Journal of Evolutionary Biology Research Vol. 2 (1), pp. 7-14, December 2010
Available online at http://www.academicjournals.org/jebr
ISSN 2141-6583 ©2010 Academic Journals

Full Length Research Paper

The effect of magnetic field on the physical, chemical and microbiological properties of the lake water in Saudi Arabia

Molouk Mohammed Khazan Alkhazan[1] and Amna Ali Nasser Saddiq[2]*

[1]Department of Botany, Faculty of Education, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia.
[2]Department of Microbiology, Faculty of Education, King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia.

Accepted 9 November, 2010

The present study aims at solving the problem of stagnant water due to receiving of sewage water in a lake at Eastern Jeddah, using state of the art safe techniques. Samples were collected from the lake, then treated using magnetic fields with different intensities in two states, static and shaking, for 30 days. Hence, the physical and chemical properties for samples were measured, in addition to their bacterial content. In both cases of static and shaking, increasing the magnetic flux density caused water clearness, in addition to a relative increase in the pH value and a remarkable decrease in its odor and electric conductivity (EC). In addition, it was observed that lead ions and bacterial content decreased. The study shows that the increasing magnetic field intensity to the level used in this study, accompanied by shacking, is supplemented with the findings of the experiment. It also suggests that the magnetic field plays a major role in finding successful solutions for a lot of environmental problems, as the strong bonds that connect man to nature should be avoided.

Key words: Magnetic field, stagnant water, electric conductivity, pH, bacteria.

INTRODUCTION

Water pollution is regarded as one of the most critical environmental problems, as it causes change in water color and increase in microscopic harmful living organisms count, which causes the spread of dangerous epidermal diseases, The water pollutants can be eliminated by physical methods like filtration, as well as chemical treatments like chlorination which is one of the most widely used disinfectants (Vesilind et al., 1990), although chlorine does treat water from change of odor and color, hydrogen sulphide, growth of algae, germs; however, its addition resulted in the appearance of increased resistance of bacteria to biological antibiotics such as ampicillin, streptomycin and sulphagolanamy (El-Zanfaly, 1991). Ozone also is used as a disinfectant in water treatment, as it oxidizes the organic blemishes, removes color, odor and taste problems and is a fast bacteria eradicator.

Nieminski and Bradford (1991) found that, water bacterial content decreased by 85 and 98.8%, respectively, after treatment with chlorine and ozone. Using Ozone has no side effects, however, some disadvantages were discovered, like the short life-time of its effect and needing water pretreatment for removing high concentration of organic substances and algae. As a result, new efficient and safe methods were needed. Thus, a biological technique using the magnetic field to purify water was introduced. This technique is considered as a simple simulation of what happens in nature, as when water is subjected to a magnetic field and as a result, becomes more biologically active.

The phenomenon of water treatment with an applied magnetic field has been known for many years and has been reported as being effective in numerous instances (Kronenberg et al., 1985; Lin et al., 1990 and Balcavage et al., 1996). Magnetism sciences has developed and become more complicated, when its properties were found to have linkage with all solid, liquid and gaseous matters in addition to living organisms. Johan-Sohaili et al. (2004) explained that, magnetic technology is a promising treatment process that can enhance the separation of suspended particles from the sewage. Tai et al. (2008) observed that on subjecting water to magnetic

*Corresponding author. E-mail: kah201017@yahoo.com.

field, it leads to modification of its properties, as it becomes more energetic and more able to flow which can be considered as a birth of new science called Magneto biology. He also pointed out that, magnetized water prevents harmful metals such as, lead and nickel, from uptake by roots and reaching fruits and roots. However, it increases the percentage of nutrient elements like phosphorus, potassium and zinc.

Magnetic wastewater treatment has been introduced to the chemical industry to remove heavy metals (Tsouris, 2001) and the magnetic wastewater treatment can also be applied to remove color, phosphates and oil at low concentration. Some researchers reported that magnetic treatment affects water properties, such as light absorbance, pH, zeta potential and surface tension (Joshi and Kamat, 1966; Holysz et al., 2002; Chibowski et al., 2003; Cho and Lee, 2005). However, these effects have not always been confirmed (Limpert and Raber, 1985; Baker et al., 1997). Chibowski et al. (2003) reviewed the literatures on magnetic field treatment and carried out tests on magnetic field effects on precipitated calcium carbonate in well-defined and controlled systems and conditions. Amiri and Dadkhah (2006) found that changes in surface tension due to magnetic treatment, can be a key point in tracing impurities in water. Meaningful changes in surface tension of a liquid sample after a day can be a good indicator for the presence of physical and chemical changes in the sample.

It was observed that magnetized water helps in dissolving minerals and acids by a higher rate than un-magnetized water, in addition to dissolving oxygen and increasing the speed of chemical reactions (Moon and Chung, 2000). Smirnov (2003) noticed that water can receive signals produced from magnetic forces that have a direct effect on living cells and their vital action. Hence, research is going on to use magnetic field in limiting microbial water pollution. Abel (2002) pointed out that water pollution and its red color is caused by reproduction of microscopic living organisms in great rates. It was found that Ferro bacteria (*Clonothrix* sp. and *Creothri*x sp.) accumulates ferric hydroxide in their cells and their walls, causing some troubles in sewers including bad odor. It also forms adhesive substances which cause trouble in nutrient labs when water is used in production. The presence of *Escherichia coli* is considered as an indicator of water pollution in sewage water (Neill, 2004) and hence higher probability of the presence of microbes that cause intestine diseases such as typhoid, paratyphoid, cholera and intestinal docentaria. El-Sayed et al. (2006) discovered that, when *E. coli* is subjected to a magnetic field (50 hertz) and electromagnetic waves (2 µT) for different time periods, it caused a great inhibition in the growth of bacteria after 6 h and became more sensitive to antibiotics, with the effects in the morphological characters which are represented in the decrease in the length of bacterial cell. However, the results were the opposite after 16 h, accompanied by a decrease in cellular thickening and disappearance in most elements from the cytoplasm. Additionally, Pengfei et al. (2007) found inhibition in the growth and concentration of *Pseudomonas aeruginosa* bacteria by using wireless magneto-elastic, which facilities the sterilization process specially in canned food.

Therefore, our aim in this study is to improve physical, chemical and biological properties of stagnant water, by subjecting samples taken at random from a lake located at Easter Jeddah, to magnetic fields with different intensities, as a new, safe biological method for man and environment.

MATERIALS AND METHODS

Study area

The lake of the study is located in Eastern Jeddah. This lake is considered as one of the environmental problems because it receives great amount of sewage water daily (50 x 103 m^3) by sewage systems. Hence, it is alarming, if it mixes with underground water which can cause soil and building collapse, in addition to bad odor that spread and cause health troubles. The size of the lake is 9.5 x 106 m^3 and its surface 2.6 km^2 approximately.

Water samples magnetic field application

Eight water samples were collected randomly from different locations in the lake. The samples were mixed together to form a homogenous sample which was subjected to magnetic fields with different intensity (µT) treatments. The treatments were 130, 260 and 390 µT in addition to control. These intensities were measured by Gauss meter in the Faculty of Engineering, University of Sudan for Science and Technology. The experiments were done statically and dynamically in a shaker incubator of 200 rpm velocity. Each of these treatments was represented by five replicates, resulting in 40 experimental units.

Physical and chemical analysis of water samples

The physical properties of the samples such as clearness, sedimentation, odor, pH and EC were measured, according to Chapman and Pratt (1978) by using pH meter WTW model 530 and conductivity meter ORION model 160. The results were recorded every week for 30 days. Some elements such as Ca, Mg, Na, K, Fe, P, Pb, Cu and Cl were measured in the laboratory of Water and Environment, Saudi Society of Area and Geology (community served).

Bacteriological studies

Bacteriological studies were carried out to show the effect of magnetic field on the bacteria counts of Heterotrophic Plate Count (HPC) after 24 h from collection and after 30 days from the beginning of the experiment. The studies also used dilution method as described by Collins and Lyne (1985). Series of dilutions were prepared from 10 to 1 to 10 to 4. 1 ml sample was taken from each dilution into sterilized plates with a suitable amount of prepared nutrient agar (Oxoid Company, 3 g beef extract, 5 g peptone, 20 g agar and 1 L distilled water) at pH 7.2 and was sterilized at 15 Ltd/$inch^2$ for 15 min in autoclave. The plates were incubated at 37°C

Table 1. Effect of different magnetic intensities of static and shaking treatments on the physical properties of stagnant water of a lake located at Eastern Jeddah through 30 days.

Treatments	Magnetic intensity (µT)	Days of measurements (magnetization)											
		Clearness				Sedimentation				Odor			
		7	14	21	30	7	14	21	30	7	14	21	30
Static samples	0.0	-	+	+	+	-	+	+	++	+++	++	-	-
	130	-	++	++	++	-	+	+	++	+++	++	-	-
	260	-	+	++	++	-	+	++	++	+++	++	-	-
	390	-	++	++	++	-	+	++	++	+++	++	-	-
Shaking samples	0.0	-	+	+	++	-	+	++	++	++	++	-	-
	130	+	+	++	++	+	+	++	++	++	+	-	-
	260	+	++	+++	+++	+	++	+++	+++	++	+	-	-
	390	+	++	+++	+++	+	++	+++	+++	++	+	-	-

-Unclear - Non sedimentation - No odor; + Low clear + Low sedimentation + Little odor; ++ Clear ++ Medium sedimentation ++ Medium odor; +++ High clear ++ High sedimentation +++ High odor.

for 24 h. The heterotrophic bacterial numbers were recorded and presented by colony forming units (CFU/ml). This count was used as a substitution for total bacterial count (Reasoner, 1990).

Some bacterial isolates which were grown on the prepared nutrient agar were chosen and re-grown on blood agar (3 g beef extract, 10 g treptose, 5 g NaCl, 15 g agar and 1 liter distilled water and sterilized at 15 LTD /inch^2 for 15 min in an autoclave) to study some of the properties and distinguish between experimental types (Gratten et al., 1994). Horse blood (5%) was added to the nutrient agar after reaching temperature of 45°C and was distributed in the plates and then incubated after making lines with bacteria at 37°C for 24 h. The results were used to distinguish the different types of tested bacteria. The hydrolyzed bacteria to blood was from the type B-haemolysis, while the non hydrolyzed one was from the type Y-haemolysis, whereas, the type ∝-Haemolysis caused partial hydrolysis and gave a green color (Broughton et al., 1981). In addition, gram pigment test was used to distinguish between the different types of bacteria. Statistical analysis (T-test) was done on the obtained results by using SPSS program.

RESULTS AND DISCUSSION

Water pollution is due to the change in physical, chemical and biological properties which is either directly or indirectly caused by human activity and their derivatives. A blackish precipitate was found in static samples while a brown one was found in samples treated by shaking. It is thought that modifications to the properties of solutions through the magnetic field changes in the molecular structure of liquids, polarization, resulted from arrangement of particles and finally from changes of the electric potential (Lebkowska et al., 1991; Szczypiorkowski, 1995 and Krzemieniewski et al., 2002). The present study has proven that a strong magnetic field, has effects on the properties of liquids such as clarity, sedimentation and odor (Table 1).

Recently, Xu and Sun (2008) have shown that the magnetized magnetic powder could improve the sludge sedimentation capability, turbidity of out flow and efficiency of bio-system. Some researchers have claimed that, homogeneous nucleation was increased and gave resultant crystals greater in number with smaller sizes (Wang et al., 1997 and Ferreux et al., 1993).

The results of pH value showed significant increase with increasing magnetic intensity in static and shaking treatments (Table 2). However, it was observed that pH value was lower in shaking samples than static ones, as it recorded 6.3 and 7.3, respectively at magnetic density 390 µT after 30 days. However, Maheshwari and Grewal (2009) stated that the use of magnetically treated irrigation water reduced soil pH. Busch and Busch (1997) reported a change in the pH difference between the surface and the bulk of magnetically treated water.

In addition to the breakage of hydrogen bonds electromagnetic fields may perturb the gas/liquid interface and produce reactive oxygen species (Colic and Morse, 1999). Changes in hydrogen bonding may affect carbondioxide hydration. The different magnetic densities have an effect on EC of experimented water, at static and shaking treatments. The results in Table 3 show a significant decrease in EC values with an increase of both magnetic intensity and time. The decrease was more remarkable for dynamic treated samples than static one which recorded 300 and 500 µm at the magnetic intensity 390 µT, respectively as compared with EC of the control sample (720 and 1003 µm, respectively) after 30 days. The decrease in EC may be explained as thus, that water treated by magnetic power contains fine colloidal molecules (in the state of constant motion resembling Brownian motion) and electrolytic substances which respond to magnetic treatment by their increasing ability to sediment that results in a decreased EC. Those results are in accordance with Kronenberg (1985) and Wie et al. (2000) who pointed out the role of the magnetic field in the increase of water nucleation. Nucleation is a process in which ions come together and form nuclei. Malkin (2002)

Table 2. Effect of different magnetic intensities and static and shaking treatments on pH value of stagnant water of a lake located at Eastern Jeddah.

Treatments	Magnetic intensity (µT)	Days of measurements(magnetization)			
		7 days	14 days	21days	30 days
Static Samples	0.0	6.47± 0.03	6.53 ± 0.29	6.70 ± 0.12	6.80 ± 0.15
	130	6.87 ± 0.03	6.70 ± 0.06	7.27 ± 0.15	7.27 ± 0.15
	260	6.97 ± 0.03	6.90 ± 0.06	7.13 ± 0.15	7.23 ± 0.12
	390	7.27 ± 0.19	7.07 ± 0.12	7.33 ± 0.09	7.30 ± 0.06
Shaking Samples	0.0	6.03 ± 0.09	5.73 ± 0.03	5.70 ± 0.06	5.60 ± 0.15
	130	6.37 ± 0.09	6.13 ± 0.09	5.77 ± 0.09	5.63 ± 0.09
	260	6.76 ± 0.7	6.53 ± 0.15	6.33 ± 0.12	6.33 ± 0.15
	390	7.23 ± 0.12	6.83 ± 0.1	6.57 ± 0.1	6.37 ± 0.09

Analysis of variance

	F- value	P
Between treatments	157.87	HS
Between magnetic intensities	33.46	HS
Between days	1.91	NN

HS = highly significant (P < 0.005) NS = non-significant (P > 0.05).

Table 3. Effect of different magnetic intensities and static and shaking treatments on EC value of stagnant water of a lake located at Eastern Jeddah through 30 days (average ± standard deviation).

Treatments	Magnetic intensity(µT)	Days of measurements (magnetization)			
		7 days	14 days	21 days	30 days
Static samples	0.0	1059±1.20	1040±0.58	1022±1.45	1003±0.88
	130	1053±1.53	1032±1.15	1008±0.58	860±0.88
	260	1045± 2.60	1020± 0,88	948±1.76	691±1.53
	390	1039±0.58	1008±0.88	500±0.88	500±0.58
Shaking samples	0.0	1048±0.33	1023±1.15	959±0.58	720±0.88
	130	1044±0.88	1015±0.58	888±1.00	600±0.58
	260	1039±0.58	1005±0.58	725±2.08	400±1.15
	390	1030±0.88	978±1.15	630±0.88	300±1.20

Analysis of variance

	F-value	**P**
Between treatments	16.922	HS
Between magnetic intensities	22.744	HS
Between days	76.710	HS

HS = highly significant (P < 0.005) NS= non-significant (P > 0.05).

reported that the ions in the water are affected by exposure to magnetic fields. A further benefit of the alteration in the ion states of both calcium carbonate and magnesium carbonate is that, the change in structure of these compounds (which are the cause of the scale build up in water pipes, kettles etc) resulting in much decrease in the build up of scale, due to the loose nature of the ions which may cause the reduction in EC for samples.

The present study showed an inverse proportional relationship between nutrient elements and intensities of magnetic fields (Table 4). The element variations in response to magnetic intensity appeared to be variable.

Table 4. Chemical analysis of elements in static and shaking samples of stagnant water of a lake located at Eastern Jeddah after 30 days.

Treatments	Magnetic intensity (µT)	Elements (ppm)								
		Fe	Pb	P	Mg	Cu	K	Ca	Na	Cl
Static samples	0,0	>0.18	0.49	6.80	9.20	12.60	15.70	38.90	153.3	254
	130	>0.10	0.12	4.80	8.20	11.50	15.70	34.55	148.0	227
	260	>0.10	0.10	1.77	8.10	9.20	15.20	28.62	147.7	222
	390	>0.10	0.10	1.21	7.80	8.76	15.10	28.42	144.8	208
Shaking samples	0,0	>0.10	0.20	6.40	8.10	10.61	15.50	31.86	147.9	233
	130	>0.10	>0.10	2.84	8.10	8.52	15.40	30.33	146.7	213
	260	>0.10	>0.10	1.82	7.90	5.53	15.30	27.50	145.3	210
	390	>0.10	>0.10	1.15	7.80	4.88	15.00	20.10	144.5	205

The decreases in both Fe and K were negligible while they were 80 and >50% in Pb and 15 and 4% in Mg for static and shaking samples, respectively, at the magnetic intensity 390 µT. Clear inverse correlations between metallic pollutants concentrations and concentration-dependant magnetic characteristics are observed by Georgeaud (1998) and Matasova et al. (2005). Krzemieniewski et al. (2004) revealed that the magnetization of tap water allows it to achieve its full oxygenation capacity. Likewise, in the municipal wastewater, the introduction of magnetic field to the technological system allowed for carbondioxide, ozone, hydrogen sulphide and chlorine reduction.

The results showed that the decreases in P, Ca, Cu, Na and Cl were 82, 27, 30, 6 and 18%, respectively in static state, while they were 82, 37, 54, 2 and 12%, respectively in shaking state, at the magnetic intensity 390 µT, as compared to the control environment (Table 4). Sodium recorded the least decrease with the increase of magnetic intensity for both treatments. These results are considered beneficial as the overconcentration of Na leads to water toxicity for living organisms (Nair et al., 1989). The decrease can be explained thus, that magnetic force breaks hydrogen bonds between water molecules, so the ions become separated and combine with elements and precipitate. In addition, Chang and Weng (2008) showed that the enhanced mobility of the ions under a magnetic field, causes serious damage to the hydrogen bond network in the high Na concentration solution. Conversely, in the low-concentration solution, the structural behavior is dominated by the properties of the water molecules and hence the hydrogen bonding ability is enhanced, as the magnetic field is increased.

The phenomenon of effective penetration of the atmospheric oxygen into the solutions prepared with the magnetic field is advantageous from another point of view. Most microorganisms breaking down the organic compounds are aerobic by nature. Thus, in the magnetized liquids, with increased oxygen concentration, their growth is more intense and so, is the degradation of organic matter (Szczypiorkowski and Nowak, 1995; Goldsworthy et al., 1999). The relatively long detention time in the technological system, which in the second phase amounted to 48 h, may have positively stimulated and determined the growth of some microorganism groups. It seems that the proliferating bacterial biomass may have taken up the organic substratum present in the magnetically-treated wastewater, which has been confirmed by laboratory studies of biological degradation of organic compounds introduced in the magnetic-activity area. It was revealed that within the induction range of 0.005 to 0.14 T, the constant magnetic field intensifies biological degradation processes by activated sludge of most of the tested organic compounds and pollutants contained in wastewater. It was also confirmed that, the magnetic field's effect on organic compound degradation continues for about 12 h after termination of exposure (Lebkowska, 1991).

The results in Table 5 showed that, the highest numbers of heterotrophic bacteria were recorded with the least magnetic intensity (130 µT) where it was 330×10^{-3} and $287\text{x}10^{-3}$ CFU/ml, for both static and shaking treatment, respectively. The bacterial numbers were decreased proportionally by the increase in the magnetic force intensity. It was recorded that 240×10^{-3} and 133×10^{-3} CFU/ml after 24 h of incubation for both static and shaking cases, under the highest magnetic intensity 390 µT. The magnetic intensity had even more inhibition effect on bacteria after 30 days of magnetic treatment, when bacteria counts were $169.67 \text{ x } 10^{-3}$ and $47.33 \text{ x } 10^{-3}$ CFU/ml, for both static and shaking cases, under the highest magnetic fields. This is due to the effect of a magnet on the metals in treated water, especially organic substances, nitrogen and phosphorus which are essential in the reactions of bacterial metabolism. Additionally, water forms 80% of bacterial cells, so when its physical and chemical properties were changed by magnetic force, the growth of bacterial cells was inhibited as their composition changed. This is in accordance with Strasak et al. (2002), the ability of bacteria to form decreased

Table 5. Effect of different magnetic intensities on the bacterial numbers (CFU x10^{-3} /ml) of static and shaking treatments of stagnant water of a lake located at Jeddah after 1 and 30 days (average ± standard deviation).

Treatments	Magnetic intensity (µT)	Number of bacteria (CFU x10^{-3} /ml)	
	0.0	330.00 ± 10.00	270.33 ± 5.77
Static samples	130	330.00 ± 10.00**	205.67 ± 1.15**
	260	288.00 ± 12.00**	191.67 ± 6.66**
	390	240.00 ± 16.62**	169.67 ± 6.65**
	0.0	298.00 ± 10.00**	167.67 ± 2.52**
Shaking samples	130	287.00 ± 28.16**	149.67 ± 6.51**
	260	200.00 ± 7.00**	76.67± 9.50**
	390	123.00 ± 12.53**	47.33 ± 7.51**

** Highly significant (P < 0.005).

Table 6. Morphological and physiological characters of isolated bacteria from stagnant water of a lake located at Eastern Jeddah, which were grown on agar medium and blood agar.

Isolates	Morphological and physiological characters of isolated bacteria					
	Cell shape	Movement	Catalase activity	Gram pigment	Haemolysis	Coagulase (simmoris)
1	bacilli	+	+	-	-	-
2	bacilli	+	+	-	-	-
3	cocci	-	-	+	+	+
4	bacilli	-	+	-	-	-
5	bacilli	+	+	+	-	-
6	cocci	-	+	+	-	+

colonies with increasing magnetic field intensity and with increasing time of exposure. The decrease in oxidoreductive activity and ability to form colonies, were compared with the assumption that, the effect of magnetic field is probably bactericidal.

In addition, Mohamed et al. (1997) found that, the exposing of *Salmonella typhi* to magnetic force of 10 and 20 gauss for 2 h, caused changes in the numbers of cells in the stationary phase. Piatti et al. (2002) found also that, when exposing *Serratia marcescens* to magnetic force of 80 ± 20 gauss lead to the inhibition of its growth. El-Sayed et al. (2006) confirmed that, the growth of *E. coli* can be reduced by exposing it to a magnetic intensity of 2 µT for 6 h of 50 Hz. Additionally, the growth of *Mycoplasma genitalium* was affected by using levofloxacin and tetracycline antibiotics, after being exposed to a magnetic field, from sensitive wireless instruments for different time intervals (He et al., 2009) This indicates the possibilities of using a magnetic force to inhibit bacterial growth in water. However, the presence of bacterial pollutants in water, also leads to appearance of some diseases like cholera, bacterial dysentery, typhoid, diarrhea, hepatitis and other epidemic diseases (Abd-Allah, 1991). Payment et al. (1991) mentioned that some types of heterotrophic bacteria were a source of enterogastritis.

Table 6 shows the variations in some morphological and chemical properties of bacterial isolates. Most isolates were negative gram cocci which recorded 56.6 % from total isolates, 23.7% from positive gram cocci and 19.7% positive gram bacillus, this indicates the diversity of microbial pollution present in the water samples. In addition, some types of bacteria such as Y-haemolysis (non-decompose blood) and B-haemolysis (decompose blood which forming clear halos around themselves) were found in isolations. The B-haemolysis is considered with other properties as indicators of the kinds of human harmful bacteria (McFeters, 1990) and as a result, it lead to many problems in the general health of humans.

The results of this study concluded that, the biological treatment of water using magnetic force has a vital role in treating stagnant water; the magnetic flux density increases the values of physical, chemical and bacteriological properties. This is one of the interesting findings in this field of research. This encourages more research in this field. Using magnetism to overcome negative effects of water pollution is considered a potential technology. It should be adapted to suit environmental and climatic conditions so that its use can be maximized.

ACKNOWLEDGMENT

The authors acknowledge Professor D. Masarrat Mohamed Abd Elaziz Migahid for her help and general assistance in the review of the manuscript.

REFERENCES

Abd-Allah SA (1991). Bacteriogical studies of house holed water reservoirs in Cairo M.Sc. Thesis in Botany (Microbiol.), Botany Dept., Girls College, Ainshams University Cairo. pp: 1-21

Abel PD (2002). Water Pollution Biology. Taylor and Francis Ltd, 2nd ed. ISBN, Published by TJI Digital, Padstow, Cornwal, p.181.

Amiri MC, Dadkhah AA (2006). On reduction in the surface tension of water due to magnetic treatment. Phsicochem. Eng. Aspects, 278: 252-255.

Baker JS, Judd SJ, Parsons SA (1997). Antiscale magnetic pretreatment of RO feed water. Desalination, 10: 151-166.

Balcavage WX, Alvager T, Swez J, Goff CW, Fox MT, Abdullyava S, King MW (1996). A mechanism for action of extremely low frequency electromagnetic fields on biological systems. Biochem. Biophys. Res. Commun., 222: 374-378.

Broughton RAR, Krafka, Baker CJ (1981). Nongroup D alpha-hemolytic streptococci: new neonatal pathogens. J. Pediatr., 99: 450-454.

Busch KW, Busch MBM (1997). Laborator studies on magnetic water treatment and their relationship to a possible mechanism for scale reduction. Desalination, 109(2): 131.

Weng CI, Chang TK (2008). An investigation into the structure of aqueous NaCl electrolyte solutions under magnetic fields. Comput. Mater. Sci., 43: 1048-1055.

Chapman HD, Pratt PF (1978). Methods of Analysis for Soils Plants and Waters. Univ. of California, Div. Agric. Sci. Priced Publication, p. 4034.

Chibowski E, Holysz L, Szczes A, Chibowski M (2003). Precipitation of calcium carbonate from magnetically treated sodium carbonate solution. Colloids Surf. A, 225: 63-73.

Cho YI, Lee SH (2005). Reduction in the surface tension of water due to physical water treatment for fouling control in heat exchangers, Int. Commun. Heat Mass Transfers, 1: 1-9.

Colic M, Morse D (1999). The elusive mechanism of the magnetic 'memory' of water, Colloids Surf. A, 154: 167-174.

Collins CH, Lyne PM (1985). Microbiological Methods, 5th ed., pp. 253-371.

EL-Sayed AG, Magda SH, Eman YT, Mona HI (2006). Stimulation and control of E.coli by using an extremely low frequency magnetic field. Romanian J. Biophys., 16(4): 283-296.

El-Zanfaly HT (1991). The need for new microbiological water quality criteria. Water Sci. Technol., 24(2): 43-48.

Ferreux M, Remy F, Vidonne A (1993). Influence of permanent magnets on crystallogenesis of $CaCO_3$ in hard water. Medical Treatments in antitartredes water by physical and electrochemical. ENSEA, Grenoble, France, pp. 57-65

Georgeaud VM, Rochette P, Ambrosi JP, Vandamme D, Williamson D (1998). Relationship between heavy metals and magnetic properties in a large polluted catchment: The Etang de Berre (south of France). Phys. Chem. Earth, 22: 211-214.

Goldsworthy A, Whitney H, Morris E (1999). Biological effects of physically conditioned water. Water Res., 33(7): 1618.

Gratten MD, Battistutta P, Torzillo JD, Manning K (1994). Comparison of goat and horse blood as culture medium supplements for isolation and identification of *Haemophilus influenzae* and *Streptococcus pneumoniae* for upper respiratory tract secretions. J. Clin. Microbiol., 32: 2871-2872.

He B, Liao L, Xiao X, Gao S, Wu Y (2009). Monitoring of Mycoplasma genitalium growth and evaluation of antibacterial activity of antibiotics tetracycline and levofloxacin using a wireless magneto elastic sensor.1: Biosens. Bioelectron, 24(7): 1990-1994.

Holysz L, Chibowski M, Chibowski E (2002). Time dependent changes of zeta potential and other parameters of in situ calcium carbonate due to magnetic field treatment. Colloids Surf. A, 208: 231-240.

Johan S, Fadil O, Zularisham A (2004). Effect of Magnetic Fields on Suspended Particles in Sewage. Malaysian J. Sci., 23: 141– 148.

Joshi KM, Kamat PV (1966). Effect of magnetic fields on the physical properties of water. J. Ind. Chem. Soc., 43: 620-622.

Krzemieniewski M, Dobrzynska A, Janczukowicz W, Pesta J, Zielinski M (2002). Effect of constant magnetic field on the process of generating hydroxyl radicals wreakcji Fenton. Chemist., 1: 12.

Krzemieniewski M, Dębowski M, Janczukowicz W, Pesta J (2004). Effect of the Constant Magnetic Field on the Composition of Dairy Wastewater and Domestic Sewage. Polish J. Environ. Stud., 13: 45-53.

Kronenberg K (1985). "Experimental evidence for the effects of magnetic fields on moving water". IEEE Transactions on Magnetics (Institute of Electrical and Electronics Engineers, Inc.), 21(5): 2059-2066.

Lebkowska M (1991). Effect of constant magnetic field on the biodegradability of organic compounds. Warsaw University of Technology Publishing House. Warsaw. Effect of a Constant Magnetic Field, p. 53.

Limpert GJC, Raber JL (1985). Tests of non-chemical scale control devices in a once-through system. Mater. Performance, 24: 40-45.

Lin IJ, Yotvat J (1990). Exposure of irrigation and drinking water to a magnetic field with controlled power and direction J. Magn. Magn. Mater., 83: 525-526.

Maheshwari A, Basant L, Grewal HS (2009). Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water. Productivity, 8: 1229-1236.

Malkin VP (2002). Magnetic-Field Processing of Industrial Effluents. Chem. Petrol. Engin., 38: 236-239.

Matasova GG, Kazansky AY, Bortnikova SB, Airijants AA (2005). The use of magnetic methods in an environmental study of areas polluted with non-magnetic wastes of the mining industry (Sal air region, Western Siberia, Russia). Geochemistry: Explor. Environ. Analy., 10: 75-89.

McFeters GA (1990). Drinking Water Microbiology: Progress and Recent Developments Spring-Verlag, New York, Inc., p. 502.

Mohamed AA, Ali FM, Gaafar EA, Magda HR (1997). Effect of magnetic field on the biophysical, biochemical properties and biological activity of *Samonella typhi*, Master Thesis Submitted for Biophysics Department, Faculty of Science, Cairo University, Egypt. pp: 12-35.

Moon JD, Chung HS (2000). Acceleration of germination of tomato seed by applying an electric and magnetic field. J. Electro-Statistics, 48: 103-114.

Nieminski EC, Bradford SM (1991). Impact of ozone treatment on selected microbiological parameters. Ozone Sci. Eng. OZSEDS, 13(2): 127-145.

Nair I, Morgan L, Keith H (1989). Biological Effects of Power Frequency Electric and Magnetic Fields. Background paper was performed as part of OTA'S assessment of Electric Power Wheeling and Dealing, p. 110.

Neill M (2004). Microbiological indices for total coli form and *E. coli* bacteria in estuarine waters. Mar. Pollut. Bull., 49: 752-760.

Pengfei P, Sijing H, Qingyun C, Shouzhuo Y, Kefeng Z, Craig AG (2007). Detection of *Pseudomonas aeruginosa* using a wireless magneto elastic sensing device. Biosens. Bioelectron., 23: 295-299.

Payment P, Richardson L, Siemiatycki J, Dewar R, Edwardes M, Franco E (1991). A randomized trial to evaluate the risk of gastrointestinal disease due to consumption of drinking water. Meet. Curr. Microbiol. Stand., 8: 703-708.

Pengfei P, Sijing H, Qingyun C, Shouzhuo Y, Kefeng Z, Craig AG (2007). Detection of Pseudomonas aeruginosa using a wireless magneto elastic sensing device. Biosens. Bioelectron., 23: 295-299.

Piatti E, Albertini MC, Baffone W, Fraternale D, Citterio B, Piacentini MP, Dacha M, Vetrano F, Accorsi A (2002). Antibacterial effect ofmagnetic field on Serratia marcescens and related virulence to *Hordeum vulgure* and *Rubs frulicosus* callus cell. Comp. Biochem

Physiol. Biochem. Mol. Biol., 132 (2): 359-365.
Reasoner DJ (1990). Monitoring heterotrophic bacteria in potable water. Drinking Water Microbiology-Springer-Verlag, pp. 45-47.
Smirnov JV (2003). BioMagnetic hydrology. The Effect of a Specially Modified Electromagnetic Field on the Molecular Structure of Liquid Water. Global Quantec. Inc., U.S.A, pp. 122-125
Vesilind PA, Peirce JJ, Weiner RF (1990). Environmental Pollution and Control. 3rd ed. Butter Worth Heinmann, Bosten, pp. 77-83.
Strasak L, Vetterl V, Smarda J (2002). Effects of low-frequency magnetic fields on bacteria *Escherichia coli*. Bioelectro-Chemistry, 55: 161-164.
Szczypiorkowski A, Nowak W (1995). Studies on application of a magnetic field to the intensification of wastewater treatment processes. G.W. T. S., 2: 31.
Tai CY, Wu CK, Chang MC (2008). Effects of magnetic field on the crystallization of $CaCO_3$ using permanent magnets. Chem. Engin. Sci., 63: 5606-5612.
Tsouris C, Depaoli DW, Shor JT, Hu MZC, Ying TY (2001). Electro coagulation for magnetic seeding of colloidal particles, Colloids Surf. Physicochem. Eng. Asp., 177: 223-233.
Wang Y, Babchin AJ, Chernyl LT, Chow RS, Sawatzky RP (1997). Rapid onset of calcium carbonate crystallization under the influence of a magnetic field. Water Res., 31: 346-350.
Wie M, Liyan G, Xuehu L, Yu J (2000). Effects and mechanism of magnetic field on the form and structure of phosphate. Chem. J., 2: 11-15.
Xu YB, Sun SY (2008). Effect of stable weak magnetic field on Cr (VI) bio-removal in anaerobic SBR system. Biodegradation, 19: 455-462.