Water Environment Quality Assessment for the Water Park

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KEYWORD: recreational water park, water quality, dissolved organic carbon, turbidity, chemical feature

ABSTRACT: Water park water quality impacts the public health illustrated by the increasing water-borne diseases outbreaks in recent years. Water samples were thus collected and analyzed for chemical constituents, organic matter, from the water park over spring and summer. Water quality varied seasonally with less contaminated in spring compared with summer ($p<0.01$), which likely corresponds to the number of visitors. Turbidities were in the range of 0.5 to 3 NTU and dissolved organic carbon (DOC) was in the range of 2 to 18 mg/L. The average water chemical parameters for investigated pools were pH=7.6, alkalinity=230 mg/L, hardness=190 mg/L, and temperature=27 °C. Water quality of the investigated water parks were divided into two groups, and only group 1 was balanced.

INTRODUCTION

With the enhance of people's life style, and the development of citizen's income, people start to pay much attention to the water quality and security of all kinds of recreational venues, such as water parks, swimming pools, etc. Water parks are very popular in China recently. A water park or waterpark is an amusement park that features water play areas, such as water slides, splash pads, spraygrounds (water playgrounds), lazy rivers, or other recreational bathing, swimming, and barefooting environments. During the hot summer, there is no activity more exciting for the children than playing in the water parks. But water recreational activities can add significant quantities of contaminants and microorganisms to a water body (Lu, et al., 2013). Therefore, water quality of the water parks is critical for public health.

Water parks have posed a risk to the patrons inadvertently ingesting contaminated water. Possible recreational water contaminants include disinfection by-products, urine, sweat, dirt, cosmetics, bacteria, algae, Cryptosporidium, Giardia, and viruses. The intent of this paper is to investigate the recreational water park water chemical properties, such as pH, total alkalinity as CaCO3, calcium hardness as CaCO3, as well as other water quality parameters, such as turbidity, DOC, and conductivity. Water quality variation will be analyzed using t-test, which will reveal the water park water quality.

Natural organic matter (NOM) is typically quantified in water treatment plants by dissolved organic carbon (DOC) measurements and ultraviolet light absorbance at 254 nm (UV_{254}). DOC is an indicator of organic loadings in water body (Edwards, 1997). DOC consists of truly dissolved substances and macromolecules with colloid-like properties. DOC plays an important role in carbon cycle, providing a key energy source for bacterial assimilation and also influencing the bioavailability of carbon (AWWA, 2012; Eaton, 2005; Kirchman, et al., 1991). Both turbidity and particle size distribution have been recognized as parameters detecting the particle concentration in water (Bellamy, et al., 1993). Turbidity reflects 'cloudiness' of water sample, which needs to be controlled for safety and effective disinfection (ISO, 1999). In terms of effective disinfection, a useful but not absolute, upper-limit guideline for turbidity is 0.5 NTU (ISO, 1999). Particle counters can be more sensitive to changes in water quality (Gregory, 1994; Hunt, 1995; Lewis, et al., 1992). The light obscuration of each particle is proportional to its size, and particle counters measure a change in light intensity as particles pass through a laser beam to report the particle size distribution in water, usually 1 μm and larger (Hunt, 1995; Lewis, et al., 1992). In many instances, turbidity and particle count trends correlate strongly with each other (Gregory, 1994; Hunt, 1993; Hunt, 1995; ISO, 1999; Lewis, et al., 1992).

Materials and Methods

Sample collection

Water samples were collected both in spring and summer (number of samples=40). All sample data were taken in triplicate to ensure accuracy. Samples were collected in 500 mL high-density polyethylene (HDPE) plastic bottles and stored at 4 °C.

Chemical analyses

Chemical constituents of each sample were analyzed using a Six-In-One Swimming Pool Test Kit (Product # 1070, Shenzhen, China). The constituents measured pH, free chlorine, calcium hardness, total alkalinity. The turbidimeter used in this study was a Hach 2100N Turbidimeter (Hach Company, Loveland, Colorado, USA). Sample cells were cleaned prior to each test and instrument calibrations were performed regularly. Samples for DOC measurements were filtered using a 25 mm, 0.4 μm polycarbonate filter (25mm0.4μm AOX, Whatman, UK). The filter was applied to the filter housing and flushed with 30 mL of ultra-pure water. The DOC of each sample was measured for each filtered water sample (GE Water and Process Technologies, Sievers 900 laboratory, Boulder, CO, USA). 6 M (molar/L) phosphoric acid (H3PO4) and 15% ammonium persulfate ((NH4)2S2O8) were used as measurement reagents.

Statistical analyses

Cluster analysis (CA) is a group of multivariate techniques to assemble objects based on the characteristics they possess. CA divides a large number of objects into a smaller number of homogenous groups on the basis of their correlation structure. The resulting clusters of objects should then exhibit high internal (within-cluster) homogeneity and high external (between clusters) heterogeneity. Hierarchical agglomerative clustering is a common approach, which provides intuitive similarity relationships between any one sample and the entire data set, and what is typically illustrated by a dendrogram (tree diagram) (Everitt, et al., 2011). The dendrogram provides a visual summary of the clustering processes, presenting a picture of the groups and their proximity, with a dramatic reduction in dimensionality of the original data. The Euclidean distance usually gives the similarity between two samples, and a distance can be represented by the difference between analytical values from the samples (Everitt, et al., 2011). Hierarchical agglomerative CA was performed in this study on the normalized data set by means of the Ward's method, using squared Euclidean distances as a measure of similarity. Ward's method is most-used hierarchical clustering technique, and this procedure links the pair of groups that produce the smallest variance in the merged group. The Ward's method uses an analysis of variance approach to evaluate the distances between clusters in an attempt to minimize the sum of squares of any two clusters that can be formed at each step (Everitt, et al., 2011). The statistics software JMP (SAS Institute Inc.) was applied for all the statistical calculation.

A commonly used tool in determining the degree of calcium carbonate saturation in pool water is the Langelier Saturation Index (LSI). The degree of saturation calculation is shown as Equation (1) and factors for calculation are shown in Table 1, Table 2, and Table 3. LSI is determined by the pH, temperature, total alkalinity and calcium hardness of the pool water. Pool water would be balanced at LSI in the range of -0.5 to 0.5. It may also be defined as pool water that is either corrosive (< -0.5) or scaling (> 0.5) (NSPF, 2009; Perkins, 2000).

Table 1. Temperature numerical values for saturation index formula

Water Temperature (°C)	Temperature Factor
0	0.0
3	0.1
8	0.2
12	0.3
16	0.4
19	0.5
24	0.6
29	0.7
34	0.8
40	0.9
53	1.0

Table 2. Hardness numerical values for saturation index formula

Hardness (mg/L)	Calcium Factor
5	0.3
25	1.0
50	1.3
75	1.5
100	1.6
150	1.8
200	1.9
300	2.1
400	2.2
800	2.5
1000	2.6

Table 3. Alkalinity numerical values for saturation index formula

Alkalinity (mg/L)	Alkalinity Factor
5	0.7
25	1.4
50	1.7
75	1.9
100	2.0
150	2.2
200	2.3
300	2.5
400	2.6
800	2.9
1000	3.0

$$LSI = pH + TF + CF + AF - TDS \qquad (1)$$

where, pH is the pH value of the water

TF is temperature factor converted from the real temperature of water

CF is calcium hardness factor converted from the real hardness of water

AF is total alkalinity factor converted from the real alkalinity of water

TDS is a factor for total dissolved solids, equals to 12.1 when TDS < 1000 mg/L (ppm) and 12.2 when TDS > 1000 mg/L (ppm).

Results and Discussions

All measured parameters were affiliated to two categories, water quality parameters (i.e., turbidity, conductivity, and DOC concentration) and water chemistry properties or operational parameters (i.e., pH, free chlorine, temperature, total alkalinity, and calcium hardness). Tables 4 briefly summarize statistical values of these parameters.

Turbidities for samples were from 0.5 NTU to 3 NTU. The DOC values for the samples were in the range of 2 to 18 mg/L (with mean of 5.3 mg/L). There was significant seasonal variation according to the t-tests results for turbidity ($p<0.01$) and DOC ($p < 0.01$). Turbidity and DOC values in summer (July, August, and September) were higher than in spring (April, May and June). Seasonal water quality variation likely corresponds to the number of visitors. The potential contamination sources derive from the skin and excretion products of visitors. These components are not necessarily harmful for human health. Samples' pH were in the range of 6.9-8.4. High pH can lead to less effective disinfection, poor coagulation, and pipe scale (Perkins, 2000).

Alkalinity means the acid neutralization capacity of the water. Smples' alkalinity was 80 mg/L-550 mg/L. A low total alkalinity makes it difficult to maintain a desired pH and can lead to corrosive water, which causes damage to equipment. High alkalinity, greater than 200 mg/L, could lead to water scale. Calcium hardness measures of the quantity of divalent cations such as calcium, magnesium or iron in water. And hardness was between 100 mg/L to 400 mg/L. The conductivity for the national pool water varied widely with the mean of 4,150 µS/cm.

Temperature was in the range of 25 to 30 °C. Additionally, temperature affects the corrosiveness or scale forming properties of water. As water temperature increases, the water tends to become more basic and scale-forming. Conversely, as the temperature decreases, water becomes more corrosive (Perkins, 2000).

Cluster analysis was based on operational parameters, for instance pH, free chlorine, hardness, alkalinity, and temperature. Water samples were divided into two groups.

Table 4. Statistical descriptive for recreational water park water samples (n=40)

	Min	Max	Mean	Std. Dev.
DOC (mg/L)	2	18	5.3	3.8
Turbidity (NTU)	0.5	3	1.4	0.4
Conductivity (µS/cm)	906	5,002	4,150	372
pH	6.9	8.4	7.6	1.4
Alkalinity (mg/L as $CaCO_3$)	80	550	230	51
Hardness (mg/L as $CaCO_3$)	100	400	190	125
Temperature (°C)	25	30	27	1.5

conclusions

The DOC values for the pools were in the range of 2-18 mg/L. Turbidities were in the range of 0.5-3 NTU. Spring water sample was less contaminated than summer as expected. pH was 6.9 – 8.4. Alkalinity was in the range of 80-550 mg/L as CaCO3. Hardness was in the range of 100-400 mg/L as $CaCO_3$. The recreational water park water groups were developed based on pH, alkalinity, hardness, and temperature. Water group 1 was balanced and water group 2 was scaling.

acknowledgment

The authors would like to thank the support by Jiang Su Collaborative Innovation Center for Building Energy Saving and Construction Technology.

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