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Water Quality in Selected Parts of the Distribution System in Kafr El-Sheikh Governorate

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Abstract: Drinking water safety is one of the most fundamental and critical responsibilities of public health authorities. There are several challenges facing water resources development in Egypt including upgrading water quality from current degradation. Sanitation service is inadequate in Kafr El-Sheikh's main cities and in the majority of the villages, and constitutes a major environmental concern for the whole Governorate, as it is for all over Egypt. The water quality in the distribution system itself may not be the same as the treated water entering the system. So, protecting and maintaining water distribution systems are crucial for ensuring high quality drinking water. This study is planned to perform a sanitary survey of a municipal water treatment plant and its distribution system in a rural area located in Kafr El-Sheikh Governorate and to examine their water quality as an example for the growing dependence on small water treatment plants in providing quality water to rural areas and alleviae the burden of water borne diseases. The biological and physico-chemical parameters of 100 water samples from a Mutubis plant and its distribution system represented by tap water, and stored water [roof tanks and reservoirs] were examined using standard methods. El Khadra treatment plant is one of the 13 minor plants supplying the rural areas in Mutubis. It supplies 25 Ezbas covering a population of about 160,000 and produces 80 Liters/second. Transport and storage of water are common practice in this area using different unhygienic reservoirs. Moreover, 60% of the studied roof tanks had unsatisfactory sanitary score. Although most of physico-chemical parameters were in compliance with the Egyptian drinking water standards, approximately all biological parameters were violating the recommended limits. 67% of all water samples were contaminated with total coliform counts, but surprisingly fecal coliforms were detected only in roof water tanks. Moreover, Coagulase & DNase-positive Staphylococci were isolated from 18.75% of all water samples. Co-incidental occurrence of *Cryptosporidium* oocysts and *Giardia lamblia* cysts has been found in 19% of samples, while co-incidental absence of the two parasites has been found in 60% of samples. These results suggest a possibility of inadequate performance of the plant in addition to post-treatment contamination and possible risk of infection from these water supply sources. Regular monitoring and enhancement of microbial and physico-chemical parameters of water quality served by different water treatment plants till reaching the population are recommended to gauge their safety for human consumption.

INTRODUCTION

Every year, unsafe water, coupled with a lack of basic sanitation, kills at least 1.6 million children under the age of five years and at least 5 million of total deaths can be attributed to waterborne diseases.[1,2] At the beginning of the Water for Life decade, 1.1 billion people did not have access to an

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improved source of drinking water, of whom 84% live in rural areas. Moreover, 2.6 billion people, more than 40% of the world population, do not use a toilet, but defecate in the open or in unsanitary places. In 2004, more than three out of every five rural people, over 2 billion, did not have access to a basic sanitation facility.[2]

Nationally, 6,847,500 people in Egypt have no access to safe drinking water, 90,000 citizens and 17,000 children die annually due to water related diseases.[3] Outbreaks of water borne diseases such as typhoid and infectious hepatitis have occurred in several provinces because of drinking water pollution. For instance, 10% of the rural population in 1995 was affected by diseases as a result of contamination of surface water with human waste. Currently, more than 90% of Egyptian villages are not provided with sanitary and hygeinic way of disposal or domestic sewage treatment plants, although more than 98% of the people in these areas have access to water. The existing wastewater treatment plants are mainly located in the large Egyptian cities and they suffer from lack of funds for operation and maintenance.[4]

Egypt is one of the most arid countries in the world and there are very limited groundwater reserves. Agriculture, industry, and the increasing population are thus dependent on the Nile which is supplying approximately 95% of the country's water needs. The maximum discharge of the river allowed to Egypt is 55.5 billion m^3/year, according to the water Nile agreement between Egypt and Sudan in 1959. Other water resources are considered to be very limited concerning efficiency and economy [1 bank cubic metre [bcm] of rainwater and 4.8 bcm of groundwater]. About 80% of the available water is used for irrigation purposes; 10% is used by industry and only 3% is used as drinking water.[4,5] Water pollution sources are mainly from sewage, industrial effluents, and agricultural run-off.[6] It is predicted that by the year 2017, the water demand will reach 97.79 billion m^3/year, while the water supply will reach 95.24 billion m^3/year. Therefore, Egypt is faced with a potential water scarcity situation due to increasing demands due to the rapidly growing population, as well as the growth in urbanization, agriculture and industry against a fixed supply of water. The deficit being replinshed by recycling wastewater and recapturing water losses.[5]

Kafr El-Sheikh Governorate, the selected area of study, lies in the north of Egypt along the western branch of the Nile. It covers an area of about 3437 km^2, and a population of about 2.22 million with a growth rate of 2.2%; 75% of them are living in rural areas. Sanitation service in Kafr El-Sheikh's main cities and in majority of the villages is inadequate, and constitutes a major environmental concern for the whole Governorate, as it is for Egypt. Since the beginning of the 1980s, the drinking water supply throughout the Governorate of Kafr El-Sheikh has been considerably improving through a series of projects supported within the framework of the Egyptian Government and the German financial co-operation. This improved water supply situation however, has led to a serious overcharging of traditional wastewater management systems and contributed to some extent to an increase in the groundwater level in the Nile Delta. Measures taken would provide approximately 30% of the population of the Governorate with conventional wastewater treatment facilities. Over the coming decades, however, the majority of the remaining population, particularly in the villages and small towns, cannot realistically be expected to be connected to these centralized wastewater treatment systems.[4]

Water quality is a technical term that is based upon the characteristics of water in relation to guideline values of what is suitable for human consumption and for all usual domestic purposes. Components of water quality include biological, chemical, and physical aspects.[6] The system of mains, pipes, pumps, valves, storage tanks, reservoirs, meters, fittings, and other hydraulic appurtenances used to deliver the water are known as the distribution system. Protecting and maintaining water distribution systems is crucial to ensuring high quality drinking water.[7] The quality of the water in the distribution system itself may not be the same as that of the treated water entering the system. Two points should be stressed: [1] the necessity of maintaining a sufficiently high pressure throughout the whole distribution system to prevent contamination from entering the system along the length of the mains by back syphonage; and [2] the necessity along distribution to have available means of chlorination to deal with accidental pollution, which is always a possibility.[7,8] Water tanks, particularly roof tanks, may be a menace to health if not properly located, constructed, and safely maintained. These tanks have always been a cause for unsatisfactory bacteriological results, outbreaks of waterborne diseases, or even a widespread epidemic.[9] Therefore, this study was conducted to carry out a sanitary survey of a municipal water treatment plant and its distribution system in a rural area located in Kafr El-Sheikh Governorate and to assess their water quality by examining biological and physico-chemical parameters in order to gauge the safety of water supply for human consumption.

MATERIAL AND METHODS

Study setting and design

Kafr El-Sheikh Governorate is subdivided into 10 markazes, namely; Kafr El-Sheikh [the capital], Disuq, Fuwa, Biyala, Sidi Salem, Hamul, Baltim, Qallin, Mutubis, and Riad. Among them only Mutubis does not have a major municipal water treatment plant. Instead, it has 13 compact small plants. In this study, one of these compact plants was randomly selected. A survey of this plant and its distribution system has been carried out through reviewing the governmental records and using a predesigned questionnaire to evaluate the roof water tanks sanitary condition. The items used for scoring included: frequency of inside cleaning [40 points], condition and type of inside paint or lining [15 points], construction material [10 points], availability of cover [10 points], and 5 points were given according to the availability of each of the following: outside paint or plaster, outside ladder, inside ladder, wash water pipe and surplus pipe, and/or float valve giving a total score of 100. When the roof tank had a score of sanitation ≥85, it was considered highly satisfactory; from 75 to 84; satisfactory, from 60 to 74; equivocal, and < 60%; unsatisfactory.

Water samples from the plant and its distribution system represented by tap water, and stored water [roof tanks and reservoirs] were collected fortnightly for one year to avoid the effect of seasonal variation giving a total of 100 samples. Water samples were collected, preserved, and analyzed physically, chemically, and biologically according to the Standard Methods for the Examination of Water and Wastewater.[10] Enumeration of Staphylococci was done according to the ISO procedures.[11] The coagulase and DNase activity were also examined.[12] The water samples were also filtered through membrane filters 47 mm in diameter with 0.45 µm pore size. After magnetic stirring and centrifugation, the sediments were examined microscopically using Lugol's iodine for identification of *Giardia* cysts. Staining using modified Ziehl-Neelson method for the detection of Cryptosporidia oocysts was also done.[13] Data were tabulated and analysed using Statistical Package for Social Sciences [SPSS] version 11.0 computer software package.[14]

RESULTS & DISCUSSION

Sanitary survey:

Selection of the water supply having the best quality and the protection of this supply from contamination are prime considerations in attaining suitable quality with a minimum of treatment.[15] Meeting drinking water standards is most difficult for water systems in small communities. Small communities often cannot afford the equipment and qualified operators necessary to ensure compliance with safe drinking water standards.[16] To this end, sanitary survey aids greatly in assuring a satisfactory water supply. In Kafr El-Sheikh, there are six major water treatment plants supplying more than 1.5 million people and associated industries with a current daily output of about 0.5 million cubic meters, covering a populated area of about 1037 km^2, and its distribution system serving nearly 1138 service pipes. All plants are situated along the River Nile course and they draw water from it, and daily treat nearly 4850 liters/second for distribution. In addition to treated surface water, some deep well stations are supplying water to some cities in Kafr El-Sheikh. These groundwater stations work under the supervision of the nearest surface water treatment plant. Mutubis covers an area of about 326.700 Km^2 representing 8.75% of total Kafr El-Sheikh area and subdivided into 3 main villages, 14 small villages, and 182 Ezbas. It has a population of about 178,201 comprising 23,678 urban and 154,523 rural. The municipal water supply in urban areas comes mainly from Fuwa plant which is one of the major plants in Kafr El-Sheikh. El Khadra treatment plant which was investigated in this study is one of the 13 compact minor plants supplying the rural areas in Mutubis. It supplies 25 Ezbas covering a population of about 160,000 and produces 80 Liters/second. Water is treated through coagulation-flocculation, sedimentation, rapid gravity sand filtration, and chlorination. The most commonly observed problems of rapid sand filters in these plants were: the presence of cracks, mud-balls, the untrained operators who did not practice "filtration to waste" for 10 minutes following backwash, and finally the filter units might not be backwashed for extended periods especially when the production of large volumes of water was required.

The unreliability of rural water supplies in parts of Kafr El-Sheikh stimulated people to store water in their houses to bridge periods when the supply ran dry. Storage and transport of water are commonly practiced in parts of the studied area where wholesome water through pipe systems is lacking to maintain the integrity of water supplies to the consumers. In these parts, people transport their needs of water from its sources, for long distances using different types of vehicles and containers as motor car-borne or motor car-drawn water tanks [63%] or separate galvanized iron tanks of different sizes [12%]. Plastic jerricans and other pots or utensils are used by a quarter of them where there is availability of public stand post "public faucets".

Although high rise buildings are not common in the studied area in Mutubis, some buildings with less than four floors are provided with water through roof tanks for augmentation in demand hours. As shown in figure 1, such tanks are made of reinforced cement [50%], concrete [40%], or galvanized steel [10%]. Contaminants from tank materials can sometimes leach into the drinking water, causing contamination. Cement-lined storage tanks can leach calcium carbonate into the water, which may significantly increase the alkalinity and pH of the water. This is especially true when the cement-lined material is new, but also depends on the type of cement used and the contact time between the water and cement material.[17] Many roof tanks [10%] are not covered, and consequently the water could be polluted with bird droppings, dust, and possible by animals or by the maliciousness of persons. Another drawback to the uncovered tanks is the growth of algae and other microorganisms in water which is exposed to the sunlight, a condition that lead to change in taste, odors, and discoloration of the water.[8,18]

Water tanks should be cleaned on a regular basis every month and not exceeding three months to be suitable for human use.

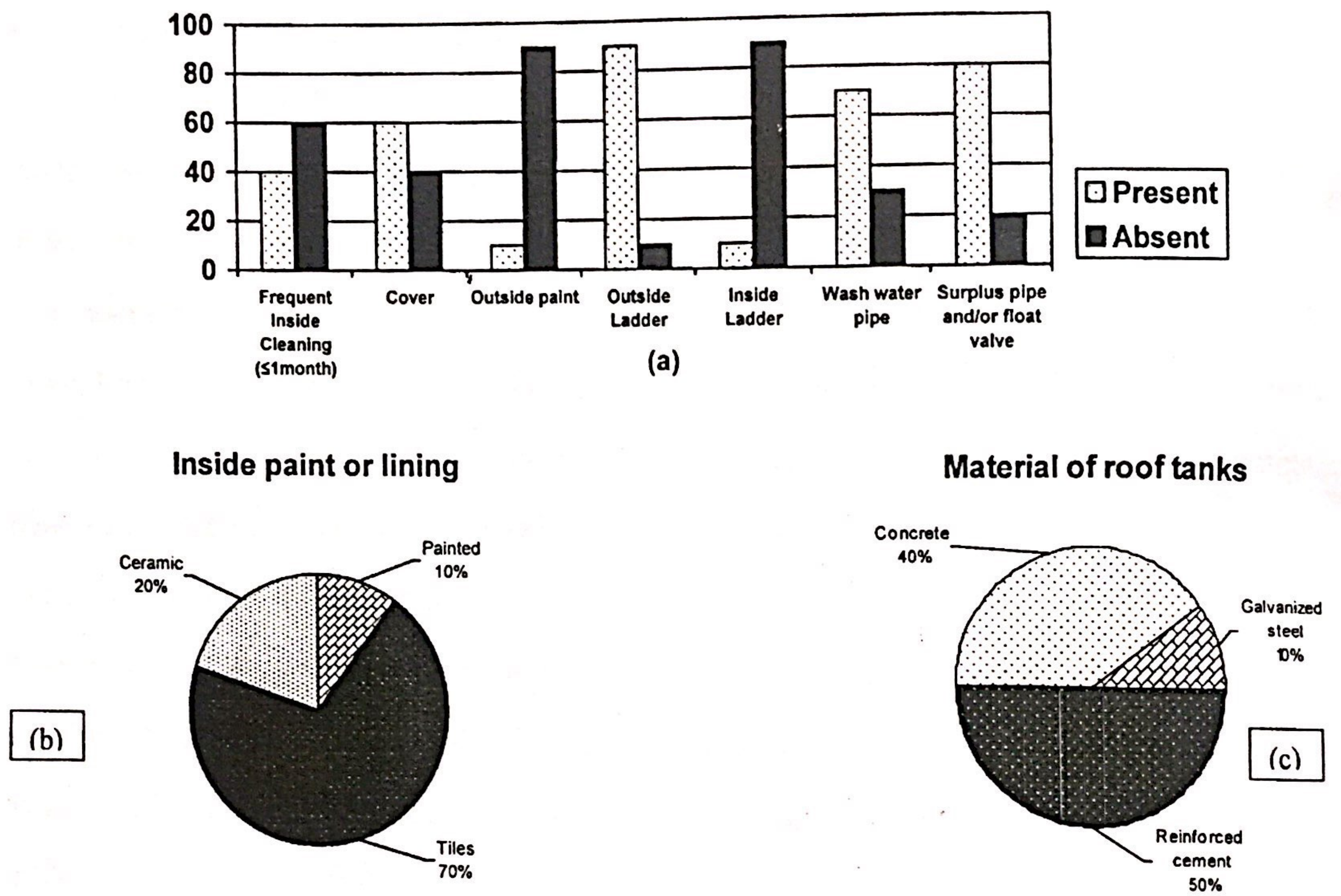

Figure 1: Sanitary conditions of the surveyed roof water tanks

Cleaning can be carried out by soap and water using brushes.[19] Stored water has been incriminated frequency as a vehicle for the spread of many intestinal diseases.[18] Most of the studied roof tanks were not cleaned frequently; only 40% were cleaned at least every month. The inside paint or lining protects the tank against aqueous chlorine corrosive effect and prevents the algal growth.[19] Cement tile-lined tanks which represented the highest percentage among the surveyed tanks were shown by Schonen and Thofern[20] to promote surface microbial growth on the reservoir 's surface. Ceramic lining which is the best inside lining owing to its glazed surface which enhances cleaning and disinfection processes was only found in 20% of the tanks.

It is worth mentioning that more than half of the studied roof tanks sanitary scores were unsatisfactory, and 20% were equivocal while only 20% were either satisfactory or highly satisfactory [Figure 2].

For water quality integrity to be compromised, specific reactions must occur that introduce undesirable compounds or microbes into the bulk fluid of the distribution system. These reactions can occur either at the solid–liquid interface of the pipe wall or in solution. Obvious microbial examples include the growth of biofilms and detachment of these bacteria within distribution system pipes and the proliferation of nitrifying organisms. Important chemical reactions include the leaching of toxic compounds from pipe materials, internal corrosion, scale formation and dissolution, and the decay of disinfectant residual that occurs over time as water moves through the distribution system. All these interactions are governed by a suite

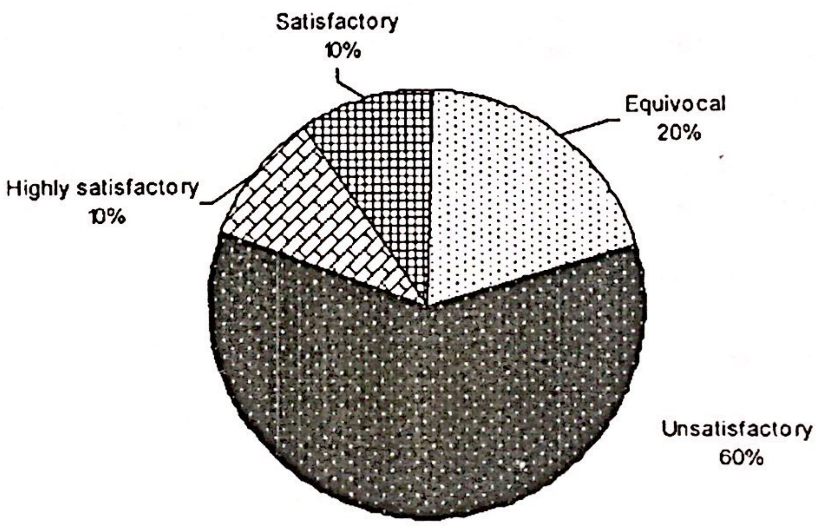

Figure 2: Distribution of roof tanks according to their sanitary score

of chemical and physical parameters including temperature, pH, flow regime, concentration and type of disinfectant, the nature and abundance of natural organic matter, pipe materials,...,etc. Many of these variables may be linked in distribution systems; for example, seasonal increases in temperature may be accompanied by changes in organic matter, flow regimes, and disinfectant concentrations. As a consequence, attempting to correlate the occurrence of a given event [such as corrosion, microbial growth, disinfectant decay, or disinfectant by products [DBP] formation within distribution systems to a single variable [such as temperature] is difficult.[7]

Physico-chemical water quality

According to Egyptian drinking water standards [Ministerial decree No.108 for 1995],[21] the mean values of all the physicochemical parameters except turbidity of water samples collected from roof water tanks [5.14 mg/L] were in compliance [Table 1]. Turbidity is an important water quality parameter because it has been reported to hide disease causing microorganisms and affect treatment performance.[22] Increased turbidity in a finished water reservoir may be an indication of a water quality problem within it which could be due to contamination in the storage tank, water age, or mixing issues or tank material degradation.[17]

The importance of pH in distributed water is normally related to the corrosive or scale forming properties of water and to the efficiency of chlorine disinfection.[22] In the present study, the recorded pH values of water samples from different sources were in compliance with pH limits specified in the decree No. 108 for 1995.[21]

The maintainance of a total chlorine residual of not less than 0.5 mg/L or a free chlorine residual of not less than 0.2 mg/L in the water throughout the distribution system is essential for providing a sanitary protection.[22] In this study, the mean residual chlorine was found to be almost nil for all water samples types. Moreover, chlorine inactivation of pathogens requires sufficient contact time. Chlorine is less efficient at inactivation in high pH water [pH>8], which is not the case in this study, and also progressively loses killing power as the turbidity of the water increases.[23]

The analytical findings of total, calcium, and magnesium hardness revealed that their mean values were lower in all water samples than the maximum permissible limits [500 mg/L, 200 mg/L and 150 mg/L, respectively] of Egyptian water quality criteria.[21] Hard water is generally less corrosive than soft water due to increased concentrations of calcium in the hard water. Depending on the water's pH and alkalinity concentration, calcium will combine with carbonate alkalinity to form a protective coating on the pipe wall that can retard corrosion. Soft waters, low pH, and low alkalinity can result in corrosive conditions affecting cement-lined pipes and storage tanks. Rather than calcium concentration itself, an increase or decrease in calcium concentration may indicate potential for contamination to be released in the distribution system. Waters that have very low ion content [soft waters] are aggressive to calcium hydroxide contained in hydrated cements. Calcium hydroxide will also leach from cement-mortar linings exposed to soft waters. The extent of leaching increases with, among other factors, the residence time in the pipe and is inversely proportional to the pipe diameter. An increase in calcium levels could indicate the potential for increased scale formation and reduced flow.[17]

Biological water quality

The results presented in Table 2 revealed that approximately all biological parameters examined in water samples collected from the selected water treatment plant and its distribution system were violating the Egyptian drinking water standards.[21] This could be attributed to bacterial regrowth especially in stagnant parts of piped distribution systems, in domestic plumbing,

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Table [1]: Physico-chemical analyses of water samples collected from the selected water treatment plant and its distribution system in Mutubis, Kafr El-Sheikh Governorate

Parameters	Unit	Water treatment plant $\bar{x} \pm$ SD	Tap water $\bar{x} \pm$ SD	Roof water tank $\bar{x} \pm$ SD	Stored water $\bar{x} \pm$SD	Egyptian Drinking Water Standards [Decree No. 108 for 1995]
pH	-	7.63 ± 0.0495	7.63 ±0.11	7.65 ±0.04622	7.79 ±0.1223	6.5-9.2
Turbidity	NTU	1.95 ± 0.15297	2.43 ±0.3463	5.14 ±0.5164	4.7±1 .9688	5
Conductivity	µs/cm	532.16 ± 74.92923	549.3± 61.15	507.5± 23.965	404.5 ±50.48	Not included
Total Solids [T.S.]	mg/L	539.52 ± 64.247	544.7 ±48.157	648.36 ±75.119	607.7 ±45.106	Not included
Total Dissolved Solids [T.D.S.]	mg/L	443.96 ± 88.213	506.7 ±40.03	346 ±84.53	313.48 ±49.924	1200
Total Suspended Solids [T.S.S.]	mg/L	96.5 ± 23.23	38 ±20.833	302.3±121.124	294.24 ±87.523	Not included
Sulphates [SO_4^{--}]	mg/L	42.3 ± 0.2536	42.5 ± 1.503	40.86 ± 2.942	42.3 ± 2.294	400
Phosphates [PO_4^{---}]	mg/L	0.34 ± 0.0141	0.33 ± 0.0611	0.29 ± 0.08158	0.27 ± 0.05609	Not included
Chloride [CL^-]	mg/L	80 ± 5.07	86.6 ± 7 2.5	81.8 ± 2.449	65 ±10.19804	500
Total Chlorine Residual	mg/L	0.32 ± 0.0662	0.2 ± 0.0509	0.13 ± 0.0204	0.26 ±0.0102	Not included
Free Chlorine Residual	mg/L	0.075 ± 0.0153	0.036 ± 0.00952	0.035 ± 0.0051	0.0376 ±0.01234	Not included
Alkalinity	mg/L	92.5 ± 2.54	82.5 ± 2.536	84.8 ± 5.099	85 ± 5.8309	Not included
Total Hardness	mg/L	273.2 ± 45.89	250 ± 45.83	256.00 ± 31.09	223.6 ±35.69314	500
Calcium Hardness	mg/L	165 ± 15.29	160 ± 30.594	160 ± 20.2843	144± 25.4951	Not included
Magnesium Hardness	mg/L	109 ± 30.59	95 ±15.297	105.6 ± 15.297	80 ±10.198	Not included
Nitrates [NO3 - N]	mg/L	0.42 ± 0.22	0.437 ± 0.1695	0.41 ± 0.19466	0.615± 0.0153	10
Ammonia [NH4 - N]	mg/L	0.18 ± 0.02	0.15 ± 0.00952	0.17 ± 0.019	0.162 ±0.03657	Not included

and in plumbed-in devices. The principal determinants of regrowth are temperature, availability of nutrients, and lack of residual disinfectant.[17,24] Stagnant water can occur in dead-end pipes or storage facilities that are over sized or have periods of limited use. Stagnant water provides an opportunity for suspended particulates to settle into pipe sediments, for biofilm to develop, and for biologically mediated corrosion to accelerate. Long-term water storage in finished water reservoirs [lasting weeks or several months] can result in waterborne heterotrophic bacteria growing in sediments, attaching to inner walls, and spreading a biofilm over surfaces. Long retention time can also result in reduction in disinfectant residual and cause the release of ammonia through the decay of chloramines. Flushing and pigging are routine maintenance practices often conducted within the distribution system to address consumer complaints and to reduce the retention time of water to improve water quality. Improper flushing can result in moving a contaminant further into the distribution system.

Total plate counts are useful for determining changes in water quality during water storage and distribution, and can be used to assess microbial growth on materials used in water distribution systems and for determining the extent of growth in distribution water.[17]

Among the examined water samples, roof water tanks had the highest mean Total Plate Count [TPC] [$2.38x10^2 \pm 2.8x10^1$ CFU/ml], and Total Coliform Count [TCC] [$1.5 \times 10^6 \pm 1.4 \times 10^6$ MPN/100ml] followed by stored water [$1.44x10^2 \pm 1.48x10^1$ CFU/ml, $1.24x10^3 \pm 1.03x10^2$ MPN/100ml, respectively] in different utensils. Both mean values differed significantly from that of the water treatment plant [Table 3] and were positively correlated [Figure 3]. Moreover, roof water tanks had also the highest mean fecal coliform count [$2.3 \times 10^1 \pm 2.9 \times 10^1$ MPN/100ml], half of them were positive for *E. coli.* The higher bacterial counts often indicate the sanitation

Table [2]: Biological profile of water samples collected from the selected water treatment plant and its distribution system in Mutubis, Kafr El-Sheikh Governorate

Sample type	Total Plate Count [CFU /ml] at 37ºC	Total Coliform Count [MPN/ 100ml]	Fecal Coliform			Streptococci		Staphylococci		Total Algae Count [unit/L]
			Count [MPN/100ml]	E .coli	IMVC	Count [MPN/100ml]	S. fecalis	Count [CFU/ml]	Coagulase & DNase	
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	% positive		$\bar{x}$±SD	% positive	$\bar{x}$± SD	% positive	$\bar{x}$±SD
Water treatment Plant	$6.55x10^1$± $2.60x10^1$	$8.52x10^2$± $1.263x10^3$	< 3	NCO	NCO	$1.81x10^1$± 3.0594	0.0	<200	NCO	$1.71x10^5$ ± $2.9635x10^4$
Tap water	$1.05x10^2$± $2.86x10^1$	$1.28x10^1$± 9.744	< 3	NCO	NCO	9.216 ± 2.9574	0.0	$5.53x10^2$± $4.10x10^2$	0.0	$3.51x10^5$ ± $5.5184x10^4$
Roof water tank	$2.38x10^2$± 2.8010^1	1.5 x 10^{6}± 1.4 x 10^6	2.3 x 10^1 ± 2.9 x 10^1	50%	- + - + inter-mediate type I mainly soil	7.8 ± 1.589	25%	$1.2x10^3$± 101.325	50%	$3.23x10^5$ ± $6.4480x10^4$
Stored water	$1.44x10^2$ ±$1.48x10^1$	1.24 x 10^{3}± 1.03 x 10^2	< 3	NCO	NCO	1.1 x 10^1 1.39	0.0	$8.0x10^2$± $6.0x10^2$	25%	$5.15x10^5$ ± $9.8095x10^4$
Egyptian Drinking Water Standards Decree No.108 for 1995	Not more than 50 CFU/ml	Not to exceed 3 coliform/ 100ml	Free			Free	Free	Not included		Free

NCO : Not Carried Out

defects or unsatisfactory disinfection process inside the roof water tanks that were obvious during the survey and were expressed in a form of defects in the bacteriological quality. In addition, roof water tanks showed the highest turbidity and the lowest free chlorine residual than the other water samples and there was a significant positive and inverse correlation between them and TPC as well as TCC, respectively [Figure 3]. Similar results regarding the inverse association between high densities of standard plate count organisms and high concentrations of free available chlorine were obtained by Reilly and Kippin.[25] Low chlorine levels in water supplies of the Western State of Nigeria were also found to promote coliform regrowth in consumer's storage containers.[26] On the contrary, some reports noted that high populations of standard plate count mask the presence of indicator bacteria.[23]

Although Egyptian standards[21] stated that the Coliform group must be nil in chlorinated drinking water for 95% of water samples collected during one year, 67% of all water samples were contaminated with total coliform counts, but surprisingly fecal coliforms [Figure 4] were detected only in roof water tanks [50%]. The presence of total coliforms in the distribution system while possibly due to inadequate treatment could also be due to cross-connections or failure to maintain an adequate disinfectant residual. Moreover, they may gain access from booster pumps, from the packing used in the jointing of mains, or from washers on service taps.[17]

Fecal coliforms yield much stronger evidence of fecal pollution and the presence of *E. coli* confirms recent fecal pollution of drinking-water.[24]

All water samples showed higher Streptococci counts than the permissible limits, an organism that has been listed as a low risk pathogen. Although, roof water tanks had the lowest mean count [7.8±1.589 MPN/100ml], a quarter of them were *Streptococcus fecalis* which was not

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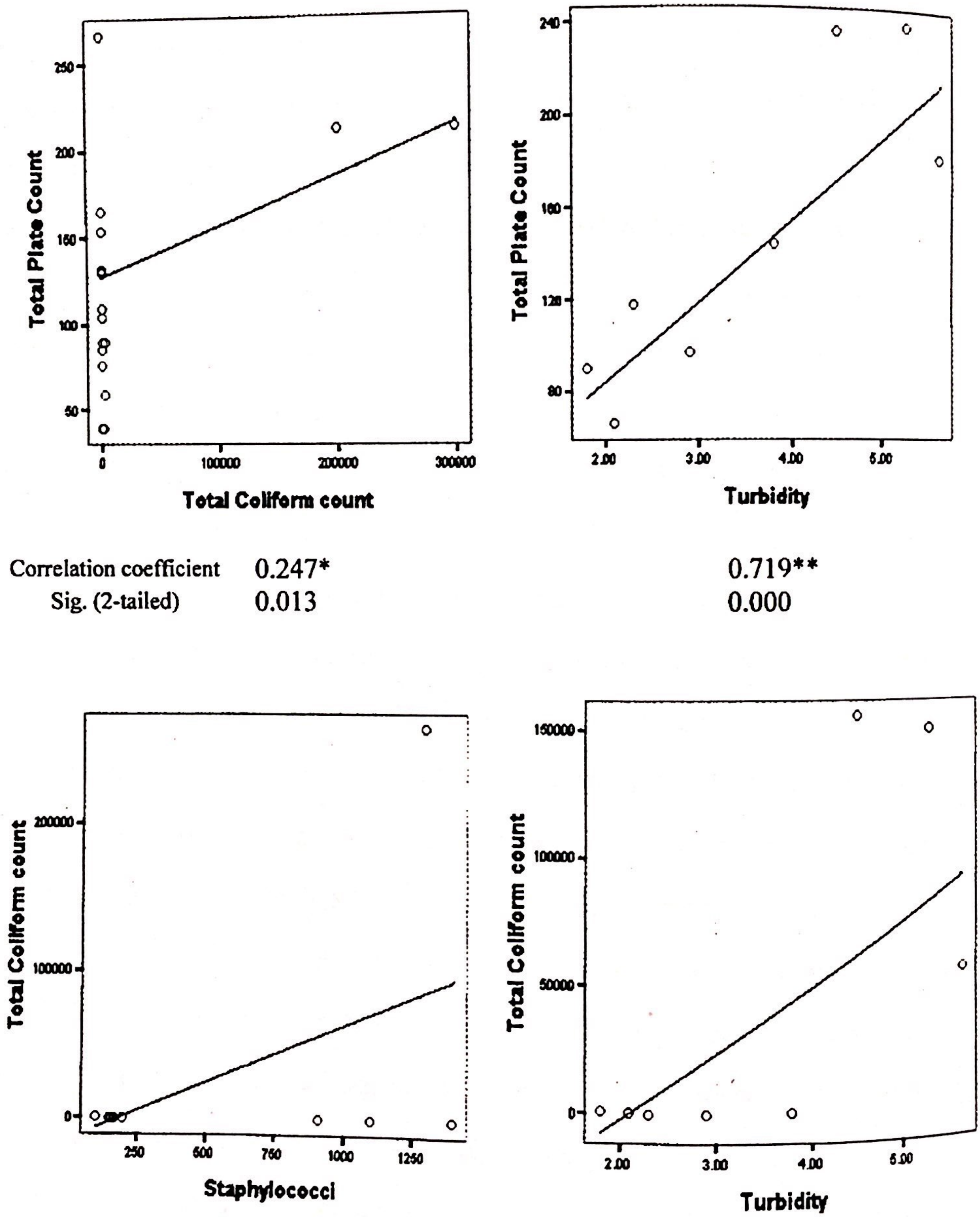
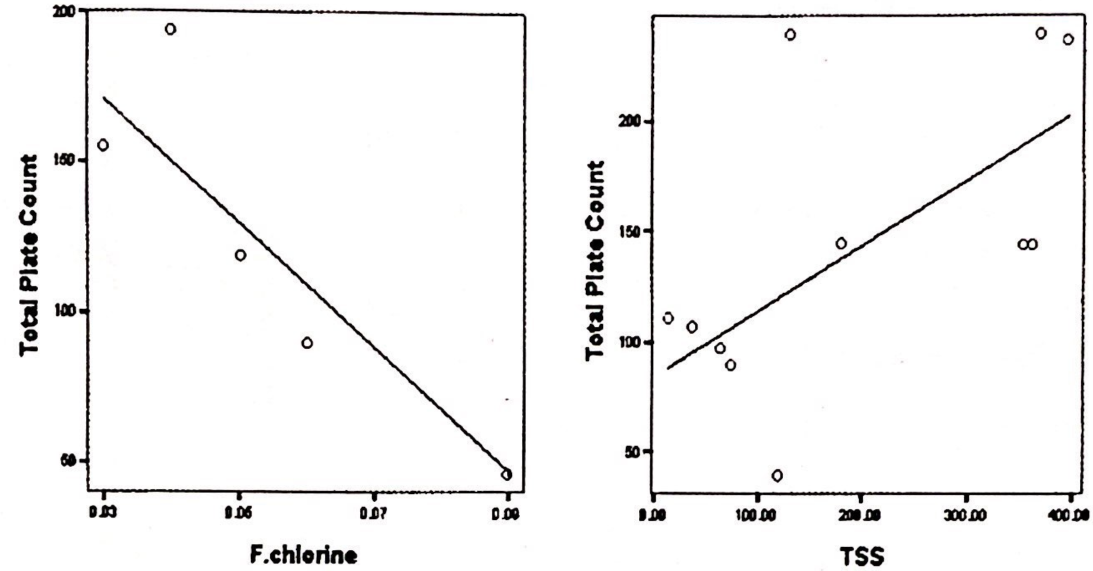


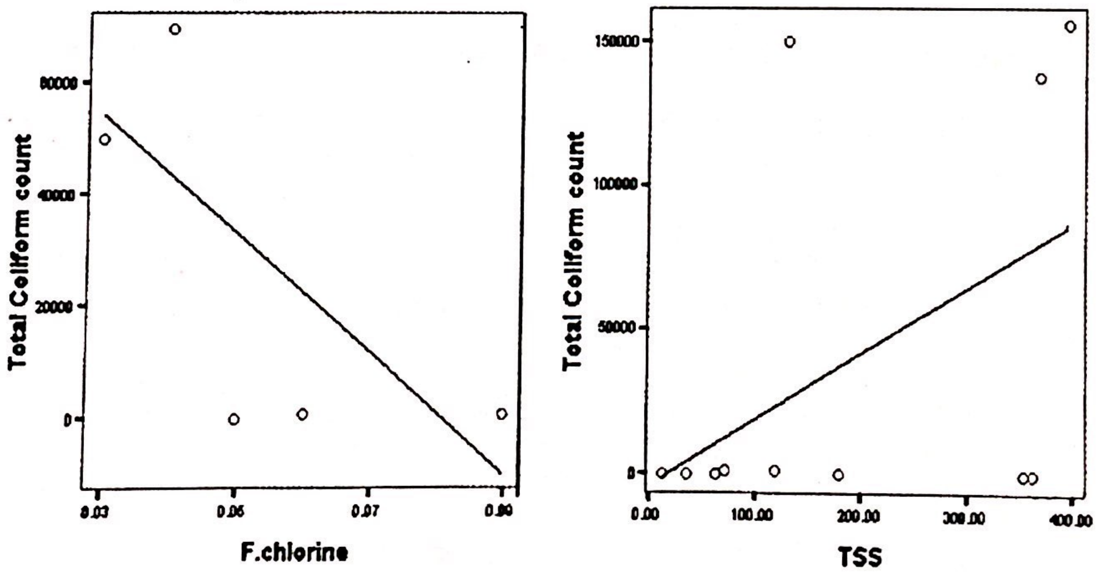
Correlation coefficient 0.247* 0.719**
Sig. (2-tailed) 0.013 0.000

Correlation coefficient 0.44** 0.281**
Sig. (2-tailed) 0.000 0.000

Figure 3a: Correlations between Total Plate Count, Total coliform count and some drinking water criteria



Correlation coefficient	-0.488**	0.603**
Sig. (2-tailed)	0.013	0.000



Correlation coefficient	-0.218*	0.463**
Sig. (2-tailed)	0.013	0.000

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

Figure 3b: Correlations between Total Plate Count, Total coliform count and some drinking water criteria revealed in any of the other samples. Similar results were obtained by El-Sehimy and El-Sawy.[19,27] who reported the presence of indicator organisms "fecal coliforms and fecal streptococci" in roof tanks in Cairo and Alexandria, respectively. Roof tanks' contamination might not only be due to the contaminated water source, but it might also be the result of fecal contamination of the roof tanks by animals or humans who might have an access to them. Abdel Rahman[28] showed that 15 samples [27.5%] of drinking water were positive for fecal coliforms, while only one sample [2.5%] was positive for fecal streptococci.

Staph. aureus is 5 to 20 times more resistant to chlorine than coliforms and also are more resistant to other halogen disinfectants than coliforms and enterococci. For these reasons, *Staph. aureus* is considered a good indicator of water quality.[27] The results of the present study revealed that although none of the analyzed water treatment plant samples were positive with respect to *Staphylococcus aureus*, all water samples from its distribution system had high *Staphylococci counts.* Moreover, Coagulase & DNase-positive Staphylococci were isolated from 18.75% of all water samples [50% and 25% from roof water tanks and stored water, respectively]. Contrary to the result of this study which revealed a positive correlation between the TCC and Staph. aureus [Figure 3], LeChevallier and Seidler[29] isolated coagulase-positive *Staphylococcus aureus* from over 6% of 320 rural drinking water specimens and found that there was no correlation between the simultaneous presence of the coliform indicator group and *Staph. aureus.*

The algae produce undesirable odors, tastes, toxic substances, the potential for increased formation of trihalomethanes [THMs], clogging of sand filters, and corrosive effect on the pipes of the distribution systems and fortunately much less common are incidences of human

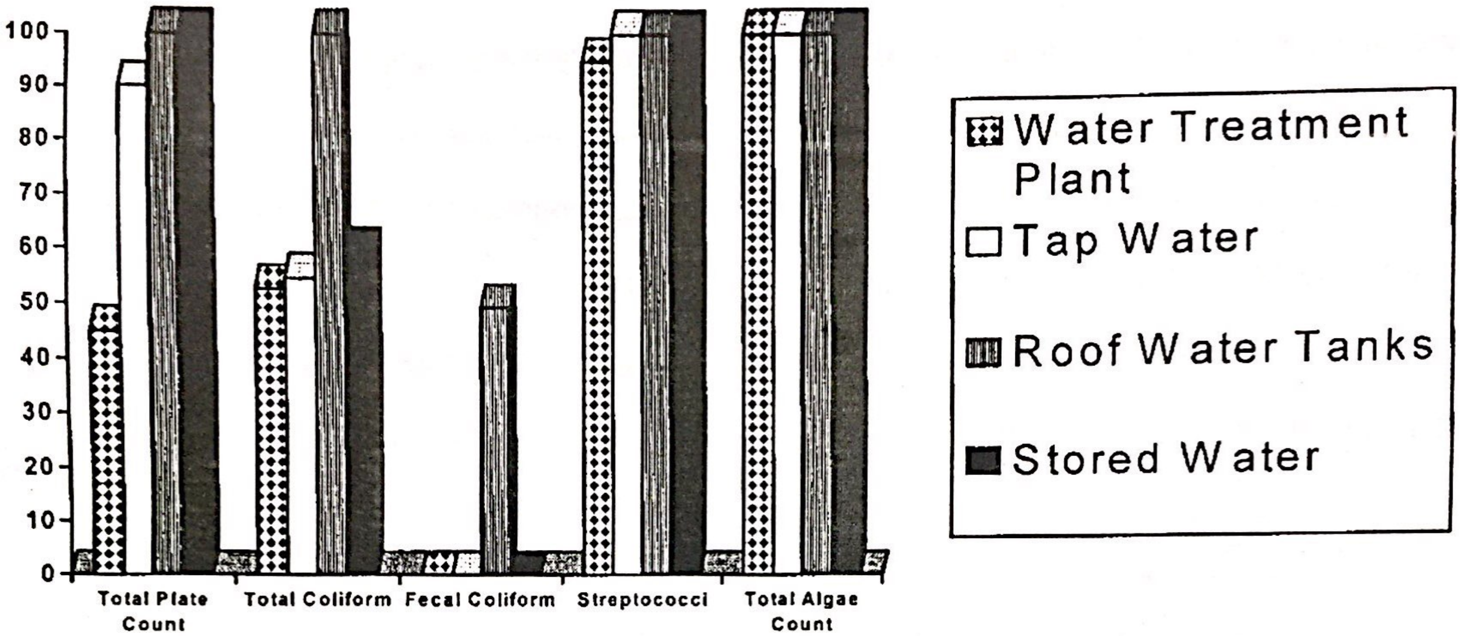


Figure 4: Frequency of Water Samples not complying biologically with Egyption Standards

illness. The presence of any objectionable odor may cause the consumer to go to a more palatable but unsafe water supply. Therefore, the importance of producing palatable water cannot be underemphasized.[30]

In this study, stored water samples showed the highest mean algal counts [$5.15x10^5±9.8095x10^4$ units/L], and despite that most of the surveyed roof water tanks [60%] were covered [Figure1], they had high mean value concerning algal counts [$3.23x10^5±6.4480x10^4$ units/L]. This could be explained by the presence of types, not differentiated in this study, which do not require light such as actinomycetes.[30] It is worth mentioning that water treatment plant samples showed high mean algal counts [$1.71x10^5±2.9635x10^4$ units/L]. Minimizing algae can be achieved by increasing the efficiency of filtration and by proper flushing of the distribution system at suitable frequent intervals.

Tables [3 & 4] demonstrate that most of the biological as well as the physico-chemical parameters of the distribution system differed significantly from those of the water treatment plant suggesting that water supplies in the distribution system may be contaminated directly by the dumping of untreated or inadequately treated sewage into a community water supply or indirectly through cross-connections, back siphonage, leaking service connection, damaged or defective hydrants during main-laying and repair or through inexpert repairs to domestic plumbing systems and defective storage tanks.[17]

Table [3]: The Biological parameters differences between the distribution system and the water treatment plant

Sample type	Total Plate Count [CFU/ml] at 37ºC		Total Coliform Count [MPN/100ml]		Streptococcus Count [MPN/100ml]		Staphylococci Count[CFU/ml]		Total Algae Count[unit/L]	
	t-test	Sig. [2-tailed]	t-test	Sig. [2-tailed]	t-test	Sig. [2-tailed]	t-test	Sig. [2-tailed]	t-test	Sig. [2-tailed]
Tap water	-13.116	.000	2.868	.006	11.051	.000	-5.575	.000	-14.381	.000
Roof water tank	-22.601	.000	-4.988	.000	15.142	.000	-54.873	.000	-10.735	.000
Stored water	-13.116	.000	2.868	.006	11.051	.000	-5.575	.000	-16.808	.000

Table [4]: The physico-chemical parameters differences between the distribution system and the water treatment plant

Parameters	Tap water		Roof water tank		Stored water	
	t-test	p-value	t-test	p-value	t-test	p-value
pH	-.431	.669	-1.642	.107	-5.649	.000*
Turbidity	-6.285	.000*	-29.671	.000*	-14.111	.000*
Conductivity	-.806	.424	1.564	.124	7.064	.000*
Total Solids [T.S.]	-.326	.746	-5.505	.000*	-4.344	.000*
Total Dissolved Solids [T.D.S.]	-3.243	.002*	4.004	.000*	6.436	.000*
Total Suspended Solids [T.S.S.]	9.069	.000*	-8.369	.000*	-10.947	.000*
Sulphates [SO_4^{--}]	-.656	.515	-8.369	.000*	-.217	.829
Phosphates [PO_4^{---}]	.645	.522	2.336	.024*	6.806	.000*
Chloride [CL^-]	-6.339	.000*	2.870	.006*	6.666	.000*
Total Chlorine Residual	6.840	.000*	-1.768	.083	3.877	.000*
Free Chlorine Residual	10.545	.000*	13.092	.000*	9.361	.0008*
Alkalinity	13.868	.000*	12.279	.000*	6.443	.000*
Total hardness	1.992	.052	6.841	.000*	4.266	.000*
Calcium hardness	.819	.417	1.551	.127	3.431	.001*
Magnesium Hardness	1.930	.060	1.020	.313	4.403	.000*
Nitrates [NO3 - N]	-.216	.830	.468	.642	-4.324	.000*
Ammonia [NH4 - N]	5.687	.000*	.333	.740	2.853	.006*

* Significant results

Protozoa: In recent years, it has become apparent that the traditional bacterial indicators of fecal contamination, i.e. the fecal coliform or more recently the *E. coli* bacteria, are not good indicators for the pathogenic protozoa, in particular *Giardia* and *Cryptosporidium*, which have been found in some water bodies allover the world. Both can contaminate filtered public water systems even when the water quality is within regulatory limits for bacterial indicators and chlorine.[23]

Egyptian standards[21] stated that drinking water must be free from any planktonic organisms, and the Maximum Acceptable Value [MAV] for total pathogenic protozoa in some countries is less than 1 [oo]cyst per 100 liters of drinking-water.[23]

In this study, *Giardia* cysts were detected in 37 of the 100 examined samples, with a geometric mean [for positive samples] of 50 cysts per 100 liters and a range of 20 to 110 cysts per 100 liters. *Cryptosporidium* oocysts were observed in 22 samples, with a geometric mean [for positive samples] of 2.52 oocysts per 100 liters and a range of 0.7 to 28 oocysts per 100 liters. Overall, *Giardia* or *Cryptosporidium* spp. or both were found in 40% of the whole water samples.

Chlorination as a sole means of disinfection within water supplies may not be entirely effective in inactivating the robust *Giardia* cysts and the infective *Cryptosporidium* oocysts.[13,23] World Health Organization reported that combination of adequate filtration and appropriate additional treatment [usually chlorination] is believed to render water safe.[31] If the turbidity removal is high, then removal of *Giardia* cysts will also be high. Again, if the filtration process removes high percentages of total coliform bacteria, then high percent\ removals of protozoa oo[cysts] can be expected also.[23]

In the current study, *Giardia* and Cryptosporidia were detected in 32% and 16% of the samples collected from the water treatment plant, respectively [Table 5] which emphasize the physical defects in plant construction or lack of effective operation or maintenance resulting in increased potential for oo[cysts] passage since there has never been a waterborne outbreak involving a well-operated and maintained treatment plant using a combination of filtration and disinfection.[31] Moreover, *Giardia* cysts were detected in 36% of tap water samples which is a figure too close to those reported from tap water samples taken in two of the Nile Delta Villages and showed a contamination rate of 36% and 37.5%.[32,33] While

Table [5]: *Giardia* and *Cryptosporidium* in water samples collected from the selected water treatment plant and its distribution system in Mutubis, Kafr El-Sheikh Governorate

Parasite	Water treatment Plant		Tap water		Roof water tank		Water treatment Plant	
	% positive	X^2 P-value	% positive	X^2 P-value	% positive	X^2 P-value	% positive	X^2 P-value
Giardia	32	10.119	36	5.252	36	5.297	44	10.048
Cryptosporidia	16	.001*	20	.022*	28	.021*	24	.002*
r & sig,	.636 & .001*		.458 & .021*		.460 & .021*		.634 & .001*	

cryptosporidium oocysts and *Giardia* cysts were present in 28% and 36% of tank water samples, respectively, they were detected in 25% and 50% of water tanks in Alexandria.[28] The high detection rate in the distribution system could be the result of both; the poor quality of the effluent and possibly post-treatment contamination of water secondary to cross connections, damage, or repairs to main pipes.

A significant association was observed between *Cryptosporidium* oocysts and *Giardia lamblia* cysts [Table 5] which may indicate a common source of pollution. Co-incidental occurrence of *Cryptosporidium* oocysts and *Giardia lamblia* cysts has been found in 19% of samples, while co-incidental absence of the two parasites has been found in 60% of samples. These results comply with those reported by Gallaher *et al.*, [34] who detected an association of the two organisms in 75% of the examined water samples.

In conclusion, periodic monitoring of water quality at the plant and distribution system levels, regular health education campaigns regarding the practice of construction and maintaining roof water tanks, and increased budgetary allocations and in-service training, in addition to other incentives would enhance the profile and quality of drinking water in Kafr El-Sheikh.

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