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Total Bacterial Quantification in Homes' Water Tanks

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Abstract

Drinking water quality is of great concern around the world. Water that is stored un-hygienically may be re-contaminated and this may represent a public health hazard. The water quality parameters of concern were microbial contamination. Water pollution caused by fecal contamination is a serious problem due to the potential for contracting diseases from pathogens. The presence of pathogens is determined by testing for an "indicator" organism such as coliform bacteria. Coliforms come from the same sources as pathogenic organisms. They are relatively easy to identify, are usually present in larger numbers than pathogens, and respond similarly to the environment, wastewater treatment, and water treatment.

This study aimed to assess the water quality in homes' tanks of Abu Dhabi Emirate and Al Ain city. For microbiological analysis, total bacterial quantification, total coliform and fecal coliform quantification and E.coli identification were evaluated using standard plate count method, most probable number (MPN) test and Eosin Methylene Blue (EMB) agar tests respectively. Thirty water samples from ground and roof-level household storage containers were tested. Out of the thirty samples analyzed, one sample showed the presence of total coliform and E. coli. Sixteen samples exceeded the bacterial growth standards approved by the UAE.

Further bacterial identification is necessary to determine the safety level of bacteria found on each sample. Regular cleaning, protection, maintenance and a good sealing of the tanks cover are highly recommended for better water quality.

Introduction

Worldwide, the land disposal of agricultural, municipal wastes and industrial wastes occurs. The application of the manure and biosolids to agricultural lands for economic and environmental purposes has increased through time (Chauret et al., 1999). However, the surface water and groundwater supplies used for drinking water can be under the risk of these wastes especially the ones that contain pathogens.

Usually homes are supplied with two large water tanks; one is on the ground level and filled with treated water that is pumped out to the second tank that in most cases is located on the house roof. Both tanks are containers for the storage of water that supply the whole house with the need of drinking water, washing clothes, showering, irrigation, fire suppression, agricultural farming, both for plants and livestock, food preparation as well as many other applications. These tanks stay for a long time without cleaning or maintenance. Definitely this has an effect on the biology of water with regard to the bacterial content that may affect the household members. Although the demand for tap water in the UAE is increasing, public perception about its quality is generally low (Wait, 2008)

Abu Dhabi Electricity and Water Authority (ADEWA), which oversees a semi-privatized consortium of companies tasked with water production in Abu Dhabi emirate. United Arab Emirates (UAE) water utilities have confirmed that the water they produce is intended for human consumption, is regulated in accordance with World Health Organization (WHO) recommendations, and leaves production facilities in a condition that is safe to drink (ADEWA, 2008).

According to Abu Dhabi Regulation & Supervision Bureau wholesome water is defined as: All water is supplied for the purposes of drinking, washing, cooking or food production. For water to be wholesome it should not contain any element, organism or substance (other than a Parameter[1]) at a concentration or value which would be detrimental to public health. Also, that the water does not contain any element, organism or substance (whether or not a Parameter) at a concentration or value which, in conjunction with any other element, organism or substance it contains (whether or not a Parameter), would be detrimental to public health. Another obligation is that the water does not contain concentrations or values that exceed the standard of the Parameters provided by the Bureau (The Water Quality Regulations, . 2009)

The standards are set to be protective of public health and the definition of wholesome reflects the importance of ensuring that water quality is acceptable to consumers. This research is concerned with the biological matter and to that effect the concentration of the microbial parameters approved by the Bureau is shown in Table 1.

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[1] **Parameter:** Is a substance or organism tested for routinely in drinking water

Table 1: The concentration of the microbial parameters approved by the Bureau

Item	Parameters	Units of measurement	Prescribed Concentration or Value (maximum unless otherwise stated)
1	Total coliforms **(i)**	Number/100ml	0
2	E.coli or thermotolerent Faecal coliform bacteria **(i)**	Number/100ml	0
3	Enterococci	Number/100 ml	0
4	Total Bacterial Count	Number/1 ml at 37°C	10 at 37°C

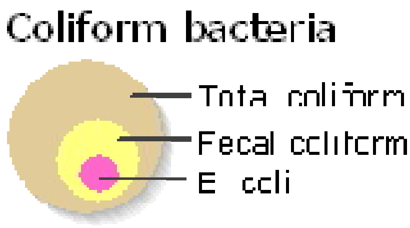
Source: The Water Quality Regulations. (2009). The Regulation and Supervision Bureau for the Water (Ed.). Abu Dhabi, U.A.E.

Table 1 show that the water should be clear from fecal coliform bacteria especially *E. coli* and Enteroccocal bacteria. Fecal Coliform Bacteria are present in the feces and intestinal tracts of humans and other warm-blooded animals, and can enter water bodies from human and animal waste. Fecal coliform by themselves are usually not pathogenic; they are indicator organisms, which means they may indicate the presence of other pathogenic bacteria (Oram, 2007). Indicator organisms are used because they tend to occur in the same sources as pathogenic organisms (e.g. fecal material), are present in greater densities, and often are easier to identify using standard culture methods (Simpson et al., 2002). If fecal coliform bacteria are found in water, it is possible that pathogenic organisms are also present in the water. While *E.coli* is a useful indicator, it has limitations (e.g. reproduce in tropical and subtropical environment) (Helena et.al., 2000). Enteric viruses and protozoa are more resistant to disinfection; consequently, the absence of *E. coli* will not necessarily indicate freedom from these organisms. (Geneva, 2008)

The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply (Coliform Bacteria In Drinking Water Supplies, 2011).

- Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste.
- Fecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. Because the origins of fecal coliforms are more specific than the origins of the more general total coliform group of bacteria, fecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms.

- Escherichia coli (E. coli) is the major species in the fecal coliform group. Of the five general groups of bacteria that comprise the total coliforms (Citrobacter, E.Coli, Serratia, Klebsiella, and Enterobacter) only E. coli is generally not found growing and reproducing in the environment. Consequently, E. coli is considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens.



If coliform bacteria are present in drinking water, the risk of contracting a water-borne illness is increased. Although total coliforms can come from sources other than fecal matter, a positive total coliform sample should be considered an indication of pollution. Positive fecal coliform results, especially positive E. Coli results, should be considered indication of fecal pollution (Coliform Bacteria In Drinking Water Supplies, 2011).

Livestock waste is a primary source of pathogens on agricultural land (Khaleel et al., 1980). A direct relationship was observed by Tiedemann et al (1987) between the increased concentration of fecal coliforms and the availability of cattle on agricultural land.

In areas where wells are used for drinking water, there is a potential risk for the fecal contaminants and agricultural wastes to leach into the groundwater the potential risk exists even where wells are not used, such as springs and base flow to streams. A farm ground water survey in Ontario, Canada, indicated that the higher risk wells were those located near pastures that spread manure (Conboy and Goss, 2000). They concluded that there was a higher risk to wells on farms that housed livestock and spread manure frequently.

The passage of surface water through soil occurs through interstices of the particles, such as in the case of dune recharge, deep-well injection and bank filtration (Schijven, 2001). In addition, the groundwater contamination is mostly related to the intrusion of surface water via poorly constructed wellheads, where the casing is not properly sealed to the borehole around the annulus (Hancock et al., 1998).

Figure 1 provides a simplified illustration of the various routes of fecal-oral transmission. This diagram shows that fecal contamination of water, hands, and the environment sets the stage for transmission of disease (Arbab D. M. and B. L. Weidner, 1986). The following are all methods for disease transmission:

- Water sources may be directly contaminated (i.e. a poorly maintained latrine or septic system can contaminate water wells).

- Stored water can be contaminated through contact with contaminated hands or utensils.
- Contaminated water may be ingested directly or used to wash dishes and utensils or to prepare food.
- Contaminated hands may directly contact the mouth, drinking or cooking water, utensils, food etc.
- Vectors such as flies may also contribute to the transmission of disease as contact both feces and food. (Actions Speak, 1993).

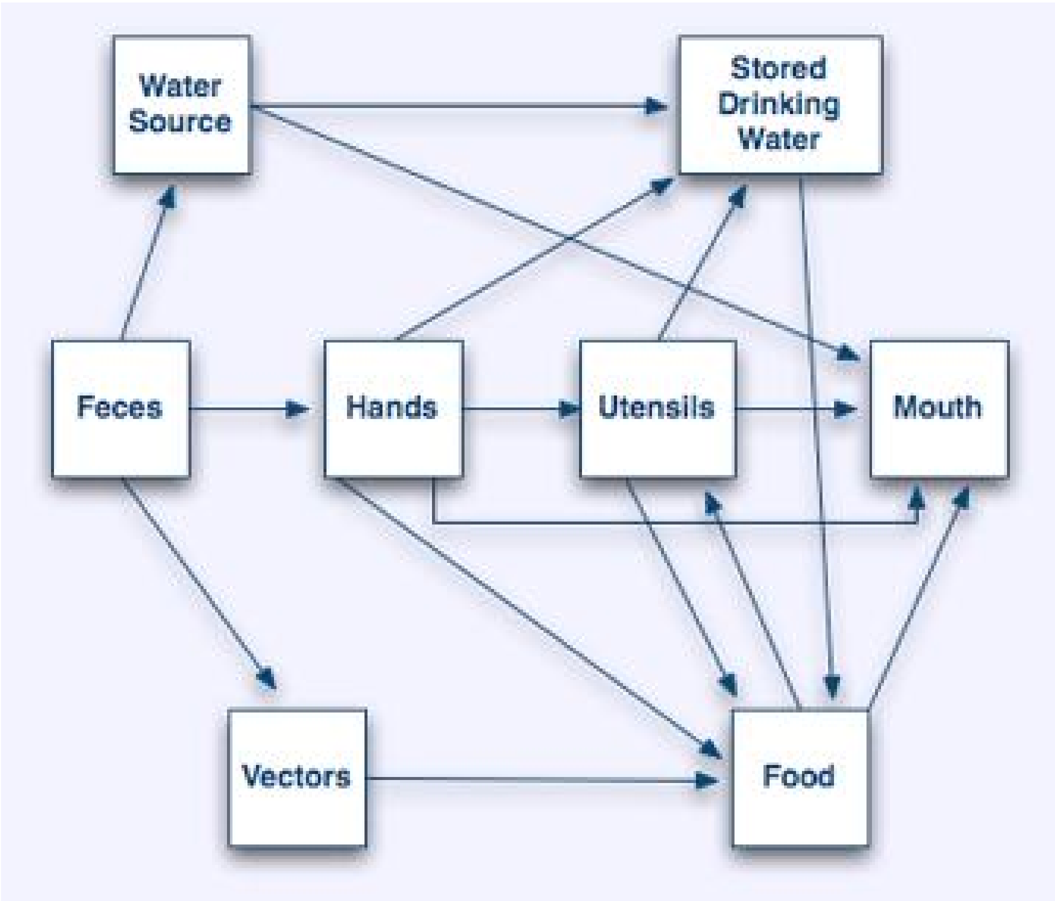


Figure 1: Illustration of the various routes of fecal-oral transmission.

Source: Infectious Diseases and Field Water Supply and Sanitation among Migrant Farmworkers. (1986): *American Journal of Public Health*

Impact of Fecal Contamination

Microbiological health risks remain associated with many aspects of water use, including drinking water in developing countries (Craun, 1986), Many illnesses, contaminants, and injuries can be water, sanitation, or hygiene-related. Waterborne diseases are caused by organisms that are directly spread through water (CDC. 2010). High concentrations of the bacteria in water may be caused by septic tank failure, poor pasture and animal keeping practices, pet waste, and urban runoff.

Numerous examples of fecal contamination of drinking water supplies have been documented. The largest documented ground water fecal-contamination outbreak occurred in Georgetown, Texas, in 1980 (Hejkal et al., 1982). About 7, 900 people became ill. Both Coxsackie virus and Hepatitis A virus were found in the raw well water; the outbreak was the result of source-water contamination.

In 2000, the World Health Organization estimated 4 billion cases of diarrhea each year occurred as a result of the lack of human access to clean water. In addition, millions of other cases of illness have also been associated with contaminated water. Most of these waterborne diseases were related to the pathogen contamination (bacteria and viruses) transmitted from human excreta into drinking water. The best current international estimates of total water-related disease mortality range from 2.2 to 5 million annually (Peter et al., 2002).

Furthermore, in year 2000 a waterborne outbreak in Walkerton, Ontario, Canada, resulted from entry of *Escherichia coli* O157:H7 and *Campylobacter* spp. from neighboring farms into the town water supply. The Health Unit investigation revealed an increase in diarrheal illness in elementary schools, long-term care facilities, and emergency departments in the Walkerton area (Bruce, 2000). Sixty-five patients were admitted to hospital, and of these, 27 developed hemolytic uremic syndrome (rapid loss of renal function and lower platelets count in blood). Six people died as a result of the outbreak. Well water serving the town of Walkerton was found to be contaminated by surface water carrying livestock waste immediately after heavy rains (Clifford et al., 2003).

The flow of pathogens responsible for illness is shown in Figure 2. The pathogens are generated by a variety of reservoirs, including animal groups on the left and infected humans on the right. Pathogens may be transmitted from food animal reservoirs to the food actually ingested along the food chain (orange arrow – Food). They may also spread from the animal reservoirs to raw waters. These contaminated waters may infect human beings through drinking water, in the case of insufficient treatment, or directly when there is contact and accidental ingestion of the raw water (blue arrow – Water). In addition, raw water that is contaminated may spread the pathogens to animal and vegetable production. People may get infected when they are in contact with animals or their environment. Finally, infected people may transmit the pathogens to other humans (pink arrow), to food (grey arrow) or to raw water (black arrow). (.Methodological Options of Source Attribution. 2011).

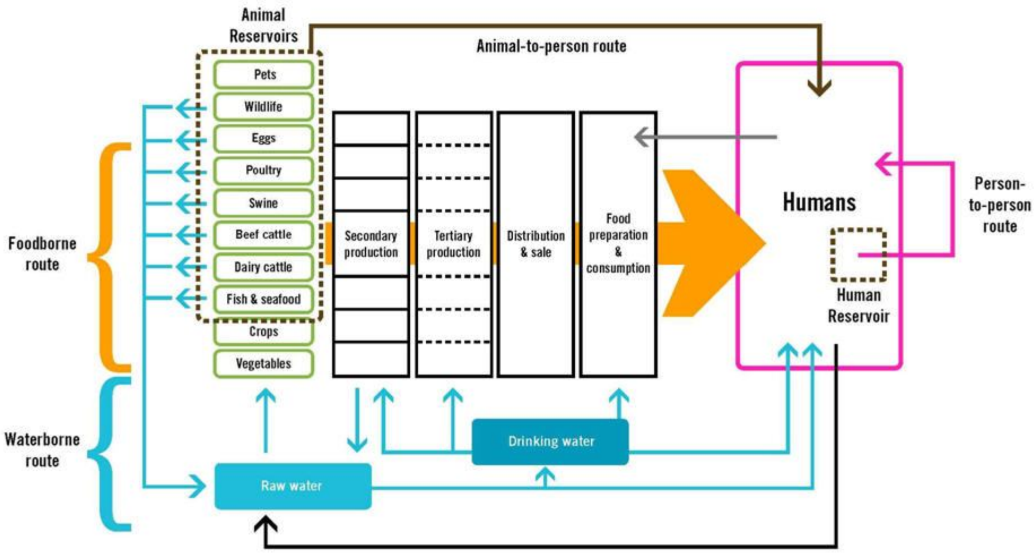


Figure 2: Potential routs of microbial infection

Source: Methodological Options of Source Attribution. (2011): Public Health Agency of Canada.

Pathogens are typically present in such small amounts therefore; it is impractical to monitor them directly. Usually, the distribution source of water that supplies homes is aseptically monitored. Water is purified before distributing to houses it is already checked for coliforms. Only if it is free from coliforms the distribution is done. (Coliform Bacteria In Drinking Water Supplies, 2011).

The failure to provide safe drinking water and adequate sanitation services to all people is perhaps the greatest development failure of the 20th century. The most egregious consequence of this failure is the high rate of mortality among young children from preventable water-related diseases (Peter H. 2002). “Access to sanitation is deeply connected to virtually all the Millennium Development Goals, in particular those involving the environment, education, gender equality and the reduction of child mortality and poverty, ” Secretary-General Ban Ki-moon said. “An estimated 42, 000 people die every week from diseases related to low water quality and an absence of adequate sanitation”

Water-related diseases are typically placed in four classes (Peter H. 2002):

- Waterborne diseases: caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria or viruses; include cholera, typhoid, amoebic and bacillary dysentery and other diarrheal diseases.
- Water-washed diseases: caused by poor personal hygiene and skin or eye

contact with contaminated water; include scabies, trachoma and flea, lice and tick-borne diseases.

- Water-based diseases: caused by parasites found in intermediate organisms living in contaminated water; include dracunculiasis, schistosomiasis, and other helminths.
- Water-related diseases: caused by insect vectors, especially mosquitoes, that breed in water; include dengue, filariasis, malaria, onchocerciasis, trypanosomiasis and yellow fever.

Water-borne pathogens infect around 250 million people each year resulting in 10 to 20 million deaths world-wide. (DWAF, 1996). This highlights the potential of infection due to water - borne pathogens. The objective of this study is to assess the water quality in homes' storage tanks in both, Abu Dhabi emirates and Al Ain city.

The current study has three objectives: 1) Total bacterial quantification, 2) Total coliform and fecal coliform quantification and 3) *E.coli* identification.

Materials & Methods

Sample Collection

Samples were collected from Abu Dhabi emirate and Al Ain city using sterilized 1 liter bottles. Representatives from both regions participated in the sample collection. The ground tanks were numbered as one on each house while the upper one numbered as two. Samples from Abu Dhabi were transported to the laboratory using an ice box.

Microbiological Analysis

The standard plate count method was used to count the total number of bacteria in the water samples. Serial dilution of each sample was made starting from 10^{-1} to 10^{-5} dilution using sterilized water. Certain volume of sample from each diluent (0.1 ml) was then spread on a nutrient agar for bacterial growth. Since the current study is more concerned with the identification of bacteria presented in samples, incubation period is set at 35° for 48 hours. Plates containing 25-250 colonies were counted for colony forming units (CFUs). Plates having less than 25 CFU were assigned as too few to count (TFTC) while those having more than 250 CFU were assigned as too numerous to count (TNTC). Bacteria per milliliter were calculated and description of bacterial colony also recorded.

The previous serial dilution of samples was used by spreading 0.1 ml on an EMB agar in the same manner to detect the presence of *E.coli* bacteria.

The number of total coliforms (*Enterobacter, Klebsiella, Citrobacter, Escherichia*) in a water sample can be determined by statistical estimation called the most probable number (MPN) test (figure 1). This test involves a multiple series of Durham fermentation tubes and is divided into three parts: the presumptive, confirmed, and completed tests.

In the presumptive test, dilutions from the water sample are added to lactose or lauryl tryptose broth fermentation tubes. After 24 to 48 hours of incubation at 35ºC, one looks for bacteria capable of fermenting lactose with gas production, presumably coliforms. (The lauryl tryptose broth is selective for gram-negative bacteria due to the presence of lauryl sulfate.)

In the confirmed test, material from the highest dilution of those lactose broth tubes that showed growth and gas production is transformer into brilliant green lactose bile broth, which is selective and differential for coliforms. The tube is incubated for 48 ±3 hours at 35ºC. Gas formation in the Durham tube is a confirmed test for total coliforms.

In the completed test, a sample from the positive green lactose bile broth is streaked onto Levine’s EMB agar and incubated for 18 to 24 hours at 35ºC. On EMB agar, coliforms produce small colonies with dark centers. Samples are then inoculated into brilliant green lactose bile broth and onto a nutrient agar slant. These tubes are incubated for 24 hours at 35ºC. If gas is produced in the lactose broth, and isolated bacterium is a gram-negative (based on a Gram stain) nonsporing rod, the completed test is positive.

An estimate of the number of coliforms (most probable number) is done in the presumptive test. In this procedure, 15 lactose broth tubes are inoculated with the water sample. Five tubes receive 10 ml of water, 5 tubes receive 1 ml of water, and 5 tubes receive 0.1 ml of water. A count of the number of tubes showing gas production is then made, and the figure is compared to a table (table 2) developed by the American Public Health Association. The number is the most probable number (MPN) of coliforms per 100 ml of the water sample.

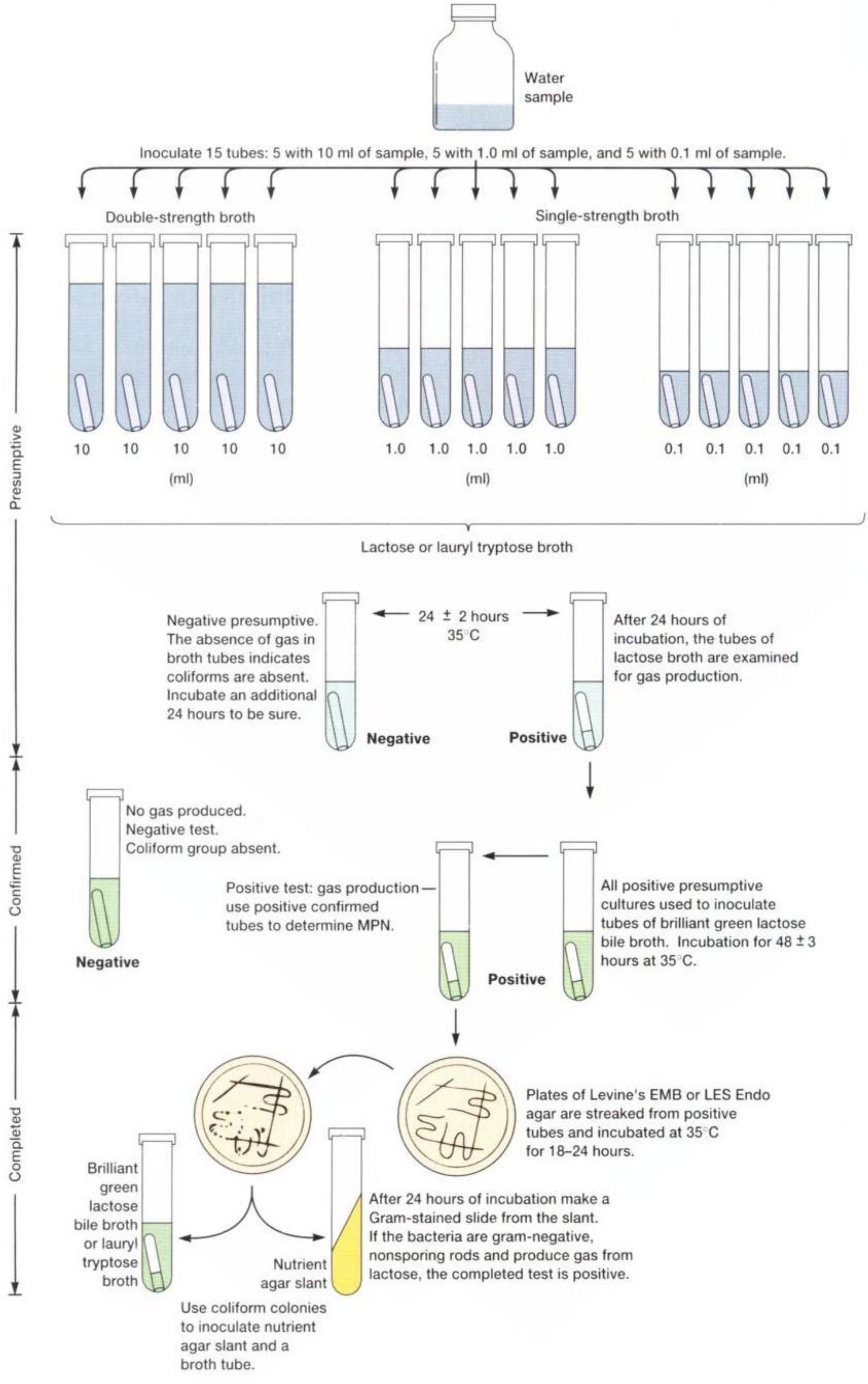


Figure 3: The most probable number (MPN) procedure for water examination.

Table 2: Most probable number (MPN) index for various combinations of positive and negative results when five 10-ml portions, five 1-ml portions, and five 0.1-ml portions are used.

No. of Tubes Giving Positive Reaction Out of				No. of Tubes Giving Positive Reaction Out of			
5 of 10 ml Each	5 of 1 ml Each	5 of 0.1 ml Each	MPN Index per 100 ml	5 of 10 ml Each	5 of 1 ml Each	5 of 0.1 ml Each	MPN Index per 100 ml
0	0	0	<2	4	2	1	26
0	0	1	2	4	3	0	27
0	1	0	2	4	3	1	33
0	2	0	4	4	4	0	34
1	0	0	2	5	0	0	23
1	0	1	4	5	0	1	31
1	1	0	4	5	0	2	43
1	1	1	6	5	1	0	33
1	2	0	6	5	1	1	46
2	0	0	5	5	1	2	63
2	0	1	7	5	2	0	49
2	1	0	7	5	2	1	70
2	1	1	9	5	2	2	94
2	2	0	9	5	3	0	79
2	3	0	12	5	3	1	110
3	0	0	8	5	3	2	140
3	0	1	11	5	3	3	180
3	1	0	11	5	4	0	130
3	1	1	14	5	4	1	170
3	2	0	14	5	4	2	220
3	2	1	17	5	4	3	280
3	3	0	17	5	4	4	350
4	0	0	13	5	5	0	240
4	0	1	17	5	5	1	350
4	1	0	17	5	5	2	540
4	1	1	21	5	5	3	920
4	1	2	26	5	5	4	1,600
4	2	0	22	5	5	5	≥2,400

Results

Table 3 represents the results gained from the standard plate count, Standard Coliform Most Probable Number (MPN) and Eosin Methylene Blue (EMB) agar tests. Total of 30 samples were collected and analyzed in a period of 6 weeks. As shown in table 3 each sample was numbered as follows: (week number: house number, letter is for water tank level); (a) represents samples taken from ground level tank, (b) represents samples from roof level tank. If the letter (a or b) is followed by a number it indicated another ground or roof level tank from the same house. AD is an abbreviation of samples collected from Abu Dhabi and AA is an abbreviation of samples collected from Alain.

Most samples showed negative result for the MPN test which indicates the absence of total coliform. However, one sample (AD3.1b) showed positive for the MPN test with total coliform of 2 CFU per 100ml. This contaminated sample reflects 3.3% of the total tested samples. Total number of *E.coli* for all samples was zero except for the sample that showed positive for the MPN test (AD3.1b). However, the number of total E. coli could not be quantified because of the small number of the total coliform per 100ml. The presence of *E.coli* was detected on the confirmed step of the MPN test. Samples from neighbor homes were tested for the MPN and showed negative results. That make the assumption on the source of contamination of the positive sample by fecal coliform is the tank itself.

All tested samples showed growth of different kinds of bacteria. Morphological features are represented in table 5. In particular, sample (AA1.3a) showed greenish on the plates and the color was increasing with increasing dilution as shown in figure 4 which most likely indicates the presence of *Pseudomonas* bacteria.

Table 3: Samples detailed information with the results of tests.

Sample No.	Date	Sample Location	Total coliform Per 100 ml	Total bacterial count Per 1ml	Total E.coli per 100 ml
AD1.1a	19/11/2011	AD, Shamkha	0	TFTC	0
AD1.1b	19/11/2011	AD, Shamkha	0	TFTC	0
AA1.2a1	19/11/2011	Al Ain, Al Bateen	0	170	0
AA1.2a2	19/11/2011	Al Ain, Al Bateen	0	$98x10^3$	0
AA1.3a	19/11/2011	Al Ain, Markhanya	0	185	0
AA1.3b	19/11/2011	Al Ain, Markhanya	0	350	0
AA2.1a	26/11/2011	Al Ain, Markhanya	0	TFTC	0
AA2.1b	26/11/2011	Al Ain, Markhanya	0	$8.6x10^3$	0
AD2.2a	26/11/2011	AD, Khalifa A	0	160	0
AD2.2b	26/11/2011	AD, Khalifa A	0	TFTC	0
AD2.3a	26/11/2011	AD, Shamkha	0	TFTC	0
AD3.1a	3/12/2011	AD, Khalifa A	0	TFTC	0
AD3.1b	3/12/2011	AD, Khalifa A	2	263	N/A
AD3.2a	4/12/2011	Al Ain, Al yahar	0	201.5	0
AD3.2b	4/12/2011	Al Ain, Al yahar	0	$3.5x10^3$	0

AA4.1a	11/12/2011	Al Ain, Al Maqam	0	$4.4 x 10^6$	0
AA4.1b	11/12/2011	Al Ain, Al Maqam	0	$32.3 x 10^6$	0
AA 4.2a	12/12/2011	Al Ain, Al jimi	0	TFTC	0
AA4.2b	12/12/2011	Al Ain, Al jimi	0	$188 x 10^3$	0
AA4.3a	12/12/2011	Al Ain, Al-Alia	0	$2.99 x 10^3$	0
AA4.3b	12/12/2011	Al Ain, Al-Alia	0	TFTC	0
AD5.1a	7/1/2012	AD, Shamkha	0	TFTC	0
AD5.1b	7/1/2012	AD, Shamkha	0	TFTC	0
AA5.2a	8/1/2012	Al Ain, Al-Amereya	0	TFTC	0
AA5.2b	8/1/2012	Al Ain, Al-Amereya	0	TFTC	0
AD6.1a	14/1/2012	AD, Khalifa A	0	$15.7 x 10^3$	0
AD6.1b	14/1/2012	AD, Khalifa A	0	$79 x 10^3$	0
AD6.2a	14/1/2012	AD, Khalifa A	0	TFTC	0
AD6.3a	14/1/2012	AD, Khalifa A	0	TFTC	0
AD6.3b	14/1/2012	AD, Khalifa A	0	$10.8 x 10^3$	0

Table 4: Detailed bacterial morphologies with average Bacterial Count per dilution

Sample No.	Dilution	General Morphology	Average Bacterial Count per dilution
AD1.1a	0.2	Off white, flat	11
	10^{-1}	Off white, flat	7
	10^{-2}	Off white, flat	5.3
	10^{-3}	Off white, flat	2
	10^{-4}	No growth	0
	10^{-5}	No growth	0
AD1.1b	0.2	Off white, flat	18
	10^{-1}	Off white, flat	3
	10^{-2}	Off white, flat	1.3
	10^{-3}	Off white, flat	1
	10^{-4}	Off white, flat	0.6
	10^{-5}	white spread ~2mm	2.3
AA1.2a	0.2	Water drops like	34
	10^{-1}	Water drops like	15.3
	10^{-2}	Water drops like	1
	10^{-3}-10^{-5}	No growth	0
AA1.2b	0.2	Water drops like	TNTC
	10^{-1}	Water drops like	310
	10^{-2}	Water drops like	98
	10^{-3}	Water drops like	22
	10^{-4}	Water drops like	1
	10^{-5}	-	No growth
AA1.3a	0.2	glossy yellow	34
		flat orange	2
		white spread	1
	10^{-1}-10^{-5}	No growth	0
AA1.3b	0.2	Water drops like	70
	10^{-1}	Colonies too close	-
	10^{-2}-10^{-5}	No growth	0
AA2.1a	0.2	White colonies	2
	10^{-1}	Water drops like	3
	10^{-2}-10^{-5}	No growth	0
AA2.1b	0.2	White colonies	TNTC
	10^{-1}	White colonies	86
	10^{-2}	Water drops like	10.6
	10^{-3}	Water drops like	4
	10^{-4}	White colonies	1
	10^{-5}	No growth	0
AD2.2a	0.2	Very small yellowish dots	32
	10^{-1}	Very small yellowish dots	1.3
	10^{-2}-10^{-5}	No growth	0
AD2.2b	0.2	Brownish white flat	13
	10^{-1}	Water drops like	6.6
	10^{-2}	Water drops like	2.3
	10^{-3}	Water drops like	2
	10^{-4}-10^{-5}	No growth	0
AD2.3a	0.2	Yellowish white flat	10

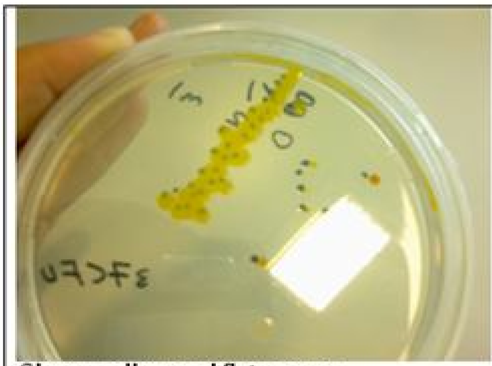
	10^{-1}		1
	10^{-2}-10^{-5}	No growth	0
AD3.1a	0.2	Off white, flat	3
		Water drops	8.3
	10^{-1}	Off white, flat	2
		Water drops	10.3
	10^{-2}-10^{-5}	No growth	0
AD3.1b	0.2	yellowish dots	36
		Water drops like	16.3
	10^{-1}	Off white, flat	0.3
		Water drops like	20
	10^{-2}	Off white, flat	0.3
		Water drops like	14.6
	10^{-3}	Off white, flat	0.6
		Water drops like	25
	10^{-4}	Water drops like	16.6
	10^{-5}	Colonies too close to count	-
AD3.2a	0.2	Water drops like	39.3
		Yellowish brown flat	1
	10^{-1} & 10^{-2}	Colonies too close to count	-
	10^{-3}	Water drops like	21
	10^{-4}	Water drops like	19.3
	10^{-5}	smear	-
AD3.2b	0.2	Colonies too close to count	-
	10^{-1}	Water drops like	35
	10^{-2}	Water drops like	18.6
		White colony	0.6
	10^{-3}	Water drops like	16.3
	10^{-4}	Water drops like	3
	10^{-5}	No growth	0
AA4.1a	0.2	Water drops like	TNTC
		Off white, flat	15
		Pale yellow	0.6
	10^{-1}	Water drops like	TNTC
		Off white, flat	37
		Pale yellow	0.3
	10^{-2}	Water drops like	TNTC
		Off white, flat	33
	10^{-3}	Water drops like	TNTC
		Off white, flat	TNTC
		Orange dots	158
	10^{-4}	Water drops like	44
	10^{-5}	Water drops like	29
AA4.1b	0.2	Smear	-
	10^{-1}	Water drops like	18
		Off white, flat	12.3
	10^{-2}	Water drops like	14
		Off white, flat	1.6
	10^{-3}	Water drops like	5

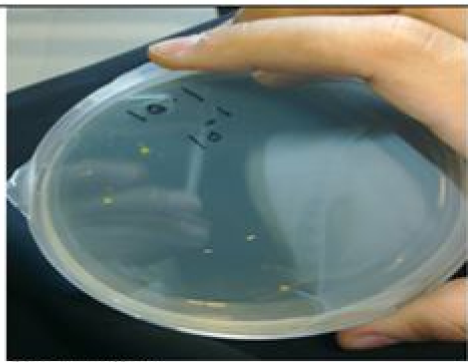
		Off white, flat	6.6
	10^{-4}	Water drops like	22
	10^{-5}	Water drops like	32.3
AA 4.2a	0.2	Off white, flat	TNTC
		Yellow dots	6.6
	10^{-1}	Off white, flat	TNTC
	10^{-2}	Yellow dots	188.3
	10^{-3}	Water drops like	46.6
		Off white, flat	0.6
		Yellowish dots	0.6
	10^{-4}	Off white, flat	11.6
		Water drops like	29
	10^{-5}	Yellow dots	4
AA4.2b	0.2	white Smear	1
	10^{-2}-10^{-5}	No growth	0
AA4.3a		Smear	-
	0.2	Water drops like	28.6
		Off white, flat	1.3
	10^{-1}	Water drops like	10
		Off white, flat	0.6
	10^{-2}	Off white, flat	7.6
	10^{-3}	Off white, flat	1
	10^{-4}	Off white, flat	0.3
	10^{-5}	No growth	0
AA4.3b	0,2	Off white, flat	0.6
		Yellowish dots	5
	10^{-1}	Yellowish dots	3.3
		Off white, flat	2.6
	10^{-2}	Off white, flat	0.6
	10^{-3}	Water drops like	5
		Off white, flat	0.3
	10^{-4}	Water drops like	1.3
	10^{-5}	No growth	0
	0.2	Off white, flat	1
		Water drops like	8.6
	10^{-1}	Off white, flat	1
	10^{-2}	Off white, flat	0.3
	10^{-3}	Off white, flat	0.6
	10^{-4}	Off white, flat	0.3
AD5.1a	10^{-5}	No growth	0
	0.2	Off white, flat	3
	10^{-1}	Off white, flat	3
	10^{-2}	Off white, flat	0.3
		Water drops like	0.6
	10^{-3}	Too close colonies	-
	10^{-4}	Water drops like	2
AD5.1b	10^{-5}	Water drops like	2.6
	0.2	White spread <2mm	10.6
	10^{-1}	White spread <2mm	1
	10^{-2}	White spread 4mm	0.6
AA5.2a	10^{-3}-10^{-5}	No growth	0

	0.2	White spread <2mm	8
	10^{-1}	White spread <2mm	6.3
	10^{-2}	White spread <2mm	5.3
	10^{-3}	White spread <2mm	1.3
AA5.2b	10^{-4}+10^{-5}	No growth	0
	0.2	White spread	TNTC
	10^{-1}	white spread	157
	10^{-2}	white spread	26
		White dots	3.3
	10^{-3}	white spread	3.6
		White dots	2.6
	10^{-4}	white spread	0.3
		White dots	2.3
AD6.1a	10^{-5}	White dots	0.6
	0.2&10^{-1}	white spread (smear)	TNTC
	10^{-2}	white spread	79
	10^{-3}	white spread	24
	10^{-4}	white spread	Too close to count
AD6.1b	10^{-5}	white spread	18
	0.2	No growth	0
	10^{-1}	No growth	0
	10^{-2}	No growth	0
	10^{-3}	No growth	0
	10^{-4}	Off white, flat	1
AD6.2a	10^{-5}	No growth	0
	0.2	White spread (Too close to Count)	~22
	10^{-1}	white spread	16.6
		White dots	5
	10^{-2}	white spread	0.6
		White dots	1.6
	10^{-3}	white spread	0.3
		White dots	2
	10^{-4}	white spread	0.3
		White dots	0.6
AD6.3a	10^{-5}	No growth	0
	0.2	White spread (smear)	TNTC
	10^{-1}	White dots	108
	10^{-2}	White dots	26
	10^{-3}	White dots	12.3
	10^{-4}	White dots	6
AD6.3b	10^{-5}	White dots	2

Table 5: Descriptions of different bacterial morphologies found in the tested samples

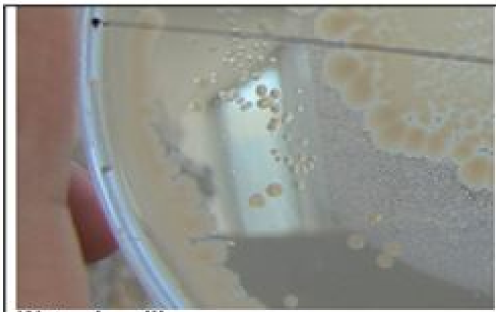
Morphology	Discription of Colonies							
	Form	Elevation	Margin	Apperance	Optical property	Pigmentation	Texure	Size mm
Water drop like	Circular	Convex to pulvinate	Entire	Shiny	Transparent	Colorless	Smooth	~0.5
Glossy yellow	Circular	Convex	Entire	Shiny	Translucent	Yellow	Smooth	~2
Flat orange	Circular	Flat	Irregular	Shiny	Opaque	Orange	Smooth	~1
White spread	Irregular	Flat	Irregular	Dull	Opaque	White	Rough	~1 – 4
0ff white, flat	Circular	Flat	Entire	Dull	Opaque	Off white	Smooth	~1-2
White colonies White dots	Circular	Convex	Entire	Shiny	Opaque	White	Smooth	~0.5-2


Glossy yellow and flat orange

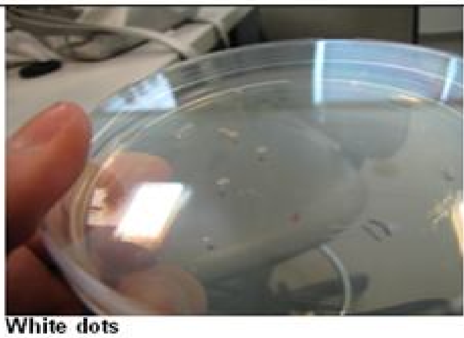

Glossy yellow


0ff white, flat

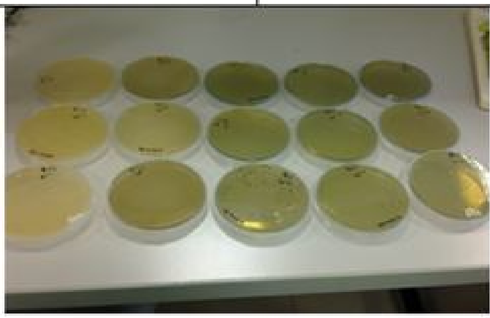

White spread



Water drop like



White dots



Possibility of pseudomonas bacteria

Figure 4: Different bacterial morphologies found in the Standard plate count of tested samples

Positive presumptive and confirmed tests of the MPN

Positive completed test of MPN

Figure 5: Results of MPN tests for sample AD3.1b

Discussion

The water samples collected from water storage tanks at different homes in Abu Dhabi and Alain were negative for total coliform in most of the samples (96.6%). However, one sample only (3.3%) was contaminated with fecal coliform (*E.coli*) bacteria. E.coli is found in the intestine of warm blooded animals and human. In addition, *E.coli* was found to reproduce outside its environment (Helena et.al., 2000). The global and local standard of coliform and *E.coli* is zero per 100ml. So, their presence exceeds the standard levels of wholesome water. This also may represent a public health hazard especially if people are using the water without prior boiling or other disinfection or filtration treatment. In order to assess the safety of the drinking water at home an identification of the total bacterial count is necessary to determine the presence of pathogens. Furthermore, the absence of *E.coli* is not an indication of the absence of viral or protozoan contamination because they are more resistant to disinfection procedures (Geneva, 2008).

Total bacterial count (TBC) is a water quality standard. The TBC must not exceed 10 CFU per 1m of water sample. This limit was exceeded by 16 sample of the water samples tested for this study including samples number AA1.2a1, AA1.2a2, AA1.3a, AA1.3b, AA2.1b, AD2.2a, AD3.1b, AD3.2a, AD3.2b, AA4.1a, AA4.1b, AA4.2b, AA4.3a, AD6.1a, AD6.1b and AD6.3b. Exceeding the standard level is not an indicator of pathogenesis. Bacterial count could be of normal flora that is safe for human. Identification of bacteria would assess on their safety level in water.

In general, Standard Plate Count test showed some morphological similarity in bacteria presented among the samples. The number of total bacterial count varied significantly from area to another in the same emirate and from tank to another of the same house. Bacterial growth is affected by number of environmental factors like temperature, pH, salinity, nutrient availability etc. Thus, bacterial count during summer may differ due to high temperature.

Number of water samples showed TFTC levels which is below the total bacterial count standard (10 CFU/1ml). The cultural plate method can underestimate the number of bacteria found in the original sample because the harsh treatment of the cells may get them injured and unable to grow on the plate.

One water sample showed the possibility of contamination with *Pseudomonas* bacteria. *Pseudomonas aeruginosa* is a Gram-negative bacterium that is noted for its environmental versatility, ability to cause disease in particular susceptible individuals, and its resistance to antibiotics (Winsor et al. 2011). Pseudomonas bacteria can be found naturally in the ground and within drinking water sources commonly. They may multiply and can cause negative health effects in humans under certain conditions. If allowed to reach unsafe levels. The presence of pseudomonas may cause several health problems including skin rash and other skin infections, ear infection, urinary tract infection, and in rare instances, pneumonia (APS water, 2004). It may also causes urinary tract infections, respiratory system infections, dermatitis, soft tissue infections, bacteremia, bone and joint infections, gastrointestinal infections and a variety of systemic infections, particularly in patients with severe burns and in cancer and AIDS patients who are immunosuppressed (Todar, 2008).

All water samples were assigned Letter (a) which indicates ground level water tank or (b) for a roof level tank. A general notice is that tanks of the roof level mostly showing higher bacterial count (sample AA1.3b, AA2.1b, AD3.1b, AD3.2b, AA4.1b, AA4.2b, AD6.1b and AD6.3b). This observation can be explained by that the pumping of water from the ground level tank is taken from the bottom of the tank where there is more bacteria is assumed to be concentrated due to the settlement with dust particles. This pumping as well as the continuous flush of water to the roof tank concentrated the bacteria in the sample.

At the time of collection some of the tanks did not have the led on or was not sealed tightly. This act gives the opportunity for insects, birds and dust to enter the tank and cause contamination. In this case the cleaning process of the tank should improve its water quality and reduce the microbial contamination.

Conclusion and Recommendations

The method used in the current study has advantages. However, MPN test alone needs about 3-5 days to be completed. If a municipality has a drinking water crisis, this timing is not practical. Fast and accurate monitoring of microbiological parameters in drinking water is essential to safeguard the consumer and to improve the understanding of treatment and distribution systems.

The IDEXX technique is a breakthrough technology that delivers a fast, clear, visual color change that makes detection easy, without bacterial culture or subjective colony counting. Furthermore, gram staining method for isolated bacteria will assist in determining the level of its pathogenesis or safety.

For further water tanks assessments, it's recommended to duplicate or triplicate the samples from each tank for more accuracy. As a point to consider, samples from different water columns of the same tank will help in the explanation of bacterial distribution in the same tank.

The water quality parameters of concern were microbial contamination including total coliform, *E.coli* and total bacterial count. The source of water in the tanks is clear of biological parameters as confirmed by UAE water utilities that the water they produce is safe to drink. It is recommended that the government and other relevant actors in the UAE establish a comprehensive drinking water system that integrates household water supply, quality, handling and related educational programs in order to ensure the safety of drinking water supplies.

Overall, prior boiling or other disinfection or filtration treatment is required for the household water. Regular cleaning, protection, maintenance and a good sealing of the tanks cover are highly recommended for better water quality.

References

[1] *Abu Dhabi Electricity and Water Authority*: ADEWA (2008). Communication with Mohammed Ali Al Masalkhi, 13 February 2008, by Isaac Wait.

[2] Arbab DM and BL Weidner, (1986) *Infectious Diseases and Field Water Supply and Sanitation among Migrant Farmworkers*, American Journal of Public Health; 76(6):694-5.

[3] Boot, M.T. and Sandy C., Ed. (1993) Actions Speak: The Study of Hygiene Behavior in Water and Sanitation Projects (IRC International Water and Sanitation Centre and London School of Hygiene and Tropical Medicine, 1993).

[4] Bruce-Grey-Owen Sound Health Unit. (2000). *Waterborne outbreak of gastroenteritis associated with a contaminated municipal water supply*, Walkerton, Ontario, May-June 2000. Canada Communicable Disease Report, 26- 20:170-173

[5] Canada, Public Health Agency. (2011). *Methodological Options of Source Attribution*, Retrieved from http://www.phac-aspc.gc.ca

[6] Chauret, C, S. Springthorpe, and S. Sattar. (1999). *Fate of Cryptosporidium*

[7] oocysts, Giardia cysts, and microbial indicators during wastewater treatment and anaerobic sludge digestion. Canadian Journal of Microbiology, 45(3):257

[8] Clifford G. Clark, Lawrence Price, Rafiq Ahmed, David L. Woodward, Pasquale L. Melito, Frank G. Rodgers, Frances Jamieson, Bruce Ciebin, Aimin Li, Andrea Ellis, (2003), *Characterization of Waterborne Outbreak–associated Campylobacter jejuni, Walkerton, Ontario.* Emerg Infect Dis. 2003 October; 9(10): 1232–1241. doi: 10.3201/eid0910.020584 PMCID: PMC3033067

[9] *Coliform Bacteria In Drinking Water Supplies* (June, 2011). New York State Department of Health, Retrieved 18 January 2012, Retrieved from http://www.health.ny.gov/

[10] Conboy, M.J., and Goss, M.J. (2000). *Natural protection of groundwater against bacteria of fecal origin*. Journal of Contamination Hydrology, 43(1), 1.

[11] Craun G. F. (1986). *Waterborne Diseases in the United States*. CRC Press, Inc. Boca Raton, Florida.

[12] *Estimation of Most Probable Number Count of Viable Cells – Microbiology Lab*, Retrieved 20 January 2012 from Microbiology Theory and Practice http://www.microbiologylabs.info/

[13] *Guidelines for Drinking Water Quality*. (2008). Third edition, Volume one, London SW1P 2AL: Retrieved from http://www.dwi.gov.uk.

[14] *Guidelines for Drinking Water Quality*. (1997). Second edition, Volume three, London SW1P 2AL: Retrieved from http://www.dwi.gov.uk.

[15] Hancock, CM., JB Rose, and M. Callahan. (1998). *Cryptosporidium and Giardia in US Groundwater*. Journal of the American Water Works Association. 90(3): 58.

[16] Hejkal TW, B. Keswick, RL Labelle, CP. Gerba, Y. Sanchez, G. Dreesman, B. Hafkin, JL Melnick. (1982). *Viruses in a community water supply associated with an outbreak of gastroenteritis and infectious hepatitis*. Journal of the American Water Works Association74:3 18-321.

[17] Helena M. Solo-Gabriele, Melinda A. Wolfert, Timothy R. Desmrais, and Carol J. Palmer. (2000). *Sources of Escherichia coli in a Coastal Subtropical Environment*. Applied and Environmental Microbiology, 66(1): 230-237.

[18] Khaleel, R., KR, Reddy, and MR Overeash. (1980). Transport of potential pollutants in runoff water from land areas receiving animal wastes: a review. Water Research, Applied and Environmental Microbiology, 61:2806-2808 2806-2808

[19] Murphy, S. F. (April, 2007). General Information on Fecal Coliform. Retrieved from http://bcn.boulder.co.us

[20] Oram, B. *Water Research Center E.coli in Water*. Retrieved from Water Research Center website: http://www.water-research.net

[21] Peter H. Gleick. (2002). *Dirty Water: Estimated Deaths from Water-Related Disease* 2000-2020, Pacific Institute Research Report.

[22] Peter, G. H., J. D. Summer, J. L. Hill, J. V. Collins, J. A. Entry, and W. I. Segars. (2002). *Geographic Variability of Escherichia coli Ribotypes from Animals in Idaho and Georgia*. Journal of Environmental Quality, 31: 1273- 1278.

[23] *Pseudomonas In Purified Water, Spas and Drinking Water Systems*, Retrieved 19 January 2012, from APS Water Services Corporation, Web site: http://www.apswater.com/

[24] Schijven, J. F. (2001). *Virus Removal from Groundwater by soil Passage*. Delft, University of Delft. The Netherlands.

[25] Simpson J., J. S. Domingo, and D. J. Reasoner. (2002). Critical Review: *Microbial Source Tracking*: *State of the Science*. Environmental Science and Technology, 36(24): 5279-5288.

[26] Sutton, S. (2006). *Counting Colonies*. PMF News letter, Volume 12 (Number 9).

[27] The Water Quality Regulations. (2009). The Regulation and Supervision Bureau for the Water (Ed.). Abu Dhabi, U.A.E.

[28] Tiedemann, D.A. Higgins, T.M. Quigley, H.R. Sanderson, D.B. Marx, (1987), *Responses of fecal coliform in streamwater to four grazing strategies*. J Range Manage, 10 (1987), pp. 322–329

[29] Todar, K. (2006). *Todar's Online Textbook of Bacteriology*. Retrieved from http://textbookofbacteriology.net/

[30] Wait, I. (2008). *Changing Perceptions: Water Quality and Demand In The United Arab Emirates*. Paper presented at the 13th IWRA World Water Congress.

[31] Winsor GL, Lam DK, Fleming L, Lo R, Whiteside MD, Yu NY, Hancock RE, Brinkman FS., (Jan, 2011). *Pseudomonas Genome Database: improved comparative analysis and population genomics capability for Pseudomonas genomes*, 39(Database issue): D596–D600. Published online 2010 October 6. doi: 10.1093/nar/gkq869