International Journal of Arts & Sciences,
CD-ROM. ISSN: 1944-6934 :: 07(03):403–417 (2014)

ENVIRONMENTAL IMPACTS BY GOLF COURSES AND STRATEGIES TO MINIMIZE THEM: STATE OF THE ART

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Golf has grown worldwide in terms of number of golfers and infrastructure; however, environmental impacts have been identified during the construction and operational processes of the fields. The assessment of these impacts has generated a global concern as results show concentrations of pesticides, heavy metals, nutrients in water and soil which often exceed current health and environmental regulations. Additionally, the high consumption of water generates changes in surrounding ecosystems and it may also cause the inclusion of foreign species. Consequently, those issues have been a concern of government agencies and organizations in different countries which have led most countries to initiate the development of methodologies and standard methods to carry out the environmental sustainability of the sport. This article will outline the state of the art of environmental impacts generated by golf courses and some practices to reduce, control and manage them, which include guides, manuals and standards.

Keywords: Golf course, Environmental impacts, Pesticides, Natural resources, Environmental sustainability.

Introduction

Golf practice and the number of fields where the sport takes place is increasing rapidly in many parts of the world mainly associated with economic growth of populations and globalization of the sport [1]; It is estimated that there are over 25,000 golf courses worldwide [2, 3]. Its roots are unknown; it is debatable whether they came from China, Netherlands or Scotland [4]. Most historians agree that it first appeared in the Netherlands because in the thirteenth century Dutch literature makes references to "*golf-like*" medieval games with names like "*mitten Colvespel*" (playing club) and "*den balmittacalven to Slåen*" (hit the ball with the club) [5, 6].

Golf, as it is currently known, began in 1744 in St. Andrews [6] and is composed of 4 types of play areas: greens and tees (3.9 % and 2.4 ha) , fairways (20% and 12 ha), practice areas (4.6 % and 2.8 ha) and roughs (34 % and 21 ha) [7].

According to the Latino Golf Report website, the sport dates from the twentieth century in Colombia and it starts by the construction of an initial 9-hole course at the Country Club in Bogota by the year 1917.The professionalism of the sport came from the hands of British and Argentine golfers who arrived in Colombia in 1919 and highlighted the sport in a national and international scope [8]. As the sport grew, fields started to appear for the first practices, which highlight The Club Campestre de Cali, where the Colombian Golf Federation was born. Colombia currently has more than fifty fields where local and national qualifying tournaments are played such as the Colombian Open Golf Tournament, one of the most important tournaments in Latin America [9].

The relationship between golf and nature has historically taken greater force as the fields where the sport is practiced integrate with landscape, wildlife and vegetation of a specific area. This is due to the construction of the fields in areas generally close to rivers, lakes, oceans, land adjacent to virgin forests and the slopes of high mountains [10-12].

However, during the construction and operation of these golf courses there are practices that can be extremely harmful to the environment such as: water consumption overage, soil and water pollution by the use of pesticides and fertilizers, increased urbanization close to fields [2, 13, 14], the clearing of natural vegetation, deforestation, destruction of natural landscapes and habitats, eutrophication and change in topography and local hydrography [10, 11, 15-18].

The magnitude of these impacts has promoted the creation of local communities and international groups against the construction of golf courses which began appearing in the early 90's. For example: the Asian Tourism Network, the Asian Pacific Environmental Network and the Global Network for the Fight against fields of Golf, which came together to launch the Movement to fight World Golf and investigate and expose environmental impacts generated by its fields [10].

Different types of government entities, universities and organizations have been working on the implementation of policies, measures and actions for the quantification, monitoring and minimization of environmental impacts. Some of them include: the manual of good practices for water sources in golf courses prepared by the Environmental Council of Pennsylvania, the guide of Good Practices for Handling Water Use in Golf Courses by the U.S. Environmental Protection Agency (EPA).

As to regulations by U.S. agencies there has been a monitoring on the use of pesticides on golf courses located in coastal areas [19]; the Environment Agency and the Ministry of Health and Welfare of Japan established the maximum levels of contamination in 1997 as 30 pesticides in golf course drainage systems after several studies since the 80's [12].

This article aims to describe the state of knowledge about the various impacts on environmental resources generated by golf courses (results of case studies) and different management activities conducted on these impacts.

Environmental Impact

An environmental impact can be defined as a significant alteration of the environment in a negative or positive nature which may lead to partial or total loss of a resource or impairment of an environmental variable [20].These impacts can be generated at different stages of a project and their magnitudes can vary similarly. Therefore, in this section the environmental impacts and the results of their measurements and evaluations are described by different authors.

Impacts Caused by Pesticides and Fertilizers

Proper management of nutrients in the root zone and pest control is very important to maintain healthy and strong grass [21-23] in golf courses. This activity is usually performed by the use of pesticides and fertilizers; but excessive nutrient levels and different chemicals in the soil can cause problems in turf quality, vigor and quality of the same [24, 25] generating environmental impacts.

According Kenna (1995), there are six processes that influence the cycle of life of the chemicals sprayed on golf courses: runoff, volatilization, photolysis, adsorption, absorption, dilution/leaching and microbial degradation as seen in Figure 1.

Even though works have been done to show the importance of a good interaction between the environment and pesticides, it has been found that a vast majority of golf course managers ignore the international and local regulations in terms of pesticides and that workers who handle them do not know the rules, the products and compounds; and implementation of adequate protection is often missing [27].

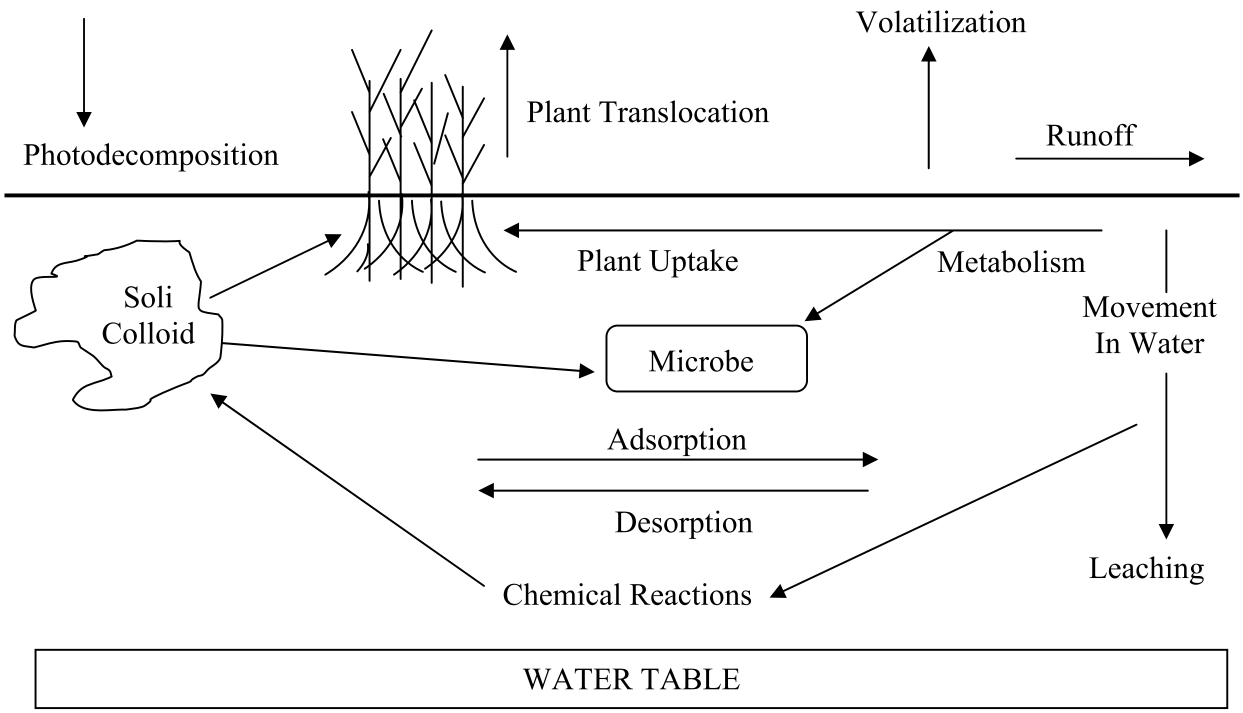

Figure 1 Processes affecting the fate of a pesticide in soils [26].

It has been determined that between 1.1 to 1.2 billion pounds of pesticides are sold annually in the United States, about 70% of these are applied in agriculture (food and textiles) and a fraction of this amount is aimed at golf courses [26]. Nevertheless, it has been established that the application rates of pesticides on golf greens and tees are usually higher than the rates in farmland applications [28].

According to Kohler et al. (2004), golf courses in the Midwest region of the United States receive about 7kg of pesticides, 41kg of nitrogen (N), 4kg of Phosphorus (P) and 22kg of potassium (K) per hectare/year [29, 30]; however, Petrovic (1990) estimated that the levels of application in modern fields are 200kg of nitrogen (N) and 40kg of Phosphate per hectare/year. Table 1 shows estimated amounts of pesticide application in Hawaii's golf courses.

Table 1. Estimated quantities of pesticides applied in Hawaii [31].

Type of pesticides	Quantity estimated by field surveys (lb/year)	Total estimated amount (lb/year)	Total percentage of use (%)
Herbicides	53.876	94.025	78.4
Fungicides	12.624	19.051	15.9
Insecticides	2.719	4.463	3.7

According to this, studies have been conducted by different authors on damages generated by pesticides and fertilizers on water resources, soil, sediments and species that inhabit these areas. Some results are shown below:

Water Resources

Different existing water sources provide a variety of services which vary in terms of their quality. It is clear that golf courses, depending on their design and management, can have a potential negative impact on water systems affecting their chemical, physical and biological properties [32, 33].

This impact is mainly due to the entry of fertilizers and other pollutants to surface bodies via runoff or groundwater infiltration [15, 32, 34-38] given that water is one of the main mechanisms by which pesticides are transported from the application area to the environment, resulting in the ability to move within and throughout the hydrological cycle [39].

It is clear that the effects of pesticides on the hydrological system generate negative impacts on the environment and populations as they can have a direct impact on aquatic life, food chains, potential uses of the water bodies when losing quality and hence its benefit for the purification and many other purposes [39].

Different studies have been focusing on the measurement of concentrations of different types of pollutants that can be generated within golf courses in canals, lagoons, rivers, drainage and groundwater; as result of these, various magnitudes have been found that can and have led this activity to be a big contributor of pollution not strut on water resources as it can be seen in Tables 2 and 3 [17, 29, 40, 41].

According to a monitoring of surface sources close to golf courses, 31 pesticides were found and 9 of them exceeded the maximum allowable concentrations for the protection of aquatic species, and in groundwater 21 pesticides [42, 43] from which 5 exceeded the maximum allowable concentrations [42]. A technical report of the Geological Survey of the United States stated that it identified 27 pesticides in surface water samples collected in a basin of Portland; 16 of the 27 are components in applications done in golf courses, which are not registered in a field near the basin [44, 45].

Ryals, et al. (1998), verified the impact on water bodies (lakes) of three golf courses located in North Carolina in the United States, for which measurements of the concentrations were made for four pesticides and two nutrients (N and P). The study found that a small fraction of samples of Chlorothalonil and chlorpyrifos, breached the levels allowed by the EPA.

Dripps et al. (2012) was able to determine an increase in temperature in streams between 3° and 4° Celsius for five different golf courses. This change in temperature is mainly due to the changes in vegetation located on the banks of water bodies and stormwater discharges.

In regard to groundwater, Lapworth et al. (2006) detected herbicides such as Dicamba, Atrazine and Benazolin. Moreover, one of the best-known cases of groundwater contamination was in Cape Cod, where 10 of the 17 pesticides analyzed were found though only one, Chlordane, was above the permitted levels of health [46] associated with the large number of golf courses in this region of the United States and the shallowness of the water [47].

As a further matter, there are other studies that have used simulations to determine concentrations, pollutant loads and risk associated with its implementation [48], Primi et al. (1994) resorted to models Pesticide Root Zone Model (PRZM) and Ground Water Ubiquity Score (GUZ) to assess the potential for groundwater contamination, finding with the first model a variety of 16 pesticides and with the second 25 [49]. Haith et al. (2007) used the TurfPQ model where pesticide loads were calculated from 0-875 g/ha depending on the city and the turf.

Impacts on Soil

Soils are an integral component of golf courses, they don't only play a natural role for plants and animals, but they also generate the landscape according to the needs of the fields. Most golf courses are built on sandy soils due to its infiltration capacity, there are others that are located on clay soils and clay loam, a few of them are build on rocky soils [50] or sometimes natural conditions are modified for this process [51].

Knowing the type of existent soils, assessments have been generated about their conditions after the construction of golf courses. Shown below are some experiences and results of these estimates of environmental impacts of pesticides on soils.

Mathews et al. (1995) conducted a study to determine mercury levels in soil and sediment in two greens, two lakes and a fairway of the Oakfield Golf Course in Halifax, Canada; results showed that the highest concentrations were found in the greens with values between 15 to 71 mg/kg, at the same time traces in sediments were found in a nearby water course with values of < 0.050 to 1.9 mg/kg. On the other hand, Miles et al. (1992) found concentrations of 0.2 ug/g of Metribuzin and 1.1 μg/g of chlorpyrifos in sediments.

As to herbicide products containing arsenic, Cai et al. (2002) were able to determine that this element moves easily through the soil, which directly correlates with high concentrations of arsenic in soil and groundwater measured in areas underlying some golf courses in the South region of Florida.

A study by Pimentel *et al*. (1984) on quail fed with earthworms from a golf course, discovered that the sludge where the earthworms inhabited, contained an average of 48 ppm (dry weight) of cadmium (associated with chemicals products for lawn care), soon after these were dehydrated cold to feed quail, finally it was found that the kidneys of the male quail had accumulated 14 ppm and females had 18 ppm [52, 53].

The results of the assessment of sediment contamination and toxicity in the coasts of the Gulf of Mexico associated with a golf course are presented in Table 4.

Ecosystem Impacts

During the construction and formation of a golf course, excavation and soil movement to generate these areas, completely alter the existing natural habitat [18, 54], reconfiguration and canalization of water streams are generated which increment the erosion processes and increase their turbidity; in addition the removal and/or cut of vegetative barriers along the banks of the water bodies [32]. All these activities generate impacts on native flora and fauna of the regions.

It is important to mention that many times golf courses may favor the generation of ecosystems, as the same or higher levels of biodiversity have been found as of the habitats they replace [2, 55, 56]. As there is less danger of extinction and greater protection to these, according to the results presented by Colding et al. (2009) about artificial wetlands constructed for the landscape improvement, they contributed significantly to the increase and control of wildlife; however, it is important to highlight that the introduction of foreign species can drastically alter the natural conditions of ecosystems [13, 51].

Bowen and Valiela (2001) determined ecological changes and alterations on water use caused by the process of eutrophication due to the urbanization of a watershed located in the Bay Waquoit in Massachusetts, United States; where higher doses of N were contributed by golf courses. It is important to mention that from area of study these represent only 1 % of the total basin area [57].

On the other hand, the demand of water for field maintenance represents a significant impact to the environment since the maintenance of pastures is continuous and severe. It is estimated that good field watering uses between 15 and 20 billion gallons per year [60]. In Florida, about 1,246.77 m3 of water is used daily for the existing 1400 golf fields [50]. It has been estimated that golf courses in Catalonia use an annual volume of water is from 94,831 m3 to 384,000 m3 [61] and in the Spanish Mediterranean it is estimated that the consumption is 2,000 m3 and 17,000 ha-1 [62, 63] .

It is clear that in order to meet these water supply, many fields, have chosen to use underground water for irrigation; however, it has been determined that during summer time golf courses are exploiting these waters [64] and this excess extraction has allowed saline waters near the bonnet golf of Manly in Australia to invade these aquifers.

Table 3. Concentration and loads of pesticides, herbicides and fungicides on surface and groundwater.

Contaminant	Ryals, et al. (1998) Sediments pond's on Golf New Hanover County Merger **(ppb)**	Ryals, et al. (1998) Lake from South Golf Course Brunswick County **(ppb)**	Ryals, et al. (1998) Canals perimeter on South Golf Course Brunswick County **(ppb)**	Hindahl et al. (2009) Runoff concentrations on a golf course **(µg/L)**	Armbrust (2001) Runoff concentrations on a golf course **(mg/L)**	Cohen *et al.* (1990) Concentrations measured in groundwater in golf **(µg/L)**	Miles, R. J. Pfeuffer Load pesticides estimated by the Water Management District South Florida **(Ton/year)**
Chlorpyrifos	0.09 (annual average)	7,21 (annual average)	0.09 (annual average)	0.04 – 0.06	0	0.04	202
Chlorothalonil	0.04 (annual average)	0.79 (annual average)	0.03 (annual average)	0.06	0.12	0.05 - 0.08	252
Atrazine	0.04 (annual average)	0.08 (annual average)	Not Detected	-----------	-----------	-----------	-----------
2,4-Dichlorophenoxyacetic acid	0.24 (annual average)	0.43 (annual average)	0.17 (annual average)	0.20	-----------	Not detected	21
Glyphosate	-----------	-----------	-----------	20	-----------	-----------	-----------
Clopyralid	-----------	-----------	-----------	0.08	-----------	-----------	-----------
Mancozeb	-----------	-----------	-----------	10	-----------	-----------	-----------
Azoxystrobin	-----------	-----------	-----------	0.6	-----------	-----------	-----------
Chlorothalonil	-----------	-----------	-----------	-----------	0.57	-----------	-----------

Table 4. Concentration and loads of heavy metals, pesticides, herbicides and fungicides in sediments [58, 59].

Contaminant	Lagoons from wastewater treatment plant	Lagoons of the fairway	Wetlands	Lagoons from wastewater treatment plant	Santa Rosa Coast	Santa Rosa Coast	Lagoons
As **(µg/g)**	< 2.3	< 2.3	1.3	2.7	0.3	< 2.3	< 2.3
Cd **(µg/g)**	< 0.07	< 0.07	< 0.07	3.5	< 0.07	< 0.07	< 0.07
Cr **(µg/g)**	8.3	0.8	5.9	20	0.5	1	0.5
Cu **(µg/g)**	35.8	3.8	4.5	24.6	0.2	< 0.09	< 0.09
Hg **(µg/g)**	126.4	3.1	15.1	62.8	2	0.02	< 1.7
Ni **(µg/g)**	2.1	< 0.9	1.8	5.5	< 0.9	< 0.9	< 0.9
Pb**(µg/g)**	5.7	1.1	3.1	15.8	0.4	1.3	2.1
Se **(µg/g)**	1.8	< 2.3	< 2.3	< 2.3	0.3	< 2.3	< 2.3
Zn **(µg/g)**	44.2	3.7	16.6	65	0.8	1.3	< 1.6
Dieldrin **(ng/g)**	17	1.3	< 1.0	3.5	< 1.0	< 1.0	-----------
Chlordane **(ng/g)**	4.8	< 1.0	< 1.0	5.5	< 1.0	< 1.0	-----------
t-nonachlor **(ng/g)**	4.6	1.4	1.1	7.1	< 1.0	< 1.0	-----------
Epoxy **(ng/g)**	2.8	3.1	< 1.0	2.3	< 1.0	2.2	-----------

Table 2. Evaluation of water quality parameters on surface water and groundwater.

Contaminante	Kohler *et al.*, (2004) Runoff concentrations on a golf course **(mg/L)**	Winter & Dillon, (2005) Concentrations of over a river downstream (D) and upstream (U) of a golf course **(mg/L)**	Kunimatsu*et al.*,(1999) Loads on a golf course **(g/ha)**	Winter *et al.*, (2003) Concentrations over a river downstream of a golf course **(mg/L)**	King *et al.* (2007) Concentrations on a waterway, **(mg/L)**	Graves *et al.* (2004) Runoff concentrations on a golf course **(mg/L)**
N-NO_3/NO_2	1.38 0.35	-----------	-----------	-----------	-----------	-----------
NO_3-N	-----------	-----------	-----------	-----------	0.33 – 0.44	-----------
NO_3	-----------	(U) 0.16 – (D) 1.017	65.9	0.004 – 0.8	-----------	-----------
NH_4-N	-----------	-----------	-----------	-----------	0.10 – 0.09	-----------
NH_3-N	2.70 1.83	-----------	-----------	-----------	-----------	0.20
P	0.31 0.13	(U) 0.0344 – (D) 0.019	81.9	0.0084 – 0.061	-----------	0.24
PO_4-P	-----------	-----------	-----------	-----------	0.12 – 0.15	-----------
K	3.35 0.56	(U) 0.4 - (D) 0.7	966	0.11 – 4.3	-----------	-----------
COD	294 147	-----------	-----------	3.2 – 46	-----------	-----------
COT	106.2 56.0	-----------	-----------	-----------	-----------	-----------
Dissolved Solids	335 107	-----------	-----------	-----------	-----------	-----------
Suspended Solids	33 22	-----------	5810	-----------	-----------	8
Al	2.04 0.78	-----------	-----------	-----------	-----------	-----------
Ca	47.83 8.61	(U) 2.9 – (D) 17.4	-----------	3.2 – 42	-----------	-----------
Cl	44.77 19.61	(U) 0.3 - (D) 0.9	-----------	1.7 – 162	-----------	-----------
Fe	1.49 0.68	-----------	-----------	-----------	-----------	-----------
Mg	13.13 2.38	-----------	-----------	0.66 – 10	-----------	-----------
Mn	0.37 0.11	-----------	-----------	-----------	-----------	0.25
Na	20.75 11.02	(U) 0.7 - (D) 1.0	581	1.6 – 79	-----------	-----------
Si	3.53 0.70	-----------	-----------	1.0 – 6.2	-----------	-----------
SO_4	26.67 7.19	-----------	-----------	3.1–160	-----------	-----------
Alkalinity (µequiv./L)	-----------	-----------	-----------	174 – 2380	-----------	-----------
TNK	-----------	(U) 0.507 – (D) 0.413	-----------	0.28 – 0.94	-----------	-----------

Strategies to Minimize Environmental Impact

Sustainability is a concept that has been implemented with greater force in sports and recreation over the last decade. Interest in examining the impact of sport in the physical environment has grown strong, including multiple domains of amateur and professional sport [65-68].

Different government agencies, golfing organizations, universities and research centers have begun to include the concept of sustainability in golf courses in the world, mainly for the reduction of environmental impacts, such as decrease water consumption, control of the application of pesticides and fertilizers [69] to take advantage of the design to service ecosystem's biodiversity [54, 70] and for the reduction of greenhouse gas emissions [71].

One of the concepts most commonly used for mitigating the environmental impacts generated by urban processes, is the *Best Management Practices* (BMPs) [72], also known as SUDS *Sustainable Urban Drainage Systems* (U.S. and Colombia) , *Water Sensitive Urban Design* WSUDS (Australia) *LIDS Low Impact Drainage Systems* (USA), SQIDS [73] *Stromwater Quality Improvement Device* (Australia) , ESD [74] *Ecological Sustainable Development* (Australia), which are based on structural and non-structural actions[75] .

Among the structural measures, constructed wetlands are one of the most used SUDS to manage pollutants in runoff [76-78] because they combine the removal of concentrations, the attenuation of tides [79], likewise they enhance biodiversity and are insensitive to variations of pollutant loads [72, 80, 81].

The United States Golf Association (USGA) has recognized wetlands as an acceptable means to reduce drainage flows and improve water quality [82], this is based on several studies conducted.

For example, in 1998 Purdue University (USA) incorporated in its golf courses a series of artificial wetlands that serve to retain water and as a quality control of runoffs. This golf course has 27.8 ha from which 10.1 drains directly into the constructed wetlands [29, 83].

The following results were obtained from measurements made to assess the efficiency of wetlands during six different rain events from April 2001 to August 2002 at 4 different points.

Table 5. Measurements from water quality parameters on the golf course in Perdue University [29].

Parameter (mg/s)	Sampling Site 1	2	3	4	Relative reduction (%)
$N\text{-}NO_3/NO_2$	8.15	3.20	1.18	0.25	97
$N\text{-}NH_3$	17.94	3.41	0.28	0.00	100
P	2.08	1.24	0.69	0.71	74
K	28.08	30.81	9.94	32.60	12
DQO	1465.06	330.18	54.04	154.66	90
COT	473.44	91.10	11.43	41.8	91
SST	173.60	339.18	256.14	1212.20	0
Al	10.48	5.51	8.14	24.24	0
Ca	376.94	358.54	93.14	254.98	46
Cl	351.96	287.36	46.33	91.96	77
Fe	9.15	9,39	12.91	19.64	11
Mg	102.31	120.26	27.87	100.32	23
Mn	1.4	1.38	0.41	0.88	51
Na	171.6	128.84	19.16	28.42	85
Si	33.72	31.52	18.32	58.52	0
SO_4	188.36	189.48	74.26	229.9	12

Table 6. Guides and manuals for sustainable design and operation of golf courses.

Guide or Statute	uthor	Country	Year	Description
Sustainable golf courses : a guide to environmental stewardship	Dodson Ronald	EE.UU.	2005	Guide that specifies environmental management methods for the design and operation of golf courses, it presents examples of research conducted by the USGA.
Environment & Sustainability	Golf course superintendents association of America (GCSAA)	EE.UU.	Online	Presents international courses for the sustainable management of golf courses, with emphasis on maintenance, water conservation, pollution prevention and water quality. http://www.gcsaa.org
Greening your BC course. A guide to environmental management	Environment Canada and the Department of Fisheries	Canada	1996	Guide that specifies environmental management methods for the design and operation of golf courses
Best Management practices enhancement of environmental Quality on Florida Golf Course	Florida Department Of Environmental Protection	EE.UU.	2007	Guide to for environmental management and good environmental practices for golf course managers.
Environmental Principles for Golf Courses in the United States	United States Golf Association	EE.UU.	Online	Presents a series of criteria for the design, construction and operation of golf courses. http://www.usga.org.
Improving the Environmental Management of New South Wales Golf Courses	Australian Golf Course Superintendents Association	Australia	2007	Presents a series of environmental problems faced by golf courses with emphasis on water consumption and reuse, use of pesticides and fertilization practices. http://www.environment.nsw.gov.au
Technical Guidance: Pesticides Act and Ontario Regulation 63/09 Golf Courses - January 2012	Ontario Ministry of the Environment	Canada	Online	Prohibits the use of four pesticides for golf course managers.
Environmental Best Management Practices for Virginia's Golf Course	Virginia Golf Course Superintendents Association	EE.UU.	2012	Guide to for environmental management and good environmental practices for golf course man
The Environmental Stewardship Toolkit: How to Build, Implement and Maintain an Environmental Plan for Grounds and Golf Courses	European Institute of Golf Course Architects	England	2012	Provides a guide for environmental and resource management, community involvement and landscaping.
Environmental Issues in Golf Course Construction (SGEG 2005)	Scottish Golf Environment Group	Scotland	2005	Description of good practices for the construction of gold courses and identification of environmental impacts.

Other authors have reported their experiences; Johnson (2007) describes one of the first artificial wetlands implemented on the field of Hillandale Golf in Durham, North Carolina, which was built in 2000 to capture rainwater from a field, a interstate path, a nearby residential neighborhood, a parking lot and a rural area where high nutrient removals were found. In the Chowan Country Club in Edenton North Carolina it was found that the wetland does an excellent control over the flow peak events of rainfall and reduction over nutrient loads (Total Nitrogen 23% and total Phosphorous 27 %) [84]. The Lonnie Poole golf course in Raleigh North Carolina showed a total nitrogen removal of 47% and a total Phosphorus of 59% [85].

However, Schwecke et al. (2007) proposed the use of constructed wetlands for treatment of rainwater, in order to use it for irrigation and to reduce groundwater consumption since according to studies of quality of rainwater, these exceeded permitted levels of total Nitrogen exposed on the Irrigation Guide of Australia.

Moreover, to minimize the consumption of water for irrigation management strategies have been proposed. For example Rodríguez-Diaz *et al* (2011) propose a set of indicators of water volumes controls, usage costs and environmental impacts generated. Additionally, the reuse of wastewater has been implemented for irrigation, decreasing in many cases the levels of groundwater use. In 2001 it was estimated that out of 419 existing golf courses in Florida 110mgd are reused [86], furthermore depending on the origin of the water, treatment could be inexpensive and simple [87] with high removals that facilitate its reuse. However, the major concern of this practice is related to the quality of the water for irrigation [88, 89], mainly microbiological parameters and physical since they can generate the proliferation of vectors [90] and contamination of soil and groundwater [91].

All these activities have led to the creation of guidelines and manuals for sustainable design and operation of golf courses. Table 6 shows some examples.

Conclusions

Golf courses have been proven to be highly impactful to the environment if they do not have measures to control and mitigate the effects on the environment during construction and operation stages; especially in regards to water resources (consumption and pollution) and soil (pollution and modification).

One of the most striking factors is the application of pesticides and fertilizers, which have been detected in a vast majority of tests conducted on water, soil and biological species; finding in many occasions traces of pesticides that environmental authorities have declared not permitted to be used and sometimes at concentrations above regulations in each country.

Moreover, it is clear that the concern of various entities and associations have created and proposed, during the last 20 years, a variety of activities and rules that could reduce environmental impacts leading golf to rationalize the use of natural resources; however, in many countries there is still no evaluation and control of such activities.

In the case of emerging countries, where the growth of this activity has been high, the development of this issue becomes an ideal and appropriate media to conduct further studies and research that will allow the creation of regulations, policies and environmental management systems appropriate to achieve protection objectives, conservation and development of the sustainability criteria for this sector.

It is important to note that currently Manuela Beltran University is implementing a project related to the evaluation and quantification of environmental impacts on golf courses and the research for environmental support schemes to ensure the efficient development and operation of these.

References

1. Dair and Schofield, "Nature conservation, legislation and environmental aspects of golf course management in England," Science and Golf. E. and FN Spon, London, pp. 330-335, 1990.
2. Gange, D. Lindsay, and M. Schofield, "The ecology of golf courses," Biologist, vol. 50, pp. 63-68, 2003.
3. J. Warnken, D. THOMPSON, and D. H. ZAKUS, "Golf course development in a major tourist destination: implications for planning and management," Environmental management, vol. 27, pp. 681-696, 2001.
4. C. J. C. Graça, "Análise comparativa de estudos de impacte ambiental de campos de golfe," Magister Faculty of Sciences, University of Lisboa, Lisboa, 2008.
5. B. Glanville, Golf: The Game of Lessening Failures: Trafford on Demand Pub, 2010.
6. Professional Golfers Association of America, First Swing golfer's guide: PGA publication, 2004.
7. R. D. Baris, S. Z. Cohen, N. L. Barnes, J. Lam, and Q. Ma, "Quantitative analysis of over 20 years of golf course monitoring studies," Environmental toxicology and chemistry, vol. 29, pp. 1224-1236, 2010.
8. Secretaría de Cultura Recreación y Deporte. (2012). El Golf.
9. Von Rothkirch and Puerta, Campos De Golf En Colombia/Colombian Golf Courses: Villegas Asociados, 2005.
10. K. Wheeler and J. Nauright, "A global perspective on the environmental impact of golf," Sport in society, vol. 9, pp. 427-443, 2006.
11. J. G. Winter and P. J. Dillon, "Effects of golf course construction and operation on water chemistry of headwater streams on the Precambrian Shield," Environmental Pollution, vol. 133, pp. 243-253, 2005.
12. T. Suzuki, H. Kondo, K. Yaguchi, T. Maki, and T. Suga, "Estimation of leachability and persistence of pesticides at golf courses from point-source monitoring and model to predict pesticide leaching to groundwater," Environmental science & technology, vol. 32, pp. 920-929, 1998.
13. R. Tanner and A. Gange, "Effects of golf courses on local biodiversity," Landscape and Urban planning, vol. 71, pp. 137-146, 2005.
14. S. C. Ryals, M. B. Genter, and R. B. Leidy, "Assessment of surface water quality on three eastern North Carolina golf courses," Environmental toxicology and chemistry, vol. 17, pp. 1934-1942, 1998.
15. J. G. Winter, P. J. Dillon, C. Paterson, R. A. Reid, and K. M. Somers, "Impacts of golf course construction and operation on headwater streams: bioassessment using benthic algae," Canadian journal of botany, vol. 81, pp. 848-858, 2003.
16. C. Espejo Marín, "Campos de golf y medio ambiente. Una interacción necesaria," Cuadernos de Turismo, pp. 67-112, 2004.
17. T. Kunimatsu, M. Sudo, and T. Kawachi, "Loading rates of nutrients discharging from a golf course and a neighboring forested basin," Water Science and Technology, vol. 39, pp. 99-107, 1999.
18. J. Choi and Y. H. Kwon, "RETRACTED ARTICLE: Comparative study on the environmental impact assessment of golf course development between Korea and China," Landscape and Ecological Engineering, vol. 2, pp. 21-29, 2006.
19. R. Pitt, S. Clark, and R. Field, "Groundwater contamination potential from stormwater infiltration practices," Urban Water, vol. 1, pp. 217-236, 1999.
20. G. A. Espinoza, Gestión y fundamentos de evaluación de impacto ambiental: BID/CED, 2002.
21. S. Matthews, I. McCracken, and G. Lonergan, "Mercury contamination of golf courses due to pesticide use," Bulletin of environmental contamination and toxicology, vol. 55, pp. 390-397, 1995.
22. Swancar and H. County, Water quality, pesticide occurrence, and effects of irrigation with reclaimed water at golf courses in Florida: US Department of the Interior, US Geological Survey, 1996.

23. H. Wan, M. Wong, and C. Mok, "Pesticides in golf course waters associated with golf course runoff," Bulletin of environmental contamination and toxicology, vol. 56, pp. 205-209, 1996.
24. T. A. McClellan, R. E. Gaussoin, R. C. Shearman, C. S. Wortmann, M. Mamo, G. L. Horst, and D. B. Marx, "Nutrient and chemical properties of aging golf course putting greens as impacted by soil depth and mat development," HortScience, vol. 44, pp. 452-458, 2009.
25. T. A. McClellan, R. C. Shearman, R. E. Gaussoin, M. Mamo, C. S. Wortmann, G. L. Horst, and D. B. Marx, "Nutrient and chemical characterization of aging golf course putting greens," Crop science, vol. 47, pp. 193-199, 2007.
26. M. P. Kenna, " What happens to pesticides applied to golf courses," USGA Green Section Record, vol. 33, pp. 1-9, 1995.
27. E. Arcury Quandt, A. L. Gentry, and A. J. Marín, "Hazardous materials on golf courses: Experience and knowledge of golf course superintendents and grounds maintenance workers from seven states," American journal of industrial medicine, vol. 54, pp. 474-485, 2011.
28. S. Z. Cohen, S. Nickerson, R. Maxey, and J. A. Senita, "A ground water monitoring study for pesticides and nitrates associated with golf courses on Cape Cod," Ground Water Monitoring & Remediation, vol. 10, pp. 160-160, 1990.
29. E. Kohler, V. Poole, Z. Reicher, and R. Turco, "Nutrient, metal, and pesticide removal during storm and nonstorm events by a constructed wetland on an urban golf course," Ecological Engineering, vol. 23, pp. 285-298, 2004.
30. C. Throssell, T. Gibb, F. Whitford, D. Kellam, C. Sadof, and J. Johnson, "Pesticide use and pest management practices by the Indiana lawncare industry 1992," Purdue University Experimental Station Bull, vol. 714, 1995.
31. B. M. Brennan, C. L. Murdoch, and A. K. Higashi, Estimated pesticide use on golf courses in Hawaii vol. 137: University of Hawaii at Manoa, College of Tropical Agriculture and Human Resources, 1992.
32. W. Dripps, K. Ashman, M. Saunders, and S. Drake, "The Impact of Golf Courses on Stream Water Temperature," Open Environmental & Biological Monitoring Journal, vol. 5, pp. 14-21, 2012.
33. K. L. Armbrust, "Chlorothalonil and chlorpyrifos degradation products in golf course leachate," Pest management science, vol. 57, pp. 797-802, 2001.
34. Fox, Thelin, Sabbagh, Fuchs, and Kelly, "Estimating watershed level nonagricultural pesticide use from golf courses using geospatial methods," Journal of the American Water Resources Association, vol. 44, pp. 1363-1372, 2008.
35. K. King, J. Balogh, K. Hughes, and R. Harmel, "Nutrient load generated by storm event runoff from a golf course watershed," Journal of environmental quality, vol. 36, pp. 1021-1030, 2007.
36. J. C. Balogh and W. J. Walker, Golf course management & construction: Environmental issues: CRC PressI Llc, 1992.
37. K. King and J. Balogh, "Nutrient loss from a golf course watershed," USGA Green Sect. Record, vol. 44, pp. 20-25, 2006.
38. G. A. Graves, Y. Wan, and D. L. Fike, "WATER QUALITY CHARACTERISTICS OF STORM WATER FROM MAJOR LAND USES IN SOUTH FLORIDA1," JAWRA Journal of the American Water Resources Association, vol. 40, pp. 1405-1419, 2004.
39. S. J. Larson, P. D. Capel, and M. S. Majewski, "Pesticides in surface waters. Distribution, trends, and governing factors," ANN ARBOR PRESS, INC., CHELSEA, MI(USA). 1997., 1997.
40. D. J. Lapworth, D. Gooddy, M. Stuart, P. Chilton, G. Cachandt, M. Knapp, and S. Bishop, "Pesticides in groundwater: some observations on temporal and spatial trends," Water and Environment Journal, vol. 20, pp. 55-64, 2006.
41. C. Miles and R. Pfeuffer, "Pesticides in canals of South Florida," Archives of Environmental Contamination and Toxicology, vol. 32, pp. 337-345, 1997.

42. D. A. Haith and M. W. Duffany, "Pesticide runoff loads from lawns and golf courses," Journal of Environmental Engineering, vol. 133, pp. 435-446, 2007.
43. S. Cohen, A. Svrjcek, T. Durborow, and N. L. Barnes, "Water quality impacts by golf courses," Journal of environmental quality, vol. 28, pp. 798-809, 1999.
44. Miltner and Hindahl, "Surface water-quiality monitoring on golf course in the Pacific Northwest," Golf Course Management, vol. 77, pp. 80-88, 2009.
45. M. S. Hindahl, E. D. Miltner, T. W. Cook, and G. K. Stahnke, "Surface water quality impacts from golf course fertilizer and pesticide applications," International Turfgrass Society Research Journal, vol. 11, pp. 19-30, 2009.
46. C. J. Miles, G. Leong, and S. Dollar, "Pesticides in marine sediments associated with golf course runoff," Bulletin of environmental contamination and toxicology, vol. 49, pp. 179-185, 1992.
47. C. Cox, "Pesticides on golf courses: Mixing toxins with play," Journal of Pesticide Reform, vol. 11, pp. 2-4, 1991.
48. S. Z. Cohen, T. E. Durborow, and N. Barnes, "Groundwater and surface water risk assessments for proposed golf courses," in ACS Symposium Series, 1993, pp. 214-214.
49. P. Primi, M. H. Surgan, and T. Urban, "Leaching potential of turf care pesticides: A case study of Long Island golf courses," Ground Water Monitoring & Remediation, vol. 14, pp. 129-138, 1994.
50. L. Q. Ma, W. Harris, and J. Sartain, Environmental Impacts of Lead Pellets at Shooting Ranges & Arsenical Herbicides on Golf Courses in Florida: Florida Center for Solid and Hazardous Wasate Manatement, University of Florida, 2000.
51. J. C. Tapias and M. Salgot, "Management of soil-water resources in golf courses," Tourism and Hospitality Research, vol. 6, pp. 197-203, 2006.
52. D. Pimentel, T. Culliney, M. Burgess, G. Stoewsand, J. Anderson, C. Bache, W. Gutenmann, and D. Lisk, "Cadmium in Japanese quail fed earthworms inhabiting a golf course," Nutrition reports international, vol. 30, pp. 475-481, 1984.
53. W. N. Beyer, "Evaluating Soil Contamination," DTIC Document1990.
54. J. Colding and C. Folke, "The role of golf courses in biodiversity conservation and ecosystem management," Ecosystems, vol. 12, pp. 191-206, 2009.
55. J. Colding, J. Lundberg, S. Lundberg, and E. Andersson, "Golf courses and wetland fauna," Ecological applications, vol. 19, pp. 1481-1491, 2009.
56. M. R. Terman, "Natural links: naturalistic golf courses as wildlife habitat," Landscape and Urban planning, vol. 38, pp. 183-197, 1997.
57. J. L. Bowen and I. Valiela, "The ecological effects of urbanization of coastal watersheds: historical increases in nitrogen loads and eutrophication of Waquoit Bay estuaries," Canadian Journal of Fisheries and Aquatic Sciences, vol. 58, pp. 1489-1500, 2001.
58. M. A. Lewis, S. S. Foss, P. S. Harris, R. S. Stanley, and J. C. Moore, "Sediment chemical contamination and toxicity associated with a coastal golf course complex," Environmental toxicology and chemistry, vol. 20, pp. 1390-1398, 2001.
59. M. A. Lewis, R. G. Boustany, D. D. Dantin, R. L. Quarles, J. C. Moore, and R. S. Stanley, "Effects of a coastal golf complex on water quality, periphyton, and seagrass," Ecotoxicology and environmental safety, vol. 53, pp. 154-162, 2002.
60. S. W. Horsley and J. A. Moser, "Monitoring Ground Water for Pesticides at a Golf Course - A Case Study on Cape Cod, Massachusetts," Ground Water Monitoring & Remediation, vol. 10, pp. 101-108, 1990.
61. G. K. Priestley and J. Sabí Bonastre, "El medio ambiente y el golf en Cataluña: problemas y perspectivas," Documents d'Anàlisi Geográfica, vol. 23, pp. 45-74, 1993.
62. J. Diaz, J. Knox, and E. Weatherhead, "Competing demands for irrigation water: golf and agriculture in Spain," Irrigation and Drainage, vol. 56, pp. 541-549, 2007.

63. J. Rodríguez Díaz, E. Weatherhead, J. García Morillo, and J. Knox, "Benchmarking irrigation water use in golf courses–a case study in Spain," Irrigation and Drainage, vol. 60, pp. 381-392, 2011.
64. M. Schwecke, B. Simmons, and B. Maheshwari, "Sustainable use of stormwater for irrigation case study: Manly Golf Course," The Environmentalist, vol. 27, pp. 51-61, 2007.
65. E. Falt, "Guest Editorial: Sport and the Environment," Environmental health perspectives, vol. 114, p. A268, 2006.
66. Lindsey, "Conceptualising sustainability in sports development," Leisure studies, vol. 27, pp. 279-294, 2008.
67. S. A. Trendafilova and S. N. Waller, "Assessing the Ecological Impact Due to Disc Golf," International Journal of Sport Management, Recreation and Tourism, vol. 8, pp. 35-64, 2011.
68. R. G. Dodson, Sustainable golf courses: a guide to environmental stewardship: J. Wiley & Sons, 2005.
69. E. Shirahama and M. Kiyozuka, "Golf course construction plans and water quality preservation," Desalination, vol. 98, pp. 505-512, 1994.
70. D. B. Jackson, S. D. Kelly, and R. D. Brown, "Design guidelines for integrating amphibian habitat into golf course landscapes," Landscape and Urban planning, vol. 103, pp. 156-165, 2011.
71. M. D. Bartlett and I. T. James, "A model of greenhouse gas emissions from the management of turf on two golf courses," Science of the Total Environment, vol. 409, pp. 1357-1367, 2011.
72. Peña-Guzmán and Lara-Borrero, "Tratamiento de aguas de escorrentía mediante humedales artificiales: estado del arte," Ciencia e Ingeniería Neogranadina, vol. 22, pp. 39-61, 2012.
73. S. Begum, M. G. Rasul, and R. J. Brown, "A comparative review of stormwater treatment and reuse techniques with a new approach: Green Gully," WSEAS Transactions on environment and development, vol. 4, pp. 1002-1013, 2008.
74. R. Harding, "Ecologically sustainable development: origins, implementation and challenges," Desalination, vol. 187, pp. 229-239, 2006.
75. V. A. Tsihrintzis and R. Hamid, "Modeling and management of urban stormwater runoff quality: a review," Water Resources Management, vol. 11, pp. 137-164, 1997.
76. J. N. Carleton, T. J. Grizzard, A. N. Godrej, H. E. Post, L. Lampe, and P. P. Kenel, "Performance of a constructed wetlands in treating urban stormwater runoff," Water Environment Research, vol. 72, pp. 295-304, 2000.
77. B. Braskerud, K. Tonderski, B. Wedding, R. Bakke, A. Blankenberg, B. Ulen, and J. Koskiaho, "Can constructed wetlands reduce the diffuse phosphorus loads to eutrophic water in cold temperate regions," J. Environ. Qual, vol. 34, pp. 2145-2155, 2005.
78. H. Bavor, C. Davies, and K. Sakadevan, "Stormwater treatment: do constructed wetlands yield improved pollutant management performance over a detention pond system?," Water science and technology: a journal of the International Association on Water Pollution Research, vol. 44, p. 565, 2001.
79. D. Bingham, Urban runoff pollution prevention and control planning: EPA, 1993.
80. M. Scholz and B. Lee, "Constructed wetlands: a review," International journal of environmental studies, vol. 62, pp. 421-447, 2005.
81. R. Schulz and S. K. C. Peall, "Effectiveness of a constructed wetland for retention of nonpoint-source pesticide pollution in the Lourens River catchment, South Africa," Environmental science & technology, vol. 35, pp. 422-426, 2001.
82. Bass K., Brchell M., Evans R., Hunt W., and Line D. (2012, Stormwater Wetlands for Golf Courses.
83. Z. Reicher, E. Kohler, V. Poole, and R. Turco, "Constructed wetlands on golf courses help manage runoff from the course and surrounding areas. USGA Turfgrass Environ. Res," Online, vol. 4, pp. 1-14, 2005.

84. K. A. Pekarek, "Hydrologic and Water Quality Assessment of Constructed Wetlands on a Coastal Plains Golf Course," Master, BIOLOGICAL AND AGRICULTURAL ENGINEERING, North Carolina State University, 2008.
85. D. Line, G. Jennings, M. Shaffer, J. Calabria, and W. Hunt, "Evaluating the effectiveness of two stormwater wetlands in North Carolina," Transactions of the ASABE, vol. 51, pp. 521-528, 2008.
86. C. L. Mattson, K. Jahan, and G. Berg, "Impact of Wastewater Reuse in Burlington County, New Jersey on Adjacent Wetlands," in Impacts of Global Climate Change, 2005, pp. 1-11.
87. R. Fuog, K. Giberson, and R. Lawrence, "Wastewater reclamation at Rancho Murieta, California; golf course irrigation with upgraded pond effluent meeting California's strictest requirements for wastewater reuse," Water Science and Technology, vol. 31, pp. 399-408, 1995.
88. M. Salgot, G. K. Priestley, and M. Folch, "Golf Course Irrigation with Reclaimed Water in the Mediterranean: A Risk Management Matter," Water, vol. 4, pp. 389-429, 2012.
89. L. Candela, S. Fabregat, A. Josa, J. Suriol, N. Vigués, and J. Mas, "Assessment of soil and groundwater impacts by treated urban wastewater reuse. A case study: Application in a golf course (Girona, Spain)," Science of the Total Environment, vol. 374, pp. 26-35, 2007.
90. R. Mujeriego and L. Sala, "Golf course irrigation with reclaimed wastewater," Water Science and Technology, vol. 24, pp. 161-171, 1991.
91. S. Fabregat, J. Mas, L. Candela, and A. Josa, "Impact of urban treated wastewater reuse during irrigation of golf courses," in EGS General Assembly Conference Abstracts, 2002, p. 6622.