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高尔夫球场管理

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喷灌技术



展新颜

天津高尔夫球场采用燃硫技术改善喷灌水的质量和草坪的总体健康状况。

Hal Phillips

天津龙海国际高尔夫乡村俱乐部的改造项目将从赛场地面到排水系统全面的改进，其中还有另外一个关键部分——燃硫系统，该系统将帮助改善该俱乐部喷灌水的质量。照片承蒙 Flagstick 高尔夫球场建造管理公司提供



燃硫装置相对简单，常常设在喷灌池的旁边，它会在水返回喷灌池之前将其与二氧化硫气体混合，来平衡钠含量较高的水。照片承蒙 Troon Golf Asia-Pacific 提供

天津龙海国际高尔夫乡村俱乐部（中国天津）正在进行的球场改造工程包括各种增强项目——从新果岭到改进后的排水系统——都旨在解决一系列持续发展和维护问题。这其中有一个问题就是喷灌水质量欠佳。龙海国际高尔夫乡村俱乐部采取的解决方案出人意外，即被称为燃硫的基本方法，根据这种方法，水从喷灌湖泵入燃烧硫元素的专用装置中。水流经一个燃烧室，与二氧化硫气体接触，之后再泵回喷灌湖中。

“天津的水总溶解固体含量较高，” 管理人 Roger Cagle 表示。“pH 值较高。碳酸氢盐的含量也很高。球场采用了想到的每一种措施，都无法达到喷灌水的标准。他们决定改造此处的主要原因是原来的高尔夫球场建造时没有考虑到水质不好这一问题。”

Cagle 解释说，含盐量高的水自然会造成土壤含盐量高。原来的球场排水能力不足，无法有效冲洗土壤中的盐分，每灌溉一次就会增加更多的盐分。此外，球场最初建造时没有覆沙层，即在每个球道下铺

设的一层引流沙。结果导致草坪健康状况不佳的恶性循环。

建筑公司 Tripp Davis 及负责为球场所有人“新加坡吉宝置业公司”管理球场的 Troon Golf Asia-Pacific 受委托设计新球场，设计中应纳入覆沙层、更广泛的排水系统和更耐盐的草种。前两项增强工程已在建造阶段完成，草坪铺设工作预计于 10 月份竣工。

剩下的就是水质问题了。Troon 和球场承包商 Flagstick 高尔夫球场建造管理公司凭借在中国以外其它地区获得的成功，选择了燃硫方法。龙海国际高尔夫乡村俱乐部开展的这一项目将被视为中国首个水质修复项目。目标是在 2013 年春末重新开放球场。

燃硫解决方案

Troon Golf Asia-Pacific 农艺主管 David Lunardelli 解释说，该方法不会改变水中的盐分比例，但会改变盐分在水中的复合状态。

“这一改变令盐分更容易从土壤剖面流出，而不是锁住土壤剖面中的钙，”他说。“这当中有一定的科学成分，但基本上我们不会通过燃硫方式将酸注入土壤中。我们正在持续过滤整个土壤剖面的盐分，这有利于草坪的成长。”

“这是一个两步系统，而龙海国际高尔夫乡村俱乐部的主要问题很简单：水中的钠含量过高。燃硫方法可以



在近期的改造过程中，为了尝试减慢盐分流失到钠含量已经较大的喷灌水中的速度，龙海国际高尔夫乡村俱乐部在球场池塘安装了重负载的衬垫。照片承蒙 Flagstick 高尔夫球场建造管理公司提供

将这一含量降到可控制的水平。但是，当我们考察盐相对于钙的含量时，发现钙并不存在。我们需要钙来抵消钠。失去了这种平衡，即使是正常的盐分或碳酸氢盐含量都会锁定土壤中的钙和镁，产生类似水泥的粘合剂，这种粘合剂会伤害排水系统，阻止氧气到达植物根部。

“对于每个钠，我们都需要一个钙来抵消，”他继续说道。“我们通过对水进行酸化，降低碳酸氢盐的含量，从而释放出钙及其抵消钠的能力。我们认识到必须进行酸化；但是，因为钙含量较低，我们必须同时增加钙含量。因此，有两个步骤：通过燃硫进行酸化；但我们还必须持续将石膏注入喷灌水中，以达到我们需要的钙水平。”

Lunardelli 表示，未经处理的水以每秒约 6 升的速度流经燃烧室，每天最多可以处理 4.8 兆升。当球场进行喷灌时，意味着燃硫和注酸过程几乎需要持续进行。

根据水的状况，燃硫方式可以每天将 pH 值降低约 2 个点。“在龙海国际高尔夫乡村俱乐部，如果每天处理 3 兆升水，那么只需一天的时间就可以将 pH 值从约 8.5 降至 6.5，”Lunardelli 说。“我们进行燃硫，然后将酸注入喷灌管道中。我们可以在控制面板上设定 6.5 的目标值，并注入适当的计量来达到这一水平。烧硫炉令我们有能力处理 90% 的水；然后，我们直接注入计量出的调整剂量。”

考虑到成本问题，两个步骤会同步部署。通过直接注入的方法处理所有的水成本高昂，因为这个问题只能通过土壤应用大量石膏来解决。Lunardelli 通过从龙海国际高尔夫乡村俱乐部得出的一些基本计算结果，解释了这一点：“我们需要 175 千克的实际钙，那么按每兆升水计算，高尔夫球场就需要大约 485 千克的石膏来抵消水中的钠。一个普通的高尔夫球场每年要用到 100 兆石膏。这是不切实际的。”

还有什么更不切合实际？尝试用未净化的喷灌水维持草坪的健康，正如 Cagle 接手龙海国际高尔夫乡村俱乐部项目时的情况。事实上，新高尔夫球场植草过程的需水量是标准球场维护的两到三倍。因此，水质不佳造成的潜在伤害，例如发展蔓生的黑土层和完全无氧土壤，对新植草的球场影响巨大。龙海国际高尔夫乡村俱乐部的拥有和管理人别无选择，只能重新设计和改变水的成分。

安装和流程

Cagle 和 Flagstick（负责监管重新设计工作的昆明公司）的负责人 Martin Moore 表示，龙海国际高尔夫乡村俱乐部的燃硫技术作为一个“高科技”项目，非常低调，根本没有引起观察者的注意。该装置类似一个小烟囱，位于主喷灌池的旁边，首先将水吸入，在与硫磺



龙海国际高尔夫乡村俱乐部的改造工程由 Flagstick 高尔夫球场建造管理公司监管，包括在果岭、梯台和球道的赛地表面种植新的本特草，以及在长草区种植新的羊茅草。

气体接触后泵回喷灌池。该过程反复进行，直到湖水的 pH 值达到理想水平。

Flagstick 曾经在美国安装过几台燃硫装置，Moore 表示对于这一技术的使用，球场管理人应了解以下重要事项：

- 该流程需要使用 99% 的纯硫，才能发挥正常功效。Lunardelli 说，幸运的是，在中国很容易获得元素硫。
- 泵的位置必须正确，以确保处理全部湖水供应，而不只是一部分。
- 每个月必须对水取样、查明已处理水的 pH 值及正在处理的土壤的导电性，借此监控各项结果。
- 必须持续监控草坪区域的总溶解固体，确保草种适应处理过的水。

此外，一段时间后应当对燃硫和注酸流程进行调整。Lunardelli 表示，龙海国际高尔夫乡村俱乐部的主喷灌池进行了重新划界，确保高盐地下水不会污染处理过的水源。

成本和可行性

Moore 说，他知道一些燃硫装置制造商：“最畅销的可能要属 Sweetwater SS-10 装置，该装置的处理量达到每分钟约 150 加仑。像 SS-10 这样的装置价格不到 10,000 美元。”

当然，这个价格不包括运费或关税，如果进口到中国，总成本可能要提高 30%。

“我不知道中国有没有生产这些装置的公司，但我确定，如果当地行业了解到燃硫的益处，生产这些装置就不难做到，” Moore 补充道。“这些装置并不复杂。操作非常简单。”

Moore、Lunardelli 和 Cagle 一致认为，尽管难以概括所有气候和球场状况，但与高盐含量有关的严重水质问题在华南地区并不多见，华南地区降雨量充沛，而降雨是一种自然脱盐方法。在天津(北京东南 150 公里)所在的华北地区，降雨量较少，高盐水较为常见。

Moore 表示，他相信随着更多高尔夫球场在中国的开发及政府限制的增强，会有越来越多的球场依赖于废水处理厂的循环水，而不论地理位置和气候状况(包括降雨量)如何。这将增大对其他水处理技术的需求，例如燃硫和注酸，以确保草坪的健康状况。

跟进测试

改造后的龙海国际高尔夫乡村俱乐部选择的草坪草组合包括球道上使用的耐盐 L-93 和南岸本特草(各 50%)、长草区使用的苏格兰林克斯羊茅混合草，以及梯台和果岭使用的 T1 本特草。曾监督过北京和海南高尔夫球场的植草工作的 Cagle 于 5 月份抵达天津。他做的第一件事，也是他在到达任何植草项目现场后做的第一件事情，就是测试土壤和水。事实上，这种测试习惯从未停止。

“你必须能够监控进度，要监控进度，就要频繁地采集水和土壤样品，了解某个地方是否需要补充石膏，”他说。“燃硫和注酸流程不会自动进行。在北京，我会在果岭和梯台特别使用大量叶面肥料。在应对高 pH 值时，必须确保植物获得适当的营养。”

Lunardelli 说，Troon Golf 极其推崇对土壤和水进行持续测试：“在了解土壤需求和应该如何处理水之前，我们不会对肥料计划或任何方案做出任何决定。这是一种科学而简单的态度。我们有责任向所有人提供真凭实据。

“而这还是一种极其切合实际、注重成本的态度。例如，如果天津的土壤中实际上天生含有丰富的钙，我们就会通过释放钙，实现(燃硫的)自然施肥效果。这就是雨后球场显得格外翠绿的原因。降雨量对无盐土壤的影响甚小，因此钙会在土壤中自然释放出来。

“如果不借助酸化降低盐含量，则需要施用两到三倍的肥料才能达到相同的结果。那么就必须利用酸化，这样就可以节省肥料成本。老实说，有了健康的草坪，你承受疾病、杂草和昆虫压力的能力会随之增强。”

Lunardelli 用了一句古老的谚语简单地概括了龙海国际高尔夫乡村俱乐部执行这一水处理技术的必要性：人如其食。

“这同样适用于土壤，”他表示。“你的土壤状况取决于你施用的肥料。如果水里都是盐，那么土壤里也都是盐。”

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Hal Phillips 是缅因州新格洛斯特的一位自由作家兼 Phillips Golf Media 总裁。



A new approach to water treatment here at Pearl Beach International Golf Club is changing the way superintendents, course-builders and club managers cope with water-quality issues in the development and maintenance markets.

The technology is known as sulfur-burning, a surprisingly basic process whereby water is pumped from an irrigation lake into a specialized unit that burns elemental sulfur to create sulfur dioxide (SO₂) gas, which, once it is introduced to the water source, creates H₂SO₃. H₂SO₃ is a very unstable gas that, during the sulfur-burning process, converts to H₂SO₄ (sulfuric acid) and neutralizes bicarbonates and carbonates, thereby lowering the pH of the water. The water continually passes through the unit and back into the irrigation lake until the desired pH level is achieved.

"It doesn't change the salt in the water, percentage-wise. It changes complexities of the salt in the water," explained David Lundardelli, director of agronomy for Troon Golf Asia-Pacific, which manages agronomy specifications and implementation at the Pearl Beach International property for its owners, Singapore-based Keppel Land. "This change allows the salts to move through the soil profile more easily and not lock up the calcium and magnesium in the soil profile. There are quite a few components to the science, but basically we are increasing the porosity of the soil and washing unwanted salts out through the profile, and that's good news for the turf."

Sulfur-burning is necessary only where the quality of irrigation water is poor, and Pearl Beach International has coped with very poor quality water indeed. The course was originally built in 2000, but today Troon and

agronomic consultant Roger Cagle are presiding over a thorough redesign of the existing layout. The low-quality irrigation water was responsible in part for the decision to redesign.

"The water in Tianjin is high in total dissolved solids," Cagle said. "It's high in pH. It's high in bicarbonates. By every measure you can think of, it doesn't meet the standards of irrigation water. It's a big reason they decided to renovate here because the original golf course was simply not built to take into consideration the poor quality of the water."

Cagle explained that water with such high salt content naturally results in soil with high salt content. However, the original course did not feature nearly enough drainage capability to effectively flush those salts from the soil — and every instance of irrigation just added more salt to the equation.

The original course was not built with a sand cap, either — a layer of drainage-promoting sand underlying the footprint of every fairway. The result was a cycle of poor turf health that could not be broken.

Troon and architect Tripp Davis were tasked with redesigning a new course that featured a sand cap, a far more extensive drainage system, and more salt-tolerant grass varieties. The first two issues were addressed at the construction stage — grassing is now underway and scheduled to be complete by Oct. 1, 2012, with the goal to re-open by May of 2013.

This left the issue of water quality still to be addressed. Sulfur-burning was the chosen solution, based on successes experienced elsewhere by Troon (at projects in the Middle East) and Flagstick Golf Course Construction Management, the Kunming-based firm overseeing



reconstruction of Pearl Beach. It is believed the sulfur-burning effort at Pearl Beach International GC is the first such water-remediation effort undertaken on a Chinese course.

"It's a two step system but the main issue at Pearl Beach is simple: The sodium load in the water is so high," Lunardelli said. "The sulfur-burning process ensures the sodium freely leaches from the soil site to a manageable level. However, when we look at the salt in relation to calcium, the latter is non-existent. We needed calcium to offset the sodium. Without this balance, even normal amounts of salts or bicarbonates will lock up the calcium and magnesium in the soil, creating an almost cement-like bond" that impedes drainage and prevents oxygen from reaching the plant roots.

"For every component of sodium we need one component of calcium to knock it back," Lunardelli continued. "By acidifying the water, we reduce the bicarbonate load, thus freeing up the calcium and its ability to offset the sodium. We recognize that we have to acidify but also, because calcium load is so low, we have to add that calcium back in as well to offset the sodium. So those are the two steps: Acidify through sulfur burning, but we have to constantly inject calcium — in the form of gypsum — into the irrigation water, as well, to get the calcium levels we need."

Lunardelli said the untreated water passes through the burn chamber at a rate of some 6 liters per second; maximally, 4.8 megaliters per day can be treated. Typically, treating the water to a pH of 6.5 reduces the bicarbonates load by 50%. Getting it down to 6.0 removes even more. When a facility is irrigating, this

means the sulfur-burning and acid injection processes are run almost continually.

Depending on the condition of the water, pH can be dropped about 2 points per day via the sulfur-burning process. "At Pearl Beach we go from about 8.5 to 6.5 in one day, if we are treating 3 megaliters per day," Lunardelli said. "We do the sulfur burning, and then direct injection of the acid right into irrigation line itself. We can set a target of 6.5 on the control panel and inject the proper dose to achieve that level. The sulfur burner gives us the ability to treat 90 percent of the water, then we do a metered adjustment dose with direct injection."

The reason for deploying both processes, in concert, is cost. To treat all the water by direct injection would be cost prohibitive — just as it would be cost prohibitive to address the problem by merely applying huge amounts of gypsum to the soil, as Lunardelli explained: "Here are some basic calculations for Pearl Beach. We needed 175 KGs of actual calcium, which is about 485 KGs of gypsum, to offset sodium per megaliter of water. A typical golf course uses 150 megs-plus a year. That's not practical."

What's even less practical? Trying to maintain healthy turfgrass with raw irrigation water the likes of which Cagle inherited at Pearl Beach. Indeed, the process of growing-in a new golf course requires 2-3 times more water than does the regular maintenance of a course. So the potential damage caused by poor water quality — the development of rampant black layer, totally anaerobic soil with no oxygen — is far greater for newly grown-in courses. The owners and managers at Pearl Beach had little choice; redesign and change the water equation.



The sulfur-burning effort at Pearl Beach International GC is rather unobtrusive and doesn't strike one as at all "high tech", according to Cagle and Martin Moore, principal at Flagstick. The unit looks quite like a small chimney. It sits right next to the main irrigation pond, sucking water in, exposing the water to sulfuric gas, then pumping it back into the pond. The process is repeated until the pH of the lake reaches the desired level.

Flagstick has installed several sulfur-burning units in the United States, and Moore says there are several important things course managers should know about the process:

- You need 99 percent pure sulfur if the process is to work properly. Luckily, according to Lunardelli, finding elemental sulfur is easily found in China.
- Location of the pump must be properly placed, ensuring treatment of the entire lake's supply, not merely a portion.
- "To ensure effectiveness, you must monitor the results with monthly water samples and read the pH of the treated water and the electrical conductivity of the soils you are treating," Moore explained.
- One must continually monitor the total dissolved salts on the turfed areas, to ensure the grass types on the course are responding well to the treated water. Adjustments in the sulfur-burning and acid-injection processes might be called for, over time. Lunardelli noted that the main irrigation pond at Pearl Beach was re-lined to make sure high-salt groundwater didn't taint the treated supply.

"There are a couple of manufacturers of these sulfur-burning units that I'm aware of," said Moore. "Probably the most popular is the Sweetwater SS-10 unit that provides a capacity of about 150 gallons per minute... A unit like the SS-10 would cost under \$10,000 USD."

Of course, if one were importing to China, this price would not include freight or duty tax, which may add an additional 30 percent to the overall cost. "I'm not aware of any company that manufactures these yet, in China, but I am sure it could be easily done if the local industry catches on to the benefits of sulfur burning," Moore added. "There is nothing too sophisticated about these units. They are simple in operation."

It's difficult to generalize but Moore, Lunardelli and Cagle agree that serious water quality issues relating to high salt content are not as common in the south of China where rainfall — a natural desalinating factor — is more abundant. In the North, where rainfall is less frequent,

high-salt issues are more common. Tianjin certainly falls in the northern tier, as it is located only 150 km southeast of Beijing.

But Moore reasoned that as more golf courses are developed in China and governmental restrictions toughen, more and more courses will rely on recycled water from wastewater treatment plants, regardless of geography and climatic conditions (including rainfall). This will increase the need for further water treatment efforts such as sulfur-burning and acid injection to ensure healthy turfgrass.

The mix of turfgrasses chosen for the renovated Pearl Beach International include a salt-tolerant, 50-50 blend of L93 and Seashore bentgrasses on the fairways, a Scottish Links mix of fescues in rough, and T1 bentgrass on the tees and greens. Cagle has overseen the grow-in of golf courses in Beijing and Hainan. He arrived in Tianjin in May, and the first thing he did — the first thing he does upon arrival at any grow-in project — was test the soil and water. Indeed, this regimen of testing never stops.

"You have to be able to monitor what's going on and you do that by taking frequent water samples and soil samples to see if you need a gypsum supplement somewhere," Cagle said. "Sulfur-burning and acid injection won't do it all by themselves. In Beijing, I used a lot of foliar fertilizer on greens and tees especially. When you're dealing with high pH, you have to make sure that plant is getting proper nutrition."

Lunardelli says Troon Golf is a huge proponent of continual soil and water testing. "We don't make any decisions about a fertilizer program or anything until we understand the needs of the soil and how the water should be treated," he said. "It's a scientific but simple approach. We have a duty to our owners to provide something that's not guesswork.

"But it's also an extremely practical, cost-conscious approach. If, for example, we actually had abundant calcium naturally in Tianjin, we'd realize a natural fertilizing effect [from sulfur-burning] by releasing the calcium."

That's why golf courses green up after a good rain. Rainfall has little to no salt content and, therefore, an acidifying affect. After a rain event, the calcium is naturally released in the soil, removing sodium and freeing up other beneficial elements the plant could not previously access from the soil.

"If you weren't reducing salts with acidification, you might be applying 2-3 times the fertilizer to achieve similar results. You'd have to!" Lunardelli explained. "So acidifying could save you money on fertilizer. And honestly, with healthy turf, your threshold to withstand disease, weed and insect pressure is increased as well.

"In Australia, where I'm from, we say 'You are what you eat'. This applies to soil. Your soil becomes what you feed it. If your water is full of salt, the soil is full of salt."

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