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# EFFECT OF MAGNETIC TREATMENT OF WATER ON CHEMICAL PROPERTIES OF WATER AND SODIUM ADSORPTION RATIO

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## *ABSTRACT*
***This study assessed effect of magnetic treatment of water on chemical properties of water, sodium adsorption ratio, electrical conductivity (EC) of the water and the lifespan of the magnetic effect on water. Magnetic flux densities used for treating the water were 124, 319, 443 and 719 gauss. All the cations (Calcium, Sodium, Magnesium, Potassium, Cadmium and Lead) were determined using the Standard Methods for Examination of Water and Wastewater by American Public Health Association (APHA, 2005). The mean values of concentration of calcium for magnetically treated water (MTW) for $1^{st}$, $2^{nd}$, $3^{rd}$ and $4^{th}$ days after the treatment were 3.197, 3.166, 3.136 and 3.104 mg/L while for non–magnetically treated water (NMTW) were 3.130, 3.095, 3.055 and 3.020 mg/L, respectively. The mean values of nitrate from MTW were 43.07, 43.04. 42.71 and 42.56 mg/L while for NMTW were 42.73, 42.57, 42.00 41.81 mg/L, respectively. The mean value of sulphate from MTW on the first day was 50.06 mg/L while that of NMTW was 47.80 mg/L. The mean values of SAR with MTW for $1^{st}$, $2^{nd}$, $3^{rd}$ and $4^{th}$ days after the treatment were 9.715, 0.710, 9.769 and 9.717 dS/m while the corresponding values of SAR for NMTW were 9.877, 9.806, 9.94 and 9.976 dS/m. All the values of SAR for NMTW were higher than the values of SAR for MTW. The values of EC were also higher for NMTW than that of MTW. MTW is better for irrigating soil than NMTW that could cause soil salinity.***

**Keywords:** Irrigation water quality, magnetic treatment of water, sodium adsorption ratio

## INTRODUCTION

Magnetic treatment of water is a non–chemical method for crops improvement and prevention of carbonate deposition in the pipe. The technology is new in Nigeria and there is need for research on the effect of magnetic treatment of water on the chemical properties of water, its applications in agriculture and for domestic water treatment. A magnetic field actually change the structure of water thereby reducing the surface tension of the water, softens the water, increases minerals dissolvability of water and hence provides adequate nutrients for plant growth (Babu, 2010; Hozayn and Abdul-Qados, 2010 and Moussa, 2011) ). Water quality is very important in irrigated agriculture because it affects soil salinity and soil degradation. Soil salinity usually affects crop yield and can render agricultural arable land unproductive for growing crops. Causes of soil salinity may be due to soil parent materials, ingress of sea water in coastal area, excessive evaporation especially in arid region and irrigating with water containing high content of sodium (Schwab *et al*., 1993 and Michael, 2008). High concentration of sodium in water is detrimental to soil as high sodium content in the body of a man induces high blood pressure (hypertension). Sharma and Sharma (2007) stated that sodium salts are generally present in irrigation water but a high proportion of this salt may be absorbed by the soil particle thereby impeding movement of water and air when the oil is wet and formation of hard clods when the soil is dry. The proportion of sodium to other cations (sodium hazard) is determined by sodium adsorption ratio (Schwab *et al*., 1993). Soil salinity can be prevented by using quality water having low sodium content for irrigation and over irrigation should be avoided.

When water flows through a magnetic field, its structure and some physical characteristic such as density, salt solution capacity, and deposition ratio of solid particles will be changed (Higashitani *et al*. 1993). Noran *et al*. (1996) pointed out that the results of their work confirmed the assumption that as a result of the influence of the magnetic field on solutes, the interaction between soil particles and salts dissolved in ordinary water does not resemble the interaction between the soil particles and the salts dissolved in magnetically treated water. Lipusa and Dobersekb (2007) discovered that the scale deposited on a heating copper pipe spiral was 2.5 times thinner due to the effect of magnetic water treatment compared with non-magnetic water treatment.

Kochmarsky (1996) indicated that the effective magnetic flux density for water treatment ranged from 1000 to 6000 gauss (G). He also pointed out that 4000 to 5000 G can attain the efficiency of 60 to 80% when applied on heater and low – pressure boilers. Mdsa'at (2006) and Chern (2012) used a permanent magnet with the magnetic field strength of 5500 G for treating water which was used to irrigate lady's finger moench (Okra) plant and the effect on plant growth and yield was significant. Maheshwari and Grewal (2009) monitored and recorded the magnetic flux densities inside the treatment pipe where the actual treatment occurred and the values of magnetic field strength obtained ranged from 35 to 1360 G. The objectives of this study were to: (i) determine the effect of magnetic treatment of water on some chemical properties of water; (ii) determine the lifespan of the effect of magnetic treatment of water and (iii) determine the effect of magnetic treatment of water on sodium adsorption ratio and electrical conductivity of water.

## MATERIALS AND METHODS

The magnetic field used for the treatment of water in this study was produced from an electromagnet with a variable voltage adjustment unit from 4 to 12 V to vary the current flowing through the coil. The magnetic flux densities used to treat the water in this study (as the treatments) were 124, 319, 443 and 719 gauss ($T_1$, $T_2$, $T_3$ and $T_4$) measured inside the transparent rectangular pipe (having an internal dimension of 1.5 by 4.6 cm and 100 cm long) using gaussmeter Model GM-2 with Serial Number 1764 manufactured by Alpha Lab I (purchased in October, 2012).

The North and South poles of the electromagnetic cores on the treatment chamber seat were alternated for effective treatment of the water by the magnetic field (McMahon, 2009). The water was allowed to pass through the treatment chamber units four (4) times for duration of 83 – 113 s using circulation flowing method through magnetic field (Mdsa'at, 2006 and Chern, 2012). Two samples were taken from each treatment (magnetized water treated with 124, 319, 443, 719 G and untreated water) and put in two separate cleaned bottles. The chemical properties of water were determined on first day, second day, third day and fourth day after the water had been treated through a magnetic field. This was done to determine the effect of magnetic treatment of water on the chemical properties of water and its lifespan on the water.

### Chemical analysis of the water

Water samples were collected in cleaned plastic bottles washed with a detergent, rinsed with tap water, 1:1 nitric acid solution and then rinsed with distilled water (cadmium – free de-mineralized water). Water samples were digested within 6 hours by addition of 5 mL concentrated nitric acid to preserve the water for a longer period against any decomposition by bacteria before chemical analysis of the heavy metals was determined. All the cations such as Calcium, Sodium, Magnesium, Potassium, Cadmium and Lead were determined using the Standard Methods for the Examination of Water and Wastewater by American Public Health Association (APHA, 2005). The instruments used during the determination of heavy metals and other chemicals analysis were Water Engineering Kit by Hach (DREL/5) while, Hannah brand (model HI83200), multi-parameter bench-photometer was used for determination of pH and electrical conductivity of water.

### Determination of sodium adsorption ratio

The proportion of sodium to other cations (sodium hazard) was determined by sodium adsorption ratio (SAR). SAR was determined from Equation (1) as given by Schwab *et al.* (1993). The Values of sodium, calcium and magnesium concentrations were converted from mg/L to meq/L using Equation (3) while Equation (2) was used to convert atomic mass of the element to equivalent weight.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \ldots\ldots(1)$$

$$E_{meq/l} = \frac{E_{conc.}}{E_{eq.wt}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$E_{eq.wt} = \frac{A_{mass}}{V_{lency}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where SAR is sodium adsorption ratio (dS/m or mmho/cm), $Na^+$ is the concentration of sodium in the water (meq/L), $Ca^{2+}$ is the concentration of calcium in the water (meq/L), $Mg^{2+}$ is the concentration of calcium in the water (meq/L), $E_{meq/l}$ is the concentration of any element (such as Sodium, Calcium, Magnesium, etc) in miliequivalent per litre (meq/L), $E_{conc.}$ is the concentration of any element in water (mg/L), $E_{eq.wt}$ is the equivalent weight of element, $A_{mass}$ is the atomic mass of element and $V_{lency}$ is the valency of the element. The three elements assessed or needed for determination of Sodium Adsorption Ratio (SAR) were Sodium ($Na^+$), Calcium ($Ca^{2+}$) and Magnesium ($Mg^{2+}$). These three elements were converted to miliequivalent per litre (meq/L) from mg/L. Other elements assessed were shown in Tables 1

**Statistical analysis for chemical properties of water by paired t–test**

Statistical analysis for the chemical properties of water was determined using paired t – test method to check if the effect of magnetic treatment of water was statistically significant on the water or not. The difference between the two means of the results was determined which was used to compute standard deviation, standard error and t-test value using Equati( 75 (4), (5a) or (5b), (6) and (7), respectively given by Montgomery *et al.* (1998).

$$\bar{d} = \frac{\sum d}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\delta = \sqrt{\frac{\sum\left(d - \bar{d}\right)^2}{n-1}} \quad \ldots\ldots\ldots\ldots (5a)$$

$$\delta = \sqrt{\frac{\sum d^2 - n\left(\bar{d}\right)^2}{n-1}} \quad \ldots\ldots\ldots (5b)$$

$$\delta_{Er} = \frac{\delta}{\sqrt{n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots.. (6)$$

$$t_{cal} = \frac{\bar{d}}{\delta_{Er}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (7)$$

Where $\bar{d}$ is the mean of the difference from the data $x_1$ and $x_2$, $\Sigma d$ is the summation of d, n is the number of the treatments (observations), $\delta$ is the standard deviation, $\delta_{Er}$ is the standard error and $t_{cal}$ is the calculated value of t which was compared with the Table value of $t_{Tab}$ at $\alpha = 5$ % significant level but 2.5 % ($\alpha = 0.05/2 = 0.025$) for paired t-test.

## RESULTS

The mean values of the chemical properties of water are presented in Table 1. The results of chemical properties of water obtained by treating water using 719, 443, 319, 124 G and that of non-magnetically treated water are presented in Table 2. The results of Sodium Adsorption Ratio (SAR) of MTW and NMTW, and Electrical conductivity of water before and after passing through magnetic field are presented in Tables 3 and 4, respectively. The statistical analysis of the treatments on chemical properties of water, SAR, EC, the effect of magnetic treatment on the first, second, third and fourth day to know the lifespan (memory) of the effect of magnetic treatment on water after being treated by magnetic field is presented in Table 5.

**Table 1** Mean concentration of selected chemicals of water Samples before and after treated with magnetic field and memory of the magnetic treatment

| S/No | Element | Unit | Magnetically treated water | | | | Non–magnetically treated water | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1st day | 2nd day | 3rd day | 4th day | 1st day | 2nd day | 3rd day | 4th day |
| 1 | $Ca^{+2}$ | mg/L | 3.197 | 3.166 | 3.136 | 3.104 | 3.130 | 3.095 | 3.055 | 3.020 |
| 2 | $Mg^{+2}$ | mg/L | 1.229 | 1.218 | 1.204 | 1.186 | 1.285 | 1.265 | 1.255 | 1.245 |
| 3 | $K^+$ | mg/L | 0.888 | 0.864 | 0.859 | 0.839 | 0.885 | 0.870 | 0.855 | 0.825 |
| 4 | $Na^+$ | mg/L | 80.55 | 80.42 | 80.28 | 80.14 | 81.91 | 81.76 | 81.66 | 81.58 |
| 5 | $NO_3^-$ | mg/L | 43.07 | 43.04 | 42.71 | 42.56 | 42.73 | 42.57 | 42.00 | 41.91 |
| 6 | $SO_4^{-2}$ | mg/L | 50.06 | 49.67 | 49.24 | 48.66 | 47.80 | 47.67 | 47.50 | 43.38 |
| 7 | P | mg/L | 0.654 | 0.640 | 0.633 | 0.620 | 0.670 | 0.660 | 0.645 | 0.635 |

**Table 2** Chemical properties of water treated using four different magnetic flux densities

| S/No | Element | Unit | Magnetically treated water | | | | NMTW |
|---|---|---|---|---|---|---|---|
| | | | 719G | 443G | 319G | 124G | |
| 1 | $Ca^{2+}$ | mg/L | 3.150 | 3.140 | 3.195 | 3.300 | 3.130 |
| 2 | $Mg^{2+}$ | mg/L | 1.125 | 1.135 | 1.355 | 1.300 | 1.285 |
| 3 | $K^{+}$ | mg/L | 0.905 | 0.905 | 0.890 | 0.850 | 0.885 |
| 4 | $Na^{+}$ | mg/L | 80.44 | 80.73 | 80.93 | 80.10 | 81.91 |
| 5 | $Pb^{2+}$ | mg/L | 0.295 | 0.310 | 0.285 | 0.310 | 0.300 |
| 6 | $Cd^{2+}$ | mg/L | 0.090 | 0.090 | 0.850 | 0.085 | 0.075 |
| 7 | P | mg/L | 0.675 | 0.665 | 0.650 | 0.625 | 0.670 |
| 8 | $CO_3^{2-}$ | mg/L | 3.760 | 3.580 | 3.960 | 3.300 | 3.690 |
| 9 | $SO_4^{2-}$ | mg/L | 52.38 | 51.20 | 49.14 | 47.53 | 47.80 |
| 10 | $(NO_3^-)$ | mg/L | 40.89 | 43.91 | 42.99 | 44.50 | 42.73 |
| 11 | $Cl^-$ | mg/L | 75.40 | 71.07 | 77.38 | 75.60 | 74.67 |
| 12 | pH | | 7.46 | 7.41 | 7.46 | 7.43 | 7.36 |
| 13 | EC | µS/cm | 185.5 | 182.5 | 186.5 | 177.0 | 186.0 |
| 14 | BOD | mg/L | 69.10 | 68.59 | 58.08 | 49.27 | 66.20 |
| 15 | COD | mg/L | 3.225 | 3.275 | 3.275 | 3.125 | 3.100 |
| 16 | Viscosity | | 1.825 | 1.815 | 1.730 | 1.720 | 1.815 |

NMTW = Non-magnetically treated water

**Table 3** Values of Sodium Adsorption Ratio (SAR) of the water used

| Treatment | Magnetic water SAR (dS/m) | | | | Non – magnetic water SAR (dS/m) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st day | 2nd day | 3rd day | 4th day | 1st day | 2nd day | 3rd day | 4th day |
| $T_1$ | 9.897 | 9.919 | 9.905 | 9.562 | 9.877 | 9.920 | 9.948 | 9.976 |
| $T_2$ | 9.933 | 9.965 | 9.971 | 9.994 | 9.877 | 9.901 | 9.948 | 9.976 |
| $T_3$ | 9.583 | 9.587 | 9.616 | 9.662 | 9.877 | 9.901 | 9.948 | 9.976 |
| $T_4$ | 9.447 | 9.367 | 9.582 | 9.655 | 9.877 | 9.901 | 9.948 | 9.976 |
| **Mean** | **9.715** | **9.710** | **9.769** | **9.718** | **9.877** | **9.906** | **9.948** | **9.976** |
| **USDA standard for SAR (dS/m)** | **0 – 10** $^{S1}$ | | **10 – 18** $^{S2}$ | | **18 – 26** $^{S3}$ | | | **26 – 30** $^{S4}$ |

$S_1$ = Class 1 = low value without effect on soil, $S_2$ = Class 2 = medium no effect, $S_3$ = Class 3 = High with little effect and $S_4$ = Class 4 = very high with serious effect on soil. SAR = Sodium adsorption ratio and USDA = United State Department of Agriculture.

**Table 4** Values of Electrical Conductivity (EC) of the water used

| Treatment | Magnetic water EC (dS/m) | | | | Non – magnetic water EC (dS/m) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st day | 2nd day | 3rd day | 4th day | 1st day | 2nd day | 3rd day | 4th day |
| $T_1$ | 0.1855 | 0.1650 | 0.1670 | 0.1710 | 0.1860 | 0.184.5 | 0.1820 | 0.1795 |
| $T_2$ | 0.1825 | 0.1695 | 0.1650 | 0.1580 | 0.1860 | 0.184.5 | 0.1820 | 0.1795 |
| $T_3$ | 0.1865 | 0.1810 | 0.1815 | 0.1745 | 0.1860 | 0.184.5 | 0.1820 | 0.1795 |
| $T_4$ | 0.1770 | 0.1750 | 0.1735 | 0.1715 | 0.1860 | 0.184.5 | 0.1820 | 0.1795 |
| **Mean** | **0.1829** | **0.1726** | **0.1718** | **0.1688** | **0.1860** | **0.1840** | **0.1820** | **0.1795** |
| **USDA standard for EC (dS/m)** | **0.1 – 0.25** $^{C1}$ | | **0.25 – 0.75** $^{C2}$ | | **0.75 – 2.25** $^{C3}$ | | **> 2.25** $^{C4}$ | |

$C_1$ = Class 1 = low value without effect on soil, $C_2$ = Class 2 = medium no effect, $C_3$ = Class 3 = High with little effect and $C_4$ = Class 4 = very high with serious effect on soil. EC = Electrical conductivity and USDA = United State Department of Agriculture.

**Table 5**. Statistical analysis of the magnetic field on chemical properties of water by pair paired t – test.

| S/No | **Parameter** | **Effect of magnetic field on** | **Degree of freedom** | $t_{Cal}$ | **$t_{Tab}$ at α = 0.05 (α/2 = 0.025)** | **Effect** |
|---|---|---|---|---|---|---|
| 1 | Calcium | Chemicals concentration of water between magnetic and non-magnetic water | 3 | 1.810 | 3.182 | Not significant |
| | Potassium | | 3 | 1.170 | 3.182 | Not significant |
| | Sodium | | 3 | 7.530 | 3.182 | Significant |
| | Nitrate | | 3 | 0.433 | 3.182 | Not significant |
| | Sulphate | | 3 | 2.100 | 3.182 | Not significant |
| | Lead | | 3 | 0.000 | 3.182 | Not significant |
| **Lifespan of magnetic treatment of water** | | | | | | |
| 2 | Calcium | 1st and 2nd day | 3 | 1.849 | 3.182 | Not significant |
| | | 1st and 3rd day | 3 | 1.947 | 3.182 | Not significant |
| | | 1st and 4th day | 3 | 1.855 | 3.182 | Not significant |
| 3 | Potassium | 1st and 2nd day | 3 | 4.019 | 3.182 | Significant |
| | | 1st and 3rd day | 3 | 4.600 | 3.182 | Significant |
| | | 1st and 4th day | 3 | 4.672 | 3.182 | Significant |
| 4 | Sodium | 1st and 2nd day | 3 | 2.778 | 3.182 | Not significant |
| | | 1st and 3rd day | 3 | 6.696 | 3.182 | Significant |
| | | 1st and 4th day | 3 | 5.919 | 3.182 | Significant |
| 5 | Nitrate | 1st and 2nd day | 3 | 1.717 | 3.182 | Not significant |
| | | 1st and 3rd day | 3 | 2.188 | 3.182 | Not significant |
| | | 1st and 4th day | 3 | 3.735 | 3.182 | Significant |
| 6 | Sulphate | 1st and 2nd day | 3 | 2.473 | 3.182 | Not significant |
| | | 1st and 3rd day | 3 | 2.663 | 3.182 | Not significant |
| | | 1st and 4th day | 3 | 3.497 | 3.182 | Significant |
| 7 | Sodium adsorption ratio | | 3 | 1.957 | 3.182 | Not significant |
| 8 | Electrical conductivity | | 3 | 3.521 | 3.182 | Significant |

## DISCUSSION

The magnetic treatment of water had more effect on the precipitation (concentration) of sulphate than other anions like nitrate. The values of sulphate ($S0_4^{2-}$) precipitation with magnetically treated water in the first day were higher by 2.8 to 9.6 % compared to the value for non-magnetically treated water on the first day. This was in agreement with the result obtained by Mostazadeh *et al*. (2011) that magnetically treated water increased the precipitation of sulphate in soil than the non-magnetically treated water. The difference in concentration of MTW and that of NMTW was in agreement with study by Noran *et al*. (1996) that there was a significant difference in the concentration of sodium compared to other solutes in magnetically treated water. Noran *et al*. (1996) also pointed out that interaction between soil particles and salts dissolved in ordinary water does not resemble the interaction between the soil particles and the salts dissolved in magnetically treated water. The effect magnetic field slightly increased calcium precipitation compared to non–magnetic water by 0.6 %. This result also showed that water could be treated and later use after some days (2 to 4 days) without losing much effect of the magnetic treatment. The four magnetic flux densities 124, 319, 443 and 719 G increased precipitation of minerals in MTW than the NMTW but 124 and 319 G were found to appropriate for water treatment because it gives higher values of $Ca^{2+}$ and $NO_3^-$ than 443 and 719 G.

The concentrations of $Ca^{2+}$, $Pb^{2+}$, $K^+$, $NO_3^-$, $SO_4^{2-}$ in MWT compared to the concentrations of NMTW were not statistically significant in this study but the concentration of $Na^+$ in MTW was lower than the of NMTW which was statistically significant as shown in Table 3. This lower concentration of $Na^+$ in MTW than the concentration of NMTW makes MTW better for irrigation than the NMTW because MTW would reduce soil salinity.

The value of SAR in Table 4 varied from 9.367 to 9.994 dS/m and the values were within the range of 1 to 10 ($S_1$ = low value) according USDA 1954 (United State Department of Agriculture) as cited by Schwab *et al.* (1993). The values of SAR with high magnetic flux densities of 719 and 443 G were higher than the values of SAR obtained with low flux densities of 319 and 124 G. This means that low magnetic flux density ranging from 124 to 319 G was good for treating irrigation water in order to have a low value of SAR and consequently to have no or low effect of sodium on soil. Again, Values of SAR also increases from first day to 4th day. All the values of sodium concentration in NMTW were higher than the values of sodium concentration in MTW. This means that magnetic treatment of water reduces the precipitation of sodium in MTW which would reduce the sodium adsorption ratio. Similarly, SAR for NMTW were higher than the values of SAR for MTW and this would make magnetically treated water good for irrigation than non-magnetically treated water. The values of EC were also higher for non–magnetically treated water than the values from treated water which was in agreement with results of Babu (2010). Magnetically treated water is better for irrigating soil than non-magnetically treated water which could cause soil salinity.

The difference between SAR of magnetically treated water and SAR of non-magnetically treated water was not statistically significant with calculated value of paired t-test ($t_{cal}$) was 1.957 was less than the Table value of t-test at 5 % significant level ($\alpha$ = 0.05 but paired t-test = $\alpha/2$ = 0.025). The values of electrical conductivity were higher on the first day for both magnetically and non–magnetically treated water but it deceases with days. The values were also within the low ($C_1$) class and which cannot cause adverse effect on soil. The effect of magnetic field on water caused a reduction in electrical conductivity of the water. The difference between the electrical conductivity (EC) of magnetically treated water and non-magnetically treated water was statistically significantly with $t_{cal}$ was 3.521 which was greater than the table value ($t_{Tab}$) 3.182) at 5 % significant level.

## CONCLUSION

Magnetic treatment of water had effect on chemical properties of water by increasing the rate of precipitation of cations and the lifespan of the effect of magnetic treatment of water could last for four days on some chemical properties of water but the increment was not statistically significant at $P \leq 5\%$. The mean values of SAR for NMTW were all higher than the values for MTW. The values of EC were also higher for non-magnetically treated water than the values for magnetically treated water and statistically significant at $P \leq 5\%$. Magnetically treated water is better for irrigating soil than non-magnetically treated water that could cause soil salinity. Magnetic flux densities of 124, 319, 443 and 719 G inside the treatment pipe were appropriate for magnetic treatment of water.

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