

Assessment of Surface Water Quality in Suburban Golf Courses in Korea

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ABSTRACT: In the current study, we examined the quality of surface water in ponds at two golf courses, located in southern (Country Club P) and eastern (Country Club B) areas of Korea respectively. Seasonal measurements were made of following physical parameters: pH, dissolved oxygen, biological oxygen demand, chloride, alkalinity, hardness, and nitrogen compounds [NH₃-N, NO₂-N, NO₃-N] and the concentrations of four heavy metals (Cd, Cu, Pb, and Zn) throughout the courses. The pH values were within the alkaline range (7.3 to 9.0), and the biological oxygen demand was generally between 0.5 and 3.1 mg/L. The alkalinity and hardness ranged from 19.1 to 68.5 mg/L and 16.1 to 63.6 mg/L, respectively. Nitrogen as ammonium (NH₃-N) was detected in all samples, and the samples had low concentrations of NO₂-N and NO₃-N. Cd concentrations were relatively high (to 22.44 mg/L); the highest Cd concentration was observed in the pond in Country Club P. Other metal concentrations were low compared to the Quebec guidelines.

Key words: Cd, Golf course, Heavy metal, Surface water

INTRODUCTION

Recent increases in the popularity of golf have led to the development of several thousand new courses in Korea. These courses occupy approximately 1,400 km², which is 1.4% of the total land in Korea. Fifty percent of these golf courses are in metropolitan areas (Lee and Hur 2001). In Korea, 70% of the land is mountainous and forests are often recklessly destroyed to plant grass. This decreases the absorption capacity of the land and increases the likelihood of landslides and floods in area that receive torrential rainfall. Also, the fertilizers and insecticides used to maintain grass can cause eutrophication of rivers. The insecticides are toxic, and some contain heavy metals that can be harmful to humans. Because of the high quantities of pesticides and fertilizers used on golf courses, there is concern about their effects on the environment, especially on water quality.

Scott *et al.* (1998) reported that the level of pesticides and fertilizers in golf courses in southeastern North Carolina exceeded the standards of the United States Environmental Protection Agency (EPA). Through a study on the movement of pesticides in golf courses, Cohen *et al.* (1990) found that the rate of contaminant movement tended to decrease with better management practices. Generally, golf courses contain a pond that can store approximately 100,000 tons water. Such ponds can protect the environment from the direct inflow of pesticides and fertilizers. Also, aquatic vegetation growing in ponds has been shown to be capable of removing

and degrading pesticides and taking up excess nutrients (Wilson *et al.* 2000).

The purpose of this study was to prepare a basis for examining the consequences on the surrounding surface water system. We examined the water quality of ponds in two golf courses located in southern (country club P) and eastern (country club B) areas of Korea. We made direct measurements of several physical parameters and four heavy metal concentrations throughout the golf courses.

MATERIALS AND METHODS

Sampling Sites and Collection

The study sites were two golf courses, referred to as country clubs P and B, which are located in the Gyeonggi-do, Korea. Water samples were collected seasonally from March to November 2004 from the pond within each of the courses. Samples were collected approximately 0.3 m from the shoreline and placed in a cooler containing dry ice. Each sample was collected in a 500-mL polyethylene bottle, except for the dissolved oxygen samples, which were sampled with biological oxygen demand (BOD₅) bottles. Samples collected from March to May were taken before noon, and those collected from June through November were taken between 3:00 and 5:00 PM.

Water Analysis

The temperature, pH, dissolved oxygen (DO), BOD₅, nitrogen of several types of nitrogen (NH₃-N, NO₃-N, NO₂-N), total phosphorus

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(T-P), alkalinity, hardness, and chloride content were measured for the water samples. The temperature, pH, and DO were recorded in the field, and all other measurements were performed in the laboratory. The pH was measured with a pH meter; and the DO was detected using an EPA-approved Winkler titration method. The BOD₅ and total suspended solids were determined using standard methods (American Public Health Association 1998) Alkalinity was determined by titration with bromocresol green-methyl red and sulfuric acid; hardness by titration with ManVer 2 (HACH, Loveland, USA) and ethylenediaminetetraacetic acid; and chloride with potassium chromate as an indicator and silver nitrate as the titrant (HACH, 1989). Both T-P and nitrogens were determined colorimetrically using the methods described by Stephens *et al.* (1981).

Metal Analysis

The total metal content (Cd, Cu, Pb, and Zn) in water was detected without acid digestion and then determined by graphite furnace and flame atomic absorption spectroscopy(AAS; AAS analysis 100; Perkin Elmer).

Pesticide Analysis

All water samples were analyzed for the presence of chlorpyrifos and diazinon, two pesticides commonly used for grass management. Water samples were screened by immunoassay analysis (Ohmicron 1996), and all positive detections were confirmed by gas chromatography (GC) by comparison with standards of known concentration. All positive samples were stored at -20°C prior to further

analysis. Two hundred milliliters of the sample was filtered through a 0.45 μ m Gelman Sciences fiberglass filter, mixed with 13g of NaCl, then subsequently filtered through a Waters/Millipore® (Millford, MA, USA) C18 environmental cartridge (1.0g). The pesticides were extracted from the cartridge with 10ml of methanol, then -20°C until analysis.

Two pesticides were analyzed by GC under the following conditions. The column was a 15-m \times 0.24-mm BPX5 (1 μ M) fused silica capillary (SGE, Austin, TX, USA). Temperatures were as follows: detector, 250°C; and inlet, 225°C. an oven temperature program was run as follows: initial temperature, 180°C, hold 2 min, raise to 230°C at 3°C/min, and 3 min.

Helium was the carrier gas at a flow rate of 1.7 mL/min. Gases to the detector were H₂ and air at flow rates of 3.8 and 60mL/min, respectively, and helium was used as the makeup gas at a flow rate of 22 mL/min. Injections were made in the split less mode. Data were quantified by area against an analytical-grade standard of known concentration.

RESULTS AND DISCUSSION

Water Quality

We first measured the chemical properties of pond water samples from the two golf courses (Table 1). The results did not show significant differences between the various seasons. The pH was within an alkaline range (7.26 to 8.99), and the DO values were relatively low (2.23 to 6.76 mg/L). The BOD₅ was generally between 0.5 and

Table 1. Water quality parameters in country clubs P and B

Parameter	Spring		Summer		Autumn		Winter	
	Country club P	Country club B	Country club P	Country club B	Country club P	Country club B	Country club P	Country club B
pH	9.0 \pm 1.15	8.2 \pm 0.03	8.2 \pm 0.36	8.2 \pm 1.02	7.3 \pm 0.26	7.9 \pm 0.57	7.3 \pm 0.63	7.8 \pm 2.95
DO (mg/L)	3.4 \pm 1.00	3.5 \pm 1.44	3.2 \pm 1.52	2.2 \pm 0.73	2.5 \pm 0.19	4.2 \pm 1.48	5.2 \pm 1.05	6.8 \pm 1.33
BOD ₅ (mg/L)	2.0 \pm 2.21	0.5 \pm 0.06	2.1 \pm 0.61	1.6 \pm 0.82	2.8 \pm 0.55	3.1 \pm 1.56	2.6 \pm 0.06	2.6 \pm 0.25
Alkalinity (mg/L)	47.0 \pm 11.01	36.5 \pm 10.61	37.6 \pm 17.24	49.0 \pm 1.01	23.5 \pm 19.09	68.5 \pm 30.41	19.1 \pm 2.65	52.0 \pm 14.77
Hardness (mg/L)	54.3 \pm 17.84	63.6 \pm 17.39	33.5 \pm 20.53	56.6 \pm 9.76	16.1 \pm 8.49	48.3 \pm 5.73	38.5 \pm 11.77	58.3 \pm 5.31
Chlorides (mg/L)	17.1 \pm 0.88	6.1 \pm 1.77	8.3 \pm 3.60	3.3 \pm 5.42	9.9 \pm 0.74	11.0 \pm 6.15	10.7 \pm 2.59	25.1 \pm 10.50
NH ₃ -N (mg/L)	0.05 \pm 0.030	0.02 \pm 0.032	0.09 \pm 0.114	0.6 \pm 1.02	0.02 \pm 0.014	0.04 \pm 0.012	0.6 \pm 0.04	0.1 \pm 0.01
NO ₂ -N (mg/L)	0.06 \pm 0.081	0.01 \pm 0.001	0.01 \pm 0.011	0.01 \pm 0.013	0.01 \pm 0.001	0.01 \pm 0.002	0.01 \pm 0.001	0.01 \pm 0.000
NO ₃ -N (mg/L)	0.5 \pm 0.33	0.3 \pm 0.17	0.2 \pm 0.14	0.3 \pm 0.19	0.3 \pm 0.25	0.6 \pm 0.30	1.1 \pm 0.20	1.5 \pm 0.04
T-P (mg/L)	0.2 \pm 0.08	0.1 \pm 0.01	0.2 \pm 0.09	0.2 \pm 0.05	0.1 \pm 0.06	0.1 \pm 0.02	0.2 \pm 0.00	0.1 \pm 0.00

Values represent mean \pm standard deviation of triplicate.

5.80 mg/L, although one sample from country club B had a value of 7.57 mg/L. The alkalinity and hardness ranged from 19.09 to 68.5 mg/L and from 16.1 to 63.55 mg/L, respectively. The concentration of chloride and T-P were 3.34 to 25.05 mg/L and 0.10 to 0.21 mg/L, respectively. We measured three types nitrogen, $\text{NH}_3\text{-N}$, $\text{NO}_3\text{-N}$, and $\text{NO}_2\text{-N}$. According to the EPA, nitrate is the most commonly found analyte in wells (U.S. Environmental Protection Agency 1990). High concentrations of it can lead to toxic algal blooms, and in infants it can lead to methemoglobinemia when present at blood concentrations greater than 10 mg/L (Burkholder 1992). The concentrations of $\text{NH}_3\text{-N}$, $\text{NO}_3\text{-N}$, and $\text{NO}_2\text{-N}$ were 0.02 to 0.6 mg/L, 0.2 to 1.5 mg/L, and 0.1 to 0.2 mg/L, respectively. In addition, these values did not significantly differ between seasons or sampling sites.

These results indicate that the level of DO, BOD_5 , and T-P exceed the Korean Anxiety Standards (Environmental data collection 1999). However, other all parameters were well under these standards, indicating that country clubs P and B are sites of moderate pollution.

Analysis of Pesticide and Heavy Metal Concentrations

To assess the extent of pesticide contamination, we examined the levels of two pesticides commonly used for grass management, chloropyrifos and diazinon (Table 2). Chloropyrifos is an insecticide used widely for the control of termites. It is a sediment-labile compound with low water solubility and a high surface loss potential (Miles *et al.* 1992). Low concentrations ($< 0.01 \mu\text{g/L}$) of chloropyrifos were found at both golf courses. Low concentrations of diazinon were also detected at the two golf courses, with the highest levels between 0.12 and $0.26 \mu\text{g/L}$. These results indicate that the pesticide concentrations did not exceed the Korean Anxiety Standard (Environmental data collection 1999).

To investigate the extent of metal contamination at the two sites, we determined the concentrations of four heavy metals (Cd, Cu, Pb, and Zn) in the pond water (Table 3). At country club P, the concentrations of Cd, Cu, Pb, and Zn were 22.44, 17.27, 15.56, and $66.45 \mu\text{g/L}$, respectively; and, at country club B, the concentrations were 17.43, 4.55, 18.89, and $35.41 \mu\text{g/L}$, respectively. The greatest

Table 2. Concentrations of the pesticides diazinon and chloropyrifos at country club P and B

Pesticide	Concentrations of the pesticides ($\mu\text{g/L}$)	
	Country Club P	Country Club B
Diazinon	0.12	0.26
Chloropyrifos	0.01	0.01

Table 3. Concentrations of Cd, Cu, Pb, and Zn in water samples from country club P and B

Heavy metal	Concentrations of heavy metals ($\mu\text{g/L}$)	
	Country club P	Country club B
Cd	22.44	17.43
Cu	17.27	4.55
Pb	15.56	18.89
Zn	66.45	35.41

concern is that the levels of Cd contamination at country clubs P and B were 2.2- and 1.7-fold higher than the Korean Anxiety Standard Level, respectively.

According to the American Agency for Toxic Substances and Disease Registry, Cd is in the top 10 of hazardous substances and is one of the most dangerous ubiquitous heavy metals (Wagner 1993). Because of its low mobility, Cd induces cancer and causes mutations (Degaeve 1981). At high concentrations, Cd is considered a hazardous waste metal that can accumulate in the human body, and it has a relatively long half-life in the food chain (Khan and Khan 1993). Therefore, removal of Cd from the golf course ponds is needed. Phytoremediation, the use of plants to restore polluted sites, has recently become a reasonable alternative to traditional methodologies for removing contaminants (Glass 2000). This technique should be especially effective for golf courses because of its financial and aesthetic aspects.

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