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Utilization of Treated Waste Water and Well Water in Agriculture in Arid Land Areas .

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ABSTRACT

During this study period the wastewater discharged from Makkah wastewater treatment plant was partially treated . This was clear from the high BOD and SS values of the wastewater in the investigated stream . The total dissolved solids was variable during the investigation period.

Well water contains waters of differents dissolved salts which is reflected in the total dissolved solids of the wastewater stream . The high rate of evaporation during summer time has also affected the dissolved salt concentration in the wastewater stream . The results of this investigation showed a serious infringement of the standards set by the Meteorology and Environment Protection Agency for the direct discharge of the wastewater .Most of the elements analyzed during this study have however exceeded the compared standards (MEPA ,FAO and MAW) .These elements are Ca , Mg, Zn, Cr, Ni Mn and KN . Lead and sodium were below FAO standards , but still higher than MEPA and MAW . Only Fe and Cd were below the compared standards during the study time .

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The extent of natural purification along the wastewater stream was little but most noticeable for the BOD and SS .Iron , K, Zn, Cr and Ni had also shown silght decrease in their concentration along the wastewater stream .The TDS , Mg and Ca , on the other hand , were partially diminishing in their concentrations downstream .The rest of the elements showed no specific trends .

The effect of the wastewater stream on the wells surrounding it (effect of location) was most distinct in the salt contents of the water of these wells (TDS) .The wells nearer to the stream showed lower TDS than those away indicating a higher recharge of the former than the latter .Similar trends , but less distinct , were shown by Mg ,Mn and Na .Only Cr showed a higher concentration in the well waters close to the the wastewater stream .The other element investigated indicated no specific trends in their concentration in the well waters acording to their location around the stream .

Of the investigated elements , the concentrations of BOD, SS ,K, Fe ,Zn, Mn and KN were higher in the wastewater . The rest of elements showed higher concentrations in the well water than that in the wastewater

Treated wastewater can be reused in many ways , the most important of which are for agriculture and ground water recharge . The understanding of chemical and microbial qualities of this wastewater and their effects on soil, plants and subsurface water is very essential for establishing the best ways of utilizing this valuable source .Quantitative studies should also go along with the qualitative investingation .

SEWAGE WATER CHARACTERISTICS

Physical properties

Sewage sludge is affected by the wastewater quality , type treatment , and sludge stabilization method .

Bauomy (1985) mentioned that the principal objective in composting sewage sludge was to produce an environmentally safe humans-like material that was free of malodorous and pathogens , and can be used beneficially on land as fertilizer and soil conditioner .Sludge density is a function of its moisture content .It is 0.58 g/cm^3 for heat dried waste activated sludge ,1.01/cm^3 laggoned digested sludge and 1.20 g/cm^3 in aged Inhoff sludge (El Keily , 1983). Papadopoulos (1992) reported that suspended solid concentrations were 500 mg/L in sewage and 50 mg/l or less in final effluent.

Chemical properties

Chemical composition of sewage sludge may vary tremendously , depending on the method of wastewater treatment and amount of industrial effuents that were discharged into the sanitary sewers(Sammers , 1977) .Berrow and Webber (1972) reported that the levels of metals in sewers sludge produced in England and Wales were as high as 5% Zn ,1% Cr ,5% Cu and Ni 0.50% .They predicted toxicity problems caused by Zn ,Cu, and Ni when sewage sludge would be applied to soils .Data represented by Konrad and Kleinert (1974) , for municipal sewage treatment plants in Wisconsin ,revealed the following ranges of heavy metals in the effluent: Cu 0.02-0.08, Zn 0.04-1.0 and Cd 0.02-0.04 ppm . EL- Gamal (1980), found that the average means of heavy metals in raw and final effluents for Cd , Co , Cr , Cu, Fe , Mn, Ni , Pb , Sr and Zn were 0.01, 0.03 ,0.06, .0.04 , 0.63 , 0.15, 0.08, 0.10 , 0.35 and 0.15 ppm , respectively .

Bouwer et al (1974) reported that secondary effluent usually contains 20 to 40 mg/L NO_4^+ _ N , 0 to 1.0 mg/L NO_3^- - N ; 0to3 mg /L NO_2^- - N and 1.0 to 6.0 mg /L organic N . Also they found that boron (B) in the secondary sewage effluents from city Phoenix , Arizona secreased from 0.4 mg/L in 1969 to 0.9 mg/L in 1971 .

Nitrogen concentration in the secondary sewage effluent of California was generally between 20 and 40 mg/L (California Department of Water Resources ,1961) .Nitrogen content of liquid waste may be essentially as lows as zero for same cannery wastes and as high as 700 mg/L for slurries of fresh swine waste (Bauomy , 1985) .

Bouwer et al (1974) observed that secondary effluent usually contained 20 to 40 mg /L , NH_4^+ - N ; 0 to 1.0 mg/L NO_2- ;0 to 3.0 mg/ L NO_3^- - N and 1.0 to 5.0 mg /L organic N. phosphate content in secondary effluent varies widely among municipalities .

Uwe (1992) obtained N concentrations of 40 to 90 mg/L .They were 30 to 98 mg/L in primary effluent. AL- Jàloud (1994) reported that N increased significantly in soils irrigation with treated sewage water in AL- Riyadh.

Trace Elements Contents

Berrow and Webber (1972) reported that the levels of metals in sewage sludge produced in England and wales were as high as 5% Zn, 1% Cr and Cu , and 0.5% Ni .Maytelka et . al., (1973) reported that concentration of selected elements in raw and treated sewage collected from treatment plants in the Interstate Sanitation District (New York) were as follows : Cd ,0.02 to 5.4 ; CO, 0.05 to 5.0 ; Cr ,0.05 to 6.80, Cu ,0.02 to 5.9 ; Ni , 0.10 to 1.50 ; Pb , 0.20 to 6.00 ; and Zn , 0.02 to 20.00 mg/L .Bauomy (1985) studied total and dissolved Cd , Cr, Cu, Ni, Pb and Zn of wastewater effluent from 58 treatment plants in Michigan and obtained the following range of heavy metals , Cd 0.005 to 0.150 , Cr 0.01 to 1.46 ; Cu 0.01 to 1.30 , Ni 0.02 to 5.40 , Pb 0.02 to 1.30 and Zn 0.03 to 4.70 mg/L . Bouwer and Chaneyy (1974) noticed that trace elements concentration in the various wastewater were generally very low .Sommers (1977) reported that the chemical composition of municipal sewage sludge , could tremendously vary depending upon wastewater treatment and amount of industrial effluent that were discharged into the sanitary sewers.

El- Gamal (1980) reported that the average values of trace elements in raw and final effluent , were 0.01 , 0.03, 0.06 , 0.04 , 0.15 , 0.63 , 0.08 , 0.10 , 0.35 and 0.15 mg/L for Cd , Co , Cr , Cu , Fe , Zn , Mn , Ni , Pb , Sr , and Zn , respectively .

POTENTIAL USE OF SEWAGE WATER EFFLUENT

Oliver and Casgrove (1974) stated that the major difficulty in predicting potential problems from an organic waste , is the inherent variability in the composition of wastes . Nearly every city has industries that dump metals into sewers . Some macronutrients such as Zn , Cu and Fe in wastes may serve to correct plant deficiencies . However , repeated or unwise use of wastes might lead to phytotoxicity of Zn , Cu , Ni or B (McCalla, 1977) .

Reuse of Sewage Water for Irrigation

Mendoza (1981) evaluated the use of Mexico City wastewater on the irrigation of crops .He concluded that there are advantages and disadvatages of the use wastewater for irrigation. The advantages are: (1) The water and its nutrient are used in the production of badly food stuffs; and (2) by percolating through the soil, the wastewater receives a level of treatment which is superior to secondary treatment, thus reducing pollution downstream. And the disadvantages are: (1) The irrigation with wastewater of crops, which are normally eaten raw, constitute health hazard to the consumer; and (2) Heavy metals, present in wastewater, have been deposited in the soil and have been introduced into man's trophic chain through the fodder fed to the cattle .

TREATED SEWAGE WATER IN SAUDI ARABIA

Singley et .al., (1981) studied wastewater reclamation at Jeddah and Makkah .They summarized that water renovation facilities have been designed the available wastewater as a source of secondary water system.It is required that the water be clear , colorless , odorless , and tasteless in order to be used by the public in any way .The major problems to be solved were the dissolved solids and pathogens at Jeddah and high ammonua and pathogens at Makkah .The current wastewater treatment plants in both cities are designed to treat 50,000 m3 /day , which is only part of the total wastewater of either city , but the maximum that is available from the existing sewerage .

Abdul Magid (1996) studied the physico- chemical and microbiological characteristics of Unayzah treated sewage water for 4 years . He found that the yearly average volume of treated waste water is 26. 4×10^5 to 36×10^5 m^3 , it is marginal with repect to the biochemical oxygen demand (BOD) level (14.3-17.8 mg/L), and mean total suspended solids content (TSS) is 23.3 to 25.3 mg /L .The soil EC and pH are with in the acceptible quality limits for irrigation , but the high total colifrom counts (48.2×10^2 to 137.9×10^2 MPN/100ml) makes it unacceptable for irrigation .

Al- Jaloud (1994) working on the effects of treated sewage water on alfalfa and wheet in Riyadh found that the content of Fe (145 mg/g) and Zn (35.5 mg/g) in wheat crop and contents of Fe (359mg/g) in alfalfa were significanty higher with treated irrigation water than with fresh irrigation water which gave (Fe 133 mg/g) and (Zn 26.5mg/g) , respectively .

THE IMPORTANCE OF WASTEWATER UTLLZATION IN AGRICULTURE AND ASSOCIATED BIOLOGICAL HEALTH RISKS

As a substitue for fresh water in irrigation or agriculture , wastewater has an impotant role to play in water resources management . By releasing freash water sources for potable water supply and other priority uses, wastewater reuse contributes to water concervation and has certain economic advantages . Wastewater is available close to urban areas , where the demand for food and fuel wood crops is concentrated .Reuse of wastewater for irrigation of these crops can thereby help both to improve the nutritional status of of urban populations and to provide energy for cooking and heating ; in some countries , such reused is essential .The primary objective must therefore be to ensure that wastewater is resued rationally while at the same time health is protected

In Saudi Arabia wastewater reuse is becoming a viable alternate source .The annual rainfall is less than 100 mm per year , the renewable surface water and ground water resources are not sufflcient to meet the increasing demand in .domestic , commercial , industrial and agricultural sectors . The use of reclaimed wastewater offers a realistic alternative.

The total water demand has increased from 2.36 billion cubic meters in 1980 to 16.23 billion cubic meters in 1990 . Water for irrigation purpose accounts for about 90 percent of the total water consumed. While non–renewable ground water resources provide about 85 per cent of the total demand, the remaining 15 per cent is met by desalinated water supply, surface water and shallow aquifers (Ibrahim, 1994)

In a research report presented during the workshop on usage of wastewater in agriculture , Gur (1994) reported that in developing countries , excreta- related diseases are rather common and wastewater contains correspondingly high concentrations of excreted pathogens (viruses, bacteria , protozoa and helminths) that cause disease in man .There are approximately 30 types of excreted pathogens of public health importance and many of these are of specific improtance in wastewater effluent reuse schemes .

MATERIALS AND METHODS

Sampling for chemical & physical evaluation of water

15 trips were made for sampling , 10 of them were made for water waste and well . Well water samples (7 wells) are also collected in each trip.

4 liters plastic containers were used to collect the wastewater and well water samples for the physical and chemical analysis .The wastewater was taken from 10 cm below the surface of the stream to avoid the floating materials .Well water was collected during pumping .If the pumps did function at time of sampling , they were allowed to run for sometime before. collection of samples . Figs 1 and 2 show the wastewater sampling sites and location of wells in the research zone .

PHYSICAL AND CHEMICAL ANALYSIS OF WATER :-

- The biochemical oxygen demand (expressed in milligrams per liter) was determined by measuring the dissolved oxygen using dissolved oxygen electrode before and after a five day incubation period at 20°C .
- The total soluble salts were measured by gravimetric mean . The water samples were filtered through a 0.45 um membrane filters . The filtrate was then evaporated . The residual salts were weighed and expressed in milligrams per liter .
- The suspended particulate matter measurements were also conducted by a gravimetric mean . The weight of residues on the filter paper was calculated . The SS values were expressed in milligrams per liter .
- The electric conductivities were determined using a self – contained conductivity meter equipped with temperature compensator YSI model 33 . The conductivity values are expressed as micromhos /centimeter (umhos /cm).
- The total nitrogen and trace metals analyses were performed for water .

Fe , Mn, Cr, Pb, Cd, Cu , Ni , Zn , Ca , Mg , K and Na were determined after extraction using the perchloric nitric digestion procedure of Shelton & Harper (1941) .The concentration of these elements were measured by a Perkin- Elmer 5000 AAS . The procedure of determining the total nitrogen involves the digestion and distillation steps according to the Kjeldahl method (Jackson , 1967) using kjeltes auto 1030 analyzer.

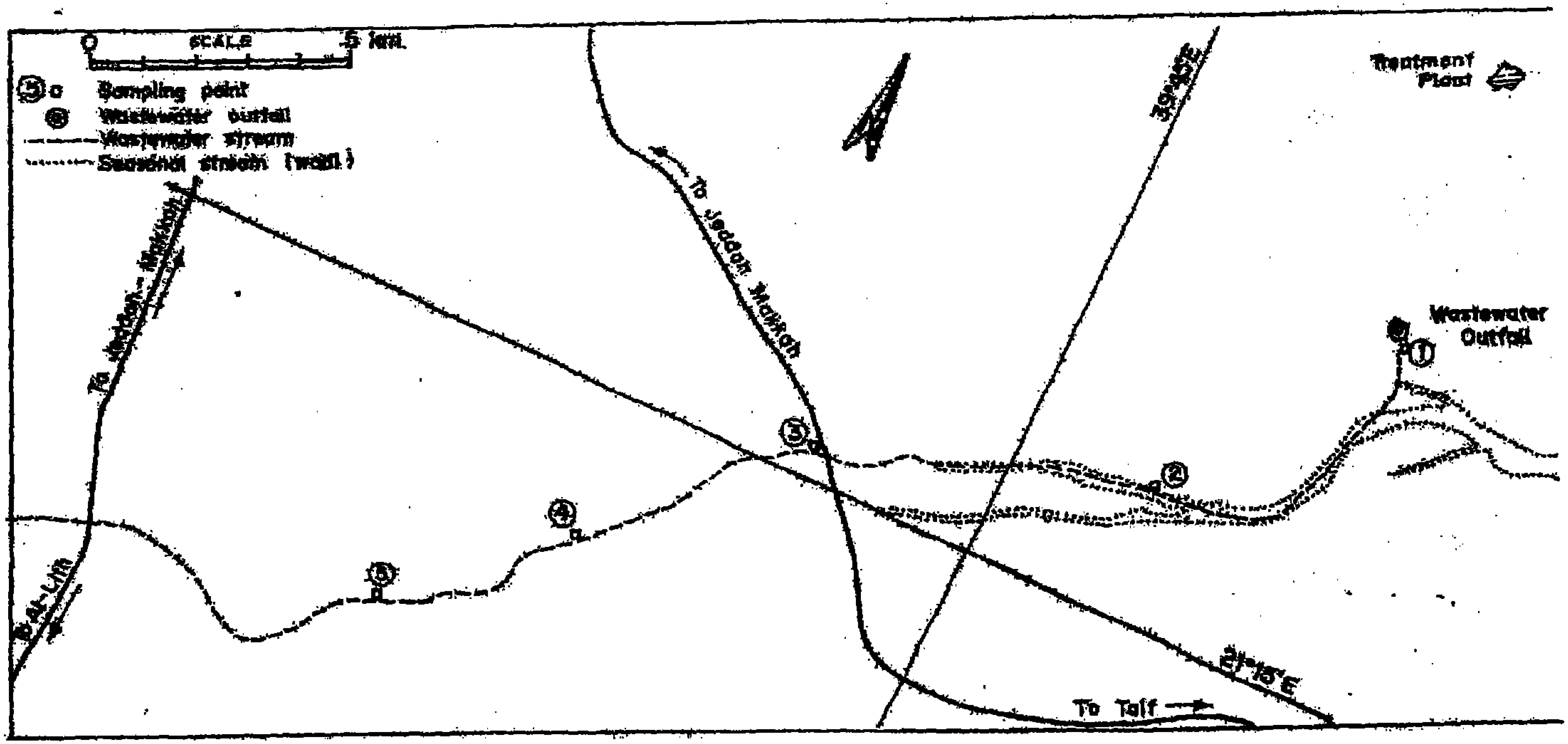

Fig (1): A map of the waste water sampling points along the waste water stream.

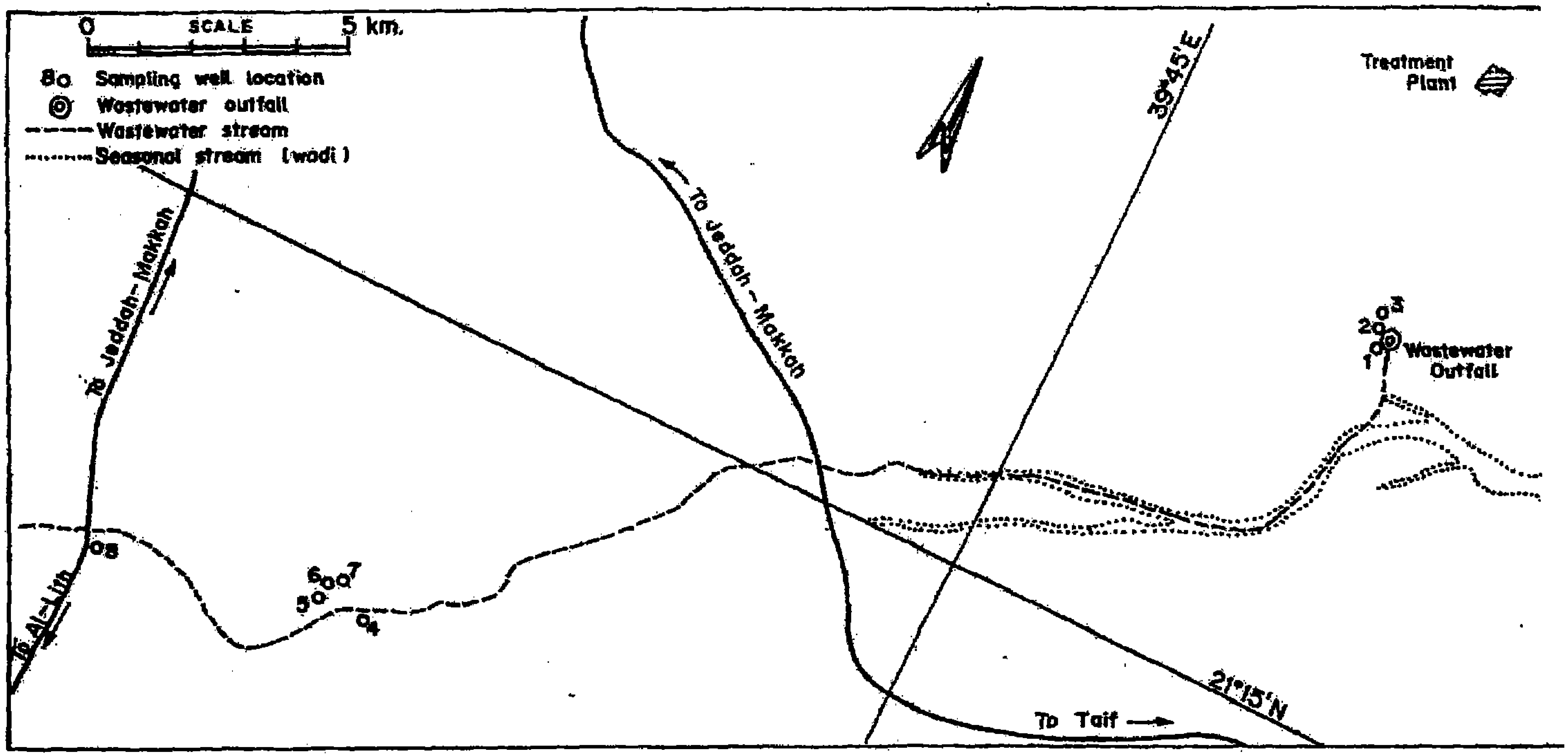

Figure (2) A map showing the location of eight investingated wells in the vicinity of the wastewater stream.

Chemical properties of Wastewater and Well Water in Relation to Standard Irrigation Water

The quality of irrigation water is determined by the following chemical characteristics:

1- Total concentration of soluble salts or salinity.

2- Concentration of sodium relative to other cations or sodicity .

3- Concentration of elements that may be toxic to plant growth .

4- Biochemical oxygen demand (BOD) and Suspended Solids (SS).

RESULTS AND DISCUSSION

Total Salt Concentration

The effect of salt on crop growth is believed to be largely of osmotic nature . Osmatic pressure is a collegative property , and is therefore related to the total salt concentration rather than the concentration of individual ionic species (Shainberg and Oster , 1978). The total salt concentration of the waste water averaged 813.7 mg/L (i.e.EC of 1.27 m mhos /cm) , and TDS (1. 172 g/L) (Table1) .

This considered value lies within the medium range of salinity and can be used for irrigating coarse textured soils with good permeability . However , the total salt concentration and TDS (Table 1) at the well water along the waste water stream being 3320 mg/L (i.e.EC of 5.187 m mhos / cm and 5.23 g/L respectively). Therefore , this water is highly saline and hence it may be recommended for irrigating salt tolerant crops .

Sodium Content

The most reliable index of sodium hazard or the tendency of irrigation water to from exchangeable sodium in the soil is the Soduim Adsorption Ratio (SAR). The average SAR of wastewater is 6.699 (Table1) which present a moderate sodium problem.This type of irrigation water on U.S. Salinity Laboratory Scale can be classified as $C_3\ S_1$.

Table (1) Average characteristics of wastewater and well water used for irrigation (mg/L) compared to MAW, F.A.O. and MEPA maximum concentration .

Parameter	waste water	well water	Saudi Arabia		F.A.O	MEPA
PH			6 - 8.4	6 - 8.4	6.5 - 8.5	6-9
EC	1217.4	5187.5			3.000	
TDS(g/L)	1.172	5.23	10	20		
BOD	52.82	0.00	10	20		
Ca	388.7	644.5			400	
Mg	187.3	332.76			60	
K	80.8	57.79				
Na	772.5	1569.59			900	
SAR	6.79	15.58			15	
NK	130.6	115.01			30	5
Cd	0.0037	0.0048	0.01	0.01	0.01	0.02
Cr	0.164	0.368	0.01	0.01	0.1	0.1
Cu	0.258	0.649	0.04	0.04	0.1	0.2
Fe	4.056	3.04	5.0	5.0	5	
Mn	0.477	0.362	0.02	0.02	0.2	0.001
Ni	0.369	0.642	0.02	0.02	0.2	0.05
Pb	2.45	2.841	0.01	0.01	5	1.00
Zn	5.081	3.78	4.0	4.0	2	

EC = Electrical Conductivity (μ mos /cm)
N = Nitrogen
K = Potassium
Fe = Iron
Zn = Zinc
TDS = Total Dissolved Solids (g/L)
BOD = Biochemical Oxygen Demand
MAW = Ministry of Agriculture and Water , Saudi Arabia (1975)
FAO = Food & Agriculture Organization (1985)
MEPA = Meteorology and Environmental Protection Agency (1981)

Cu = Copper
Ni = Nickel
Cd = Cadmium
Cr = Chromium
Pb = Lead

However , the SAR of well water is 15.58 (Table 1) which presents a highly sodium problem .This type of irrigation water on U.S. Laboratory Scale can be classified as C_4 C_2 .In this respect S_2 and C_4 stands as follows :

S_2 : Sodium classification is medium sodium water . This water can be used on coarse textured soils with good permeability .

C_4 : salinity classification is very high salinity warter .This water can be used only on soil with good drainage .The irrigation water must be applied in excess to provide considerable leaching . High salt tolerant crops should be selected . However , a number of documented report indicated successful use of saline water for irrigation . Of these , Jurey et . al ,. (1978) grew wheet in Iysimeters with water up to 7.1 mmhos /cm (4544 mg/l); whereas Frenkel and Shainberg (1975) reported that cotton could be grown commercially with water having an electrical conductivity of 4.6 mmhos /cm ; serveral workers : Harden (1976);Bressler (1979); and Dhir (1976) , using waters of relatively high salt concentration levels lying between 4 mmhos /cm to 15 mmhos /cm concluded that such water could be used for certain crops without drastic yield reduction .

MACRONTRIENT ELEMENTS (N , K, Mg AND Ca)

Nitrogen

Nitrogen is a major nutrient for plant growth if within optimum limit . However , one of the main constituents of sewage effluent that can cause problems in crops is nitrogen , if it exceeds the safe limit (30 mg/l) (Table 1) , (Bouwer , 1982) . The average total N content of both wastewater (130.6 mg /l , and well water (115.01 mg /l , exceeds the safe limit (Table 1) (MAW Standard FAO , 1985) . Too much nitrogen fertilization of crops can produce too much vegetative growth and not enough fruits of adequate size ; it can cause crop lodging , delay the maturity or harvestability of crops , lower its sugar or starch content or adversely affect texture, flavor , or color of fruit and vegetable crops. High nitrate concentration in vegetable crops would be a problem when consumed by infants because of the danger of infant oxnosis methemoglobinemia (Bouwer , 1982) . The same problem could occur with alfalfa for cattle .

Potassium

It is one of the main plant nutrient present in wastewater . The potassium content of both wastewater (80.8 mg/l) and well water (57.79 mg/l) (Tables 1) will not cause any problem for plant growth .

Magnesium

Magnesium (Mg) is an essential nutrient for plant growth . The Mg content of both wastewater (187.3 mg/l) and well water (332.76 mg/l) exceed the safe limit (60 mg/l) (Table 1) (FAO, 1985)

Calcium

Calcium (Ca) is an essential nutrient for plant growth . The concentration of Ca in well water (644.5 mg/l) exceeds the safe limit (400 mg /l).However , the concentration of Ca in wastewater (388.7 mg /l) did not exceed the safe limit (FAO , 1985) , (Table 1) .

TRACE AND MICRONUTRIENT ELEMENTS

The trace and micronutrient elements may have inhibitory effect on plant growth , if their concentraion exceeds a safe limit . The use of sewage water and well water from this ‘ wadi’ as a source for irrigation is governed by the quality criteria for quality reuse wastewater in MAW Standard and FAO (1985).

The contents of total Pb , Mn , Ni , Cr , Cu and Zn in both wastewater and well water (Table 1) are likely to exceed the safe limit of both MAW and FAO (1985). However , the concentration of Cd and Fe did not exceed the safe limit .

The BOD Values , Suspended Solids (SS) and Total Dissolved Solids (TDS)

The BOD values of the wastewater averge 52.82 mg/L (Table 1) . This value , however , is considered high compared to the MAW standard (Table 1) . High BOD adversely affects the growth of plant . Well water normally has little or no BOD . The suspended solids on the other hand affect the plant growth since it reduces the permeability of soil and reduces the oxygen used by plant roots . In the study area ,the overall mean value of suspended solids (SS) was 97.7 mg/L . Compared with the allowed maximum set by MEPA (25 mg/L), this reported value is more than six times higher than MEPA standard (Fig.3) . No certain trend can be seen during the investigated period . The water current action and the suspension of bottom sediments may have contributed to the observed irregularity. The chemical and mineralogical composition of the SS is needed to be studied to assess the detailed environmental impacts of these solids.

Similar to the observation made for BOD and the SS, the total dissolved solids (TDS) showed no consistent trend (Fig .4) .There are two peak values at the fourth and tenth periods ; these periode are in summer time as there is a high rate of evaporation .The overall mean value of TDS (1.172 g/L) is an indication to the high salt content of the source water. The desired TDS value for drinking water is less than 0.5 g/L

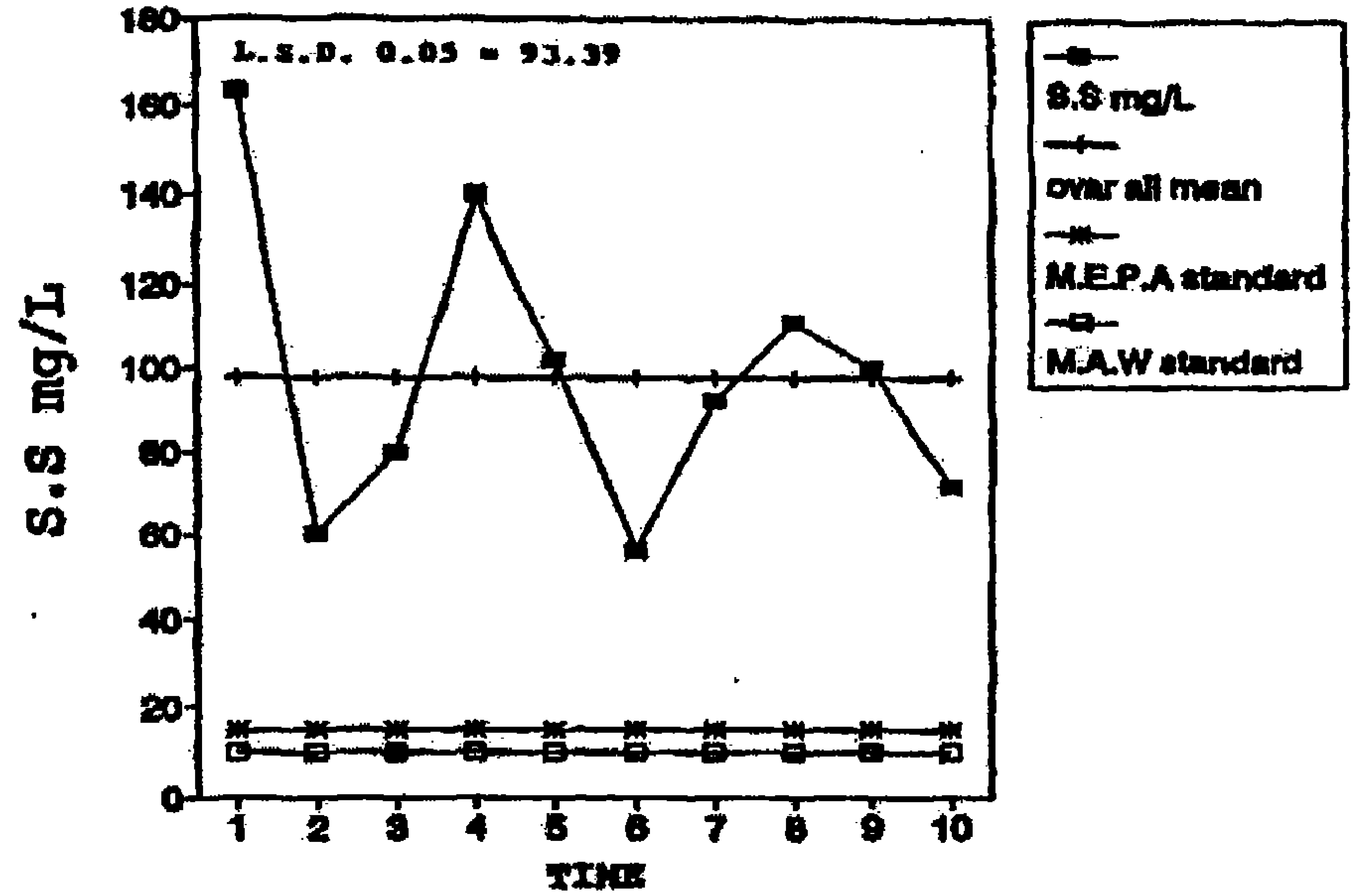

Fig (3): The mean values of suspended solids in the stream of wastewater.

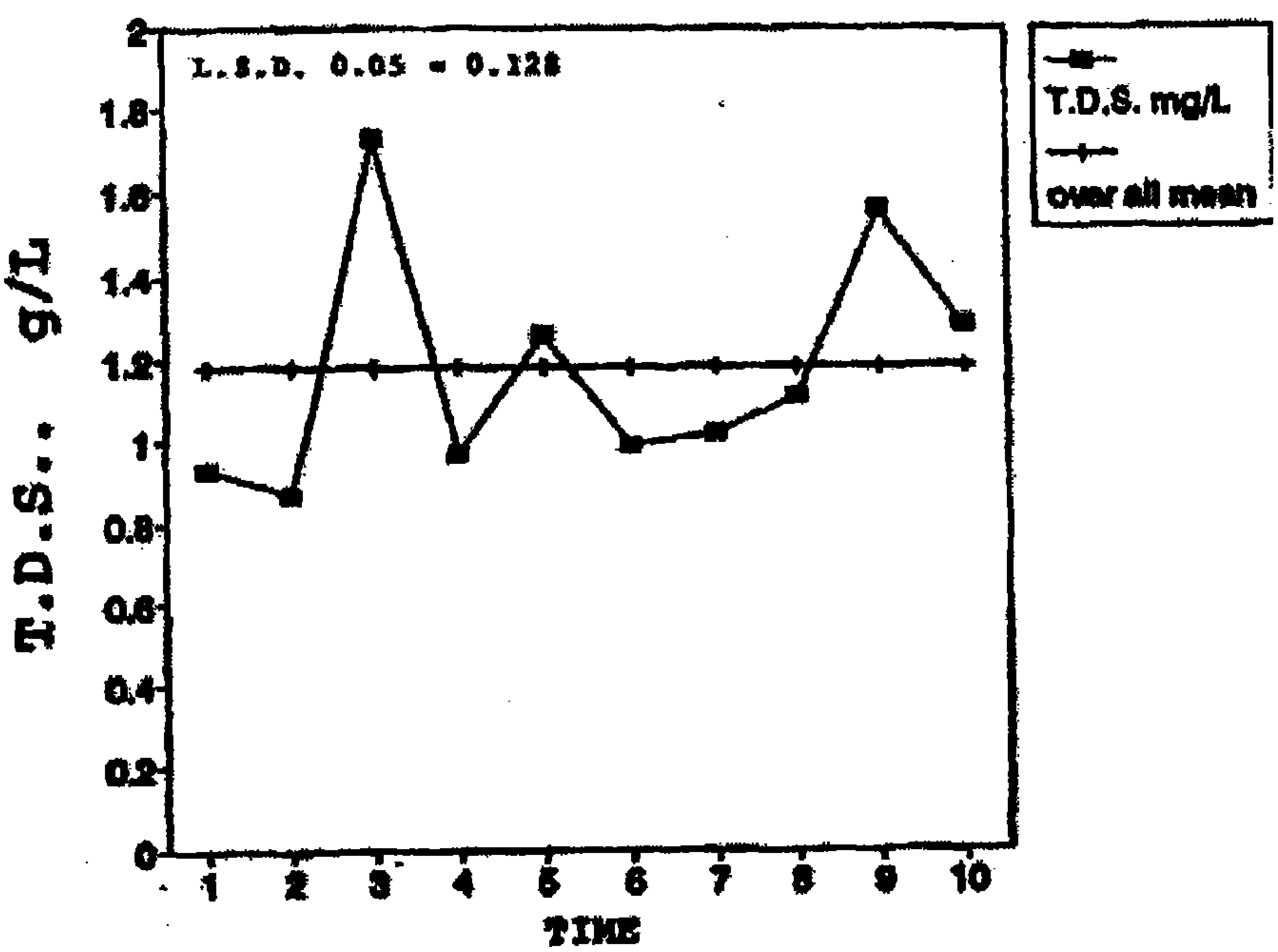

Fig (4): The mean values of total dissolved solids in the stream of wastewater.

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استخدامات مياه الصرف الصحي المعالجة
ومياه الآبار في زراعة المناطق الجافة

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ملخص

تم معاملة مياه الصرف الصحي من محطة مكة المكرمة أثناء فترة الدراسة ، وكان هذا واضحاً من خلال قيم الأكسجين الحيوي والأجسام الصلبة المعلقة في مياه الصرف الصحي . تحتوي مياه الآبار علي نسبة مختلفة من الأملاح الكلية الذائبة وتعزى نسبتها المرتفعة إلي معدل البخر المرتفع في فصل الصيف ، وتأثرت ملوحة مياه الآبار بالملوحة الكلية لمياه الصرف الصحي علي طول المجري .

أوضحت نتائج تحليل المياه أن تركيز معظم العناصر يزيد إلي حد ما عن التركيز الموصي به من قبل MAW, MEPA, FAO وهذه العناصر هي الكالسيوم ، المغنسيوم ، الزنك ، النحاس ، الكروميوم ، النيكل ، البوتاسيوم ، النيتروجين . كانت تركيزات الرصاص والصوديوم أقل من التركيزات الموصي بها من قبل منظمة الـ FAO ولكنها ما زالت أعلي قليلاً من تلك الموصي بها من قبل MAW, MEPA. كانت تركيزات الحديد والكادميوم فقط دون المستوي الموصي به .

أوضحت النتائج أيضا أن التنقية الطبيعية للمياه علي امتداد مجري الصرف الصحي كانت قليلة ولكنها مميزة بالنسبة للأكسجين الحيوي والأجسام الصلبة المعلقة . كذلك أوضحت بعض العناصر نقصاً خفيفاً في التركيز على طول امتداد مجري المياه ، وبصفة عامة فإن الأجسام الصلبة المعلقة والماغنسيوم والكالسيوم أظهرت نقصاً تدريجياً عند مصب مجري المياه ، أما باقي العناصر فلم تظهر اتجاها محدداً .

وبالنسبة لتأثير مياه الصرف الصحي علي مياه الآبار المحيطة بها (تأثير الموقع) فقد كانت واضحة مع المواد الصلبة الكلية الذائبة TDS، وقد لوحظ أن

ملوحة الآبار القريبة من المجري كانت أقل من البعيدة مما يعني وجود تغذية مستمرة للآبار البعيدة . أوضحت عناصر الماغنسيوم والمنجنيز والصوديوم اتجاهاً مشابهاً ، بينما أظهر عنصر الكروميوم تركيزاً أعلي في الآبار القريبة من مجري الصرف الصحي ولم تظهر باقي العناصر اتجاها محدداً بالنسبة للموقع .

أوضحت الدراسة كذلك أن بعض العناصر K, Mn, Zn, Fe, SS, BOD كان تركيزها أعلي في مياه الصرف الصحي ، بينما باقي العناصر أظهرت تركيزاً أعلي في مياه الآبار عن مياه الصرف الصحي.