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Novel method of iron removal from underground dug well waters in communities around Okada town, Ovia North-East L.G.A. Edo State

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Some indices of pollution were studied in water samples from 25 dug wells randomly selected from Okada town and it's environ. Physicochemical parameters measured include temperature, pH, colour, turbidity, total dissolved solids (TDS), toxic shock syndrome (TSS), total hardness, Ca, Mg, Fe, Mn, nitrate and phosphate etc. The results of the study showed that dug wells from this area contain Fe and Mn concentrations in nuisance quantity, far in excess of WHO recommended limits, with obvious consequence for drinking and domestic uses. The use of sodium hydroperoxide, a powerful oxidant for the removal of the Fe and Mn from the dug well water samples is described. This novel method is preferable to most conventional methods because it is cost effective, environmentally friendly, very fast and easy to apply.

Key words: Iron removal, dug well water, sodium hydroperoxide.

INTRODUCTION

Ground water in form of springs, dug wells or borehole are major sources of drinking and domestic water usage throughout the world (Masters, 1998; Sharmer et al., 2005). It is considered better than surface water because it is free from pollutants and other harmful pathogens (Sharmer et al., 2005). However, in some locations, ground water contains dissolved ions such as ferric and ferrous ions, either from geological formation or from iron pump components.

Iron can be present in water either as ferrous iron, ferric iron, organic iron or iron bacteria (Machmeier, 1971). Based on taste and nuisance considerations, the World Health Organization (WHO) recommends that the iron concentration in drinking water should be less than 0.3mg/l (WHO, 1996). Iron concentration in excess of 0.3mg/l is undesirable in drinking water as it causes several aesthetic and operational problems including bad taste, discolouration, staining and deposition in distribution systems (Sharmer et al., 2005).

Several methods namely: oxidation-precipitation, filtration, lime softening, ion exchange e.t.c have been employed for iron removal from underground waters (Wong, 1984; Michalakos et al., 1997 and Twort et al., 2000). The oxidation-precipitation-filtration method is the preferred method in most developing and developed countries because it is more economical and less complicated (Sogaard et al., 2000). In oxidation-precipitation-filtration method, two basic physicochemical mechanisms are involved (Rott, 1985), namely, oxidation floc formation and absorption-oxidation mechanisms (Sharmer et al., 2005). Both mechanisms occur simultaneously in most conventional iron removal plants. However, under certain conditions, the dominant mechanism depends on the water quality and process conditions applied.

In this research work, we report the physicochemical properties of dug well waters in Okada town and its environs with a view to determine the extent of

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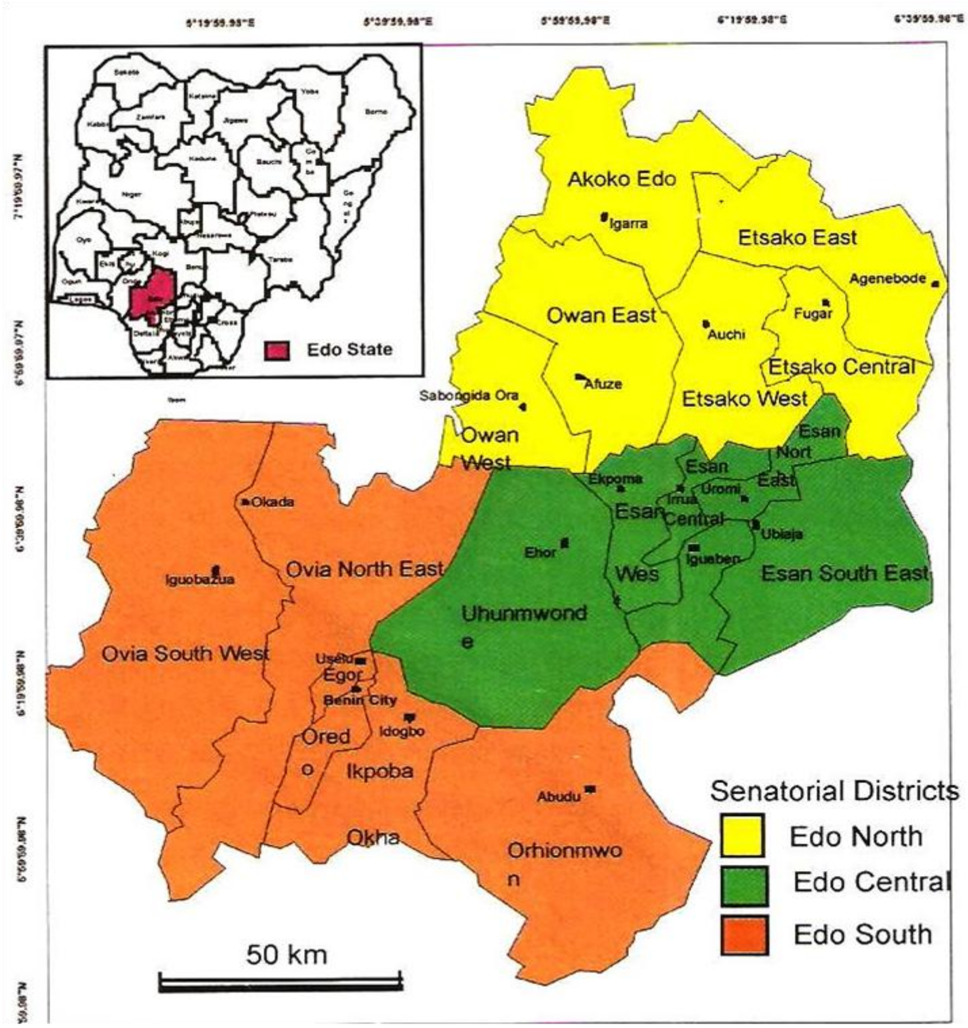

Figure 1. Edo state senatorial districts.

pollution. Also included is the novel method of iron removal from the dug well waters by treatment with sodium hydroperoxide.

MATERIALS AND METHODS

Apparatus

The equipments used were Celsius thermometer (0-100°C), pH meter scale, Gooch funnel, oven, filter papers and flasks, conductivity cell, Hach colorimeter, Atomic Absorption spectrophotometer, 200 litre pressure tank, Electric motor mixer, water pump, vacuum pump, Calcite filter and storage tank.

Reagents

The reagents used for this study were purchased from Aldrich Chemical Company. They are all of analytical grades and were used directly without further purification. They include hydrogen peroxide, H_2O_2, sodium carbonate, Na_2CO_3 and distilled water.

Sampling area

25 underground dug well water were randomly selected and sampled within five communities in Ovia North-East Local Government area of Edo State. These are labeled DW_1 to DW_{25}. The map of the sampled area is shown in Figures 1 and 2.

Physicochemical properties

The measurement of temperature, pH, conductivity, TDS, TSS, total hardness, colour, turbidity, nitrate, phosphate, dissolved oxygen, calcium, magnesium, iron and manganese ion in the dug well water samples were carried out according to previously reported standard methods (Ademoroti,1996 and Chike et al., 2006).

Treatment of water samples with sodium hydroperoxide

About 180 L of dug well water was taken into the pressure tank with the aid of a water pump. 50% H_2O_2 solution and 2 M Na_2CO_3 solutions was prepared from the stock samples provided. 30 ml of 50% H_2O_2 and 5 ml of 2M Na_2CO_3 were mixed together in a beaker

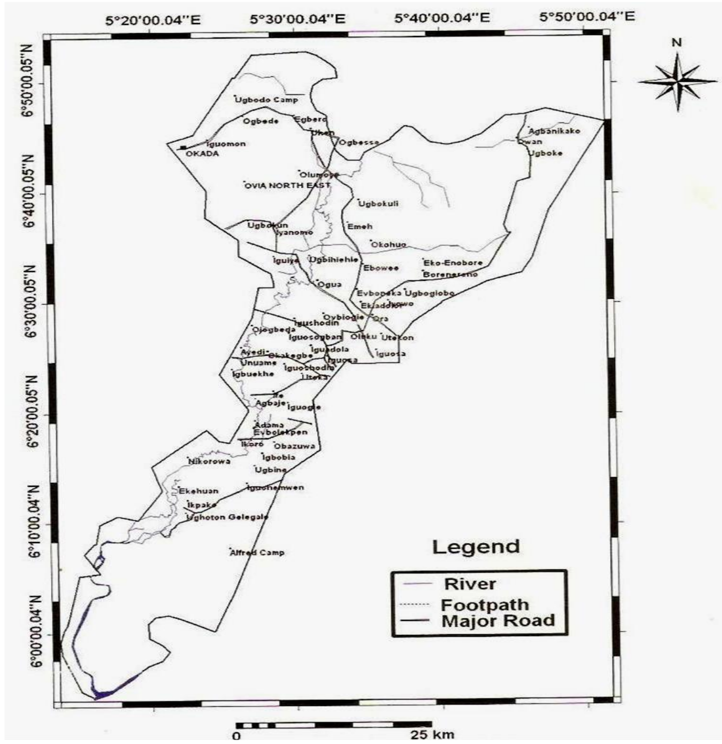

Figure 2. Map of Ovia North-Esat Local Government Area.

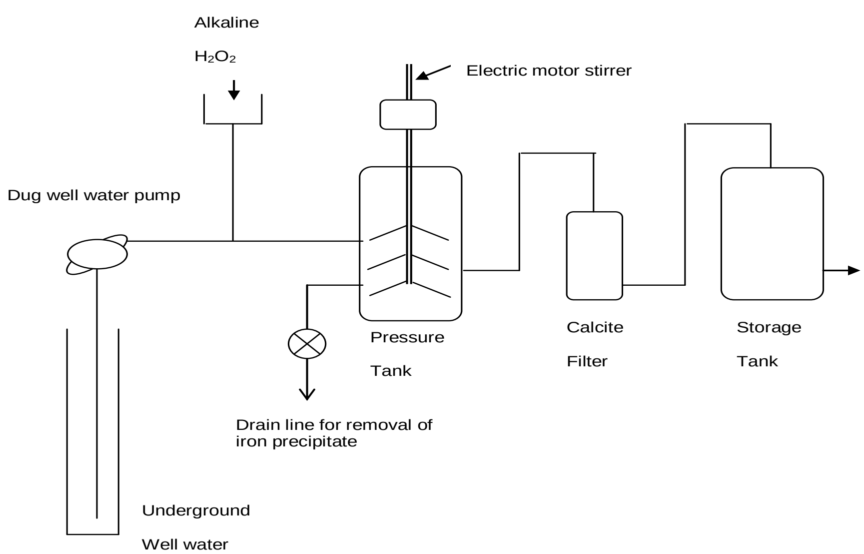

Figure 3. Iron removal by treatment with sodium hydroperoxide.

and allowed to stand for about 3 min to generate sodium hydroperoxide, NaOOH which is the oxidant. The NaOOH mixture was then poured into the tank and stirred with the aid of electric motor mixer for about 1 min. There was immediate precipitation of ferric hydroxide, $Fe(OH)_3$. This was consequently allowed to settle for about 30 min, filtered and stored in the storage tank before distribution, (Figure 3).

RESULTS AND DISCUSSION

The results of the physiochemical characteristics of dug well water samples from Okada town and other surrounding community is presented in Table 1. The temperature of the dug well water samples ranged from

Table 1. Results of physicochemical properties of dug well water samples from Okada Town and its environs.

Community	Dug well Water sample	Temp. (°C)	pH	Λm (ms/cm)	TDS (mg/L)	TSS (mg/L)	Total hardness (mg/L)	Ca (mg/L)	Mg (mg/L)	Fe (mg/L)	Mn (mg/L)	Colour (Pt Co)	Turbidity (fau)	Nitrate (mg/L)	Phosphate (mg/L)	(DO) (mg/L)
Iguomon	DW_1	28.19	7.06	88	44	56	36	28	8	5.8	1.8	334	93	0.15	0.09	5.20
	DW_2	28.10	7.10	90	50	54	36	27	8	6.0	2.0	324	88	0.13	0.08	5.40
	DW_3	28.00	6.90	94	55	55	40	26	9	6.2	1.6	320	86	0.20	0.09	5.50
	DW_4	28.10	7.10	90	50	56	40	27	9	5.8	1.8	324	84	0.14	0.10	5.30
	DW_5	28.10	7.06	90	45	57	36	28	8	6.0	2.0	340	95	0.16	0.10	5.30
Ogbese	DW_6	28.05	6.90	45	23	13	18	14	4	4.0	1.4	12	16	0.18	0.06	4.76
	DW_7	27.90	7.00	44	22	12	16	12	5	4.2	1.2	13	15	0.17	0.07	4.90
	DW_8	27.80	7.10	40	22	11	17	13	6	4.4	1.6	13	17	0.17	0.06	4.90
	DW_9	27.90	7.00	44	24	14	17	12	5	4.2	1.2	13	16	0.18	0.07	4.70
	DW_{10}	28.10	6.90	46	23	13	18	14	4	4.0	1.4	12	15	0.20	0.08	4.80
Okada	DW_{11}	28.28	7.35	198	99	10	70	50	20	8.0	2.6	22	16	0.09	0.06	5.19
	DW_{12}	27.90	7.20	182	90	14	68	49	21	7.8	2.4	21	15	0.08	0.05	5.20
	DW_{13}	28.00	7.45	170	85	12	66	48	22	8.4	2.8	24	15	0.11	0.07	5.30
	DW_{14}	27.90	7.30	183	90	14	67	51	20	8.4	2.4	21	16	0.10	0.06	5.10
	DW_{15}	28.30	7.20	190	100	12	72	49	21	7.8	2.6	23	18	0.09	0.05	5.20
Uhen	DW_{16}	28.17	6.89	96	48	119	42	31	11	6.0	2.0	495	184	0.12	0.07	5.21
	DW_{17}	28.00	7.00	88	45	124	40	29	12	6.2	1.8	490	180	0.11	0.06	5.30
	DW_{18}	27.90	7.10	84	40	130	39	30	13	6.4	2.2	500	190	0.14	0.08	5.40
	DW_{19}	28.00	7.00	86	46	123	40	32	12	6.0	2.0	490	182	0.12	0.07	5.10
	DW_{20}	28.20	6.90	94	50	120	41	29	12	6.2	1.8	492	188	0.13	0.07	5.30
Utese	DW_{21}	28.19	7.07	46	23	8	18	12	6	4.0	1.4	7	14	0.12	0.06	5.20
	DW_{22}	28.10	7.20	55	22	7	19	13	7	3.8	1.2	7	13	0.13	0.04	5.20
	DW_{23}	28.00	6.90	45	20	9	20	14	6	4.4	1.4	8	15	0.14	0.05	5.30
	DW_{24}	28.10	7.20	56	22	7	18	12	7	4.2	1.2	7	14	0.11	0.05	5.10
	DW_{25}	28.20	7.10	60	24	10	18	13	8	4.0	1.6	7	14	0.12	0.06	5.30
WHO		24.50-8.80	6.50 - 8.00	< 10	< 6	< 2	< 100	< 75	< 25	0.3	0.05	< 500	< 0.1	< 0.3	< 0.10	> 100

Table 2. Iron and manganese content of the dug well water samples before and after treatment With NaOOH.

Communities	Dug well water sample	Fe and Mn content before treatment with NaOOH		Fe and Mn Content after treatment with NaOOH	
		Fe (mg/L)	Mn (mg/L)	Fe (mglL)	Mn (mg/L)
	DW_1	5.8	1.8	0.15	0.02
	DW_2	6.0	2.0	0.18	0.03
	DW_3	6.2	1.6	0.20	0.02
Iguomon	DW_4	5.8	1.8	0.20	0.03
	DW_5	6.0	2.0	0.15	0.03
	DW_6	4.0	1.4	0.10	0.02
	DW_7	4.2	1.2	0.15	0.02
	DW_8	4.4	1.6	0.15	0.03
Ogbese	DW_9	4.2	1.2	0.10	0.02
	DW_{10}	4.0	1.4	0.15	0.03
	DW_{11}	8.0	2.6	0.20	0.03
	DW_{12}	7.8	2.4	0.15	0.02
	DW_{13}	8.4	2.8	0.20	0.03
Okada	DW_{14}	8.4	2.4	0.15	0.02
	DW_{15}	7.8	2.6	0.20	0.03
	DW_{16}	6.0	2.0	0.15	0.02
	DW_{17}	6.2	1.8	0.10	0.02
	DW_{18}	6.4	2.2	0.10	0.03
Uhen	DW_{19}	6.0	2.0	0.09	0.03
	DW_{20}	6.2	1.8	0.09	0.04
	DW_{21}	4.0	1.4	0.10	0.03
	DW_{22}	3.8	1.2	0.08	0.03
	DW_{23}	4.4	1.4	0.10	0.03
Utese	DW_{24}	4.2	1.2	0.10	0.02
	DW_{25}	4.0	1.6	0.09	0.02
WHO		0.3	0.05	0.3	0.05

27.8 - 28.3 °C which is within the acceptable range recommended by World Health Organization (WHO). The maximum allowable limit for pH by WHO for safe drinking water is 6.50 - 8.00. The pH of all the dug well water samples also fell within this range. The conductivity of the water samples is a measure of the dissolved ions in the water.

Dug well water samples from Okada have the highest conductivity values, which corroborate its highest values for Ca, Mg, Fe and Mn ions. Dug well water samples from Uhen community has the highest average TSS value of about 123 mg/L which surpassed the WHO guideline value of 2.0mg/L for TSS. This corroborates very well with the highest average values of 495 PtCo and 185mg/L measured for colour and turbidity respectively. All the dug well water samples from the five communities contain Fe and Mn exceedingly in nuisance quantity far above the WHO allowable limit. Dug well water samples from Okada community have the highest values. The results were expected considering the fact that the soil from these areas is mostly laterite, with high iron content. Therefore the iron must have got into the underground water through leaching and seepage from the soil. The high content of Fe and Mn ions has obvious deleterious consequences on the use of the dug well waters for both domestic and drinking purposes. Such consequences include bad taste, staining and browning of clothes, food, containers and skin.

In this regard, a pretreatment procedure is advocated for the dug well water to bring the concentration of Fe and Mn to a tolerable level. Table 2 shows the content of Fe and Mn of the dug well water samples after treatment with sodium hydroperoxide and NaOOH. The dug well water was clear when drawn but gradually turned brown due to precipitation of ferric hydroxide and $Fe(OH)_3$ caused by atmospheric oxidation of the dissolved ferrous iron. The result indicates that the iron is present mostly as dissolved ferrous bicarbonate and $Fe(HCO_3)_2$. After treatment, the iron and manganese concentrations in the dug well water samples are considerably reduced to below 0.2 and 0.04 mg/L respectively. These values are tolerable concentration level for these ions since they fall within the WHO allowable limits.

The Na_2CO_3 solution was used to generate the sodium hydroperoxide, which is the powerful oxidant (Equation 1). The sodium hydroperoxide decomposes insitu to generate oxygen atom, [O] which then oxidizes the iron (II) to insoluble iron (III) (Equations 2 and 3).

The following mechanistic steps have been suggested for the reaction:

$$Na_2CO_3 + 2H_2O_2 \longrightarrow 2NaOOH + CO_2 + H_2O \quad (1)$$

$$2NaOOH \longrightarrow 2NaOH + 2[O] \quad (2)$$

$$Fe^{2+} + 3/2[O] + 3/2H_2O \longrightarrow Fe(OH)_3 \quad (3)$$

The overall equation of the reaction is therefore given by equation below:

$$2Fe(HCO_3)_2 + ½O_2 + H_2O \rightarrow 2Fe(OH)_3\downarrow + 4CO_2\uparrow \quad (4)$$

The ebullition of hydrogen peroxide aids the coagulation of the suspended ferric hydroxide particles. Apart from iron removal, this method is particularly better than most conventional methods for the following reasons:

(1) The hydrogen peroxide, H_2O_2 is a very important powerful germicide and is capable of disinfecting the water.
(2) The reaction is very fast and cost effective since reaction is completed in a few minutes and just about 35ml of the NaOOH mixture is required per 180 L of raw water (cf. 1Kg of Calcium hypochlorite per 100 Kg of raw water)
(3) It is environmentally friendly when compared with other conventional methods such as chlorination or ozonation e.t.c.
(4) It does not require external coagulant.

Conclusion

Raw water from dug wells from Okada town and neighbouring communities have very high iron concentration because of the high iron content of the laterite soil. Treatment with alkaline hydrogen peroxide is one surest way of removing dissolved iron from underground dug well or borehole waters. The method is preferable than most conventional methods because it is fast, cost effective, environmental friendly and does not require external coagulant.

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