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IMPACT OF A WASTEWATER TREATMENT FACILITY ON WELLS WATERS IN BEIT LAHIA, GAZA STRIP

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تأثير محطة معالجة المياه العادمة على مياه الأبار الجوفية في منطقة بيت لاهيا – قطاع غزة

ملخص أجريت هذه الدراسة بغرض بحث تأثير محطة معالجة المياه العادمة في منطقة بيت لاهيا على مستوى تلوث 20 بئر من اَبار المياه الجوفية المحيطة والتي تبعد240–3000 متر من المحطة، وتم ذلك بإختبار عينات مياه الابار من حيث الخصائص البكتريولوجية والتي شملت العدد الكلي للبكتريا ومجموعة القولون والقولون البرازية وستربتوكوكس البرازية والكلوستريدم بيرفرنجنس ومجموعة السالمونيلا والسيدوموناس ايروجينوسا والكامبيلوباكتر، بالإضافة إلى مجموعة من الخصائص الفيزيقوكيميائية والتي شملت درجة الحرارة، درجة الحموضة، التوصيل الكهربائي، الاملاح الكلية الذائبة، الامونيا، النيتريت، النيترات، الكلوريد وإحتياج الاكسجين الحيوي، كما وتم دراسة تأثير كل من عمق الابار، موقع الابار وبعدها عن محطة المعالجة على مستوى التلوث البكتريولوجي والفيزيقوكيميائي للمياه.

أظهرت الدراسة مؤشرات للتلوث في العديد من الابار التي تم إختبارها وكان التلوث اكثر وضوحا في الابار الاقل عمقا والاقرب مسافة من محطة المعالجة والواقعة في المنطقة الغربية من المحطة. إستخلصت نتائج البحث إلى أن المصدر الاساسي لتلوث مياه الابار التي تم دراستها يرجع الى محطة المعالجة القريبة من هذه الابار.

ABSTRACT The impact of the wastewater treatment facility (WWTF) of Beit Lahia on wells water located to meters in the vicinity of twenty wells surrounding the facility were evaluated for various bacteriological parameters (heterotrophic plate count, Total coliform, Fecal coliform, Fecal Streptococci, *Salmonella* species, *Campylobacter* species, *Clostridium perfringens*, and *Pseudomonas aeruginosa*). Also several physicochemical parameters (temperature, pH, electrical conductivity, total dissolved solids, biological oxygen demand (BOD), nitrate, nitrite, ammonia and chloride) have been studied.
The effects of well depth, location and distance of wells with respect to the wastewater treatment facility on the level of water contamination were also investigated.
Signs of contamination were encountered in many of the examined wells, and contamination was pronounced in wells located to the western region of the WWTF. Moreover, wells of lower depth and shorter distance from the WWTF showed higher contamination.
The results indicate that the main source of contamination of the wells water in this region, is the WWTF.

INTRODUCTION

Gaza Strip relies entirely on groundwater drawn from its aquifer. Gaza Strip aquifer is only a few meters from the surface, ranging in depth from 10 to 120 meters. This makes the aquifer vulnerable to contamination from the uncontrolled discharge of sewage, agricultural and industrial activities.

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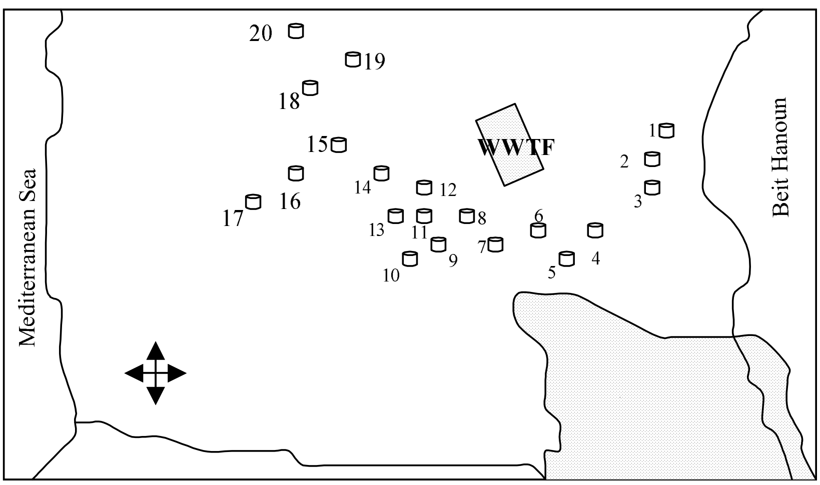
Beit Lahia is a small village located in the northern area of Gaza Strip and inhabited by about 40,000 people. Most of its people work in the agricultural field and many of the families live in the farm and use wells water for drinking and irrigation. Many of those wells, however, are located in the vicinity of a wastewater treatment facility (WWTF).
The WWTF has been constructed in 1973. Due to the rapid population growth and the lack of financial resources to rehabilitate the plant, the sewage influent has been constantly overflowing the designed capacity. The amount of the sewage influent is approximately 8,000 to 10,000 m^3/day, and less than 30% is currently being treated (PWA, 1999).
The Beit Lahia treatment facility is located near one of the finest ground aquifers in Gaza. High levels of nitrate has recently been detected from the aquifer (PWA, 1999; Aish, 2000) but no microbiological examination was done. It is likely, that the excess overflow of sewage from the facility onto the nearby sand dune area will result in further deterioration of the water quality in the surrounding aquifer.
The soil in the study area consists of different layers of dunestone and silt clays (Zoller et al., 1998). This structural matrix adds to the vulnerability of the area to contaminant infiltration.
Contamination of ground water with sewage is a serious problem worldwide, and especially prominent in the developing countries, and many chemical and microbial contaminants are potential threats to human health (Zoller et al., 1998; Macler & Merkle, 2000).
This study was initiated in order to investigate the effect of the wastewater treatment facility on contaminating the surrounding groundwater.

MATERIALS AND METHODS

Water samples were collected in the winter season (November-December, 2000 to January, 2001) from 20 wells located at various distances and directions from the wastewater treatment facility (Figure 1), and suitable analyses were carried out. The winter season was chosen for sampling since preliminary investigations in the study area showed that the highest levels of contamination were predominant in this season. All water samples were collected in pre-sterilized containers by the aid of mechanical pumps already installed on the wells, the water was left to run for few minutes before collection. Bacteriological and chemical analyses were done using the procedures described by the American Public Health Association (APHA, 1985). All the bacteriological media used throughout the study were prepared according to Difco Manual (1985).
Well depth and distance from the wastewater treatment facility were related to the tested parameters by simple correlation analysis according to Snedor and Cochran (1981).
The average water temperature of water was fairly constant and ranged between 18.7 and 19.8°C. Likewise, the average pH of water samples from the twenty wells was almost neutral and ranged between 6.71 and 7.42. Concentrations of total dissolved solids (TDS) were uniform and characteristic of freshwater (Table 1).

Figure 1. Location of examined wells with respect to the WWTF.



RESULTS

Data presented in Table (1) show the bacteriological, physicochemical, well depth, location and distance from the facility.

Heterotrophic Plate Count (HPC)

The HPC determined on nutrient agar at 37°C for 48 h is presented in Table 1. It is clear from the table that all the water samples were positive for this parameter. Water from the different wells, however, showed that there are differences in HPCs. Water from wells 8,9,11,12,13 and 15, which are located west and south west to the WWTF, showed the highest values of HPCs.

Total Coliform (TC)

TC counts expressed as colony forming units (CFU)/100ml for the examined water samples are illustrated in Table 1. Samples from of 90% (18/20) of the wells were positive for TC. Higher counts were encountered in the wells located in the western region of the WWTF.

Fecal Coliform (FC)

The FC test was positive for 13 wells. The results are depicted in Table (1). It is clear that southwest and western wells showed higher FC counts than other wells.

Fecal Streptococci (FS)

The results of FS determination for the water samples are given in Table 1. Only 35% (7/20) of the wells were positive for FS. Those wells are also located in the western surrounding of the WWTF.

***Salmonella* & *Pseudomonas* species**

Neither *Salmonella* sp. nor *Pseudomonas aeruginosa* was detected in the groundwater samples analyzed.

***Campylobacter* species**

Water samples from only two wells (number 12 & 13) were positive for *Campylobacter* species.

Clostridium perfringens

This parameter was detected in water of four wells (Table 1). The trend was similar to that of the other parameters in that, those wells are also located in the western region of the WWTF.

Chloride (Cl)

The chloride concentrations in water samples from all the wells complied with the Palestinian Standard (600 mg/l).

Nitrite Nitrogen

Waters from eight wells, located southwest and west to the WWTF contained nitrite in amounts exceeding the permissible standard of 0.2 mg/l.

Ammonium Nitrogen

Waters from three wells (number 11,12 & 13), located in the western region of the WWTF, showed ammonia concentrations higher than allowed by the Palestinian Standard (0.5 mg/l) .

Nitrate Nitrogen

Waters from two wells (number 12 & 13) showed nitrate concentrations that exceeded the Palestinian Standard of 70 mg/l. Generally, wells located to the west and southwest of WWTF showed higher nitrate concentrations than others (Table 1).

BOD5

Fifteen of the examined wells water showed BOD5 values higher than the Standard limit. Moreover, the highest BOD5 concentrations were encountered in the waters of the wells situated in the western region with respect to the WWTF.

Table 1. Summary of the results of the bacteriological* and physicochemical parameters investigated in the 20 wells.

Location	Distance	Depth	HPC	TC	FC	FS	Clost	Camp	Temp	PH	E.C.	TDS	NH4	NO2	NO3	Cl
East	1300	127	65	9	2	0	0	0	18.8	7.06	610	407	0.1	0	22	55
East	1100	88.2	70	5	1	0	0	0	19.1	7.42	1435	957	0.1	0	42	198
East South	1400	71	160	40	0	0	0	0	19.1	7.21	581	387	0.2	0.1	19	71
East South	1700	60.9	65	5	0	0	0	0	18.8	7.02	512	341	0.1	0	54	112
South	2200	42.3	55	1	0	0	0	0	18.7	7.31	748	799	0	0	9.1	117
South	1750	47.7	50	6	0	0	0	0	19.2	7.31	1050	700	0.1	0	23	177
South	1900	53	50	0	0	0	0	0	19.6	7.33	382	255	0.1	0	5.3	38
South West	450	33.6	260	120	72	15	10	0	18.9	7.06	1195	797	0.5	0.3	47	166
South West	750	29.3	400	120	90	20	0	0	19.8	7.11	1220	813	0.5	1.2	33	202
South West	1100	39.5	180	6	1	0	0	0	19.3	7.30	1080	720	0.2	0.1	26	172
West	700	32.7	450	120	32	3	10	0	18.9	7.40	672	448	0.5	1.4	36	73
West	240	28.8	700	130	110	15	10	+	19.2	6.71	708	472	0.6	2.0	73	164
West	560	29.5	450	130	120	17	12	+	18.8	7.03	991	660	0.5	1.0	109	118
West	900	32.9	320	80	10	1	5	0	18.8	7.05	1334	889	0.3	0.2	20	228
West	1200	31.2	450	120	70	3	0	0	19.1	7.01	642	428	0.3	0.2	24	135
West	1800	32.2	210	65	7	0	0	0	18.8	6.98	381	254	0.2	0.1	21	38
West	2200	42.2	180	26	2	0	0	0	19.7	7.38	361	240	0.2	0.1	9	32
West North	2500	30.9	60	13	0	0	0	0	18.9	7.23	1046	697	0.1	0	14	168
West North	2600	39.2	180	22	3	0	0	0	18.2	7.20	1455	970	0.1	0.1	11	190
West North	3000	47	3	0	0	0	0	0	19.3	7.02	472	315	0	0	21	44
n Standard			**ND**	**0-5**	**0**	**0**	**0**	**0**		**6.5-8.5**	**3300**	**1500**	**0.5**	**0.2**	**70**	**600**

* All the samples were negative (0) for the presence of Salmonella and Pseudomonas species

HPC Heterotrophic Plate Count at 37°C (CFU/ml)
Temp Temperature in °C
TC Total coliform (CFU/100ml)
E.C. Electrical conductivity (µS/cm)
FC Fecal coliform (CFU/100ml)
TDS Total dissolved solids (mg/l)

FS Fecal streptococci (CFU/100ml) BOD5
Biological oxygen demand (mg/l)
Clost *Clostridium perfringens* (CFU/300ml) NH_4 Ammonia
nitrogen (mg/l)
Camp *Campylobacter* sp. (CFU/2000ml) NO_2 Nitrite
nitrogen (mg/l)
NO_3 Nitrate nitrogen (mg/l) Cl Chloride
ND Not defined

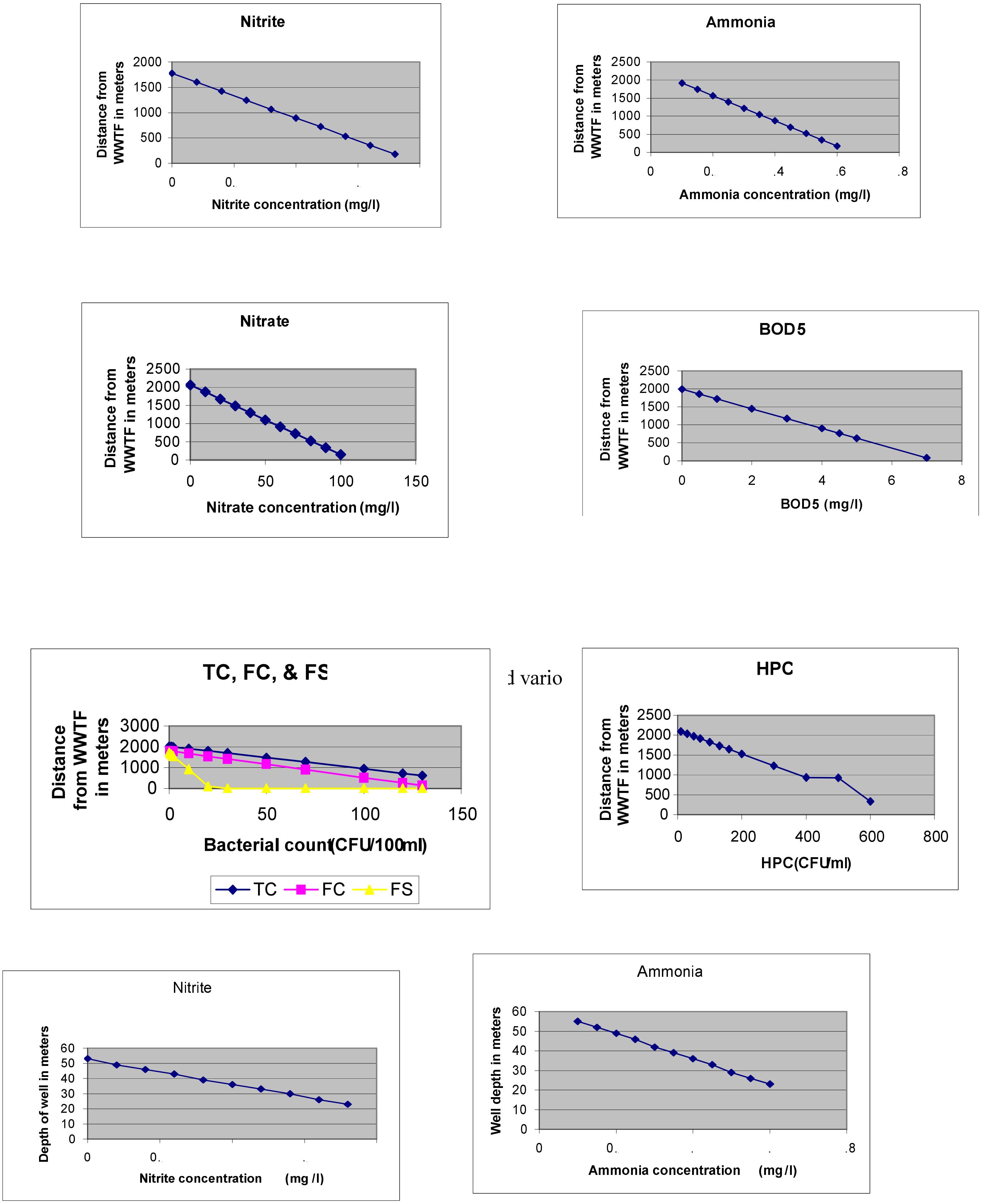
Relationship between distance of the wells from the WWTF and the tested parameters

The examined wells are located at 240 to 3000 meters from the WWTF. The relationship between various chemical and bacteriological parameters is presented in Figure 2. The observed pattern showed that the closer the wells to the WWTF the higher is the level of contamination.

Effect of well depth on the level of water contamination

Depth of the examined wells ranged between 28.8 and 127 meters (Table 1). Figure 3 illustrates the relation between various chemical and bacteriological parameters and well depth. It is clear from the Figure that the depth influences the degree of contamination. For all examined wells the level of contamination increased with decrease of the depth.

Figure 2. Correlation between distance of wells from the WWTF and various parameters



ISCUSSION AND CONCLUSIONS

The present study illustrates an example of man-made contribution to the deterioration of water quality. It describes the impact of Beit Lahia WWTF on the quality of water in 20 of the surrounding groundwater wells.

The bacteriological and physicochemical parameters investigated in this study are the most commonly employed indicators for monitoring water quality (Ward et al., 1981).
The 20 wells included in this study were selected to cover all the possible directions around the WWTF (Figure 1). The results have shown that the highest levels of contamination were encountered in wells located in the western regions of the WWTF. Those results are consistent with the natural east to west flow of groundwater in this area (Zoller et al., 1998).

Among the examined wells, it was found that wells number 12 & 13 were the most heavily contaminated ones in terms of the investigated parameters. The factors responsible for this observation include; the relatively low depth (28.8 and 29.5 m, respectively), location and the relatively short distance (240 and 560 m, respectively) of these wells to the WWTF.

The lateral distance migrated by contaminants is governed by the hydrogeological characteristics (soil type and structural matrix) of the soil. It is believed that the sandy nature and the deteriorated soil matrix in the study area provide a path for contaminants to enter the aquifer. This explains the relatively long distances, especially in the western area of the WWTF, travelled by the contaminants investigated in this study.

Regarding the depth of groundwater wells, similar observations have been reported by Brooks and Cech (1979) and Martino et al. (1998). Both studies have implicated that higher contamination was found in wells of lower depths. Obviously, in the presence of contaminants on the soil surface, the infiltration of contaminants to wells of low depth would be easier and faster.

TC, FC and FS were detected in many of the analyzed samples. Interestingly, wells that were negative for TC were invariably negative for the other investigated bacteriological parameters. This confirms the importance of TC for routine screening of the microbiological quality of groundwater. Testing for TC, however, should be supplemented by examining FC and FS in order to rule out contamination by environmental coliforms (Cabelli, 1982).

As can be deduced from Table 1, the presence of FC is almost always associated with high HPCs and both FC counts and HPCs are associated with high BOD5 values. This pattern reflects the availability of organic matter that help extending the surviva; rate of FC and heterotrophic bacteria.

In the water samples analyzed in this study, FS has been encountered in 7 wells. According to Hamit and Cole (1998) the FC/FS ratio can be used to differentiate the contamination of human origin (FC/FS > 4) from that of animal origin (FC/FS < 0.7). In the wells positive for FS, the FC/FS ratio is always greater than 4. Therefore, it is possible to conclude that the contamination source is domestic wastewater and consequently the overflow of raw sewage from the WWTF in the vicinity of the investigated wells.

Samples from five of the examined wells were positive for *Clostridium perfringens*. The natural resistance of *C. perfringens* endospores may indicate old pollution of those wells since this parameter is considered a good indicator for old fecal pollution (Edberg et al., 1997).

Campylobacter sp. has been detected in only two wells (number 12 & 13). *Campylobacter* sp., particularly *C. jejuni*, has only recently been recognized as a relatively common cause of human diarrhea, and polluted water is believed to be an important source of transmission of this pathogen (Cilimburg et al., 2000).

The absence of *Pseudomonas aeruginosa* and *Salmonella* sp. in the tested water samples, despite the availability of organic matter (represented by elevated BOD5 values), may be due to the unsuitable quality of the organic matter for the survival of these bacteria.

In terms of the physicochemcial parameters investigated during this work, the average water temperature, pH values, E.C. and TDS were all characteristic of fresh water and the little variations of these parameters observed in the different samples should have negligible effect on the other tested parameters.

Only one well (number 9) showed chloride concentration higher than allowed by the Palestinian Standard, over pumping from this well and upconing of the deeper, highly saline aquifer, rather than contamination could be the reason for this finding.

Nitrate, nitrite and ammonia have been always considered as the chemical indicators for monitoring the chemical quality of potable water (Ward et al., 1981).

Samples from wells number 8,9,11,12 and 13 have shown ammonia concentrations at the cutt-off value or higher than allowed by the Palestinian Standard. Elevated ammonia concentrations in drinking water sources are either due to intensive use of nitrogenous fertilizers or sewage pollution. The close proximity of wells of high ammonia to the WWTF indicate that sewage is the primary source of pollution with this parameter. Moreover, water samples from wells of high ammonia concentration also showed considerably high nitrite contamination.

Nitrate is the end product of oxidation of nitrogen in the environment and its presence in high levels in an aquatic system is often taken as an indicator for old pollution from either fertilizers or sewage. Elevated nitrate levels, above the standard, were encountered in wells number 12 and 13. Waters of these two wells are the most heavily polluted in terms of all the examined parameters and it can be safely concluded that the source of pollution here is due to seepage of wastewater from the WWTF. Similar conclusion was reported by Geoffery et al. (1999) who studied the relationship between nitrate in wells waters and the nearby sewage tanks in Indonesia.

Elevated levels of bacteriological and chemical parameters investigated during this work are true threats to human health. Several investigators have linked various bacteriological and chemical contaminants with human illnesses such as diarrhea, stomach cancer, and blue babies syndrome (Macler & Merkle, 1994 and Nagaraju and Sastri, 1999).

In conclusion, seepage or overflow of inefficiently treated wastewater from the WWTF is believed to be the point source of bacteriological and physicochemcial contamination detected in the analyzed wells water. Wells located in the western regions of the WWTF are the most heavily polluted and the most vulnerable to contamination due to the natural east to west flow of groundwater. Distance of wells examines from the WWTF and depth of wells from ground level influence the degree of contamination.

Therefore, quick actions should be taken in order to prevent further deterioration of Beit Lahia groundwater aquifer and protect the downstream users of the water. One quick action is the protection of vulnerable wells in the vicinity of the WWTF from sewage infiltration. Another better solution, which is being considered by the

Palestinian Ministry of Environmental Affairs, is to relocate the WWTF outside the residential area of Beit Lahia.

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