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Assessment of Water Quality for Some Roof Tanks in Alkharj Governorate, KSA

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Abstract.- This study evaluates the sanitary conditions of ten selected roof water tanks in Alkharj Governorate, KSA and examines their water quality. A survey was conducted using a questionnaire to collect information about the sanitation of these tanks. The physical, chemical and biological parameters of 60 water samples were examined using standard methods. The survey results revealed that 40% of tanks received unsatisfactory grades. The physical and chemical analyses indicated that the turbidity and levels of residual chlorine were above the maximum permissible water limits set by the SASO, WHO and EPA. The Cd, Pb, Fe, and Mn concentrations also exceeded the standards. A microbiological examination revealed that all tanks were contaminated with heterotrophic bacteria: 80% contained coliform, 30% contained *fecal coliforms* and *E.coli* was not detected. *Streptococcus fecalis* was isolated from 1.6% of water samples. Moreover, 60% of the tanks contained algal counts exceeding 10^3 unit/l. The results support the need for periodic monitoring and cleaning of these tanks.

Keywords: KSA; roof tanks; water standards; water storage; water quality.

INTRODUCTION

Water quality and safety is an important aspect of public health. Several studies have described water issues in the Arab World. Water situation in the Kingdom of Saudi Arabia (KSA) and the Gulf countries reflects the individuality of this region (Qunaibet, 2002) due to its location within an arid and semi-arid belt characterized by the scarcity of water resources (Al-Zahrani and Munir, 2007).

Saudi government has attempted to provide household water and sanitation services during the past three decades. Therefore, more than half (75%) of the Saudi households are connected to municipal water supply and about 50% are connected to sewers. The unserved quarter receives their water via water trucks, wells and water containers (Elhadj, 2004).

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Water quality problems in storage facilities may be classified as microbiological, chemical or physical. The excessive age of the water in many storage facilities has most likely caused the deterioration of water quality. The long holding times leading to the excessive age of the water may be conducive to microbial growth and chemical changes (AWWA, 2002). Water tanks, particularly roof tanks, may be a menace to health if they are not properly located, constructed and safely maintained. These tanks have always generated unsatisfactory bacteriological results, outbreaks of waterborne diseases, or even widespread epidemics (LeChevallier, 1990).

The Saudi Arabian Standards Organization (SASO) has issued decree No.701/2000 to specify the physical, chemical and biological guidelines for drinking water quality, and steps are being taken to maintain continuous surveillance over the water quality by periodically checking all relevant water quality parameters and confirming that the drinking water from the desalination plants complies with the SASO standards (Kutty *et al.*, 1995). However, authorities have failed to install efficient system for inspecting, continuously monitoring and supervising household water tanks. In addition, the Saudi Ministry of Municipal and Rural Affairs (2001) has listed the technical and health requirements necessary for domestic water tanks to protect stored water from pollution and protect public health overall. However, the majority of home owners are careless when applying the instructions regarding the design, construction and maintenance of roof water tanks due to the weakly enforced legislation. Other issues must also be considered, including awareness regarding the regular monitoring and a lack of training for appropriate cleaning. Therefore, this study was conducted to carry out a sanitary survey of the roof water tanks in different areas located in Al-Kharj Governorate and assess the water quality in these tanks relative to the SASO drinking water standards and other international guidelines specified by the World Health Organization (WHO) (1993) and the Environmental Protection Agency (EPA) (2003) that gauge the safety of water supplies destined for human consumption.

MATERIALS AND METHODS

Study setting and design

Al-Kharj Governorate is subdivided into new and old districts. The old districts include the following: Al-Aziziyah, Al-Oaqem, Al-Salmaneyah, Al-Hezam, Al-Sheaba, Al-Nasefa, Malaf Awad and Farzan. The new districts include the following: Al-Nahdah, Hay Bin Turki, Saudi Arabia, Al-Faisaliah, and Al-Khaldiya. Two districts were randomly selected with one from old district (Al-Salmaneyah) and one from new district (Al-Nahdah). Five roof tanks were chosen at random from each district, providing ten tanks for the study.

Data collection

A survey of regarding roof water tanks in both districts has been undertaken using a pre-designed questionnaire to evaluate the roof sanitary condition of the water tanks. The items used for scoring included the frequency of cleaning the interior (40 points), the condition and type of the interior paint or liner (15 points), the construction material (10 points), the availability of a cover (10 points), and 5 points were given according to the availability of each of the following: exterior paint or plaster, exterior ladder, interior ladder, wash water and surplus pipes and/or a float valve. The total possible score was 100. The scores of 85-100, 75-84, 60 to 74 and less than 60 were graded as highly satisfactory, satisfactory, fair and unsatisfactory, respectively, according to Abd El-Salam and El-Ghitany (2007).

Sampling and analysis

Water samples were collected from each tank once a month over six months to provide 60 samples. The collection, preservation, and physical-chemical analyses and biological examination of the water samples were performed in accordance with the Standard Methods for the Examination of Water and Wastewater (Eaton and Franson, 2005). The studied physicochemical parameters included the pH, turbidity, total dissolved solids (TDS), free residual chlorine, alkalinity, and total hardness. Assessing certain parameters required on-site sample testing (e.g., pH, turbidity, and free residual chlorine). The concentrations of seven heavy metals [cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), and zinc (Zn)] were determined using an Atomic Absorption Spectrophotometer Schimadzu model AA-6650 flame system (Eaton and Franson, 2005). The bacteriological examination included a total viable count (TVC), a total and fecal coliforms count and counts of both *E. coli* and fecal streptococci.

Statistical analysis

After completing the assessments, the data were revised, coded, entered into a computer and statistically analyzed using the Statistical Package for Social Sciences (SPSS) version 11.0 computer software package for tabulation and analysis (Daniel, 1995).

RESULTS AND DISCUSSION

Sanitary survey

The survey results from the current study revealed that, although high buildings are uncommon in the studied area, the buildings with less than four floors provide water through the roof tanks for consumption during high demand periods. Contaminants from the tank materials may be leached into the drinking water causing contamination (U.S.EPA, 2006). Half of these tanks are made of fiberglass (30%) and plastics (20%); 30% are constructed from galvanized steel, and 20% are composed of reinforced cement or concrete. Fiberglass is the best and safest material for constructing water tanks because it can withstand the high temperatures that occur on its surfaces. However, fiberglass provides a fertile environment for bacterial growth in these reservoirs. Galvanized steel is a superior environmental choice over plastic but tends rust during long use (Almataz, 2008).

In Egypt, roof water reservoirs were studied by Alzenvli (2004) to detect any danger toward consumer health and to inspect the quality of the water; reinforced concrete tanks lined with ceramic to avoid rough surfaces or tanks made of stainless steel are the best types of water tanks, provided that they can be closed. The use of galvanized steel reservoirs is not recommended due to rust formation and the leaching of metals or other components into the water; in addition, any painting material may seep into the water. Moreover, asbestos tanks are not recommended because asbestos may separate from the tanks and penetrate the walls of the stomach or intestines after being consumed through drinking water, causing cancer in some cases. In addition, plastic tanks allow certain types of bacteria to stick to the plastic surface an enable growth. According to the U.S.EPA (2006), cement-lined storage tanks may leach calcium carbonate into the water, increasing the alkalinity and pH of the water. This leaching process depends on the age, type, and the contact time with water of the cement lining with.

Figure 1 indicates that one-third of the roof water tanks (30%) are uncovered; consequently, the stored water might be contaminated with animal and bird feces, as well as dust and airborne particulates. Uncovered tanks also facilitate the growth of algae when they are exposed to sunlight, lead to undesirable changes in the taste, odor and color of water. In addition, insects, nematodes, and other invertebrates may multiply inside the roof water tanks (AWWA, 2002). These results were lower than those obtained from a similar survey conducted in Egypt (2007): 40% of the studied roof water tanks remained uncovered (Abd El-Salam and El-Ghitany, 2007).

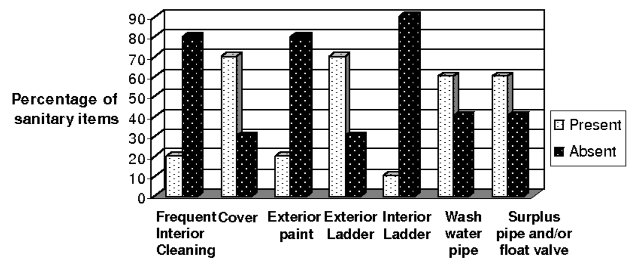

Fig. 1. Sanitary conditions of the studied roof water tanks in Alkharj Governorate, Kingdom of Saudi Arabia

Stored water has been responsible for major outbreaks of severe gastric illnesses (AWWA, 2002). El-Sehimy (1986) recommended that water tanks be cleaned regularly; cleaning once a month to once every three months should be suitable for human use. In the present study, most of the surveyed roof tanks (80%) were not cleaned at least once every six months, as stipulated by the Saudi Ministry of Municipal and Rural Affairs (2001) requirements; the remainder (20%) were cleaned twice a year. Similar results were obtained from a survey of the roof tanks in Riyadh, KSA conducted by Al-ElShaikh (2005) stating that 23.9% of water tanks were cleaned every six months, while the rest were cleaned after periods exceeding 12 months.

The results of the present study were also consistent with the survey results obtained by Mullah (2010) in Jeddah, KSA indicating that most (81%) of the water tanks were cleaned every two or more years, while the rest (19%) were cleaned at least every year. Outside the KSA, a survey for assessing the quality of the roof water tanks in Egypt revealed better sanitation practices than those reported in the present study: 40% were cleaned at least every month, while 60% were not cleaned continuously (Abd El-Salam and El-Ghitany, 2007).

The interior paint or lining protects the tank against corrosion by aqueous chlorine and prevents algal growth (El-Sehimy, 1986). Ceramic linings are the best choice because their glazed surfaces facilitate the cleaning and disinfection processes. These tanks represented the highest percentage among the surveyed tanks. Tile-lined tanks promoted microbial growth on the surface of the tanks encompassed only 20% of the tanks. This finding contradicts the results obtained by Schonen and Thofern (1981) and Abd El-Salam and El-Ghitany (2007) indicating that tile-lined tanks were the most common (70%).

The sanitation scores of more than one third (40%) of the investigated roof water tanks were unsatisfactory, more than quarter (30%) were fair, 20% were satisfactory, and only 10% were highly satisfactory. These results contrasted with findings of a survey conducted in Egypt indicating that more than half of the studied roof tanks had sanitation scores that were unsatisfactory, 20% were fair, and only 20% were either satisfactory or highly satisfactory (Abd El-Salam and El-Ghitany, 2007).

In Riyadh, Al-ElShaikh (2005) demonstrated that most citizens (71%) do not use the domestic water reservoir for drinking. Of these 71%, half used domestic water reservoir in cooking, revealing that citizens of the central and southern areas of the Riyadh region are less likely to use the household water reservoirs for drinking and cooking; this tendency may be because most of the population lives in apartments and do not trust the cleanliness of the tanks on their buildings. However, the denizens of the East area of Riyadh commonly used water tanks for drinking and cooking due to the economic level of the population or their confidence in the water reservoirs at their home. Another study carried out by Al-Saleh and Al-Doush (1998) found that the household water surveyed in Riyadh region was used mainly for drinking and cooking. This finding confirmed the results of the present study; the survey results indicated that more than half of the households (80%) did not use roof water tank for drinking, while the rest (20%) used it for food preparation. Notably, the distributions of usage behavior varied from one area to another area in the Al-Kharj Governorate.

Physical and chemical quality of the roof water tanks

The average physical and chemical characteristics of the water samples collected from ten surveyed roof water tanks are shown Table I. The recorded pH values ranged from 6.9 to 7.6 with a mean of 7.3 and were in compliance with limits (6.5-8.5) specified by the SASO (2000), WHO (1993) and EPA (2003) standards. Similar results were obtained by Al-Salamah and Nassar (2009); in that study, every water sample collected from the Qassim region, KSA had pH values from 6.77 to 7.28 with a mean of 7.02. The results of the present study were also consistent with that of Abdelmonem *et al*. (1990), who found that the average pH of the water samples in Buraydah, KSA was 7.1. In contrast, Abed and Alwakee (2007) mentioned that all tap water samples collected from Riyadh, KSA had alkaline pH values above the allowable range (7.2-7.4).

The high turbidity levels in the water tanks are urgently problematic because high turbidly may shield disease-causing microorganisms from disinfection processes, stimulate the growth of bacteria, and generate a significant chlorine demand (WHO, 2008). In the present study all mean turbidity values violated the EPA (2003) limits (0.5-1.0 NTU), while only 20% of roof water tanks had mean turbidity values exceeding the desirable limits (less than 5 NTU and not more than 5.0 NTU) established in the WHO (1993) and SASO (2000) standards, respectively.

High TDS levels (greater than 1200 mg/l) may be objectionable to consumers because they cause excessive scale formation in water pipes, heaters, boilers and household appliances (WHO, 2008). In the present study, although lower levels of TDS ($\bar{x}$=966 mg/l) were measured than were reported in another study ($\bar{x}$=1190 mg/l) (Abdelmonem *et al*., 1990), all samples were above the enforcement level for TDS (500 mg/l) according to EPA (2003) standards, while 60% of the studied roof water tanks fell within the allowable TDS limits (1000 mg/l) according to SASO (2000). These high TDS values may be attributed to the old pipes and water tanks in the older selected districts located in the Southern Region of Al-Kharj province; these tanks may be damaged and have possibly experienced a lack of ongoing maintenance and cleaning. These results contradicted those reported by Al-ElShaikh (2007) indicating that 81% of the

Table I.- **Physical-chemical analyses and heavy metals concentrations of water samples collected from the selected roof water tanks in Alkharj Governorate, KSA.**

Parameters	Roof water tanks (n=10)	SASO (2000)	WHO standards (1993)	EPA (2003)
pH (units)	7.3±0.23	6.5-8.5	Not guideline[a]	6.5-8.5
Turbidity (NTU)	4.36±0.95[a]	> 5.0	Not guideline[b]	0.5-1.0
Total dissolves solids (mg/l)	966±202.02	1000	Not guideline	500
Free residual chlorine (mg/l)	0.075±0.04	Not included	Not included	Not included
Alkalinity (mg $CaCo_3$/l)	161±35.99	Not included	Not included	Not included
Total hardness (mg $CaCo_3$/l)	342±52.31	Not included	Not guideline[c]	Not included
Cadmium (mg/l)	0.13 (0.02-0.26)	0.003	0.003	0.005
Copper (mg/l)	0.07 (0.02-0.09)	1.2	2.0	1.3
Iron (mg/l)	0.54 (0.16-1.74)	0.3	Not guideline[d]	0.3
Lead	0.18 (0.06-0.39)	0.01	0.01	0.015
Manganese	1.03 (0.33-2.94)	0.05	0.5	0.05
Nickel	0.03 (0.01-0.06)	0.02	0.02	0.1
Zinc	2.98 (1.75-4.81)	2.6	3.0	5.0

[a]Desirable: 6.5-8.5
[b]Desirable: Less than 5 NUT
[c]Desirable: 150-500 mg/l
[d] Desirable: 0.3 mg/l

water samples exceeded the permissible TDS limits (1000 mg/l) for drinking water specified by the SASO (2000). The current study also contrasted with a survey carried out in Jeddah, KSA (2009) that stated the TDS values of the drinking water samples were compliant with the WHO (500 mg/l) and Saudi (1000 mg/l) standards (Hashim and El-Baggar, 2009). Khanfar (2008) evaluated the water quality in the Bel-Ahmar area in KSA and demonstrated that the majority of samples have TDS < 800 ppm. Higher results were obtained by Al-Redhaiman and Abdel Magid (2002) after studying the quality of 70 drinking water samples in the Qassim region, KSA; they found that the concentrations of TDS varied from 109 to 6995 mg/l with a mean of 1427 mg/l.

The long retention times for water stored in the reservoirs and/or the impact of high temperatures may reduce the disinfectant concentrations and trigger the release of ammonia via the decay of chloramines (U.S.EPA, 2006). In the current study, the free residual chlorine ranged from 0.028 mg/l to 0.191 mg/l with an average of 0.075 mg/l. Although the Saudi Ministry of Municipal and Rural Affairs (2001) stated that the residual chlorine must be regulated at 1.0 ppm in roof water tanks, all surveyed tanks were below this limit. Lower results were reported by Abd El-Salam and El-Ghitany (2007) indicating that there was almost no residual chlorine in the water samples from the roof tanks.

Although the alkalinity ranged from 95 to 210 mg $CaCO_3$/l, it exceeded 200 mg in the samples from only one roof water tank. Lower results were recorded in another study with a maximum alkalinity value <50 mg/l (Khanfar, 2008). The data for the total hardness revealed that every studied roof water tank had mean values below the maximum permissible limits (500 mg/l) established by the WHO (1993). This finding is consistent with that reported by Abd El-Salam and El-Ghitany (2007); this their study, all of the mean total hardness values in samples from roof water tanks were below the Egyptian limits. Lower values were obtained by Al-Salamah and Nassar (2009); the total hardness of all water samples in Qassim, KSA was 278.26 mg/l. Khanfar (2008) studied the water quality in the Bel-Ahmar area of the Southwestern region of Saudi Arabia and found that all samples had total hardness values above 400 mg/l.

Table I also presents the concentrations of the heavy metals in the water samples from the surveyed roof water tanks. This table revealed that, among the seven studied heavy metals, Cd and Pb appeared in high concentrations with means of 0.130 mg/l and 0.180 mg/l, respectively that exceed the SASO (2000) and WHO (1993) standards (0.003 mg/l and 0.01 mg/l, respectively). Similar results were obtained by Al-ElShaikh (2007), who found that Cd and Pb exceeded the allowable levels in all water samples in Riyadh, KSA.

Iron and manganese levels above 0.3 mg/l and 0.05 mg/l, respectively, tend to stain laundry and plumbing fixtures (WHO, 2008). In the present study, more than half (60%) of the studied roof water tanks had mean iron concentrations (0.536 mg/l) that exceeded the EPA (2003) standards (0.3 mg/l); the concentrations ranged from 0.157 to 1.742 mg/l. Although Mn data revealed that the maximum mean concentration was 2.941 mg/l in only one of the roof tanks, most tanks (90%) surpassed the 0.05 mg/l EPA (2003) limit for Mn.

Neither Cu (0.067 mg/l) nor Zn (2.979 mg/l) exceeded the WHO (2.0 mg/l and 3.0 mg/l) or EPA (1.3 mg/l and 5.0 mg/l) standards. In the United Kingdom, Fuge and Perkins (1991) analyzed the heavy metals concentrations in potable water and demonstrated that, despite the wide use of Cu piping for supplying water, low Cu values were detected. However, Zn levels were highly variable due to the dissolution of the Cu pipes.

In Riyadh, KSA, the heavy metals contents were measured in 101 of the household drinking water samples. This study found that some trace elements, such as Cd, Fe, Hg, Ni and Zn exceeded the published limits (Al-Saleh and Al-Doush, 1998). High concentrations of Pb, Cu, Zn and Cd may be dissolved in water from pipework and solder (Fuge *et al*., 1992). Trace metals in drinking water are positively correlated to the occurrence cardiovascular diseases, kidney-related disorders and various forms of cancer, among others (Goldberg *et al*., 1990). These values may be attributed to the water storage and plumbing systems.

Abdelmonem *et al*. (1990) studied the water quality in Buraydah, KSA and revealed that high concentrations of Cd and Pb (0.02-0.47 mg/l and 0.05-0.31 mg/l, respectively), medium concentration of Hg (0.00-0.004 mg/l) and low concentrations of Fe (0.56 mg/l), Zn (3.72 mg/l) and Cu (0.06 mg/l).

Biological quality of the roof water tanks

Microbiological contaminated drinking water may cause serious waterborne diseases, such as typhoid, cholera and hepatitis (Legnani *et al*., 1999). Bacterial growth is common on tank surfaces and other non-circulating areas in. Bacterial re-growth is encouraged by the insufficient residual disinfectant levels, high temperatures, adequate nutrient levels, dissolved oxygen depletion, and long water detention times (USACHPPM, 1997).

According to WHO guidelines, drinking water should not contain intensive pathogenic microorganisms that pose a danger to public health (EEA *et al*., 2002). Four fifths of all diseases reported in developing countries are water-borne. Diarrhea is the single leading cause of death among children in these countries (Diet and Health net, 2011).

A field study carried out by Al-Zahrani (1979) disclosed the public health aspects of the drinking water tanks in Riyadh city. This study covered 667 sites with 1807 total water samples; drinking water samples in the distribution network were safe and in compliance with the criteria recommended by SASO (2000). However, the water samples collected from reservoirs were bacteriologically contaminated due to their lack of periodic cleaning.

Bacteriological contamination was detected in more houses in the Shebaa area (38.4%) than in Abha city (7.9%), KSA. The desalinated water was contaminated during storage in household reservoirs rather than during transportation in the water tankers (Abu-Zeid *et al*., 1995).

The bacterial analyses of the collected water samples are presented in Table II. These data revealed that approximately all examined biological parameters violated the SASO (2000) drinking water standards. The Table demonstrates that, although all the ten surveyed roof water tanks were contaminated according to the Total Viable Count (TVC), four of them (40%) exhibited TVC that exceeded 10^2 Colony Forming Units (CFU)/ml, and one of them (10%) exceeded 10^3 CFU/ml at 37°C. The amount of time that water is stored in the roof tanks may facilitate the growth of heterotrophic bacteria in sediments, promoting their attachment to the inner wall of tanks and spreading biofilm over the surfaces (U.S.EPA, 2006).

Abdelmonem *et al*. (1990) studied the water contamination in Buraydah, KSA and found that 61% of samples were contaminated with the total bacterial counts ranging from 1.0 to 4.6×10^4 CFU/ml. The bacterial counts in 27% of samples exceeded 1.0×10^4 CFU/ml. Both *E. coli* and *salmonella* were isolated from 44%.

In the present study, although coliforms were detected in most (80%) of the studied roof water tanks, *fecal coliforms* were detected only in three tanks; *E. coli* was not detected in any tanks. Manwarring *et al*. (1980) examined the bacteriological quality of the drinking water in the central region of the KSA and reported that, although coliforms were detected in a quarter (25%) of the examined samples, *fecal coliforms* were detected in only one sample. In another study carried out by Alaa-EL-Din *et al*. (1994) to survey the quality of 319 tank water samples distributed in houses throughout the KSA, 5% of the samples contained elevated *fecal coliforms* levels. Al-ELShaikh (2007) studied the water quality in Riyadh, KSA and found that 38% of samples were contaminated with coliforms or *E. coli*.

AlOtaibi (2009) evaluated the bacteriological quality of the urban water sources in the Khamis Mushait Governorate in Southwestern Saudi Arabia. The total and fecal coliforms were detected in desalinated (12.9% and 3.23%), surface (80.0% and 60%), and well (100% and 87.88%) water, respectively. *Fecal streptococci* were also detected in 6.45% of the desalinated water, 53.33% of the surface water, and 57.58% of the well water. The contamination of the desalinated water that is the primary urban water source may occur during transportation from the desalination plant or in the consumer reservoirs.

In the present study, although three of the investigated roof water tanks contained higher *Streptococci* counts the SASO (2000) allows, *Streptococcus fecalis* were detected only in one sample collected from one tank. Similar results were obtained by Abd El-Salam and El-Ghitany (2007) while reporting the presence of indicator organisms, such as fecal coliforms and fecal streptococci, in the roof tanks of Alexandria, Egypt; however, *Streptococcus fecalis* were isolated from a quarter of the water samples.

Barbour *et al*. (1982) studied the bacterial contamination of water in the Al-Riyadh region, discovering that 58.57% of the examined samples were bacteriologically unacceptable and had failed to meet the Saudi standards; coliforms were detected in 60.5% of the examined water samples.

Al-Mohizea (1987) evaluated the bacteriological quality of water in the Riyadh area, revealing that the total bacterial counts varied from 3.0 to 3.7×10^4 CFU/ml with a mean value of 4.6×10^2 CFU/ml. Although coliforms were detected in more than half (67%) of the examined samples and ranged from 2.2 to 4.8×10^1 MPN/100ml, only three samples exceeded the permissible limits (10 MPN/100ml). *Fecal coliforms* were detected only in 8.3% of samples.

Abdel Magid (1997) investigated the chemical and microbiological quality of the potable water in the Qassim region of Saudi Arabia. For the chemical constituents, every water sample exceeded the permissible levels of the Saudi drinking water standards; the highest mean concentrations were found in the stored municipal water samples. The microbiological data indicated that the *total coliform* were too numerous to count.

A gastroenteritis outbreak from contaminated water in Hail, KSA was recorded by the General Health directorate of Hail (2003); this area has no municipal water network or sewerage system, and therefore the community receives their water supply from the AlMurma well. These people relied on this tank for to provide water for both drinking and non-drinking purposes. The water samples were contaminated with *E. coli*, *Salmonella* and/or *Pseudomonas* (Al-Mohaimeed and Al-mazroua, 2005).

In the present study, although most of the studied roof water tanks (70%) were equipped with covers and ceramic linings as shown in Figures 1 and 2, six tanks were contaminated with algae; the algal counts ranged from 8.94×10^3 to 6.0×10^4 unit/l with a mean value of 1.7564×10^4 unit/l. These levels might be attributed to algae that do not require sunlight to multiply, such as actinomycetes; the algae were not differentiated in this study (O'Connorr and O'Connorr, 2000).

Table II.- Biological examination of water samples collected from the selected roof water tanks in Alkharj Governorate, KSA.

Parameters	Roof water tankes (n=10)	SASO (2000)	WHO standards (1993)	EPA (2003)
Total viable counts (CFU[1]/ml)	$4.5x10^2±0.10x10^2$	Not more than 300 CFU/ml	Not mentioned	TT[3]
Total coliform count (MPN[2]/100 ml)	$1.26x10^4±0.04x10^4$	Not more than 1.0 MPN/100 ml	Not mentioned	<1/100 ml
Fecal coliform (MPN/100 ml)	49±10	Free	Not mentioned	Not included
E. coli (%)	0.0			
Streptococci (MPN/100 ml)	4.3±2.1	Free	Not mentiioned	Not included
S. fecalis (%)	1.6			
Total algal count (Unit/l)	$1.75x10^4±0.23x10^4$	Free	Not mentioned	Not included

Mean±SD.
[1]CFU, colony-forming units; [2]MPN: most probable number; [3]TT, treatment technique is specified, not the measured concentration.

Table III displays the correlation between the TVC and the total coliforms with some physical parameters, such as turbidity and residual chlorine. This table clearly indicates that there was a significant positive correlation between turbidity and both of the TVC and the total coliforms; an inverse correlation was observed between residual chlorine and both TVC and the total coliforms.

Table III.- Correlation between Total Viable Count and Total coliform count with turbidity and residual chlorine parameters of the selected roof water tanks in Alkharj Governorate, KSA (n=60).

Bacterial indicators	Turbidity		Free chlorine residual	
	Correlation coefficient	Sig. (2-tailed)	Correlation coefficient	Sig. (2-tailed)
Total viable count	0.692 [a]	0.026	-0.575[a]	0.042
Total coliforms	0.748 [a]	0.013	-0.909 [a]	0.059

[a]Correlation is significant at 0.05 level (2-tailed)

CONCLUSION AND RECOMMENDATIONS

Based upon the guidelines for drinking water contents, the surveyed roof water tanks contained water unfit for human use. Periodical monitoring and clearing is essential to ensure clean water supply.

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