systems were allowed to stand for 24 hours at room temperature of 28^{o}C. Treatment at a particular BGD concentration was repeated three times. Treated water samples were filtered using Whatman No.1 and filtrates analyzed for Fe, pH, EC and TDS following standard procedures at analytical service laboratory of International Institute for Tropical Agriculture (IITA) Ibadan, Oyo State. All quantitative data were subjected to descriptive, T-test and correlation analysis using IBM SPSS Version 20.

3. RESULTS AND DISCUSSION

3.1 Removal of Iron from water

Typical discoloured surfaces due to Fe in water captured in the course of this study is presented in Fig.1. BGD administered in aqueous form was able to remove up to 471.79 ± 85.48 mg/L of total dissolved iron Fe from polluted water. The concentration of dissolved Fe removed from water

Fig.1: A typical impact of Fe in raw water on a surface in Bayelsa State

varied with BGD concentration as shown in Table 1 and Fig.2. Pearson correlation gave a linear relationship between concentration of BGD and total dissolved iron removed with positive and strong correlation coefficient (r) of + 0.922 ($p < 0.05$) as shown in Fig.3. This indicates improved total dissolved iron removal with increasing concentration of BGD. Iron in drinking water is not usually higher than 10.0 mg/l, since BGD could be used to remove up to 471.79 ± 85.48 mg/L, it implies that BGD is a material with promising potential for Fe removal from drinking and waste water.

Table 1: Total dissolved Fe removed from raw water and indicators of water quality

S/N	**BGD Concentration (mg/L)**	**Fe removed from water (mg/L)**	**Water Quality Indicators**			
			TDS	**pH**	**EC**	**(µS/cm)**
			Values in BHW	6.44 ± 0.13 (6.31 – 6.57)	100 ± 13 (87 – 113)	50 ± 0.14 (49.86 – 50.14)
			Values PBHW	2.53 ± 0.01 (2.52 – 2.54)	3747 ± 10 (3737 – 3757)	1873 ± 12 (1861– 1885)
1	5	163.96 ± 65.74 (71.97 – 291.32)	Values in BGD-Treated water	6.81 ± 0.13 (6.64 – 7.07)	133.3 ± 6.67 (120 -140)	66.67 ± 3.33 (60-70)
2	7	246.08 ± 91.99 (148.92 – 429.87)		7.19 ± 0.02 (6.95 – 7.59)	153.33 ± 6.67 (140 – 160)	76.67 ± 3.33 (70 - 80)
3	8	456.71 ± 71.81 (374.90 – 599.84)		7.49 ± 0.11 (7.27 – 7.62)	126.67 ± 6.67 (120 -140)	63.33 ± 3.33 (60 -70)
4	9	466.97 ± 86.65 (297.87 – 584.39)		7.59 ± 0.02 (7.55 – 7.85)	126.67 ± 6.67 (120 -140)	63.33 ± 3.33 (60 -70)
5	10	471.79 ± 85.48 (275.06 – 569.79)		7.78 ± 0.04 (7.73 -7.85)	126.67 ± 6.67 (120 -140)	63.33 ± 3.33 (60 -70)

Values in parenthesis stand for minimum and maximum values, BHW = borehole water, PHW = polluted borehole water

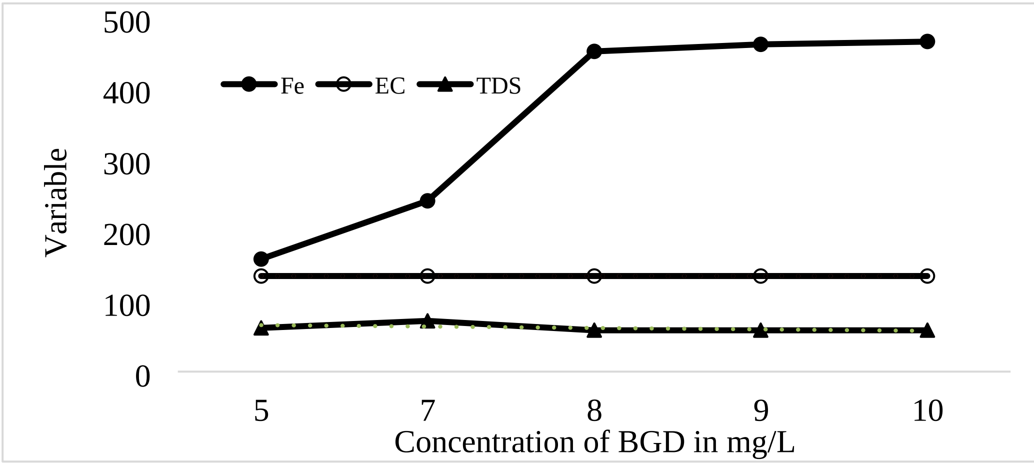


Fig.2: Trend in concentration of dissolved Fe removed from water and resultant pH, EC and TDS of treated water as a function of BGD concentration

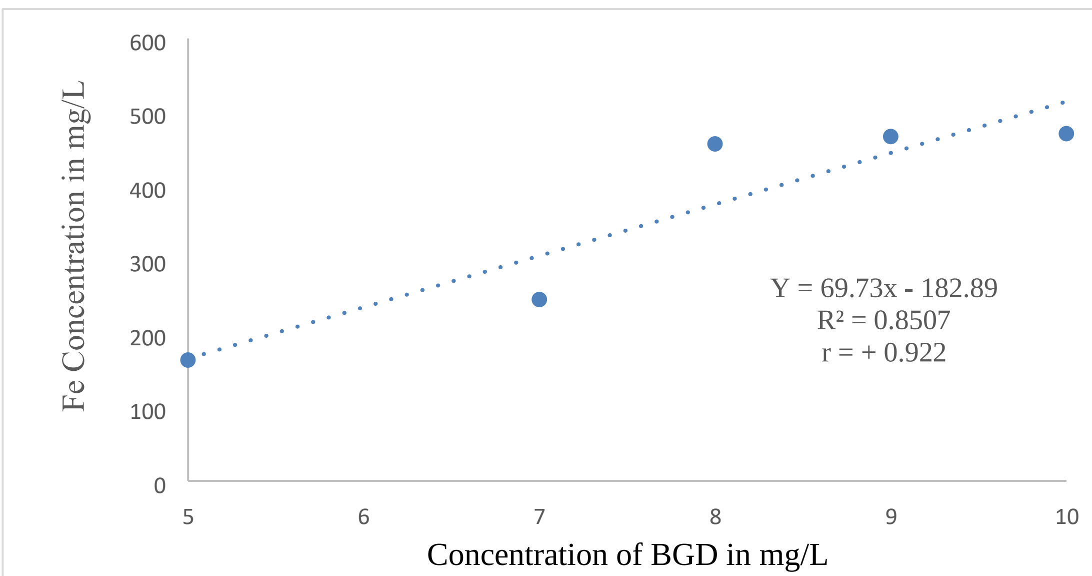


Fig.3: Linear correlation between BGD concentration and Fe removed from water

3.2 Effect of Water Treatment on Selected Quality Indicator Parameters

The effect of the use of BGD in Fe removal on selected water quality parameters (pH, TDS and

EC) are presented in Figs. 4 to 6.

3.2.1 Effect on water pH

Unpolluted raw borehole water (BHW) gave a pH of 6.44 ± 0.14. Induced Fe pollution reduced the pH to 2.53 ± 0.01, implying acidic condition. Water treatment using BGD transformed the acidic condition to normalcy in the pH range of 6.64 to 7.07. pH is a measure of acidity or how basic water is. Pure water should either be neutral or near neutral, hence, are in line with World Health Organization stipulated standard of 6.5 to 8.5 (WHO, 2007).

3.2.2 Effect on TDS of Water

The effect on TDS, presented in Fig. 4, showed that unpolluted raw borehole water (BHW) gave a mean value of 50 ± 0.14 mg/L. Induced Fe pollution raised TDS to 1873 ± 12 mg/L, which is above USEPA recommended value of 500 mg/L implying possible water hardness. TDS reflects total dissolved solids, which stands as a measure of total dissolved substances made up of largely inorganics. Water treatment using BGD gave TDS values less than 100 mg/L, indicating good quality in terms of solids.

3.2.3 Effect on Electrical Conductivity of Water

The electrical conductivity (EC) of unpolluted raw borehole water (BHW) was 100 ± 13 μScm^{-1}.

Induced Fe pollution raised EC to 3747 ± 10 μScm^{-1}, a value higher than the acceptable limit of 1000 μScm^{-1} (WHO, 2006). However, subjecting the polluted water to BGD treatment gave an average EC of 140 μScm^{-1}, which is below the upper limit of 1000 μScm^{-1}. EC is a measure of water's ability to conduct electricity and a measure of total dissolved ions or electrolytes in it. The values obtained in this work for unpolluted borehole water and treated water samples' quality parameters were in concordance with the values reported for drinking water by Meride and Ayenew (2016).

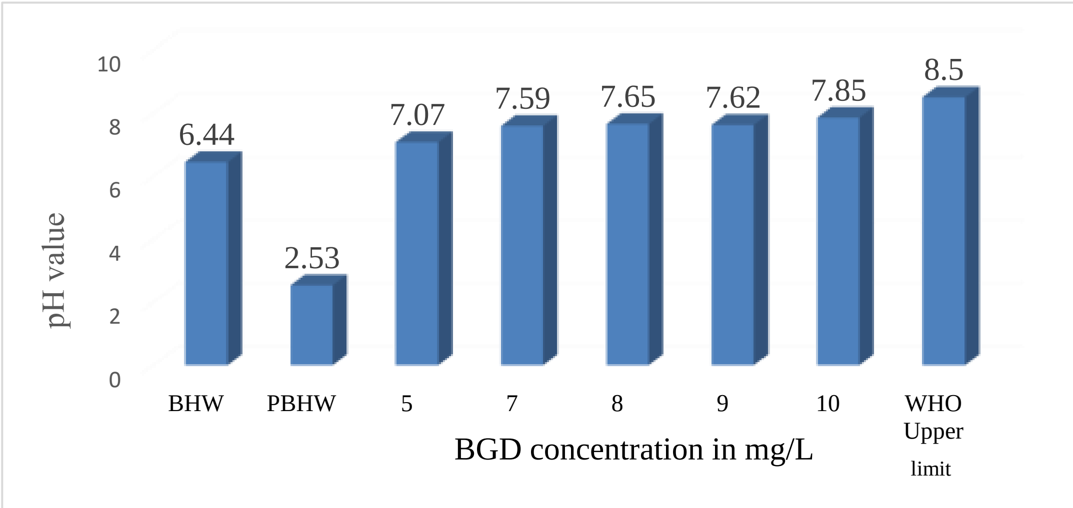


Fig.4: Effect of BGD-water treatment on water pH

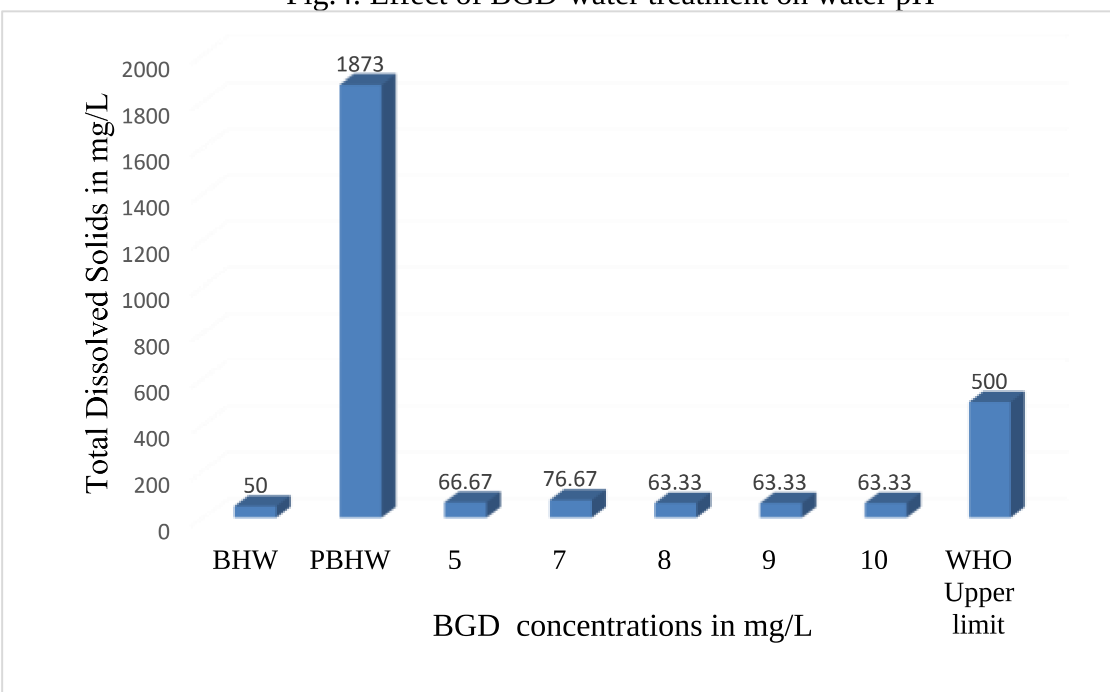
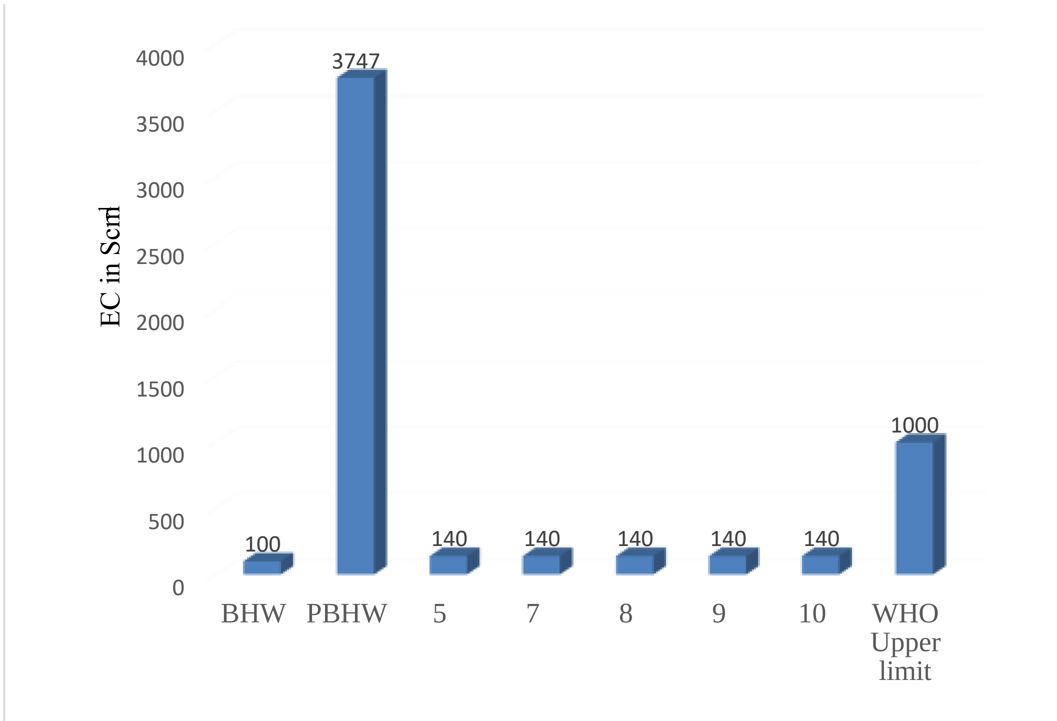


Fig.5: Effect of BGD-water treatment on water TDS



BGD Concentration in mg/L

Fig.6: Effect of BGD-water treatment on water EC

CONCLUSIONS & RECOMMENDATIONS

This investigation revealed that the in-country technology involving the use of BGD is potent in the removal of Fe from water. Furthermore, the quality of treated water appeared not to be compromised. It is recommended that further studies be carried out to optimize procedures that can enhance its use in water treatment protocols in the region or related environments. Assessment of a wider range of water quality parameters should also be conducted.

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