Egyptian Journal of Biology, 2003, Vol. 5, pp 1-9
© Printed in Egypt. Modern Press. Egyptian British Biological Society (EBB Soc)

Potential contamination of groundwater in the World Heritage Site of the St. Katherine Protectorate, Egypt

Hesham Abdulla[1*], Kamal Ghodeif[2], Sahar El-Shatoury[1] and Ahmed Dewedar[1]

1. Botany Department, Faculty of Science, Suez Canal University, Ismailia, Egypt.
2. Geology Department, Faculty of Science, Suez Canal University, Ismailia, Egypt.

ABSTRACT
Groundwater is the main water source for St. Katherine city inhabitants, South Sinai. The rapid population growth, high levels of tourism and poor sewage waste disposal (at least for the foreseeable future) in St. Katherine have resulted in potential contamination of groundwater and subsequent high risk to human health. To evaluate the safety of well water for human use in St. Katherine, water samples were collected from 14 different wells covering various inhabited locations in the area. These samples were subjected to extensive physical, chemical and microbiological analysis. Nitrate values of the majority of the studied wells water exceeded the accepted limits recommended by the Egyptian environmental legislations and the World Health Organization for drinking water standards. Counts of faecal indicators (faecal coliform and faecal streptococci) ranged between 2-142 cfu/100ml in wells. Bacterial pathogens including *Salmonella*, *Shigella* and *Vibrio* spp. were detectable in all wells, indicating heavy contamination of the groundwater with domestic sewage. We discuss the impact of the geological structure of the aquifers and human activities on the safety of groundwater for human use in St. Katherine, as well as possible solutions.

KEYWORDS: Sinai, wells , faecal coliform, faecal streptococci, pathogenic bacteria.

INTRODUCTION

The Egyptian Environmental Affairs Agency declared the St. Katherine area, 4300 km^2 of South Sinai in Egypt, as a Natural Protectorate in 1987. Within this Protectorate, UNESCO at its 26th session in Budapest in June 2002 declared as a World Heritage Site (WHS No. 954) an area that coincides with the St. Katherine ring dyke. The nomination is of an area of 601 km^2 located in the high mountainous region of southern Sinai (average 1500-2000 m above mean sea level), containing the Monastery of St. Katherine at its centre; the region is composed mainly of granite rocks (Eyal & Hezkiyahu 1980). The demand for water resources in the St. Katherine area has shown a continuous increase during the last two decades due to the rapid growth in population, increasing tourism activities and the prevailing arid conditions. Groundwater represents the main water source in St. Katherine, where wells are used for drinking and other domestic purposes. The number of inhabitants in the St. Katherine area was 3373 according to the 1986 census, increasing to 4349 in 1996. Recently, numbers were estimated to be 6000 inhabitants, split between the indigenous Bedouin and new settlers from the Nile valley and the Delta (South Sinai Statistical Data Book 1997). Groundwater was produced through both alluvial (gravel and sand) and fractured-granite aquifers for long periods, but recently the alluvial aquifer has become completely dried up due to overexploitation and consequently the region is relying on the fractured-granite aquifer (Ghodeif & El-Shafey 2003). Nevertheless, on a worldwide basis this aquifer has low yield (UNESCO 1984).

* Address for Correspondence

Currently, domestic sewage disposal in St. Katherine city still depends on non-sewer systems, despite the construction of a new sewer system since this is non-functional due to lack of water. The active system in the city consists of septic tanks and cesspits constructed directly over the fractured-granite and alluvial layers. Concern for this type of waste disposal practice arises from the very shallow level of the groundwater aquifer in St. Katherine, high permeability of the subsurface strata (Ghodeif *et al.* 1999) and uncertainty about the holding capacity and migration of contaminants in such strata. Recent studies have demonstrated that groundwater systems are increasingly vulnerable to microbial and chemical contamination, especially in developing countries (Foster 1985; Colwell *et al.* 2003). Outbreaks of hepatitis, gastroenteritis and Norwalk virus dysentery have been attributed to groundwater contamination from septic tanks (Yates & Yates 1988).

After the St. Katherine Protectorate was activated in 1996, public awareness of the possible harmful impact of the existing inadequate sewage disposal increased. Residents restricted the use of certain wells (less than 5 metres from cesspools) for domestic and irrigation purposes. However, they still suffer from health problems such as diarrhea and skin infections due to the use of well water for household purposes. The poor sanitation of the area has resulted in unpleasant odours, the spread of mosquitoes and generally unacceptable environmental conditions. Accordingly, the objectives of this study were to monitor and evaluate the pollution status, the characteristics of pollution sources and the threat to aquifers in the area of St. Katherine. This was achieved through determining the microbiological and physicochemical characteristics of groundwater as well as studying the impact of the hydrogeological environment on the levels of contamination in wells water within the World Heritage Site of the St. Katherine Protectorate.

MATERIALS AND METHODS

Wells and the distribution of potential contamination sources in the studied area are shown in Figure 1. All the wells have wide mouths (1-2 m) and have been dug manually to depths varying between 2 and 43 metres, depending on the local hydrogeological environment of each well site. Figure 2 is a schematic representation of the geological setting of the site, illustrating relative depths of wells and a convective flow direction of contaminants in the groundwater flow system. Water samples were collected during June 2003; pumps of the wells were turned on for 30 min before sampling. Water samples were collected in sterile 500-ml polyethylene bottles and kept in iceboxes until analyzed. Microbiological and chemical analyses were carried out within 24 hr of sampling.

Estimation of phosphate, nitrite, ammonia, copper, tin and cyanide were carried out using WinLab® Photometer LF 2400. Readings were recorded according to the manufacturer's instructions. Nitrate was determined using methods described by Greenberg *et al.* (1992). Conductivity and salinity were measured using portable meter Testo® 240. pH values were measured by Testo® 230 pH-mV meter. Turbidity was determined by Orbeco–Hellige® digital direct-reading turbidimeter. Total dissolved salts (TDS) were determined by filtration and evaporation at 120°C according to Greenberg *et al.* (1992).

Total viable bacteria were enumerated in water samples after having been serially diluted in phosphate buffer and plated onto nutrient agar plates. Other bacterial groups (total coliform, faecal coliform, faecal streptococci, *Salmonella*, *Shigella* and *Vibrio* spp) were determined using the membrane-filter technique (Greenberg *et al.* 1992). One hundred millilitres of each sample were aseptically filtered through sterile 0.45μm-pore size membrane filters (Whatman®), and the filters then laid onto the appropriate media. Endo-agar medium was used for counting coliform bacteria; SS-agar medium (Oxoid®) for counting *Salmonella* and *Shigella* spp.; TCBS-medium (BDH®) for *Vibrio* spp.; and m-*Enterococcus* agar for faecal streptococci (MacFaddin 1985). Total viable bacteria plates were incubated at 28°C; faecal coliform plates at 44.5°C; and plates for other bacterial groups at 37°C. All bacterial groups were counted after 24 hr of incubation except for faecal streptococci, which were counted after 48 hr.

Physico-chemical and microbiological data sets were analyzed using one-way analysis of variance (ANOVA) tests for differences. Bacterial counts were transformed into logarithms to achieve normal distribution. Differences reported were significant at $P < 0.05$. Correlation analysis was performed to test the degree of association among indicators of pollution with the depth of wells. Counts of all bacterial groups are reported in untransformed numbers.

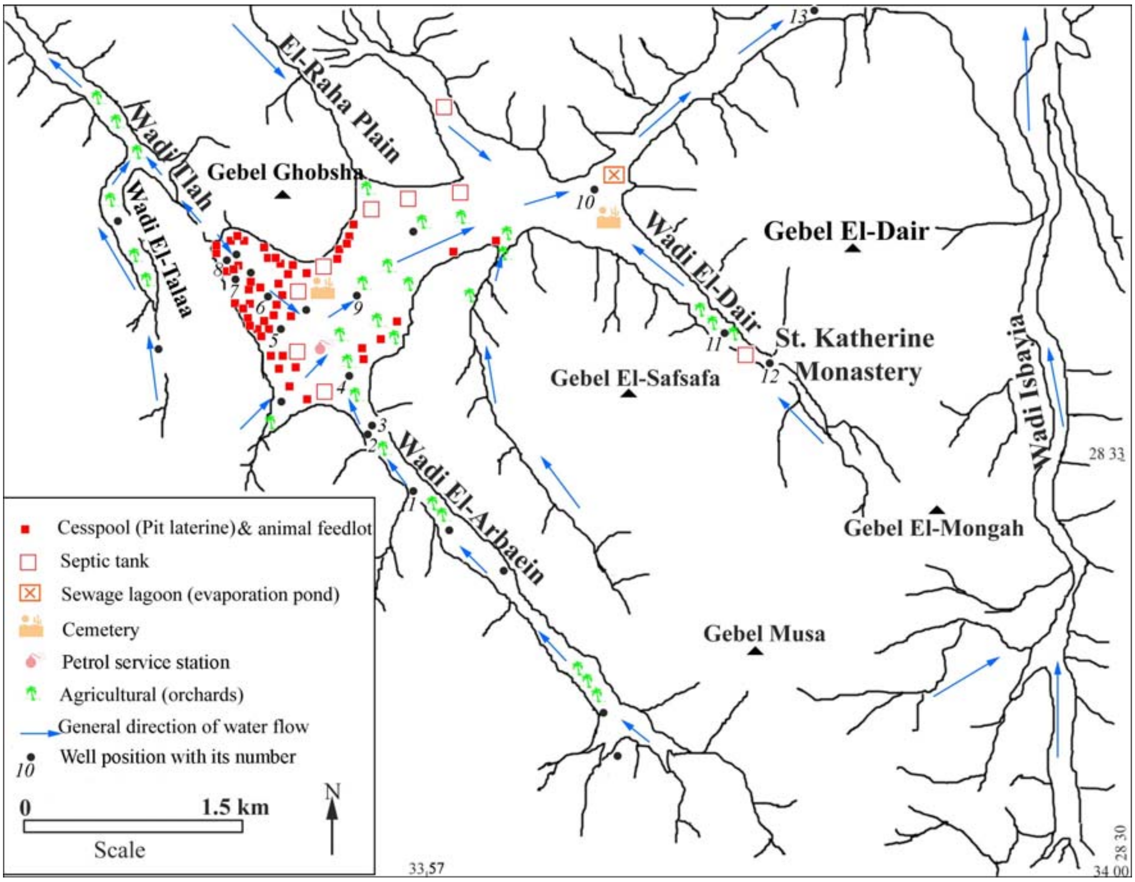

Figure 1. Inventory map showing location of the studied wells, potential sources of contamination and direction of flow of water in the World Heritage Site of the St. Katherine Protectorate. Wells 13 and 14 are located at 4 km and 20 km, respectively, downstream, north of well 10.

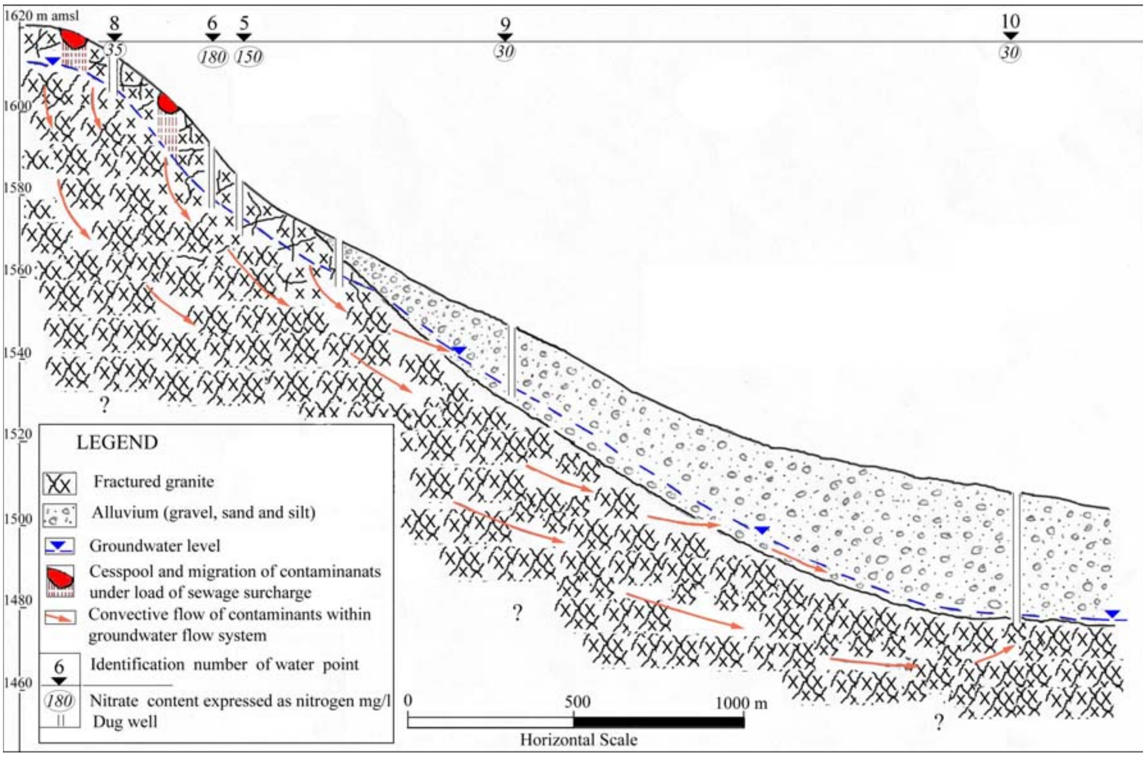

Figure 2. The hydrogeological cross-section of the studied area in the World Heritage Site of the St. Katherine Protectorate, showing the relative depths of wells and the convective flow of contaminants within the groundwater flow system.

RESULTS

Table 1 gives descriptive information of the investigated wells and the physicochemical characteristics of the collected water samples. Variations among temperature, pH and turbidity of water samples were not significant ($P>0.05$), all being within the accepted limits. Similarly, levels of the examined heavy metals (copper, cyanide and tin) were not significantly different among the wells ($P>0.05$) and were in agreement with national and international standards. However, water showed high significant differences among wells ($P<0.001$) in their salt content, as indicated by values of conductivity, salinity and total dissolved salts. Wells 5, 6 and 7 were far from the acceptability standards in their salt contents. The nutrient loads of nitrogen and phosphorous were significantly different among the 14 wells ($P < 0.05$). Levels of nitrate nitrogen in particular were very far from the recommended levels in 67% of the wells, being only acceptable in upstream wells (1, 2, 3 and 12). Ammonia levels were also outside the acceptable standards in six wells (1, 2, 5, 7, 11 and 12). On the other hand, nitrite and phosphorous levels were acceptable in all wells, varying between 0.06–0.98 mg/l for nitrite and 0.1–1.5 mg/l for phosphorous. Correlation analysis indicated a negative association between a pollution indicator (ammonia) and well depth (Fig. 3).

Microbiological analysis indicated total viable bacteria (TVB) counts ranging between $1x10^3$ to $70x10^3$ cfu/100ml, which greatly exceed acceptable limits (100 cfu/100ml) in all the investigated wells. Figure 4 shows that faecal coliform (FC) bacteria were detected in wells 2 to 14 with values up to 140cfu/100ml. Faecal streptococci (FS) were detected in wells 1 to 13 with values up to 142cfu/100ml. Faecal indicators (FC &

FS) decrease with increasing well depth from which the water was derived. However, TVB counts were not statistically associated with well depth (P>0.05).

Table 1: Physicochemical parameters of water samples collected from 14 wells within the World Heritage Site of the St. Katherine Protectorate, compared to the Egyptian and WHO standards for potable water. EGY Std = Egyptian acceptable limit; WHO Std = World Health Organization acceptable limit; bgl. = below ground level; **NSV** = no acceptable limits set.

Parameter	Value in the well														EGY Std	WHO Std
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**		
Depth to water (m) bgl	7	3	6.3	16.8	8.8	12.7	7.4	6.4	14	28.8	5.5	4.5	43.5	34	**NSV**	**NSV**
Yield (l/h)	518	370	72	260	107	60	72	79	290	2900	89	187	1458	4166	**NSV**	**NSV**
Temp (^{o}C)	21	22	21	22	21	20	21	21	22	22	21	22	23	22	**22**	**NSV**
pH	7.61	7.62	7.5	7.54	7.27	7.15	7.27	7.55	7.26	7.88	7.65	7.48	7.92	7.86	**6.5 – 9.2**	**6.5 – 8.5**
Conductivity (µS/cm)	243	257	241	322	1679	1540	1541	562	590	690	373	218	465	436	**NSV**	**NSV**
Salinity (mg/l)	121.8	117.5	116.9	158.2	851	780	754	250	305	303	163.4	110.2	241	205	**NSV**	**NSV**
TDS (mg/l)	280	304	330	394	2654	2832	2876	762	866	1030	426	286	588	568	**1500**	**1000**
Turbidity (NTU)	0.92	2.36	0.8	0.61	7.6	1.2	3.34	1.05	1.75	0.9	4.94	1.24	1.26	0.92	**5**	**5**
Nitrate N (mg/l)	3.2	3.5	3.5	23.5	150	180	125	35	30	30	20	5.2	16	18	**10**	**10**
Nitrite (mg/l)	0.7	0.82	0.15	0.19	2.2	0.51	0.06	0.98	0.03	0.44	0.24	0.25	0.14	0.15	**NSV**	**3**
Ammonia (mg/l)	0.09	0.1	0	0	0.1	0	0.09	0	0	0	0.05	0.09	0	0	**nil**	**nil**
Phosphorus (mg/l)	0.1	0.1	0.2	0.2	0.1	0.1	0.3	0.1	0.3	0.1	1.5	0.5	0.1	0.1	**NSV**	**NSV**
Sulphate (mg/l)	38	40	37	42	300	135	200	70	72	95	60	33	78	78	**400**	**250**
Copper (mg/l)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	**1.5**	**2**
Cyanide (mg/l)	0.01	0.02	0.01	0.01	0.02	0	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**NSV**	**NSV**
Tin (mg/l)	0.14	0.14	0.17	0.14	0.21	0.12	0.25	0.14	0.1	0.25	0.23	0.29	0.23	0.27	**NSV**	**NSV**

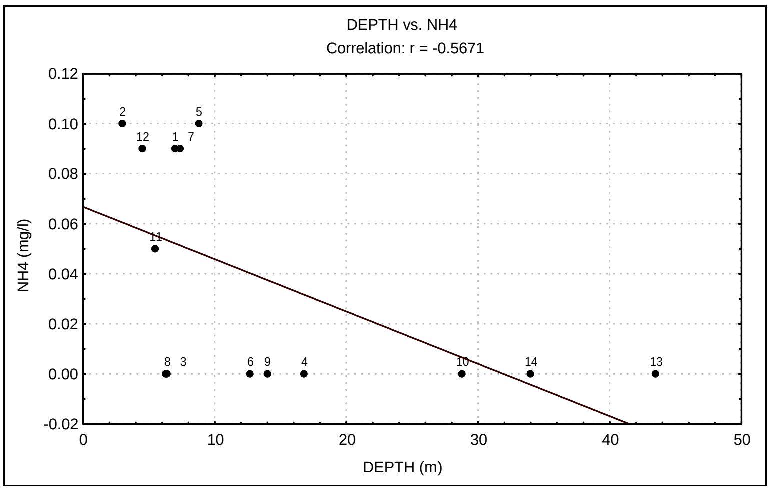

Figure 3. Scatter plot showing the distribution of ammonia (NH_4 mg/l) relative to well depth (m) of the investigated 14 wells in the World Heritage Site of St. Katherine

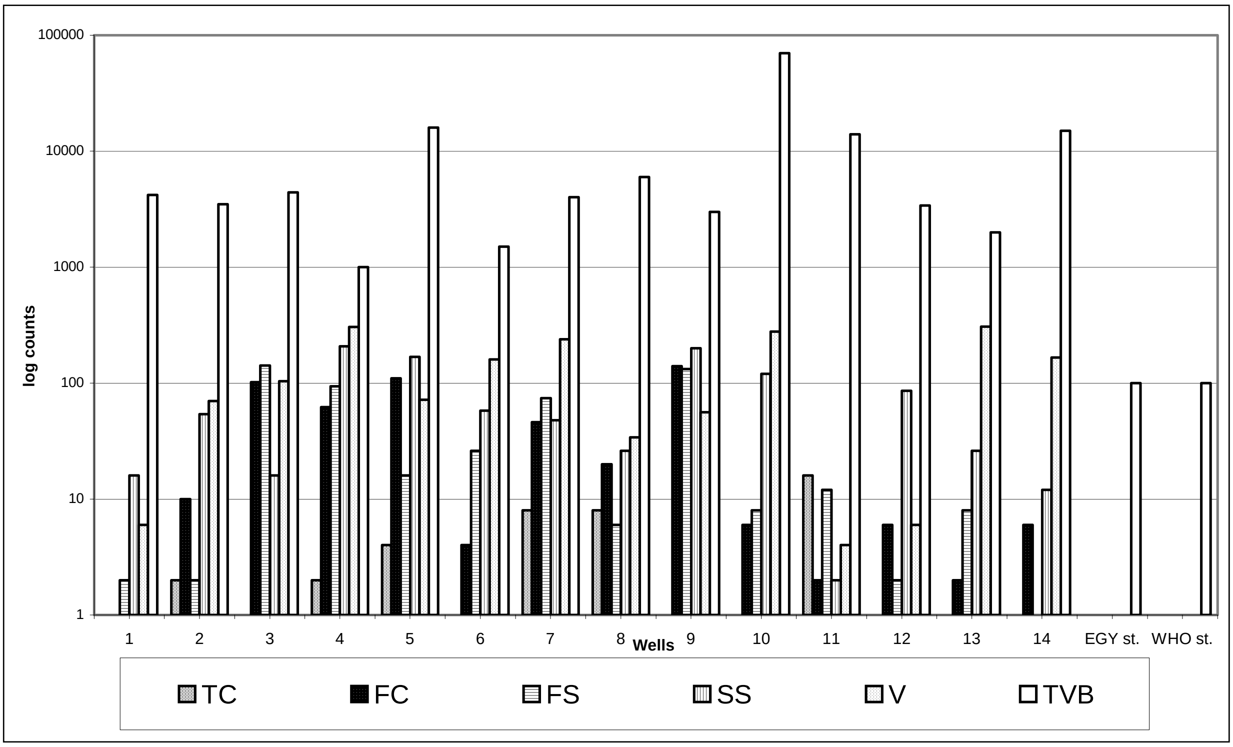

Figure 4: Counts of bacterial groups (cfu/100ml) in water samples collected from the studied 14 wells in the World Heritage Site of St. Katherine, compared to the Egyptian and WHO standards of acceptability for potable water. The guideline values for total coliform, faecal coliforms and pathogens are all 0 cfu/100ml, and for TVB are 100cfu/ml, according to Egyptian and WHO standards. (TC = total coliform; FC = faecal coliform; FS = faecal streptococci; SS = *Salmonella* and *Shigella* spp; V = *Vibrio* spp; TVB = total viable bacteria).

DISCUSSION

There is a high concern that contamination and availability of water resources are two major problems in St. Katherine. Contamination of groundwater can result in poor drinking water quality, loss of water supply, high clean-up costs, high costs for alternative water supplies and potential health problems (USEPA 1986). Epidemiological evidence indicates that enteric/respiratory and eye diseases can be associated with and caused by the use of water contaminated with pathogenic bacteria and viruses resulting from exposure to pollution from domestic wastewater sources (WHO 1998).

In the current study, all 14 of the evaluated wells were contaminated, despite varying in depth and distance to habitation. According to the local Egyptian and international WHO guidelines, water derived from these wells is heavily contaminated with faecal sources: faecal indicator (FC, FS) counts should be nil in drinking water. High counts of faecal indicators were observed in wells near the town (wells 3 to 9), reaching 142 cfu/100ml of water. Previous study of St. Katherine has also reported the presence of high levels of faecal indicators in the groundwater of the studied area (Shendi & Geriesh 1998). Faecal-indicator bacteria are not native to the subsurface environment and should not survive there long, but could persist around waste disposal areas such as septic tanks (Bonwer 1984). Besides from humans, other potential sources of such bacteria include goats and sheep, the major domestic animals for local Bedouin (SCU 1996). To meet the challenge of identifying sources of faecal pollution, the ratio of faecal coliform to faecal streptococci was calculated for different wells. A ratio greater than 4 would indicate human pollution, whereas less than about 0.7 would indicate animal sources, since human faeces contain high faecal coliform counts whilst animal faeces contain high levels of faecal streptococci (Greenberg *et al.* 1992). The current study indicated major pollution by animal sources (ratios ≤ 0.7) in eight wells from Wadi El-Arbaein and downstream, where grazing activities are concentrated. However, it should be noted that some authors have recently cast doubt on the reliability of this method for tracking faecal sources (Scott *et al.* 2002), due to variable survival rates of faecal streptococci in water.

The detection of faecal indicators in well water implies the potential presence of pathogenic bacteria that may cause health hazards. The current study indicated the presence of high numbers of *Salmonella*, *Shigella* and *Vibrio* spp. in all the investigated wells. This may be due to direct passage through wide fracture openings in the granite without filtration. St. Katherine residents have recently suffered from diarrhea, skin and gastrointestinal diseases, unpleasant water odours, and an abundance of mosquitoes, in addition to generally unacceptable environmental conditions concerning water shortage and contamination (personal communication). Furthermore, a recent study has indicated the prevalence of intestinal parasites in the domestic goats of St. Katherine (Soliman & Zalat 2003), which may be related to the poor water quality for both Bedouins and their domestic animals.

Keswick (1984) reported that fifty percent of waterborne diseases are attributable to contaminated groundwater. The present data indicate that groundwater quality in St. Katherine is getting worse with time. This is quite obvious when our results are compared with the earlier work of Diab (1984), since the numbers of faecal indicators have increased by up to 20-fold within twenty years.

In addition to microbial contamination of groundwater, on-site disposal systems such as septic tanks and cesspits are known to result in N and P concentrations exceeding the acceptable limits for groundwater (Entry & Farmer 2001). Nitrogen in drinking water is of concern because concentrations above the range of 10 mg/l can contribute to lymphoma in infants (Ward *et al.* 1996). Well water in St. Katherine clearly suffers from very high nitrate levels, reaching 150–180 mg/l in the densest areas of habitation (wells 5 and 6). Estimated nitrate levels in both these wells were within acceptable limits in 1996 (9 mg/l), but increased to 21 ppm in 1998 (Shendi & Geriesh 1998). The currently estimated seven-fold increase in nitrate pollution after a further five years is probably related to the rapid population growth and improper sewage disposal.

The detection of high levels of nitrate and faecal indicators in the more remote wells (10 to 14) at some distance downstream from the densest area of habitation may be related to the specific hydrogeological environment of the St. Katherine area. Wide fractures in the granite (about 0.1 cm) and the alluvial geological materials which characterize the area can potentially accelerate the rate and extent of contamination by fast migration. These granite fractures probably create an aeration zone in which ammonia is easily oxidized to nitrate (Domenico & Schwartz 1998). This may explain the extremely high levels of nitrate in some wells (150–180 mg/l in wells 5 and 6 respectively). Moreover, the prevailing arid conditions and scarcity of recharge in the St. Katherine area decrease the dilution and flushing potential of these aquifers. It should be noted that all wells in the study area are unprotected, i.e. are uncovered; this makes them easily subjected to external contamination that would worsen the water condition even more.

In conclusion, the present study presents evidence of high contamination of the groundwater aquifers in the town of St. Katherine, as determined by the presence of high numbers of faecal-indicator bacteria and elevated nitrate concentrations, particularly in the downstream zone where the majority of residents live. The mismanagement of sewage disposal and non-sewer sanitation represent high risks of pollution for the rapidly growing populations of the area. Therefore groundwater in this area cannot be considered safe for drinking unless properly treated. To achieve this safety we recommend the following:

1. A low technology method such as simple filtration through multiple cloth layers (Colwell *et al*. 2003) can be applied by residents as a short-term solution.
2. A monitoring program should be initiated for the St. Katherine area, aiming to study seasonal variation and to trace the extent of groundwater contamination, shown by the current investigation to increase rapidly.
3. The proper management of sewage disposal in the area should be expedited. It is necessary to overcome the problems that prevent the operation of the newly constructed sewage system, and to apply a suitable technique for wastewater recycling. A constructed wetland system of the Gravel Bed Hydroponic (GBH) type is highly recommended. The GBH system is a safe and inexpensive technology for wastewater treatment and reuse in small communities and it has been successfully applied for domestic sewage treatment in different areas of Egypt (Butler & Dewedar 1991).
4. The search for alternative drinking water resources for this culturally important city is highly recommended as a long-term strategy. This could be achieved by enhancing natural aquifer recharge through establishing simple traditional retardation dams for floodwater in Wadi El-Arbaein and/or Wadi El-Talaa. These Wadis are in the upstream parts away from the contaminated areas. Locating high-yielding wells in the fractured aquifer of these Wadis is another suggested alternative that deserve further detailed study.

REFERENCES

Bonwer H (1984) Elements of soil science and groundwater hydrology. In: Ground water pollution microbiology (Bitton G & Gerba CP, Eds.). John Wiley & Sons, Inc., New York. pp. 9-38.

Butler J & Dewedar A (1991) Gravel Bed hydroponic sewage treatment: Its performance, design and potential for crop production. Environmental pollution. 1-ICEP-1. Inderscince, Enterprises (Ltd). pp. 772-779.

Colwell R, Huq A, Islam M, Aziz K, Yunus M, Khan N, Mahmud A, Sack R, Nair G, Chakraborty J, Sack D & Cohen R (2003) Reduction of cholera in Bangladeshi villages by simple filtration. *Proceedings of the National Academy of Sciences* 100(3): 1051-1055.

Diab A (1984) Bacterial survey of well waters of Wadi El-Sheikh in south of Sinai. M.Sc. Thesis, Suez Canal University, Ismailia, Egypt.

Domenico P & Schwartz F (1998) Physical and Chemical Hydrogeology, 2nd ed. John Wiley and Sons.

Entry J & Farmer N (2001) Ground water quality: Movement of coliform bacteria and nutrients in ground water flowing through basalt and sand aquifers. *Journal of Environmental quality* 30: 1533-1539.

Eyal M & Hezkiyahu T (1980) Katherina Pluton-The Outlines of a Petrologic Framework. *Israel Journal of Earth Sciences* 29: 41-52.

Foster S (1985) Ground water pollution protection in developing countries. In: Theoretical Background, Hydrogeology and Practice of Groundwater Protection Zones. (Matthess G, Foster S & Skinner A, Eds.) Inter. Conf. Hydrogeology. Vol. 6. UNESCO-IUGS. IAH, Hannover, West Germany: pp. 159-166.

Ghodeif K, Dragon K & Gorski J (1999) Ground water quality in the Arabian-Nubian shield, Mount Sinai, Egypt. *Geologos* 4: 30-46.

Ghodeif, K & El-Shafey, M (2003) High-yield groundwater bearing fractures in crystalline rocks: A case study from Saint Katherine area, South Sinai, Egypt. In: 3rd International Conference on the Geology of Africa. In press.

Greenberg A, Clescerl L & Eaton A (1992) Standard methods for the examination of water and wastewater. 18th ed. Am. Public Health Assoc., Washington, DC.

Keswick BH (1984) Sources of groundwater pollution. In: Ground water pollution microbiology (Bitton G & Gerba CP, Eds.). John Wiley & Sons, Inc., New York. pp. 39-64.

MacFaddin JF (1985) Media for isolation, cultivation, identification and maintenance of medical bacteria. Williams & Wilkins, Baltimore/London.

Scott TM, Rose JB, Jenkins TM, Farrah SR & Lukasik J (2002) Microbial source tracking: current methodology and future directions. *Applied and Environmental Microbiology* 68(12): 5796-5803.

SCU report (1996) Evaluation of the Bedouin settlement activities in Sinai. Suez Canal Univ., Faculty of Environmental and Agricultural Sciences. ARE & WFP. Progress report No. 11.

Shendi EH & Geriesh MH (1998) Landfills as a tool for controlling the environmental pollution of the natural protectorates (Saint Catherine area as a case study. *Proceedings of the 5th conference on Geology and Sinai Development, Saint Katherine*: 65-81.

Soliman MFM & Zalat SM (2003) Prevalence and intensity of intestinal parasite infections in domestic goats of St. Katherine's Protectorate, Sinai, Egypt: Relation with some biological and ecological factors. Egyptian Journal of Biology 5: 78-85.

South Sinai Statistical data book (1997) Describing South Sinai. Information Center, South Sinai Governorate, El-Tor. (In Arabic).

UNESCO (1984) Ground water in hard rocks. Project 8.6 of the International Hydrological Programs, United Nations, UNESCO, 197pp.

USEPA (1986) Ambient water quality criteria for bacteria, office of water regulations and standards, criteria and standards division, U.S. Environmental Protection Agency, Washington DC, Federal Register 51:45

Ward MH, Mark SD, Kantor KP, Wesisenburger DD, Correavillasenor A & Zahm SH (1996) Drinking water nitrate and the risk of non-Hodgkin's lymphoma. *Epidemiology* 7: 465-471.

WHO (1998) Draft guidelines for safe recreational-water environments: Coastal and fresh water, draft for consultation, Geneva, October 1998, World Health Organization (EOS/DRAFT/98.14), Geneva, 207 pages.

Yates MV & Yates SR (1988) Modeling microbial fate in the subsurface environment. *Critical Review in Environmental Control* 17: 307-344.

الملخص العربى

تقييم تلوث المياه الجوفية فى منطقة التراث الإنسانى العالمى بمحمية سانت كاترين – مصر

هشام عبدالله[1]، كمال غُديف[2]، سحر الشطوري[1]، أحمد دويدار[1]

1. قسم النبات – كلية العلوم – جامعة قناة السويس - الإسماعيلية
2. قسم الجيولوجيا – كلية العلوم – جامعة قناة السويس - الإسماعيلية

تعتبر المياه الجوفية المصدر الوحيد للمياه فى مدينة سانت كاترين بمحافظة جنوب سيناء، التى تتميز بزيادة سكانية مضطردة ونشاط سياحى مكثف. وبالرغم من ذلك فإن الغالبية العظمى من منازل المدينة تعتمد على أنظمة بدائية لتجميع مخلفات الصرف الصحى وهي عبارة عن خزانات تجميع غير معزولة بجوار المنازل. بالتالي يسهل تسرب الملوثات العضوية والميكروبية من خزانات الصرف إلى المياه الجوفية، مما ينتج عنه من مخاطر التلوث البيئى وإنتشار الأمراض والأوبئة. لذلك إستهدفت هذه الدراسة تحديد مدى تلوث المياه الجوفية فى منطقة التراث الإنسانى العالمى بمحمية سانت كاترين وصلاحيتها للإستخدام الآدمي وكذلك تقييم خطورة إنتشار الملوثات خلال الطبقات الهيدروجيولوجية المميزة لمنطقة سانت كاترين. علي ذلك تم إختيار عدد 14 بئرا ممثلين للتجمعات السكانية المختلفة وممتدة بطول مجرى المياه الجوفية بالمنطقة. خلال الدراسة تم إجراء تحاليل مكثفة للخواص الطبيعية والكيميائية والميكروبيولوجية لمياه هذه الآبار. وقد خلصت الدراسة إلى وجود نسب عالية من الملوثات الميكروبية والكيميائية وبخاصة النترات فى جميع آبار المنطقة محل الدراسة، مما يجعلها غير صالحة للإستهلاك الآدمى طبقا للمقاييس المصرية ومنظمة الصحة العالمية WHO أثبتت التحاليل الميكروبية وجود أعداد عالية من دلائل التلوث البرازى البكتيري fecal coliform and fecal streptococci حيث تراوحت اعدادها بين 2 - 142 خلية/ 100مل, كما وجدت أعداد كبيرة من البكتيريا الممرضة مثل *Vibrio*, *Shigella* and *Salmonella* فى جميع الآبار تحت الدراسة. كما توضح الدراسة إحتمالية سرعة إنتشار الملوثات مع تيار المياه الجوفية نتيجة للتركيب الهيدروجيولوجي المميز للمنطقة حيث تتكون الطبقة السطحية من غرين تليها طبقة كسر الجرانيت ذات فراغات بينية واسعة تسهل مرور الملوثات بسرعة ولا تسمح بترشحيها. كما أن طبقة الجرانيت تحدد عمق حفر الآبار نظرا لصعوبة أعمال الحفر بها. ومما يزيد من حجم مشكلة تلوث المياه الجوفيه بسانت كاترين ندرة مياه الأمطار بصفة عامة خلال السنوات الأخيرة وسيادة المناخ الجاف كذلك الأستخدام الجائر لمياه الآبار وعدم وجود أغطية لفوهات الآبار.

وقد انتهت الدراسة الي دق ناقوس الخطر للتنبيه للوضع المتردي لمياه الآبار في سانت كاترين، كما بينت أن مصدر التلوث الأساسي هو تسرب مياه الصرف الصحي الي الخزانات الجوفية. وقد تم وضع بعض التوصيات والحلول المقترحة التى قد تساهم فى حل مشكلة المياه كيفاً وكماً بمنطقة سانت كاترين فيما يلى:

1- ضرورة وضع البرامج الفورية لاستخدام تقنيات رخيصة كالترشيح البسيط للمياه داخل المنازل كحل علي المدي القصير.

2- إيجاد برنامج متابعة يهدف إلى تتبع مسار وتلوث المياه الجوفية، الذى أثبتت الدراسة أنه فى زيادة مستمرة.

3- وجوب عمل نظام صرف صحى للمنطقة لمعالجة وإعادة إستخدام المياه المعالجة فى أغراض الرى. ومن الضرورى أن يشتمل نظام المعالجة على شبكة تجميع لمياه الصرف من المنازل ونظام معالجة مياه لإعادة الإستخدام يتناسب مع البيئة، ويقترح تطبيق نظام الأحواض الزلطية المستزرعة(Gravel Bed Hydroponic System (GBH الذى ثبت نجاحه فى مناطق متعدده بمصر.

4- لتعظيم الموارد المائية للمنطقة يجب الإستفادة من المياه السطحية الناتجة عن الأمطار والتى تفقد خلال إنسيابها فى الوديان كما يحدث فى وادى التلعة، وذلك بعمل سدود إعتراضية لتخزين المياه فى الخزان الجوفى أو تحويل مسارها وتجميعها فى أنابيب للإستفادة منها فى أغراض الشرب والرى.