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Biotreatment of acidic and high iron containing groundwater for aquaculture using plantain (Musa paradisiaca) tissues

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Abstract - The Niger Delta is endowed with both surface and underground water from shallow aquifer. Unfortunately, the suitability of both sources water for aquaculture has been problematicdue high iron levels and acidic pH.The untreated water (i.e. control) had iron content of 8.22-8.62 mg/L with pH of 4.15-4.45. Results shows that pH had significant inverse relationship (P<0.01)with iron, hardness and BOD but direct relationship with dissolved oxygen. The water samples were subjected to treatment using the leaves, bract and trunk of Musa paradisiaca for 4 weeks. Results after treatment show decreased iron level to 2.12 mg/L,1.05 mg/L, and 0.11 mg/L for the leaf-, bract- and trunk-treated water respectively with corresponding increase in pH to 6.48, 6.85 and 7.88(p < 0.05) respectively. All the treatments resulted in the improvement of the water quality, especially with respect to pH and iron. The trunk-treated water had the best quality, which fell within the WHO guideline for drinking water.

Keywords: **Acidic, aquaculture, biosorption, biotreatment, coagulation, fertilization, iron, pH.**

I. INTRODUCTION

Water is avital and inevitable resource required by all earthly organisms. Over 70% of the Niger delta land mass is filled with water [1], yet water shortage persists in the Niger Delta and most developing countries [1 – 3]. For instance, statistics aboundsglobally that, about 1.0-1.2 billion people have no access to potable water [2 – 6] and in Africa, over 300 million people lack access to quality water [2, 6 –7]. Estimates suggest that in the next decade, over ten African countries could experience water shortage [2, 7 – 8].

The Niger Delta region is blessed with reservoirs of both surface and ground water[2].The surface water serve as a major source of water for rural settlements along coastal areas, while the groundwater are exploited by private boreholes owners mostly in urban areas [3]. The portability or suitability of groundwater water for both domestic and aquaculture purpose has become a major challenge in the Niger Delta due to acidic pH and high iron content [1 – 3, 5, 9], as well as microbial contamination [10].

Groundwater has been recommended as the best-fit water for aquaculture purpose due to natural infiltration and purification [1], and lesser microbial contamination [11 – 12]. Groundwater of the Niger Delta contains high level of iron, and has been reported to be toxic to aquatic life especially fish [1, 2]. High iron level affects wateruse. For instance, Ohimain and Angaye [1] reported that the presence of iron in water impairssome vitalphysicochemical parametersrequired tosustain aquatic life.Over the past decade, several multifaceted measures aimed at remedying high iron levels in the Niger Delta have been tested including filtration, coagulation and aeration and sedimentation. But adaptation of some of these technologies has been slow due to high cost of fabricating and maintaining contemporary treatment plants [1].

In the Niger delta, plantain has becomeanimportant staple food, it is farmed for both commercial and subsistence purposes. Adeolu and Enesi [13] reported that plantain fruitremains the sole interest of the farmer, as other organs of the plant are usually regardedas wastes. Thebye products ofplantain harvest (i.e. the leaves, bracts and trunk) largely constitutes environmental nuisance, if not properly managed.On the other hand these bye products are now been used for agricultural application as manure forsoil replenishment.

Poormanagement practicelargely attributed to inadequate technical know-how, has significantly threatened the aquaculture sector in Nigeria [1, 2, 10, 14]. Ohimain and Angaye [1] reported that fish kill prevails in most

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developing countriesdue to lack of technical know-how, which makes farmers administer wrong and ineffective treatment. Fish kill are largely linked to infectious or non-infectious disease, and in rare cases due to mechanical trauma and excessive usage of exogenous hormone [10]. Notwithstanding, in the Niger Delta, fish kill has been attributed to the high levels of iron, with a corresponding acidic pH [1]. Studieshave showed that untreated groundwater is toxic to fresh water fish [15], in both concrete tank and earthen pond as a result of high iron levels and acidity [1].

Fertilization is the application of certain synthetic and natural formulation in order to stimulate the growth of aquatic flora and fauna. Nutrients produced during fertilization, results in the availability of phytoplankton which are primary producers in the food chain [16]. In the Niger Delta, the indigenous application of plantain trunk, bract and leaves as pond fertilizer has become a common practice, though the science behind this practice has not been reported. Ohimain et al [2] using single and double trickling filter and [17] using activated carbon from bamboo significantly remediated high iron level and acidic pH of Niger Delta water. But adaptation of some of these technologies has been slow due to high cost of fabricating and maintaining contemporary treatment plants [1], hence the need for this study, which is a low cost method for water treatment.

II. MATERIALS AND METHOD

A. *Samples Collection and Analysis*

Fifty liters of untreated groundwater was collected (13th of June 2014) from a borehole (depth 60±5Ft) in Yenagoa metropolis, Bayelsa state, Nigeria. The water was quickly preserved in air-tight gallon, in order to prevent aeration which could result to the precipitation ofiron III (red or brown). Meanwhile, another 4 litres of the same water was collected for *in-situ* physicochemical analysis. Furthermore, the water samplewas preserved and transported for*ex-situ*laboratory analysis for parameters such as biochemical oxygen demand (BOD), total nitrite and as well as the total iron (preserved in glass bottle rinsed with Nitric acid). The pH and dissolved oxygen (DO), were measured using portable field kits (Hach's CO 150 and JK-OXY-006 meters respectively), while Winkler's method was used for biological oxygen demand (BOD_5). The total iron was analysed using Perkin Elmer 5100PC AA Spectrometer AAS (Atomic Absorption Spectrophotometer), while nitrate was analysed using Colorimetric method.

B. *Plant collection and Phytochemical Screening*

Freshleaves, bracts and stem of plantain (*M. paradisiaca*), was collected from a nearby farm. The various organs of the plant (i.e. leaves, bract and stem), were sorted out and rinsed with distilled water. Prior to phytochemical analysis, the plant tissues were shade-dried and oven-dried at 70^{o}C for 30minutes.The samples were pulverized filtered through a 0.1mm mesh size and stored in polythene container for phytochemical analysis [13].

Analysis for phytochemical constituents was carried outusing standard procedures [18].Tannins and phytates were analyzed using the method reported by Adeolu and Enesi [13], while alkaloids, glycosides, flavonoids, saponins and phenols were determined using AOAC [18] method. The abundance of phytochemical in the different tissues of the plants were scored qualitativelyusing method described by Onyenekwe et al [19]; Salehi-surmanghi et al [20].

C. *Experimental Design*

Ten grams of triplicate samples of fresh leaves, bract and stem of *M. paradisiaca* were distinctly macerated in 4 Litres of the collected water sample. The results were monitored for the selected parameters and total iron) weekly for a period of one month.

D. *Statistical analysis*

All results wereanalyzed in triplicates. The results generated were subjected to statistical analysis using the IBM SPSS, Version 20, while Duncan statistic was used to establish the significance of the observed differences at P=0.05.

III. RESULTS AND DISCUSSION

Results of the phytochemical analysis of the plant (*M. paradisiaca*) showed varying phytochemical constituents in tissues of the leaves, bracts and trunk. Alkaloid, Flavonoids and Saponin were conspicuously present in the leaf compared to the bract and trunk. The bract and trunk contained more of Tannin and Glycosides compared to

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the leaf; while phenols and phytates were moderately present. Adeolu and Enesi [13] similarly reported the presence of these phytochemicals in plantain wastes.

Results of the laboratory analysis show that the raw ground water is acidic and high in total iron (Table 2). The pH was 4.15; total iron 8.62mg/L and low DO of 3.11mg/L. Low pH and high iron content of ground water in the Niger Delta have been reported by several authors. Reference [3] reported a pH of 4.39-5.17 and total iron content of 5.32-9.96mg/L from ground water from Bayelsa State. Other authors have also reported acidic pH levels in the ground water of the Niger Delta; 3.84-7.72mean 6.17 [21], 6.40-7.23 mean 6.54 [9], 5.21-7.00 mean 6.02 [7], 6.40-7.23 mean 6.54 [22], 5.20-7.20 [12] and 3.84-7.72 [23]. The pH of the ground water in this study (4.15) and others listed above was by far lower than the WHO permissible limits for drinking water, which is in the range of 6.5-8.5.

Table 1: Phytochemical analysis of the leaves, bract and trunk of plantain

S/N	Phytochemicals	Plantain Leaf	Plantain Bract	Plantain Trunk
1.	Alkaloids	++	+	+
2.	Flavonoids	++	+	+
3.	Tannins	+	++	++
4.	Phenols	+	+	+
5.	Saponins	++	+	+
6.	Phytates	+	+	+
7.	Glycosides	+	++	++

++: Present in abundance; +: Present; -: Absent

In this study, pH showed significant inverse relationship with iron (P<0.01), hardness and BOD but direct relationship with dissolved oxygen (Table 3). Other authors have similarly recorded high iron levels beyond WHO limits of 0.3mg/L in the Niger Delta; 5.32-9.96mg/L [2], 2.08-12.3 [21], 0.4-10.0mg/L [24], 0.05-5.27 [22], 0.4-1.4mg/L [12],0.57-1.41mg/L [7], 0.05-0.48 [9], 0.05-6.87mg/L [25] and 0-6.2mg/L [26]. A recent study revealed that acidic and high iron containing ground water used for aquaculture was toxic to African catfish, *Clarias gariepinus* [15].

After 4 weeks of treatment, results show that plantain tissues were able to significantly (P<0.05), reduce iron concentrations and acidity to varying levels. Plantain trunk treated water had the highest pH of 7.88 (within neutrality), followed by the bract (pH = 6.85) and leaf with pH of 6.48 (P<0.05)—as against the raw water pH of 4.15. Iron concentration exhibited an inverse pattern being highest in the raw water (8.62 mg/L), followed by the plantain leaf treated water (2.12 mg/L), bract (1.05 mg/L) and least (0.11 mg/L) in the trunk-treated water, which was below the WHO limits of 0.3mg/L.

Table 2: Changes in water physicochemical parameters following biological treatment

Description	Duration (Week)	Temperature °C	pH	DO mg/l	BOD mg/l	Nitrate mg/l	Hardness mg/l	Total iron mg/l
Control	1	27.14±0.05a	4.15±0.03a	3.11±0.01a	1.09±0.01h	2.13±0.01 gh	433.10±0.01j	8.62±0.01k
	2	27.14±0.05a	4.45±0.03b	3.11±0.01a	1.09±0.01h	2.13±0.01 gh	433.10±0.01j	8.62±0.01k
	3	27.14±0.05a	4.45±0.03b	3.11±0.01a	1.09±0.01h	2.13±0.01 gh	433.10±0.01j	8.62±0.01k
	4	27.14±0.05a	4.45±0.03b	3.11±0.01a	1.09±0.01h	2.13±0.01 gh	433.10±0.01j	8.62±0.01k
Plantain leaf	1	27.46±0.21b	5.02±0.01c	3.45±0.02b	0.97±0.01g	2.87±0.01j	392.74±1.66i	8.22±0.00j
	2	27.55±0.13b	5.73±0.02d	3.81±0.01c	0.82±0.01f	2.66±0.00i	366.27±0.01h	8.01±0.00i
	3	29.40±0.04g	6.12±0.06f	4.14±0.02e	0.60±0.05e	2.19±0.02h	310.22±4.65e	5.11±0.00g
	4	27.87±0.04c	6.48±0.08g	4.52±0.22f	0.50±0.09cd	1.14±0.06cd	213.98±2.25c	2.12±0.06c
Plantain bract	1	28.44±0.02e	5.64±0.01d	3.93±0.01cd	0.95±0.01g	2.08±0.01gh	351.13±0.01g	6.72±0.00h
	2	28.23±0.02d	5.97±0.01e	4.08±0.02de	0.79±0.01f	2.02±0.02g	309.14±0.02e	6.58±0.00h
	3	27.46±0.02b	6.42±0.04g	4.86±0.02g	0.40±0.00bc	1.24±0.06d	251.94±3.63d	3.08±0.01d
	4	28.07±0.03cd	6.85±0.04h	5.81±0.10i	0.41±0.05bc	0.95±0.03b	143.21±3.01b	1.05±0.03b
Plantain trunk	1	27.95±0.02c	5.97±0.01e	4.09±0.01de	0.61±0.02e	1.73±0.00f	320.02±0.02f	4.91±0.00f
	2	28.87±0.02f	6.07±0.01ef	4.97±0.01g	0.54±0.01de	1.54±0.01e	311.78±8.32ef	3.38±0.27e

	3	28.04±0.02cd	6.75±0.11h	5.07±0.01h	0.34±0.01b	1.03±0.00bc	211.51±1.86c	0.91±0.00b
	4	28.93±0.02f	7.88±0.06i	5.95±0.03i	0.19±0.04a	0.53±0.12a	93.62±2.76a	0.11±0.00a
WHO Limits	NA	28	6.5-9.2	N/M	N/M	N/M	100-500	0.3

Mean ± standard error (n=3), mean with the same alphabets are not significantly different according to the Duncan Multiple Range Test. Note N/M means not mentioned.

Table 3: Correlation coefficients (r) between physicochemical parameters

	Temperature	pH	DO	BOD	Nitrate	Hardness	Iron
Temperature	1						
pH	0.679**	1					
DO	0.609**	0.937**	1				
BOD	-0.591**	-0.945**	-0.928**	1			
Nitrate	-0.355*	-0.767**	-0.838**	0.820**	1		
Hardness	-0.562**	-0.959**	-0.957**	0.932**	0.865**	1	
Iron	-0.561**	-0.920**	-0.950**	0.956**	0.911**	0.956**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
N =48, n=3

Apart from iron and pH other parameters improved significantly ($P<0.05$) as a result of the treatment. Dissolved oxygen increased while BOD, nitrate and hardness decreased ($P<0.01$) during the 4 week treatment, though to a ranging degree depending on the plantain tissue used for treatment. In addition, large and slimy flocs of degraded (i.e. dark slimy floc as oppose to the normal red or brown iron mass), iron were found at the base of the treated water (after 4 weeks); which could suggest *M. parasidiaca* as coagulating agent. Notwithstanding,all the parameters tested showed a significant ($P<0.05$) relationship among one another. We therefore suspect the mechanism of treatment is biosorption of the iron which resulted in the increase of pH and dissolved oxygen with a corresponding decrease in BOD, hardness and nitrate. Further research is therefore necessary to validate these claims.

IV. CONCLUSION

Water is an essential and inevitableresource to all life on earth (especially aquatic life). Globally, ground water is the recommended water for aquaculture. Unfortunately, groundwater sample in this study (from the Niger Delta) showed high level of iron and acidic pH. As a result of the biotreatment with the leaf, bract and trunk of *M. paradisiaca* the untreated water showed significant reduction in iron ($P<0.05$), with an increasing pH ($P<0.01$)to meet the WHO limits/standards for safe water.Based on our finding, the tissues of *M. paradisiaca* can be considered putative plant for the biotreatment of high iron containing acidic water. However, further research is necessary to confirm the mode of treatment using plantain tissues fertilization.

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