IMPACT OF SEPTIC SYSTEM ON GROUND WATER QUALITY IN A NILE VALLEY VILLAGE, EGYPT

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ABSTRACT

Sewage is the primary source of pathogenic microbial contamination of ground water as it is in surface water. Bacteria are the most diverse microbes within this group with respect to their ability to travel through soil matrix. In addition, many diseases caused by bacteria such as diarrhoeal, dysentery, cholera, and typhoid fever. The threat to public health due to the transmission of pathogenic bacterial organisms from sewage system to ground water is reported worldwide (FAO, 1979). Although, it is generally agreed that the soil complex provides some protection, it is by no means eliminates it.

The situation of sewage contamination is worsening due to the unsafe method of sewage system construction and the shallow depth of water table. Wastewater in rural areas of Upper Egypt is disposed and collected into an underground sewage room. The sewage room in rural areas is constructed to be in direct contact with ground water. Handpumps, 17 m deep, and wells, 50 m deep are used to supply drinking water in rural areas. The shallow depth of handpumps and high capacity of wells is likely to create a susceptible condition of rural water supply. However, detection of pathogenic bacteria such as fecal coliform in the handpump and well water provides an indication of biological contamination from sewage system.

In this investigation, water samples from many handpumps and deep well s in an Nile Valley village, were analyzed biologically and chemically. All the samples were reported pathogenic contaminated. Therefore, immediate action is needed to prevent the pathogenic bacteria leaching from sewage rooms in Upper Egypt part of Nile Valley aquifer. In addition, the handpumps and wells must be dug deeper and far away from the sewage tank.

KEYWORDS: Sewage; septic tank; rural water supply; handpump; fecal contamination; ground water quality.

INTRODUCTION

Domestic septic system effluent typically contains about $3x10^7$ coliform bacteria/100 mL and, following some types of human viral infections up to $1x10^7$ virus/L (DeBorde et al. 1998).

In rural areas of Egypt where residents, schools, worship buildings, and other businesses depend on ground water for their potable water and on septic systems for wastewater disposal (Kuttab 1993). All volume of liquid portion of sewage effluent leaves the septic tank and percolate to the underlying ground water. Thus, such systems represent the largest volumetric source of pathogenic organisms to the ground water. Furthermore, the method of which the septic tank (sewage room) is constructed makes it easy for such pathogenic organisms to leach and move toward subsurface environment. This is due to the fact that, there is a direct contact between the wastewater in the sewage room and the surround ground water.

In recent years, most of the rural areas were provided with the municipal piped water. Deep wells, 50 m from ground surface, were used to extract and supply ground water. This piped water is distributed to residents with minimal charge. In addition, quality of that piped water is not completely suitable for rural households. As example, the total dissolved solids and sulfate ion of that piped water is around 500 and 300 mg/l, respectively. For those reasons, many of households in the rural areas still use the handpump, 15 m deep, to provide them with drinking water. Drinking water that is contaminated with pathogenic organisms leads to many waterborne diseases such as diarrhea (Platenburg and Zaki 1993).

This study extends previous work (Shamrukh and Khalaf 2000) by using other biological indicator. In the recent work, many ground water samples from handpumps and water supply wells were examined. The examination includes chemical analysis and biological testing. The chemical analysis includes pH, total dissolved solids, and some other ions. PathoScreen medium of Hach Company was used as an indicator of biological contamination. This medium indicated the presence or absence of fecal coliform in the water samples. Four sites of handpumps and two extraction wells in Upper Egypt village were selected to apply this study.

SITE DESCRIPTION

Hydrogeological Setting

The Nile Valley aquifer located between Aswan and Cairo, 900 km length. The Nile River has formed a long narrow valley, about 20 km in width. The edges of the valley on both the east and west flanks are marked by steep erosional scarps that rise greatly onto adjacent desert plateaus. The climate in summer is hot (38°C) and dry, being cold (12°C) with some precipitation in winter. The annual average precipitation is less than 20 mm, which is insignificant. The relative humidity in winter is higher than in summer, varying between 25% and 55%.

A village in the Abou-Tishit County was selected to carry out this investigation. This county is one of the counties of Kena Governorate in Nile Valley, Upper Egypt. The geology of the Nile valley in the site can be classified into two geologic units. The Nile River alluvium, which comprises the main aquifer and the basement rocks. In the floodplain part, the aquifer is formed from graded sand and gravel and covered by a clay-silt layer, which creates semi-confined conditions as shown in Fig. 1. The basement formation is composed of sandstone and shales of clay, which act as the impervious boundary at 200~300 m from surface.

The Nile aquifer in the study site is not a resource in itself, but acts as a reservoir. The only significant recharge source to the aquifer is the infiltration of leakage, irrigation water and seepage from irrigation canals. Discharge from the aquifer occurs due to flow to Nile River, extraction pumping wells and evapotranspiration from the clay-silt layer. The aquifer generally contains easily accessible fresh water that is used for both drinking and irrigation. The aquifer in the flood plain is highly productive and the groundwater salinity is below 1000 mg/l. Pollution of groundwater in the region may originate from agricultural, domestic, or industrial activities.

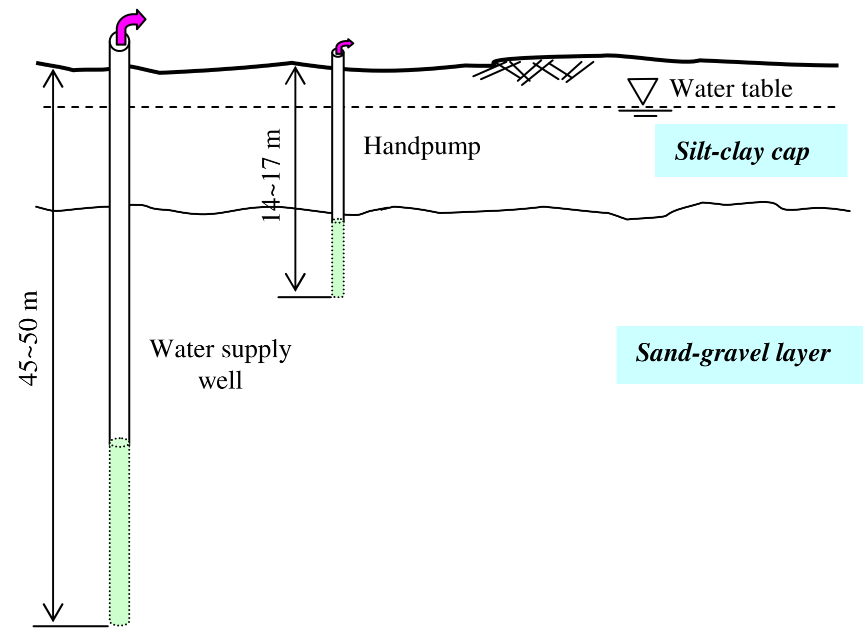

Fig. 1 Hydrogeology of Nile valley aquifer with handpumps and extraction wells

Sewage Disposal

The rural areas in the Nile Valley consist of scattered villages where residents live. All the rural areas in Nile Valley are not provided with the sewer system to collect and treatment the sewage. Septic system is the traditional way of the disposal of domestic wastewater. The used septic system is completely different than the typical one (septic tank and drainfield). Wastewater of each rural household is collected through a collection sewer and discharged into one or more holding room of sewage. This room is called a sewage room as shown in Fig. 2. Dimensions of that sewage room is about

3 m by 3 m horizontal area in 3 m depth. This depth is variable and the room must be dug till the ground water appears. The vertical walls of the sewage room are constructed from the brick. No foundation or lined bed is used to prevent the direct contact and leaching of the wastewater from the sewage room to ground water. This situation creates dangerous threat to the subsurface environment. Thus, the pathogenic organisms are easily move with ground water flow to contaminate the closest drinking water supplies (Fig. 2).

Ground Water Supply

Drinking water needs for households in the Nile Valley is supplied through extraction deep wells and group of handpumps which were shown in Fig. 1. The major part of drinking water is provided from wells filed. The well filed consist of two extractions wells, 45 to 55 m deep, with capacity of 2200 m^3/day. Ground water is lifted from those two deep wells to a high elevated tank and to a distribution network. It is believed that this depth of current extraction wells is safe from biological and other surface contaminants. Handpumps usually extract water from the top portion of the sandy clay layer penetrating the silt-clay cap. Therefore, their depths are around 14 to 17 m below the ground surface (Fig. 2). The screen length of that handpump is around 1.5 to 2 m. Discharge of the handpump is about 0.5 to 1.0 m^3 /day. The Handpumps in the study area are located in distance (x) from the sewage room in range of 10 to 25 m. That short distance because of the handpump and sewage room is usually used to serve the same household. Consequently, the shallow depth and close distance of handpumps make them more vulnerable to biological contamination from the sewage room.

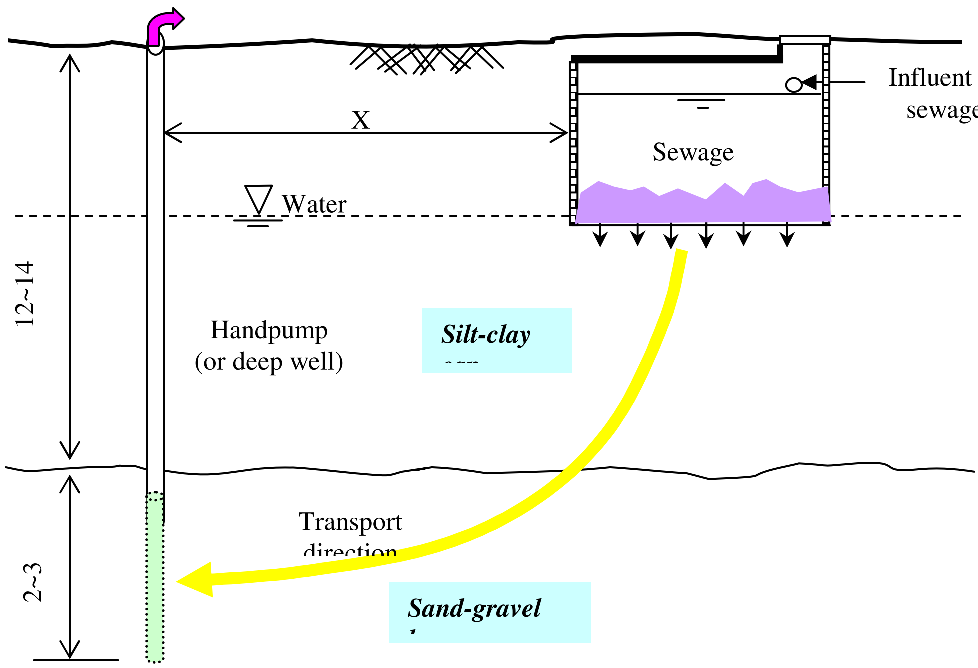

Fig. 2 Schematic diagram of the sewage room and the transport to handpump

SAMPLES AND ANALYSIS

Two extraction wells and four locations of handpumps were selected to carry out this investigation during the summer of 1999. The locations of those ground water sampling handpumps and extraction wells is shown in Fig. 3. The distance (x) between the handpump and the sewage room is an important parameter in the occurrence of biological contamination. That distance was variable and in the range of 10 to 25 m, as shown later in Table 1. The samples were taken from those seven sampling sites and incubated for 24 to 72 hr after the addition of the reagents. All samples were analyzed chemically and bacteriologically on the contents of fecal coliform. Coliforms are species that inhabit the intestines of humans and other warm-blooded animals. Presence of fecal coliform in large number in water samples is indicative of human contamination (El Attar et al. 1982). To detect fecal contamination, a PathoScreen medium from Hach Company was used.

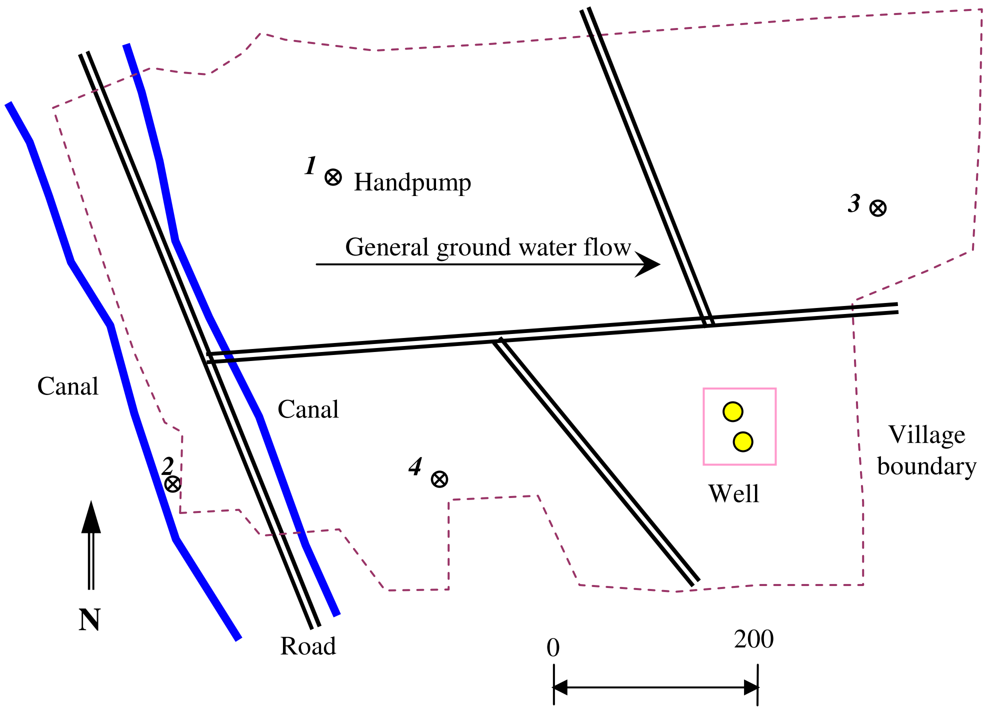

Fig. 3 Study site location and schematic diagram of sampled handpumps

Hach's PathoScreen medium can detect *Salmonella, Proteus, Klebsiella, Citrobacter, Clostridium, Edwardsiella* and other hydrogen sulfide-producing organisms proven to be associated with fecal contamination and the presence of coliform. In most tropical climates, such our site, indigenous E. coli positive reactions when traditional coliform tests are used. These positive reactions may not indicate fecal contamination. However, indigenous E. coli does not interfere with the PathoScreen test, which makes it an alternative to coliform testing. Most Probable Number (MPN) technique was used in the microbiological testing. A set of five tubes, 20-mL, at each sampling site was examined to predict statistically MPN for each sample. PathoScreen medium was used as a powder pillows, one pillow is added for each 20-mL sample. Samples were incubated at 25 to 35^{o}C for 12 till 72 hr. Positive samples are easily identified by the formation of a black solution or black precipitate.

RESULTS AND DISCUSSION

The results of microbiological and geochemical testing of ground water of handpumps and extraction wells are presented in Table 1. All biological results are expressed as the numbers of positive tubes in order to facilitate the MPN statistical calculation. The relationship between the number of positive tubes and MPN index is taken from the literature (Platenburg and Zaki 1993). Increasing the number of positive tubes indicates statistically large number of waterborne pathogens.

Microbiological Analysis

Microbiological results that presented in Table 1 and the effect of some parameters on it will be discussed. It is very clear that all the selected and analyzed handpump sites are biologically contaminated. Furthermore, contamination with fecal coliform was detected in high levels. It is anticipated that the distance (x), the presence of other water resources and the discharge of handpump affect the level of contamination (i.e., number of positive tubes). From results (Table 1), the increasing of distance (x) decreases the number of positive tubes of fecal coliform. The relationship between distance (x) from the sewage room and MPN/100-mL of fecal coliform for handpumps is shown in Fig. 4. The long the distance the more the travel time needed for microorganisms originating from sewage room to approach the screen of handpump. So, if that travel time is shorter than the survival time of those microorganisms then they can reach and pollute the handpump water. It is observed from Fig. 4, that the most far away site, which is site (4), has the smallest number of positive tubes of fecal coliform. Because there are many variables other than distance affect the number of positive tubes, the minimum safe distance for the handpump from the sewage room could not be estimated.

Table 1. Results of microbiological and geochemical testing

Site	Distance (x) m	*Microbiological results*		*Geochemical results*			
		Positive sample	No. of ✓ tubes	pH	TDS	NO_3	PO_4
1	8	Positive ✓	4	7.2	300	1.4	1.1
2	10	✓	2	7.5	220	0.6	0.6
3	12	✓	3	7.4	480	1.6	0.9
4	18	✓	2	7.6	230	2.5	1.3
Well-1	40	✓	0	7.7	540	9.5	0.6
Well-2	35	x	1	7.6	500	7	1.0
Sewage (Khalil and Hussein 1997)				7.3	950	2.1	22

*: Number of positive tubes out of the total set (five tubes)

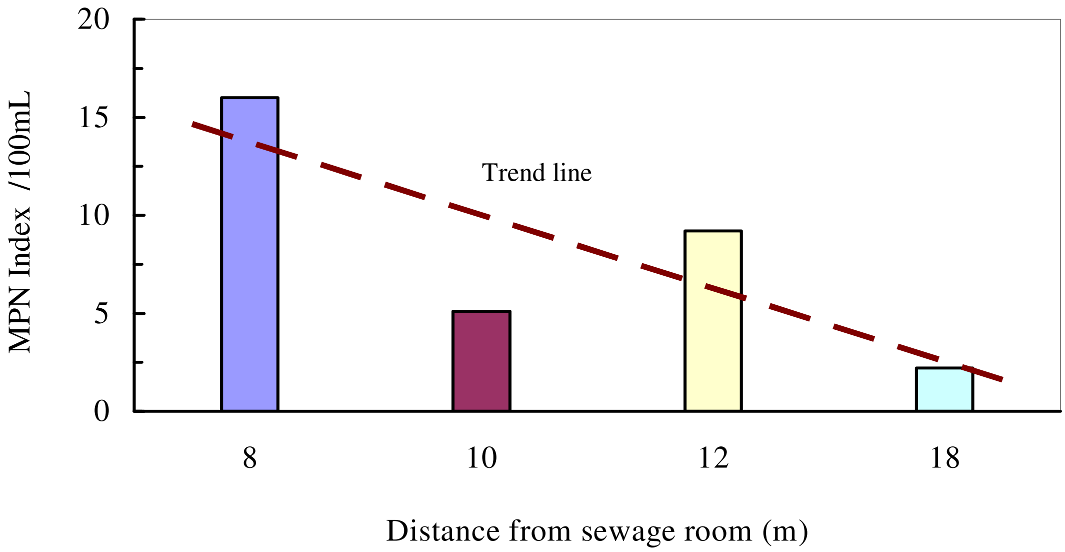

Fig. 4 MPN index of fecal coliform for the four handpump sites

Existence of any recharging water resources close up to handpump is anticipated to affect the level of fecal contamination. From Table 1 and despite the site (2) is the closest to sewage room than sites (3) and (4) but it has less or equal number of positive tubes. This result may be due to the seeping of fresh water from a water stream that located 6 m to site (2) as was showed in Fig. 3. This water stream provides an additional water resource for handpump (2) leading to dilution of pathogens count in the handpump water.

In addition, the discharge rate of handpump influences the travel time of pathogens. Increasing of discharge will increase the velocity of pore water, which decreases the travel time of pathogens to handpump. In Table 1, the number of positive tubes of site (4) is more than site (3) despite site (4) is far away from the sewage room than site (3). This finding can be referred to the actual high discharge rate from site (4) handpump. In fact there is a small pump, about 1 HP, installed on the handpump of site (4) which is used to irrigate the garden of the owner.

On the other hand, the microbiological results (Table 1) revealed that there is a tracer of fecal contamination of extraction wells (Well-2). Despite of the high discharge rate of those two wells (2200 m^3/day), and the long distance from surround sewage rooms, the degree of fecal contamination is very low. In fact the deep depth (50 m) of well screen and the far distance (40 m) from the nearest sewage room work to protect those wells. Supply water from those deep wells is safer than using the handpumps but it needs to dig them in the future deeper.

Geochemical Analysis

As reported in the literature (DeBorde et al. 1998), raw sewage of domestic wastewater has high concentrations of heavy metals and dissolved solids such as sodium, chloride, nitrogen, phosphate and organic constituents with low pH. A complete list of raw wastewater characteristics in Egypt is given by Khalil and Hussein (1997). In general, results of all sampled handpump locations indicate that pH is lower than the background deep ground water (pH=7.6). These low pHs also reveal the impact of sewage percolating water on the handpump water. The only exception is site (2) which is affected by the fresh seeping water from the closed canal. Moreover, the influence of that seeping fresh water on ground water at site (2) is clear on decreasing the TDS of it, as shown in Table 1.

From results shown in Table 1, the impact of sampling distance from sewage room on TDS, nitrate, phosphate concentrations is not clear. May be there are some other local variables affected those concentrations rather than sewage. In general, the nitrate and phosphate concentration in sampled ground water is elevated than the surround fresh water. Those high concentrations may be due to the impact of sewage room on handpumps and to a less on wells water. In fact, wastewater effluent has a high content of nitrogen as ammonium and phosphorus. Another source of elevated nitrate and phosphate concentrations in ground water samples may be the using of chemical fertilizers in agricultural activity in the studied area. This is very clear in the elevated nitrate content of well-1 and 2 (Table 1). Due to this interfere, the relationship between distance (x) from the sewage room and TDS, nitrate, and phosphate concentrations in handpump water could not be drawn.

CONCLUSION

Rural residents in the Nile Valley use the sewage room as the disposal facility of household wastewater. On the other hand, drinking water is supplied by shallow handpumps and deep extraction wells. The construction method of sewage room, direct contact with groundwater, creates a dangerous point source of ground water pollution. The water samples from four handpumps and two deep wells were analyzed biologically. As anticipated all shallow and close sites were microbiologically contaminated from the nearest sewage room. Fecal coliform was detected in the ground water of all handpump samples and to a less degree in deep wells water. The distance of handpump location from the sewage room has a clear impact on the level of fecal contamination. Periodical biological examination of wells water is recommended to insure their safety. More work is needed to specify the safe practical distance of the handpump. Also, an immediate action is required to use the appropriate method sewage room construction to prevent leaching or to build it impermeable. In addition, current handpumps must be avoided to provide drinking water unless it deepens to a safe depth.

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