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Assessment of Water Quality of a Manmade Lake in Dubai, UAE

[1]Mohammad Armin, [2]Aimina Ayoub, [3]Ryan Sisson, [4]Rami El Khatib

[1,2,3,4] School of Environment and Health Sciences, Canadian University of Dubai

Abstract: **A study was conducted to assess the water quality of a manmade lake supplied with reclaimed water in Dubai. Tests were performed to determine whether or not microbiological and physico-chemical parameters complied with local standards. The microbiological properties tested were above local requirements. Those results reflect the potential occurrence of infectious agents in the water that could be a risk to public health in cases of direct or indirect contact with the water. To identify the possible causes of water impairment, physico-chemical parameters were assessed. The results showed that the majority of them including pH, temperature, conductivity, total suspended solids, dissolved oxygen, nitrates, and phosphates were within the local standards for reclaimed water discharged into lakes, whether natural or artificial. However, total chlorine and free chlorine levels, which are indicators of chlorine residual concentrations in the water, were not within the local recommended range. 0.1 mg/L Cl_2 of free chlorine was found in all samples, and total chlorine levels oscillated between 0.1 and 0.2 mg/L Cl_2 while values for both parameters should vary between 1 and 2 mg/L Cl_2. The low levels of chlorine residuals found in the lake seem to be correlated with the high concentrations of indicator bacteria. The dissipation of chlorine in the distribution systems transporting the reclaimed water from the wastewater treatment plants to the lake, which is the end point of use where the water is stored, probably favors the persistence and regrowth of pathogens in the reclaimed water.**

Keywords: **reclaimed water, water quality, microbiological parameters, physico-chemical parameters, lake, free chlorine, total chlorine.**

1. INTRODUCTION

Nowadays, regions around the world, including Dubai, are facing water shortages. This water crisis has been the consequence of a rapidly growing population. Dubai has witnessed an important increase of its population in a relatively short period of time which has accelerated urbanization of the area. The major residential, commercial, and tourism projects that Dubai has undertaken account for the Emirate's economic flourishing and prosperity [1]. Dubai's limited freshwater supply is not compatible with the Emirate's freshwater consumption which is one of the highest in the world. Its freshwater resources cannot supply the increasing water demand linked to the fast development of the Emirate [2]. This major challenge is forcing Dubai to seek alternative, non-conventional resources including desalinated water and reclaimed water from wastewater treatment plants [3]. Reclaimed water may be used for different purposes including agriculture, industrial processes, and groundwater recharge of aquifers as well as recreational impoundments for aesthetic and recreational purposes. However, in Dubai, treated wastewater usage is limited to the irrigation of parkland, landscape and streets due to water quality and safety concerns in relation to human and environmental health [2]. As the quantities of effluent generated by sewage treatment plants in Dubai exceed the volume of water needed for irrigation, the surplus is discharged into different waterbodies. Ensuring the highest quality of water effluent from the treatment plant is essential to protect public health from potential risks. The microbiological quality of water is a major concern. Pathogenic microorganisms can cause various waterborne diseases as a result of dermal contact, ingestion, or inhalation of water droplets containing the pathogens [4]. Several infectious agents such as Cryptosporidium, Giardia, and Legionella can be transmitted to humans through water via those routes of exposure [5]. Therefore, accidental contact or ingestion of water may lead to adverse health conditions if the water quality and safety of the lake have been negatively altered. This issue

can be particularly problematic for most vulnerable people including children and older adults. Several factors could explain the possible impairment of the lake water quality. Pathogenic microorganisms may survive the wastewater treatment process and persist in the treated effluent [6]. Certain pathogens may have developed resistance to disinfectants such as chlorine and are now able to persist in reclaimed water [7]. Furthermore, physico-chemical parameters including pH, temperature, and dissolved oxygen, of water may play a major role in water quality degradation [8]. Furthermore, high nutrient concentrations in water, including nitrogen and phosphorus, may encourage bacterial growth. Excessive levels of nutrients promote algae blooms which may result in the growth of harmful microorganisms that feed on dead algae bodies [9]. Water quality may also be prone to impairment due to the prompt dissipation of chlorine or other chemicals used in the disinfection phase of the treatment process. Consequently, pathogenic microorganisms may regrow in the water distribution systems [10]. Assessing the water quality of reclaimed water at the end point is crucial due to the risk of survival or potential regrowth of certain pathogenic microorganisms after the water treatment process.

2. MATERIALS AND METHODS

Safa Park is a very popular park in Dubai usually frequented by families with children. Three manmade lakes are located in the park. A quantitative research has been conducted to evaluate the physico-chemical as well as the microbiological quality of the largest lake in Safa Park which is continuously supplied with reclaimed water surplus via the irrigation system. This manmade lake is not intended for recreational activities apart from boating. To assess the microbiological quality of water, coliform bacteria, including total coliform and *Escherichia coli (E.coli),* were tested. Temperature, pH, conductivity, total suspended solids, dissolved oxygen, nitrates, total phosphate, total chlorine, and free chlorine levels were determined to examine the physico-chemical quality of the lake as well as the possible relation between those parameters and microbiological parameters.

The water sampling procedure was performed over a three day period. The first day represented the "before peak" period, the second day corresponded to the peak period when the park is the most visited, and the last day represented the "after peak" period. This methodology aimed at determining whether or not human activities occurring near the lake could have contributed to water impairment if the results revealed that water quality parameters tested did not comply with local standards. Each day, three samples were collected from various areas across the lake and the average of the samples was calculated. Sample apparatus used for water collection were 2L plastic bottles for chemical parameters and 100 mL sterile bottles for microbiological parameters. Regarding microbiological characteristics, samples needed to be refrigerated between +2 to +4°C for proper preservation of the samples in order not to alter the parameters before they were tested. The sampling procedure used was Grab (Spot) sampling, which consisted of taking samples manually a few centimeters below the water surface.

Various devices were used to assess water quality properties. A Multi-Parameter Meter was utilized for testing pH, conductivity, and dissolved oxygen on-site. A pH probe, a dissolved oxygen probe, and a conductivity probe were connected to the Multi-Parameter. APHA and HACH pocket test methods were used for the testing of chemical parameters. For the on-site testing of total and free chlorine, a HACH pocket colorimeter has been added to 5mL water samples, and a colorimeter was used to measure the levels of residual chlorine present in the samples. For the testing of phosphate, water samples were added to LCL 350 indicator and placed in a DRB 200 reactor at 100°C. To determine nitrate concentrations, the water samples were added to LCL 339 Nitrate reagent. Phosphate and Nitrate were read with a Spectrophotometer (DR 5000 machine). Samples were placed in an oven (BD 115 machine) for 1 hour and 15 minutes at 100°C to measure total suspended solid levels. After this phase, samples cooled down for 15 minutes in desiccators before suspended solid concentrations could be determined. The results were read with an analytical balance. The IDEXX Quanti-Tray sealer with Colilert reagent was used for the testing of the microbiological parameters. IDEXX Quanti-Tray/2000 gives quantities of bacteria in 100 mL sample. The Quanti-Tray was placed in a Low-Temp Incubator (BD 115 Machine) for 24 hours at 35°C. After this phase, total coliform values could be read. Fluorescence Analysis Cabinet and UV hand lamp have been used to read *E.coli* levels (CM – 10A Machine).

3. RESULTS AND DISCUSSION

In the present study, coliform bacteria including total coliform and *E. coli* were used to evaluate the microbiological quality of the lake. When assessing microbiological water quality, coliform bacteria are universally accepted indicators of fecal contamination [11]. Those bacteria are usually not harmful or pathogenic but their presence in water indicates the

likely occurrence of disease-causing microorganisms which may represent a risk to human populations. The microbiological parameters assessed, which were total coliform and *E. coli*, did not comply with local standards. Total coliform and *E. coli* values for all samples exceeded the local recommended limits of 1000 MPN/100mL and 200 MPN/100mL respectively, for reclaimed water discharged into lakes. Those results are indicators of fecal contamination of the lake and are predictive of the potential presence of pathogenic microorganisms in the water. Those microorganisms may have survived the disinfection phase of the water treatment process, and their persistence in the water effluent could pose a potential risk to public health. Physico-chemical parameters such as pH, temperature, conductivity, or dissolved oxygen as well as excessive nutrient concentrations may also influence the survival of pathogenic microorganisms present in the water [8][9]. Moreover, inadequate levels of chlorine residuals in the water may favor the persistence of pathogens [10]. As physico-chemical properties may promote the survival and growth of pathogens, monitoring those factors, and limiting their effects on the lake water quality is essential to prevent adverse health effects associated with impaired waterbodies.

Table 1 encompasses the results and analysis of the data collected for the study.

Table: 1. Analysis of physico-chemical properties

PARAMETER	UNIT	DAY 1	DAY 2	DAY 3
pH	–	7.6 @ 29°C	7.73 @ 27°C	7.7 @ 26°C
Total suspended solid	mg/L	16	22	18
Conductivity	mS/cm^{-1}	79.7	80	81.3
Dissolved oxygen	mg/L	8.51	9.08	8.88
Nitrate (NO_3–N)	mg/L	0.617	0.574	0.773
Total phosphate (PO_4-P)	mg/L	Nil	Nil	Nil
Free chlorine	mg/L cl_2	0.1	0.1	0.1
Total chlorine	mg/L cl_2	0.2	0.1	0.2

The majority of the physico-chemical parameters tested for this study were within the local standards (Table 1). PH values varied between 7.6 and 7.73. Those values are consistent with local requirements for this parameter since pH should be between 6 and 8 to be acceptable. Total suspended solid values ranged from 16 to 22 mg/L. Those numbers are below the local standard value which is 30 mg/L meaning that the levels of total suspended solids present in the water were within the acceptable limit. Furthermore, negligible traces of total phosphate were found in all water samples. Since the acceptable limit for this parameter is 0.1 mg/L, the amount of phosphate present in the lake complied with local requirements. Other physico-chemical properties including conductivity, dissolved oxygen and nitrate concentrations seemed to be consistent with local standards for reclaimed water discharged into lakes. The conductivity oscillated between 79.7 and 81.3 mS/cm^{-1}. Dissolved oxygen varied between 8.51 and 9.08 mg/L. Nitrate rates fluctuated between 0.574 and 0.773 mg/L. It appears that the above-mentioned physico-chemical properties are not the cause of water quality impairment in the lake.

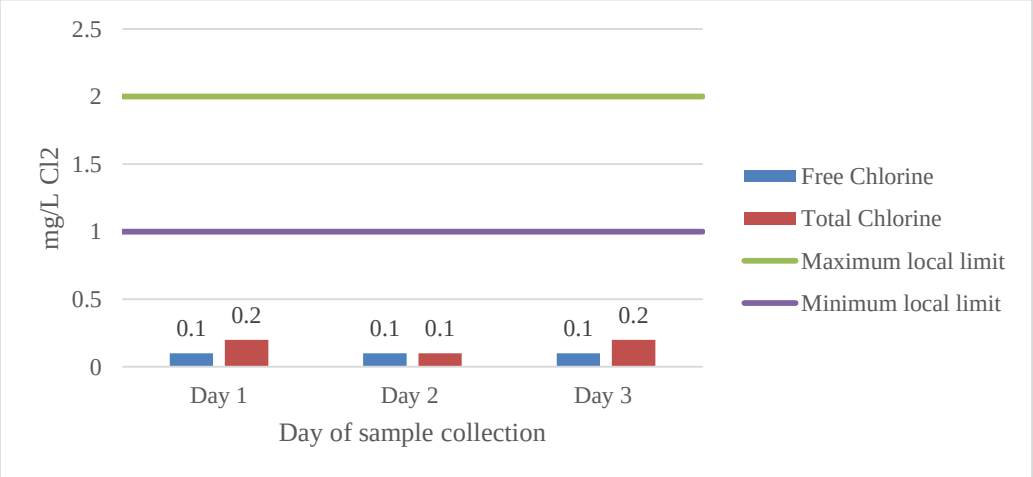

Fig. 1. Chlorine residuals in lake water

Among all physico-chemical parameters tested, free chlorine and total chlorine were the only parameters which did not comply with local standards for lakes supplied with reclaimed water (Table 1). Indeed, the results showed that the free chlorine value was 0.1 mg/L Cl_2 for all samples tested while total chlorine concentrations oscillated between 0.1 and 0.2 mg/L Cl_2. However, the local recommended free and total chlorine levels in reclaimed water discharged into lakes should be between 1 and 2 mg/L Cl_2 (Figure 1). Values for both parameters should be above 1 mg/L Cl_2 to ensure a sufficient quantity of residual chlorine in the lake in order to inactivate pathogens [12], but below 2 mg/L Cl_2 to prevent to formation of harmful toxins due to the interaction of chlorine with other substances present in the reclaimed water [13]. The results of the study indicated that the chlorine concentrations in the lake were below the local recommended range. It suggests a negative correlation between coliform bacteria and levels of chlorine residuals present in the lake. Pathogen regrowth may occur if the quantities of chlorine residuals are not sufficient to prevent microbiological water quality impairment. The absence of those residuals can be a sign of water contamination [12]. The low levels of residual chlorine in the lake water may promote the regrowth of bacteria. The long reclaimed water distribution systems transporting the water to the end point, which is the lake, is a factor that could possibly contribute to a greater dissipation of chlorine. Ensuring sufficient levels of chlorine residuals in the water is paramount to prevent pathogen reactivation. As chlorine easily dissipates, it is crucial to monitor and maintain adequate levels of chlorine from the sewage treatment plant to the final point of use. However, since this disinfectant has the potential to interact with other substances present in the water, which may result in the formation of by-products that could be harmful to public health, chlorine levels must be maintained within acceptable limits [13].

Regarding the impact of human activities, although the lake water quality has been assessed before, during and after peak period, no noticeable changes in the parameters tested were observed over the days. The results for all parameters tested did not show significant variations to assert that human activities around the lake impair its quality. However, the construction of the Dubai Water Canal which will pass through Safa Park may have influenced the results since the construction work currently occurring in the park is close to the lake.

4. CONCLUSION

High concentrations of coliform bacteria in the lake proved that its microbiological quality has been impaired. The occurrence of pathogens is likely to pose a threat to public health. The assessment of physico-chemical parameters to determine the potential cause of this impairment revealed very low levels of chlorine residuals in the lake, below the local recommended range. Chlorine concentrations seem insufficient to minimize the survival and growth of pathogens in the lake. Other physico-chemical parameters and human activities did not appear to impact on the lake water quality. Continuous monitoring of the reclaimed water throughout the distribution system and at the final point of use is paramount to ensure the safest water quality in order to prevent any adverse effect to human and environmental health. As the presence of indicator bacteria does not clearly reflect the occurrence of pathogenic microorganisms in water, further tests are needed to identify the actual risks to public health. Maintaining proper water quality in Dubai is challenging especially since the region is undergoing tremendous change in a short time span, and projects such as the Dubai Water Canal are springing up all over the region at a rapid pace.

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