Quantitative Analysis of Over 20 Years of Golf Course Monitoring Studies (2010)

Baris, R.D., S.Z. Cohen, N.L. Barnes, J. Lam, and Q. Ma.
Env. Tox. Chem., 2010, 29(6):1224-1236

Abstract: The purpose of the present study was to comprehensively evaluate available golf course water quality data and assess the extent of impacts, as determined by comparisons with toxicologic and ecologic reference points. Most water quality monitoring studies for pesticides have focused on agriculture and often the legacy chemicals. There has been increased focus on turf pesticides since the early 1990s, due to the intense public scrutiny proposed golf courses receive during the local permitting process, as well as pesticide registration evaluations by the U.S. Environmental Protection Agency under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Results from permit-driven studies are frequently not published and knowledge about them is usually not widespread. Forty-four studies involving 80 courses from a 20-year period passed our quality control and other review criteria. A total of 38,827 data entries (where one analysis for one substance in one sample equals a data entry) from pesticide, pesticide metabolite, total phosphorus, and nitrate analyses of surface water and groundwater were evaluated. Analytes included 161 turf-related pesticides and pesticide metabolites. Widespread and/or repeated water quality impacts by golf courses had not occurred at the sites studied, although concerns are raised herein about phosphorus. Individual pesticide database entries that exceed toxicity reference points for groundwater and surface water are 0.15 and 0.56%, respectively. These percentages would be higher if they could be expressed in terms of samples collected rather than chemicals analyzed. The maximum contaminant level ([MCL]; 10 mg/L) for nitrate-nitrogen was exceeded in 16/1,683 (0.95%) of the groundwater samples. There were 1,236 exceedances of the total phosphorus ecoregional criteria in five ecoregions for 1,429 (86.5%) data entries. (This comparison is conservative because many of the results in the database are derived from storm flow events.) Thus, phosphorus appears to present the greatest water quality problem in these studies. Pesticides detected in wells had longer soil metabolism half-lives (49 d) compared with those not detected (22 d), although the means were not significantly different.

Urban BMPs Can Protect Water Quality: Non-Pesticides as Models for Pesticides (2009)

Cohen, S.Z. and Q. Ma
Presented August 19, 2009 at American Chemical Society 228th National Meeting, Division of Agrochemicals, (Paper #222)

Abstract: Residential/urban developments are typically designed and built with BMP features. Examples are detention basins, sand filters, wetlands, porous pavers, infiltration basins, and wet ponds. This practice has been standard operating procedure in most counties in the US for several decades. One objective of these BMPs is the control of peak storm flow to control erosion. Of greater interest for this symposium is the other key objective, the protection of water quality. Civil engineers and urban planners are familiar with this standard of care for urban environments, but pesticide scientists and regulators are generally not. Many studies have been done on contaminant attenuation by urban BMPs. For example, the International Stormwater BMP Database contains data from over 300 studies. Most analytes in BMP studies are not pesticides, e.g., TSS, nitrate, lead, and P. However, this extensive amount of data could be used to guide risk assessment and risk reduction discussions and investigations for urban pesticides.

Water Quality Impacts by Golf Courses: A Metastudy (2008)

Baris, R.D., J. Lam, S.Z. Cohen, and N.L. Barnes.
Presented at the Society of Environmental Toxicology and Chemistry (SETAC) North America 28th Annual Meeting, Milwaukee WI. (Poster # MP 93)

Interest in water quality impacts by golf courses has grown significantly in the last two decades, due in part to the intense public scrutiny proposed golf courses receive during the local permitting process. Results from permit-driven studies are frequently not published nor is there usually widespread knowledge about them. We previously reported an assessment of data from 17 studies of 36 golf courses (Cohen et al., 1999). This current study is an update of the previous effort, involving data collected from a total of 80 golf courses. Forty-four studies involving 80 courses from a 20 year period passed our quality control and other review criteria and were incorporated into a detailed data review. A total of 40,791 data points (where one analysis for one substance in one sample equals a data entry) from pesticide, pesticide metabolite, total phosphorus, and nitrate analyses of surface water and ground water were reviewed. Analytes included 195 pesticides and pesticide metabolites (194 in the surface water database and 176 in the ground water database). Widespread and/or repeated water quality impacts by golf courses had not occurred at the sites studied. None of the authors of the newly added individual studies concluded that toxicologically significant impacts were observed, although HALs, MCLs, or MACs were occasionally exceeded. The percent of individual pesticide database entries that exceed HALs/MCLs for ground water and surface water are 0.07% and 0.33% respectively. The percentages would be higher if they could be expressed in terms of samples collected rather than chemicals analyzed. The MCL (10 mg/L) for nitrate-nitrogen in surface water was exceeded in 20/2,493 entries (~1.2% of nitrate-N entries), and only 16/1,377 (1.2%) of the samples exceeded the MCL in ground water. There were 1,236 exceedances of the total phosphorus ecoregional criteria in five ecoregions of 1,429 data entries - - 1,083 for rivers and streams, and 153 for lakes and reservoirs. The inclusion of the EPA's ecoregional criteria, pesticide use data, specific ground water regions, climate zones, as well as additional data for golf courses in the northwestern, mid-continent, and southwestern portions of the country provide a more comprehensive analysis of water quality impacts by golf courses compared with the 1999 meta-analysis.

Calibration and Validation of Runoff and Leaching Models for Turf Pesticides, and Comparison with Monitoring Results (2000)

Durborow, T.E., N.L. Barnes, S.Z. Cohen, G.L. Horst, and A.E. Smith
ACS Symposium Series 743: Fate and Management of Turfgrass Chemicals
Chapter 12, pp. 195-227. American Chemical Society, Washington, D.C., 2000

Computer models that simulate pesticide leaching and runoff were originally developed with a focus on agriculture. Due to distinct botanical and agronomic differences, there are questions about the applications of these models to turf. We evaluated the U.S. EPA's PRZM model (v. 2.0, 2.3, 3.0 and 3.12) and the USDA's GLEAMS model using data from turf test plot studies funded by the U.S. Golf Association. The plots simulated golf greens and fairways in Georgia, Nebraska, and Pennsylvania. The GLEAMS model performed surprisingly well in the Georgia evaluation: 11 of 12 runoff events were predicted moderately to very well for hydrology and pesticides. The PRZM 3.0 evaluation of the Penn State study produced less favorable results, but the differences may be more related to the nature of the field study and not the model's performance. The PRZM 2.3 and 3.12 predictions of percolate volumes ranged from poor to fair for the Georgia study and very good for the Nebraska study, and predictions of pesticide leachate ranged from poor to good, but PRZM generally tended to over predict pesticide mass.

Ground Water and Surface Water Risk Assessments for Proposed Golf Courses (2000)

Cohen, S.Z., T.E. Durborow, and N.L. Barnes
ACS Symposium Series 522: Pesticides in Urban Environments - - Fate and Significance
Chapter 19, pp. 214-227. American Chemical Society, Washington, D.C., 2000

Proposed golf course developments usually require environmental impact statements in the U.S. Concerns about ground water, surface water, and near-shore coastal water quality and wetlands often require state-of-the-art risk assessments and complex computerized simulation modeling. It is extremely important to obtain site-specific data for these risk assessments. Thus soil sampling, test borings, stream surveys, and coastal surveys are often done. Daily weather records are obtained or generated. The new PRZM-VADOFT model pair is used for leaching assessments, even though nonlinear adsorption isotherms cannot be used. The SWRRBWQ model is difficult to use but it is appropriate for the modeling of complex drainage patterns at the basin and sub-basin scale, as with golf courses. Annual and storm-event runoff values are computed for pesticides, nutrients, runoff water, and sediments. It is best used for areas expected to experience appreciable runoff. EXAMS II provides useful predictions of stream water quality. An uncertainty analysis is a critical but often overlooked part of modeling. These results help fine tune proposed turf management programs and may indicate the need for design changes. Risk assessments in Hawaii are especially complex; they often indicate the need for detention basins.

WATER QUALITY IMPACTS BY GOLF COURSES (1999)

Cohen, S.Z., A. Svrjcek, T. Durborow, and N.L. Barnes
J. Env. Qual., 1999, 28(3):798-809.

Interest in water quality impacts by golf courses has grown significantly over the last 10 years due mostly to the intense public scrutiny proposed golf courses receive during the local permitting process. Results from permit-driven studies are frequently not published nor is there usually widespread knowledge about them. Seventeen studies (36 golf courses) passed our quality control and other review criteria and were incorporated into a detailed data review. A total of 16,587 data points from pesticide, metabolite, solvent, and nitrate analyses of surface water and ground water were reviewed. There were approximately 90 organics analyzed in the surface water database and approximately 115 organics in the ground water database. Widespread and/or repeated water quality impacts by golf courses are not happening at the sites studied. None of the authors of the individual studies concluded that toxicologically significant impacts were observed, although HALs, MCLs, or MACs were occasionally exceeded. No solvents were detected in any of the studies. The percent of individual pesticide database entries that exceeded HALs/MCLs for ground water and surface water were 0.07% and 0.29% respectively. The percentages would be somewhat higher if they could be expressed in terms of samples collected rather than chemicals analyzed. The MCL (10 mg/L) for nitrate-nitrogen in surface water was not exceeded, and only 31/849 (3.6%) of the samples exceeded the MCL in ground water; however, most of the nitrate MCL exceedances were apparently due to prior agricultural land use. There was a slight trend for detected pesticides to be more persistent and more mobile than pesticides that were not detected, but the trend was not statistically significant. There are major data gaps in this review, particularly in the midcontinent area.

Agriculture and the Golf Course Industry: an Exploration of Pesticide Use (1995)

Stuart Z. Cohen, Ph.D., CGWP
Golf Course Mgmt, 1995, 63(5):96-104.

The golf course industry is frequently attacked by environmental activists and others raising environmental concerns. In the majority of the 30-plus public hearings and legal proceedings in which I have testified, the opposition has had an underlying presumption that the turf industry uses large amounts of chemicals. This presumption was quantified in 1991 by a New York State Attorney General's Office report that stated ". . . between four and seven times as much pesticides are used on Long Island golf courses than are applied on food crops". Unfortunately, this comparison has received widespread exposure. This brief article will attempt to set the record straight and address this emotional issue in an objective manner. However, one thing is clear: pesticide use is extremely complicated and is best addressed on a site-specific basis.

Offsite Transport of Pesticides in Water: Mathematical Models of Pesticide Leaching and Runoff (1995)

Cohen, S.Z., R.D. Wauchope, A.W. Klein, C.V. Eadsforth and R.Graney
Pure & Applied Chemistry, 1995, 67(12):2109-2148. International Union of Pure and Applied Chemistry.

The process of modeling the leaching and runoff of pesticides is simple in concept but complex in execution. Models are physical, conceptual, or mathematical representations of reality. Screening-level models are an appropriate first step for examining pesticide leachate and runoff potential, as long as conservative input assumptions are used. They may consist of comparisons of certain mobility and persistence properties with numerical criteria, or they may require pencil, paper, and a hand calculator. At a higher level of sophistication, a wide variety of computer models are available that can quantitatively simulate pesticide leaching and runoff in the aqueous phase. It is important to pick a model that has been validated in more than one study, has good user support, requires an amount of data input appropriate for the application, and has a history of producing results acceptable to scientists and regulatory authorities. Considering these various criteria for acceptability, EPA's PRZM2 model and the German modification, PELMO, would be appropriate for evaluating leaching potential. The GLEAMS, LEACHM, and CALF models are also scientifically acceptable, but have not been as widely used. The GLEAMS model is appropriate for quantifying runoff potential in simple, field-scale drainage patterns. The more complex SWRRBWQ model is more appropriate for watershed-scale assessments. The most appropriate use of these computer simulation models is to rank the contamination potential of a particular pesticide at several sites or rank several pesticides at one site. Another excellent application of these models is to calibrate them to fit the results of an intensive field study at one site, and extrapolate to other points in time and space for the same pesticide. One should always recognize the variability in natural processes and field conditions, and use probabilistic (stochastic) analysis whenever possible. More model validation and calibration is needed in tropical climates and in special situations such as turf, forests and orchards.

Conservative Ground Water and Surface Water for Golf Courses in Vermont (1993)

Barnes, N.L., T.E. Durborow, S.Z. Cohen, A.J. Svrjcek, and M.J. O'Connor
Proceedings of the Focus Conference on Eastern Regional Ground Water Issues. NGWA, 1993.
Ground Water Management Book 16 of the Series.

The State of Vermont has comprehensive regulations controlling pesticide use on golf courses. The regulations apply to every golf course in the State -- new and old -- and require the submission of a proposed turf management program that includes, among other things, a pesticide application schedule. Ground water and surface water dilution analyses are required for the pesticides not included on a "prescreened list." These conservative dilution calculations are less resource intensive than computer simulation modeling. Data on pesticide mobility, persistence, human toxicity, and aquatic toxicity are collected and evaluated. Health Advisory Levels (HALs) and water quality criteria usually must be calculated due to lack of government standards. Parallel to these activities, local hydrogeology and surface hydrology are characterized to an extent slightly more intensive than the reconnaissance level. Staff walk the site, sample the soils, observe surface drainage patterns, and look for surface features that would be indicative of subsurface geology. The soils are analyzed for drainage and pesticide retention characteristics. Well logs are obtained and evaluated. Regional hydrogeology reports are reviewed. This information is combined with rainfall and irrigation data to estimate annual recharge rates as well as to describe the hydrogeologic setting. In addition, low flow exceedance data are obtained or estimated for adjacent streams. At this screening level of assessment, pesticide losses are conservatively estimated based on a literature review and without explicit consideration of site-specific attenuation processes. A fraction of the pesticide -- typically 10% -- is "mixed" into the top 10 ft of the aquifer. Predicted concentrations are compared with HALs. A different fraction -- typically 5% -- is "washed off" in a 10-yr return, 24-hr storm event. Runoff volumes are calculated using the runoff curve number method. Runoff is "diluted" into receiving streams and compared with water quality criteria. This approach has been applied successfully to four Vermont golf courses. Mitigation measures requiring selective pesticide limitations were required to at least some extent for each golf course.

THE CAPE COD STUDY (1990)

Stuart Z. Cohen, Ph.D., CGWP
Golf Course Mgmt, 1990, 58(2):26-44

The scientific community began to emphasize the study of nitrates in groundwater as a result of fertilization in the mid- to late 1970s. The emphasis on the study and regulation of pesticides in groundwater also began late in that decade. By the mid-1980s, tens of thousands of wells were found to contain elevated nitrate concentrations and detectable concentrations of pesticides. But few, if any, of the data points were collected from wells associated with the nation's 13,626 golf courses. The first comprehensive field investigation of the effects of turf chemicals on groundwater was recently completed on Cape Cod. This article will describe that study and discuss its results in the context of a brief overview of the water quality issue.