Proceedings of the 3rd International Conference on Materials Chemistry and Environmental Engineering (CONF-MCEE 2023), Part II
DOI: 10.54254/2755-2721/7/20230515

Investigation of golf course chemical and herbicide contamination

Dewei Tan

Shanghai High School International Division, 400 Shangzhong R.D., Shanghai, China

deweitan123@gmail.com

Abstract. In golf course management, fertilizers and herbicides are often used to maintain the healthy growth of green and fairway grass. Using these chemicals often comes with the drawback that they tend to leech into local water bodies, from where they are dispersed outside of the golf course, harming organisms. In this study twelve water samples were collected from two golf courses in Shanghai and tested them from several indicators such as total, chemical oxygen demand, and common herbicides. The experiment found that the total nitrogen in each of the twelve samples exceeds the level rated for drinking and industrial use. Levels of chemicals other than nitrogen, however, resembles those rated for drinking water reserves, while herbicide levels are borderline undetectable. Results from this study provide insight regarding the identification of pollutant based on the abnormality of some indicators, helping golf course management in achieving eco-friendliness.

Keywords: Herbicide Contamination, Spectrophotometer, Golf Course.

1. Introduction

Golf is a popular participatory sport in which the player's objective is to strike a golf ball from designated starting areas (teebox) to a hole cup placed distantly away in as few strokes as possible [1].

This modern form of golf took shape in 1774, when the first dedicated golf club was established in St. Andrews, Scotland, hosting annual competitions. In the 19th century, Britain's colonial expansion resulted in the first major explosion of golf's popularity, as golf courses started to appear in Canada, United States, and Australia [1]. China, however, was not introduced to golf until the late twentieth century, when the construction of Zhongshan Hot Spring Country Club finished [2]. Golf recognition in China grew significantly in the past decades, marked by the establishment of China Golf Association (CGA), multiple international golf tournaments host in China, and further construction of public golf courses [3]. It is projected that this positive trend in public golf consumption would continue for the next few decades.

Golf courses' construction depends largely on the topography of the environment around which they are built [4]. Factors such as elevation, slopes, water bodies, irrigation, and vegetation are considered preconstruction such that each specific golf course caters toward these aspects [5]. Maintenance of golf courses, though, may result in detrimental consequences to the environment. Excessive fertilizer use can lead to adverse contamination and nutrient pollution such as eutrophication. Besides, turf's massive water consumption undermines agricultural water use [6].

DOI: 10.54254/2755-2721/7/20230515

In order to keep the fairways and greens of a golf course desirable to players, high concentrations of herbicide are typically used to eliminate weed. In fact, concentrations applied to golf courses exceed those of farmland, making golf courses one of the land uses with the highest intensity of herbicide application [7]. This intense application can pose serious threats to wildlife should herbicide leach into runoff. Golf courses typically use 312 gallons of water per day for maintenance, so considerable amounts of herbicide can be picked up by this water and enter larger bodies of water [8].

In China, golf course construction is often coupled with building of residential areas alongside and within golf courses. Most of these housings serve as resort hotels, while others serve a more permanent housing purpose in the form of rent houses and sold houses. Golf courses with the ladder form of housing typically have other public facilities nearby or within. Such is the case with the golf course Shanghai Links, which contains bungalow housing for students who attend Shanghai American School, situated inside of the golf course. Moreover, these golf housing amenities often come at a premium, as they typically cater towards those who play golf frequently and thus are willing to pay more for proximity to the golf course in which the housing is situated in [9]. The on-site residential housing contributes a non-negligible amount of environmental impact, potentially rivaling that of golf courses themselves. Since the impact of golf courses and the associated residential housing on environment is integrated in nature, this study considers their impact as a whole.

2. Methodology

2.1. Site information and sample collection

Shown in Figure 1 and 2, twelve water samples from two different golf courses in Shanghai (six from Lanhai International and six from Sheshan) were collected using disposable plastic water bottles and test tubes. Each of these two golf courses is connected to branches of the river that both flow into and out of the golf courses, so samples of both upstream and downstream waters were taken(shown in Figure 3 and 4).

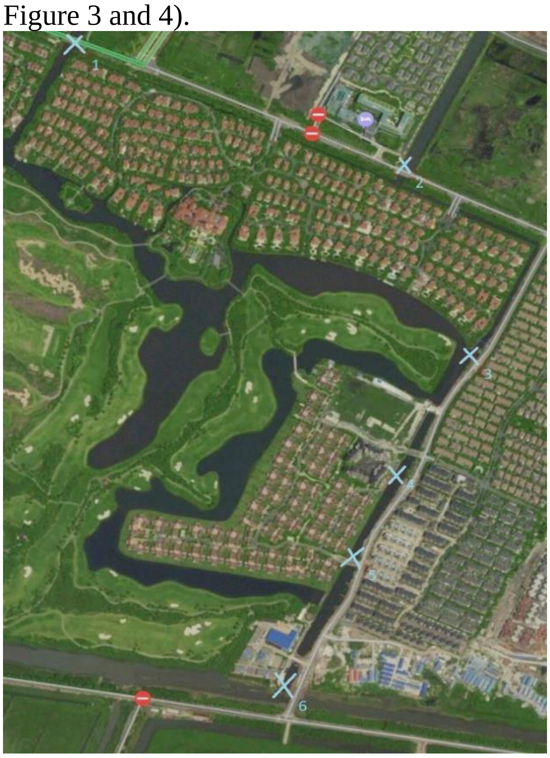

Figure 1. A satellite map of Lanhai international golf course. X marks on the map indicates where each sample was taken, whose number is denoted in the subscript.

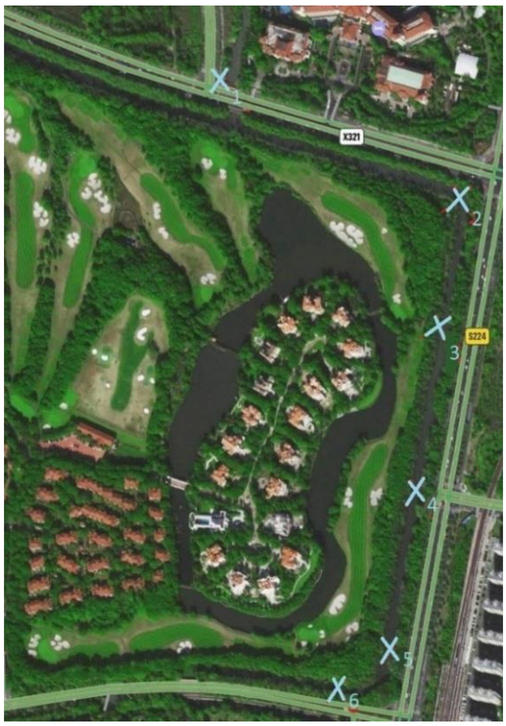

Figure 2. A satellite map of Sheshan golf course. X marks on the map indicates where each sample was taken, whose number is denoted in the subscript.

DOI: 10.54254/2755-2721/7/20230515

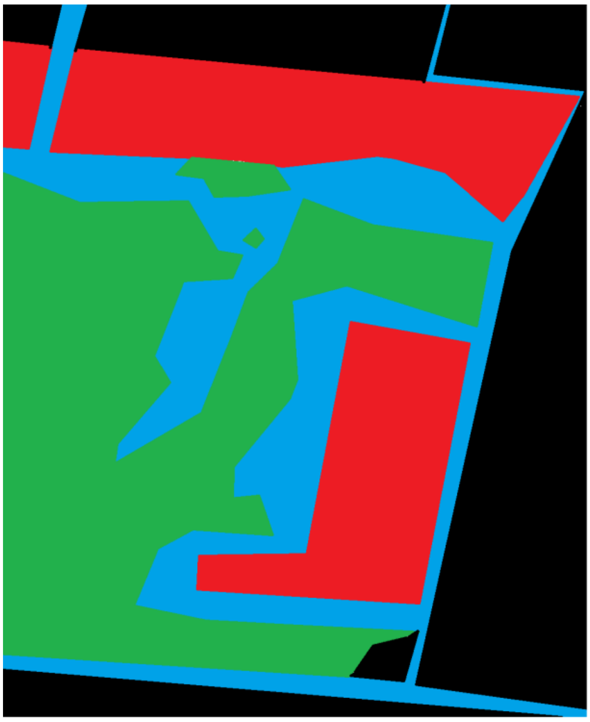

Figure 3. General outline of Lanhai International.
Red: On site housing
Blue: Water body
Green: Golf course
Black: Other buildings

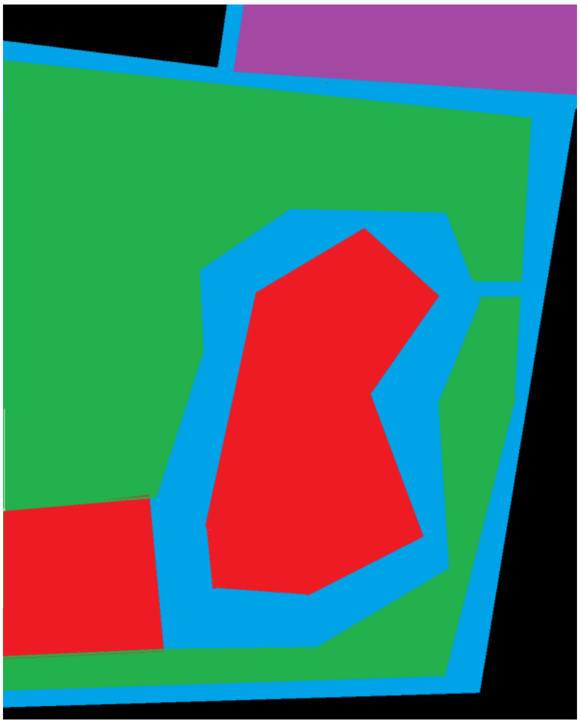

Figure 4. General outline of Sheshan.
Purple: Nearby hotel

2.2. Chemical analysis

We used a spectrophotometer to analyze water samples. First, 1.5 mL of distilled water is added into a small vial that is opaque in one horizontal direction and translucent in another horizontal direction after rinsing it with distilled water. This vial is inserted into the spectrophotometer, and the measured transmittance is manually set to 100%. 1.5 mL of sample water is pipetted into the same vial after rinsing the pipette and the vial using the corresponding sample water. The vial is then inserted into the spectrophotometer, and the device returns the measured transmittance pertaining to a specific input wavelength. Nitrate concentration is measured by monitoring the transmittance of water samples at 220nm ultraviolet light, the signature frequency of nitrate ions. The transmittance for each water sample is recorded as a percentage from 0 to 100%. A higher measured transmittance corresponds to a lower nitrate level, and vice versa.

Standard samples of known concentrations were also measured. 6.3g/L nitric acid stock solution was diluted to concentrations that are 1/1000, 1/750, 1/500, 1/250 in relation to the stock solution. The transmittance of these solutions is measured to produce a calibration curve, with which the exact concentrations of water samples can be deduced.

Moreover, a portion of each sample was packaged into a labeled test tube and submitted to Shanghai Jiao Tong University laboratory for mass spectrometer scan under Chinese national standard GB 23200-8.2016 to identify Herbicide remanent and measure concentrations of heavy metal ion. Total nitrogen, phosphorus, ammonia-nitrogen, and nitrite-nitrogen were also analyzed.

2.3. Data analysis and error propagation

A directly linear equation relating absorbance and total nitrogen concentration was generated using Microsoft excel using standard samples. Absorbance of each sample can be calculated with $A =$

$\log\left(\frac{1}{T}\right)$, where A represents absorbance and T represents transmittance. The slope's value and uncertainty can be deduced. The uncertainty of the spectrophotometer used has an uncertainty of 0.001.

3. Results

3.1. Nitrate-nitrogen concentration

Table 1. Concentrations of nitrate-nitrogen in Lanhai and Sheshan.

Lanhai Sample	Nitrate-nitrogen concentration (mg/L)	Error	Sheshan Sample	Nitrate-nitrogen Concentration (mg/L)	Error
1	0.85	± 0.05	1	1.3	± 0.1
2	0.86	± 0.05	2	0.81	± 0.05
3	0.89	± 0.05	3	0.99	± 0.06
4	1.0	± 0.1	4	0.62	± 0.04
5	0.93	± 0.05	5	0.81	± 0.05
6	1.4	± 0.1	6	0.85	± 0.05

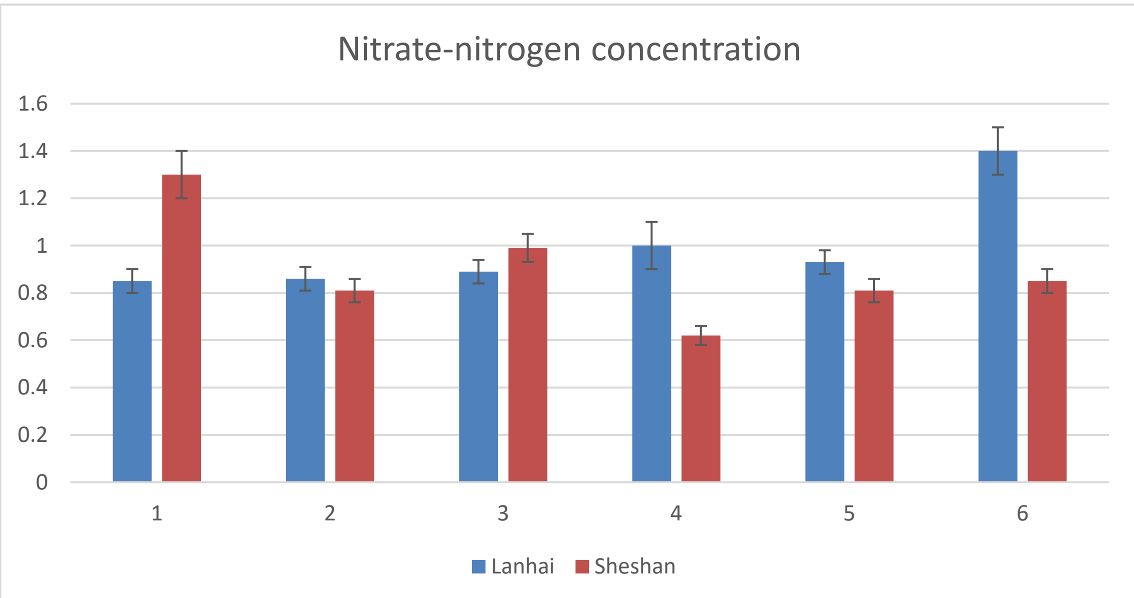

Figure 5. A bar graph displaying data presented in table 1, indicating concentration values and errors.

Concentration of nitrate-nitrogen pertaining to the twelve samples are summarized in table 1 and figure 5. The six samples collected at Lanhai displayed a range of 0.55 mg/L (0.85-1.4), exhibiting a general upwards trend in nitrate concentration from sample 1 to sample 6. Samples collected at Sheshan yielded a greater range of 0.68 mg/L (0.62-1.3). These samples do not display any noticeable trend, though.

3.2. Pesticide, herbicide, and heavy metal contamination

Table 2. Levels of various pesticides and heavy metals detected in Lanhai samples.

Lanhai samples	1	2	3	4	5	6
Propanil (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molinate (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Prosulfocarb (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T.mongolicum (mg/L)*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Flumetsulam (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
D.sanguinalis (mg/L)*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
O.japonicus (mg/L)*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
S.viridis(mg/L)*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Diclofop-methyl (mg/L)	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Hexavalent chromium (mmol/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper (mmol/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mercury (mmol/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 3. Levels of various pesticides and heavy metals detected in Sheshan samples.

Sheshan samples	1	2	3	4	5	6
Propanil (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Molinate (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Prosulfocarb (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T.mongolicum (mg/L)*	0.02	<0.01	<0.01	<0.01	<0.01	<0.01
Flumetsulam (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
D.sanguinalis (mg/L)*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
O.japonicus (mg/L)*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
S.viridis(mg/L)*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Diclofop-methyl (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hexavalent chromium (mmol/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper (mmol/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mercury (mmol/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Names of herbicide marked with * denote the specific plant species it is designed to target.

All twelve samples were sent to (Shanghai Jiaotong University) laboratory for testing. Table 2 and table 3 summarize the results of the test. None of the twelve samples from either Lanhai or Sheshan displayed any detectable amounts of chromium, copper, or mercury. With exception of Lanhai sample

DOI: 10.54254/2755-2721/7/20230515

3 and Sheshan sample 1, none of the samples yielded detectable amounts of any of the nine herbicides listed above.

3.3. Total nitrogen, phosphorus, ammonia-nitrogen, and nitrite

Table 4. Table indicating total nitrogen, phosphorus, ammonia-nitrogen, and nitrite nitrogen in samples collected from both golf courses.

Lanhai sample	Total nitrogen (mg/L)	Total phosphorus (mg/L)	Ammonia-nitrogen (mg/L)	Nitrite-nitrogen (mg/L)
1	1.86	0.21	0.35	<0.01
2	2.12	0.2	0.33	<0.01
3	2.2	0.23	0.36	<0.01
4	2.56	0.19	0.35	<0.01
5	2.54	0.28	0.39	<0.01
6	3.07	0.52	0.6	<0.01
Sheshan sample				
1	2.66	0.28	0.55	<0.01
2	2.13	0.2	0.54	<0.01
3	2.48	0.21	0.48	<0.01
4	2.1	0.24	0.41	<0.01
5	2.38	0.33	0.45	<0.01
6	2.4	0.32	0.4	<0.01

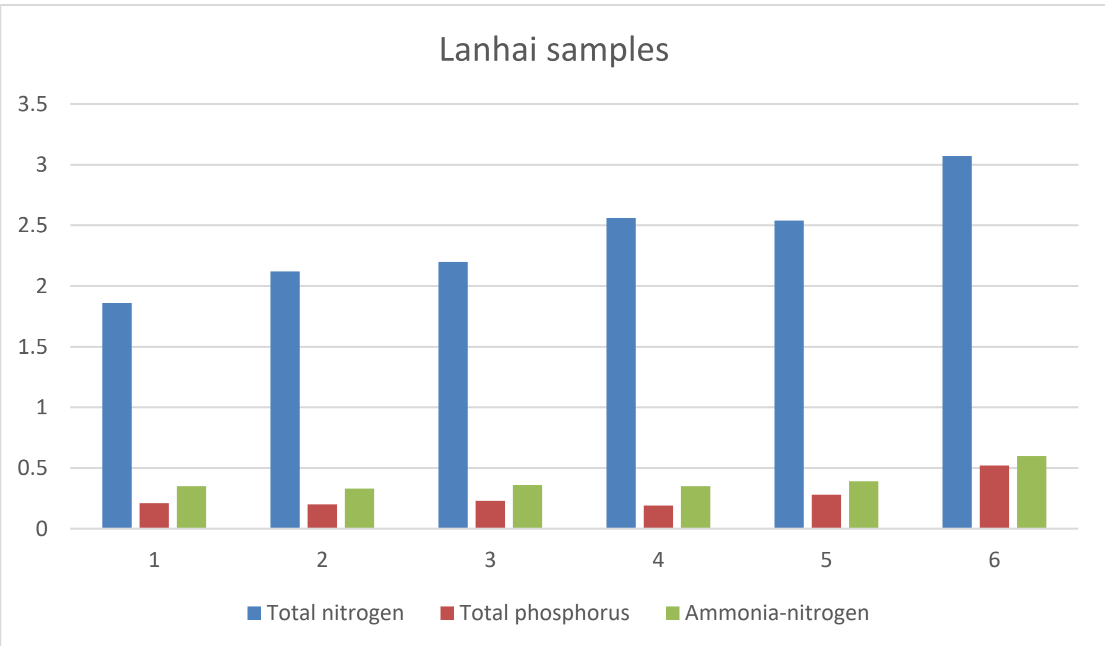

Figure 6. Graph displaying levels presented in table 4 for each Lanhai sample.

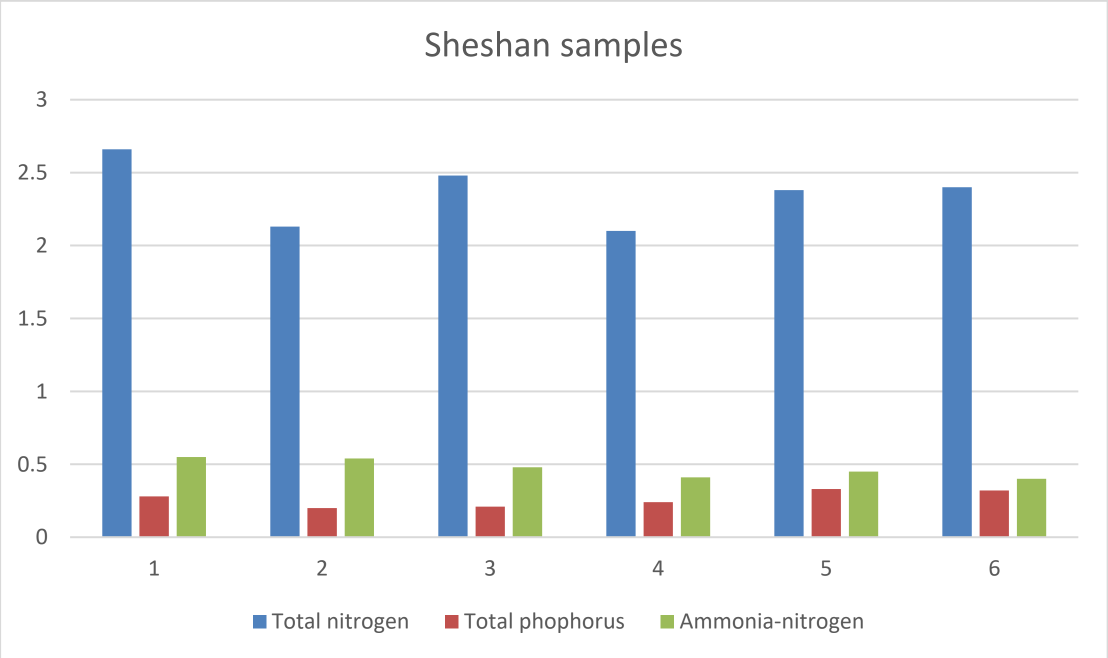

Figure 7. Graph displaying levels presented in table 4 for each Sheshan sample.

Table 4 listed above summaries the result of lab analysis. Total nitrogen, phosphorus, and ammonia-nitrogen all displayed a generally increasing trend from Lanhai sample one to sample six(shown in Figure 6). This is similar to the results in 3.1 regarding nitrate-nitrogen, where samples displayed a generally upwards trend from one to six as well. As for Sheshan, both total nitrogen and total phosphorus do not display any significant trend just like nitrate-nitrogen. Ammonia-nitrogen does however decrease from sample one to sample six(shown in Figure 7). None of the twelve samples show any detectible amounts of nitrite-nitrogen.

3.4. Chemical oxygen demand

Table 5. Chemical oxygen demand of each sample from Lanhai and Sheshan

COD	**Trial (mg/L)**			**Mean (mg/L)**
Lanhai	1	2	3	
1	13.3	13.3	13.5	13.4
2	14	14.1	14.1	14.1
3	13.5	13.4	13.7	13.5
4	12.8	13	12.6	12.8
5	15.6	15.4	16	15.7
6	18.9	19	18.7	18.9
Sheshan				
1	20.2	20.1	19.5	19.9
2	18.8	19.3	19.1	19.1
3	20.5	19.3	19.2	19.7
4	17.2	18.8	18.7	18.2
5	21.7	20.6	20.8	21.0
6	19.3	21.4	20.4	20.4

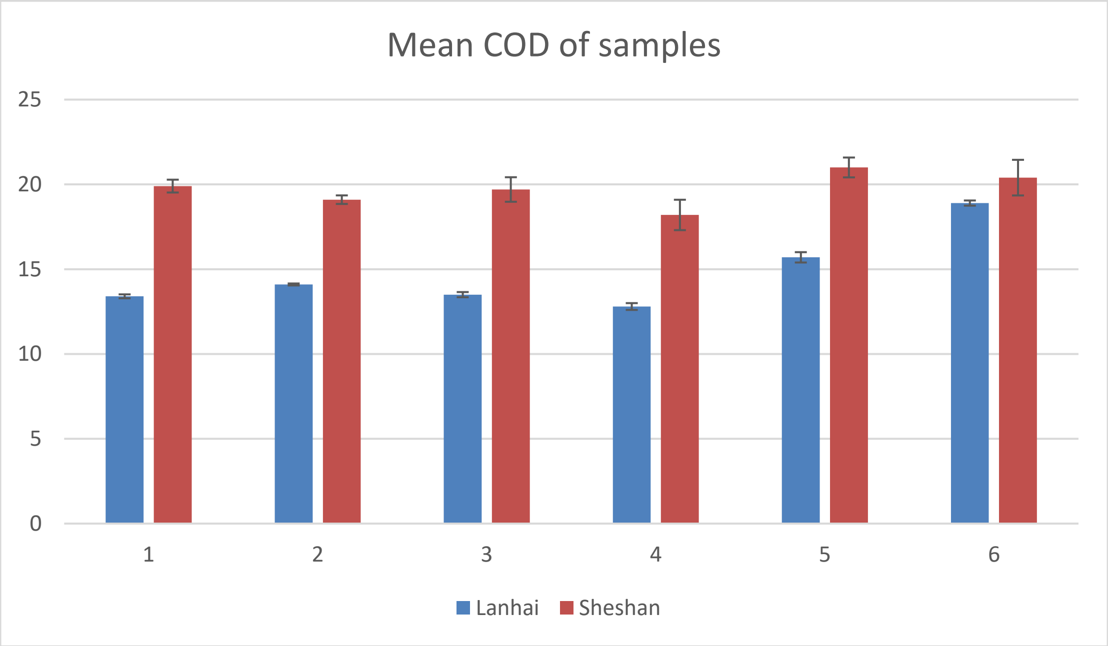

Figure 8. Bar graph of data presented in table 5.

Table 5 and Figure 8 lists the chemical oxygen demand (COD) of the twelve samples. Each sample was tested three times, so the result of each trial—as well as the mean of them—are reported above. The six samples from Lanhai displayed a generally increasing trend in COD, having a range 6.1 mg/L. Samples one to four are almost equal in COD, having a mean of approximately 13 mg/L. This increases to 15.7 at sample five and 18.9 at sample six. The COD of the six samples from Sheshan were all higher than the samples from Lanhai, with the exception of Sheshan sample four being 0.7 mg/L lower than Lanhai sample six. The Sheshan samples exhibits a range of 1.9 mg/L—significantly lower than those of Lanhai. It also has an increasing trend, but not as significant as Lanhai's trend, though.

4. Conclusion

Analysis from both Shanghai Jiaotong university lab and spectrophotometer classifies Sample one of Lanhai as class IV and the rest eleven samples as class V, pertaining to national standard GB 3838—2002. Class V indicates that water bodies flowing through Lanhai and Sheshan are "suitable as agricultural or regular touristy site water," as opposed to water that are adequate for drinking, endangered aquatic species habitat, fishing, or swimming [10]. The main factor for these water samples to be categorized as such is the overabundance of total nitrogen, suggesting that fertilizer may have been used in golf course maintenance. Aside from total nitrogen, levels of other chemicals and chemical oxygen demand are similar to those of class II or class III waters. Most importantly, lab analysis returned undetectable levels heavy metal and little to no amounts of herbicides for all samples. This means that the only source of pollution in both Lanhai and Sheshan is likely from fertilizer runoff. Data from this study contribute to the understanding of golf course pollution. Identifying what kinds of pollution are present in golf courses is key to understanding what steps are best suited to reduce it. With the pollutant identified, management of golf course will become easier in order to eliminate it and promote environmental stewardship.

Reference

[1] Johnson, B. (2017). The History and Origins of Golf. Historic UK. https://www.historic-uk.com/HistoryUK/HistoryofScotland/The-History-of-Golf/

[2] Review of Golf Course Development in China in the last thirty years. (n.d.). Sports.qq.com. Retrieved September 12, 2022, from https://sports.qq.com/a/20100812/001090.htm

[3] Major development in Chinese golf development. (n.d.). Www.sohu.com. Retrieved September 12, 2022, from https://www.sohu.com/a/333609226_750705

[4] Peña, Carlos & Fernandez, Duvan. (2014). Environmental impacts by golf courses and strategies to minimize them: state of the art. International Journal of Arts & Sciences. 07(03):403-417

[5] Guide for developers - How to build a golf course - European Institute of Golf Course Architects. (n.d.). Www.eigca.org. Retrieved December 12, 2022, from https://www.eigca.org/build-a-golf-course#:~:text=A%20golf%20course%20architect%20will%20examine%20the%20physical

[6] Golf and the Environment. (n.d.). https://auduboninternational.org/wp-content/uploads/2019/03/GE-Golf-and-the-Environment.pdf

[7] published, Ker Than. “Scientists Measure Pesticide Runoff from Golf Courses.” Livescience.com, 9 Sept. 2005, www.livescience.com/9331-scientists-measure-pesticide-runoff-golf-courses.html. Accessed 12 Dec. 2022.

[8] Pollution Exposures at Golf Courses | PartnerOne Environmental. (2019, January 30). P1enviro.com. https://p1enviro.com/recent-activity/spotlight-pollution-exposures-at-golf-courses/

[9] Singer, Richard. “Golf and Housing – a Challenged Partnership.” National Golf Foundation, 12 June 2018, www.ngf.org/golf-and-housing-a-challenged-partnership/. Accessed 12 Dec. 2022.

[10] Chinese National Enviromental Protection Agency. (2002, April 28). Environmental quality standards for surface water [Review of Environmental quality standards for surface water]. https://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/shjbh/shjzlbz/200206/W020061027509896672057.pdf