and curative application programs that have traditionally served the home lawn market are often employed in the management of public sports fields and grounds due, in large part, to the fact that they can be readily integrated into the public bid process.

Contractor-submitted bids are typically based on a scheduled application of fertilizer and pesticide products on a specified date (or range of dates), to a known acreage, and at label-derived rates. Realistically, calendar-based contracted programs may be the only avenue in which fertilizers and pesticides are ever applied to sports fields and grounds in a public setting. However, the environmental suitability of these applications is often called into question as one-size-fits all protocols can result in pesticide and fertilizer applications that are poorly timed and/or unnecessary.

INTEGRATED PEST MANAGEMENT (IPM)

While numerous definitions have been authored to describe IPM, no conventional definition addresses fertilizer selection nor entails the elimination of synthetic pesticide use. The following is a definition developed by the Rutgers Pest Management Office: *As a long-term approach to maintaining healthy landscapes and facilities that reduces the risk to people and the environment, instead of routine chemical applications, IPM employs site assessment and monitoring, and pest management tactics that include horticultural, mechanical, physical, and biological controls and selective use of pesticides when needed to keep pests within acceptable limits*.

Site assessment and setting pest thresholds (i.e. acceptable limits) are IPM principles that can be used to reduce the quantity of pesticides applied to sports fields and grounds. Town properties and school district sports fields and grounds can be subdivided into zones (e.g. A, B, and C) based on turf function and aesthetic priority. Pest threshold levels can then be established for individual zones.

For example, a school district may classify certain sports fields and lawns as Zone A turf locations on the basis that they have the highest expectations for function (playing surface quality) and aesthetics; thus, these locations have the lowest threshold level for weeds, diseases, and insect pests. Examples of Zone A turf areas may include varsity sports and practice fields used by high school athletes and high profile lawn and grounds locations.

Zone B sports fields and grounds may include turf locations where stakeholders have a moderate expectation level for playing surface and aesthetic quality such as sports fields used by middle school athletes, passive recreation areas, and lower visibility lawns. A greater level of weeds, diseases, and insect activity can be tolerated given the less intense recreational activity, younger age of athletes, and/or lower aesthetic importance.

Sports fields and grounds designated as Zone C can be determined to have the greatest threshold for pest activity and may include sports fields used by elementary school students, 'alternate fields' that are always open to users when high value fields are closed, and turf locations where soil stabilization (no wind or soil erosion) is the primary function of these grounds.

MANAGEMENT WITHOUT SYNTHETIC PESTICIDES

Laws essentially prohibiting the use of synthetic pesticides on school sports fields have been implemented in the State of New York (playgrounds, turf, athletic or playing fields at day care centers and schools [kindergarten through grade 12]) and Connecticut (grounds

▼ **Left:** As part of an Integrated Pest Management (IPM) plan, middle school sports fields may be deemed to have a higher threshold level for broadleaf weed populations compared to high school varsity fields. **Right:** Failure to develop any pest management plan resulted in nearly complete white grub damage of this municipal baseball outfield during late September.

of day care centers, elementary and middle schools [grade 8 and lower]). Additionally, at the time of the authoring of this article, a bill has been introduced in the New Jersey State Legislature prohibiting 'lawn care pesticide' use on the grounds of day care centers, schools, and sports fields at municipal, county and state park facilities. The proposed New Jersey Safe Playing Fields Act defines a 'lawn care pesticide' as "… any pesticide labeled, designed or intended for use on lawn, gardens, turf or ornamental plants". These laws and proposed bill provide allowances for 'emergency' pesticide applications per approval from varying authorities.

It is important to note that these laws and bill do not address fertilizer use; thus, it is a mischaracterization to state that organic management is being legislatively mandated in these cases.

The New York and Connecticut laws and proposed New Jersey legislation allow the application of Minimum Risk Pesticides. These products contain active ingredients that are exempt under Section 25b of the Federal Insecticide Fungicide Rodenticide Act (FIFRA) and do not require EPA registration (i.e. they do not require an EPA registration number) because the EPA considers their ingredients, both active and inert, demonstrably safe for the intended use. (www.epa.gov/oppbppd1/biopesticides/regtools/25b_list.htm). Examples of minimum risk active ingredients included in products marketed for use in turf include, but may not be limited to: cedar oil, citric acid, clove oil, corn gluten meal, eugenol (oil of cloves), lauryl sulfate (sodium lauryl sulfate), 2-phenethyl propionate (2-phenylethyl propionate), sodium chloride (common salt), and sodium lauryl sulfate.

It is extremely important to understand the specifics of the laws under which one is governed. For example, pesticide products that have an EPA registration number are not allowed for use on the grounds of day care centers and elementary and middle schools in Connecticut, regardless of whether or not the product is approved for use in organic production (e.g. Avenger Weed Killer; OMRI-listed; EPA Reg. No. 82052-1; and M-Pede; OMRI-listed; EPA Reg. No. 62719-515).

A thorough evaluation of the success of a management program that excludes synthetic pesticides must take into consideration prior management history. Sports fields and grounds where synthetic herbicides and insecticides have been routinely applied typically have few weed and insect problems. Initiating a program (and maintaining acceptable turf quality) without synthetic pesticides on properties with minimal weed and insect problems presents less of a challenge compared to beginning such a program on turf riddled with annual and perennial weeds and/or insect pests.

ORGANIC MANAGEMENT

The USDA NOP defines 'organic' as a labeling term that indicates that the food or other agricultural product has been produced through approved methods that integrate cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity (www.ams.usda.gov/AMSv1.0/nop). Materials allowed for use in organic production are either essentially derived from living things or naturally occurring minerals.

The USDA NOP definition underscores that organic management, to this point, has been employed primarily in agricultural production systems, as opposed to turfgrass and

▼ **Left:** Within a school district, the greatest broadleaf weed population can often be tolerated on the sports fields and grounds surrounding elementary schools. **Right:** This suburban New Jersey sports field has not received a synthetic pesticide application since 2009 (photo taken October 2013). Before this program, synthetic pesticides were routinely applied to the sports field which consisted of good turfgrass cover. Current cultural practices promote competitive turfgrass: regular mowing (3 inches), fertilization, aerification, and overseeding.


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landscapes. The USDA NOP was developed to create standards for organic farming and administer organic certification – which verifies that a farm or handling facility complies with the USDA organic regulations and allow the sale, labeling, and representation of a product(s) described as organic.

To meet USDA NOP certification requirements for crop production, organic farmers are prohibited from applying non-conforming substances to the land for three years before the harvest of an organic crop. This requirement, albeit rigorous, preserves the integrity of products labeled organic and drastically contrasts with a recent effort to develop standards for organic land care (including lawns) that allows applications of non-organic materials under an 'Emergency Non-Organic Rescue Treatment' provision. The standards, developed by Northeast Organic Farming Association (NOFA), emphasize that emergency non-organic rescue treatments must be rare, must only be undertaken as a last resort, and must be approved by the client (www.organiclandcare.net/accreditation/standards). Where a pest population exceeds a pre-established threshold (established by the turf manager and/or client) and a synthetic pesticide is used reduce the pest population to an acceptable limit, the management system should be characterized as IPM.

In its broadest sense, organic turf management seeks to apply the principles of organic crop management to the maintenance of turfgrasses. A primary tenant of organic management is the emphasis on systems-based management as opposed to product-focused management. Synthetic pesticides and fertilizers are commonly applied using a calendar-based approach; organic-conforming products can be applied in a similar manner by simply removing the synthetic product from a calendar program and inserting an organic product. Organic philosophy discourages this type of simple input substitution as it is inconsistent with broader systems-based models that emphasize soil preparation, proper establishment methods, turfgrass selection, and cultural practices that favor healthy, competitive turfgrass.

Per USDA NOP guidelines, synthetic fertilizers, sewage sludge, irradiation, and genetic engineering may not be used in organic agricultural systems. "Materials for Organic Crop Production" (NOP 5034-1), currently in Draft Guidance form, lists materials (including some synthetic) that comply with USDA organic regulations (www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5103311). Additionally, Organic Materials Review Institute (OMRI) is a nonprofit organization that provides organic certifiers, growers, manufacturers, and suppliers an independent review of products intended for use in certified organic production, handling, and processing (www.omri.org). The OMRI Products List is a directory of all products OMRI has determined are allowed for use in organic production, processing, and handling according to the USDA National Organic Program.

To preserve the integrity of an organic turf program, turfgrass managers should confine their product choices to those that are OMRI-listed or can be found on the "Materials for Organic Crop Production" list. All too often, confusion arises over what materials are allowable as part of organic management. Restricting product use to those products that appear on OMRI and USDA NOP lists provides a level of validation that the system is being managed in a manner that can legitimately be characterized as organic.

An example of non-organic materials readily mischaracterized as organic involves 'organic-based' fertilizers. These fertilizers will often contain one or more natural organic fertilizer sources (e.g. bone meal, blood meal, feather meal, etc.) allowable in organic production but also contain synthetic nitrogen (N) sources and/or biosolids. Synthetic N sources and biosolids are prohibited for use in organic production; thus, when these materials are applied to turfgrass, the management system should not be characterized as organic.

Because there is no national organic program for turf management, the validity and integrity of an organic program is the responsibility of the turf manager, whether the manager is directly employed by the property owner (i.e. school or town) or working as a contractor.

CONCLUSIONS

The underpinnings of successful IPM, synthetic pesticide free, and organic turf management programs include sound agronomic decision making, as opposed to simply figuring out what products can be applied and when (including Minimum Risk Pesticide, organic-approved products, etc.). Examples of systems-based management include utilizing construction methods that preserve topsoil quality and if necessary amending soils with compost to improve soil organic matter; timely establishment and selection of the best adapted turfgrass species and varieties that have demonstrated lower disease and insect susceptibility; and properly executing all cultural practices including raising mowing heights to encourage more competitive turf and returning clippings to recycle nutrients. Systems-based management strategies for sports fields include the aforementioned in addition to frequent cultivation to alleviate soil compaction on native soil fields; aggressive overseeding to account for voids in the turf cover caused by traffic; supplying ample fertilization to ensure active turf growth and recovery; and using growth blankets to promote seed germination and turfgrass growth when soil and air temperatures discourage turfgrass physiological activity. ■

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John Mascaro's Photo Quiz

John Mascaro is President of Turf-Tec International

Can you identify this sports turf problem?

Problem: Brown areas on field
Turfgrass area: University athletic field
Location: Denton, Texas
Grass Variety: Celebration bermudagrass

Answer to John Mascaro's Photo Quiz on Page 33

Background illustration courtesy of istockphoto.com

SOIL DYNAMICS and effective irrigation management

Over the past year, I have had the opportunity to become involved in the day to day management of an irrigation system installed 3 years before a newly reconstructed sports complex. I must admit that since becoming a sports field manager 25 years ago, I have never had the opportunity to become so intimately involved in irrigation management. However, on this particular field, problems had arisen which required serious consideration of all the facets of the turf management program.

Conceptually, irrigation management is simple. Just replace the water lost to evapotranspiration; the combined effects of soil evaporation and moisture loss thru turf transpiration. I was told by one employee that the previous year he had gotten daily evapotranspiration data from a local weather-related website. A basic understanding of his irrigation system allowed him the ability to use this information and program the system to apply what was required.

As I ran through the different irrigation zones on the field, I noticed some heads were not rotating, others were puddling and still others were watering in the wrong direction. Irrigation heads within the same zone were randomly fitted with different size nozzles. An irrigation audit completed by a certified irrigation auditor later reported that the system was only about 60% efficient.

Examination of the soil profile revealed major differences in soil compaction. In some areas of the field I could insert a soil probe 7 or 8 inches, in other areas only two or three. By coincidence, areas of sod replaced the year before due to fungus, coincided with these areas of heavier compaction. The areas of heavy compaction were programmed to receive the same amount of water as areas with much less compaction. Poor drainage in the heavily compacted areas was causing standing water to accumulate after irrigation. I can only assume that wet feet coupled with restricted root development had some bearing on sod loss.

In an attempt to optimize the effectiveness of the irrigation, I purchased a soil moisture meter. I did this intent on gaining a better

Image ©istockphoto.com/AdShooter.

understanding of the moisture needs of the turf. Initial readings revealed differences in soil moisture which at the time seemed counterintuitive. Areas of the field with minimal compaction showed moisture content to be around 25%. Areas of high compaction with visual signs of standing water and obvious saturation showed soil moisture content only to be around 18%. I am not the sharpest tool in the shed and came to the conclusion that these moisture readings, alone, meant absolutely nothing to me and I would need more information. I continued to take readings hoping an epiphany would suddenly make it all clear to me. It instead became clear that my efforts were in vain.

As I began to research a little deeper, it started to make sense that in order to competently program irrigation based on evapotranspiration data; it would first require a baseline soil moisture measurement or irrigation threshold. This irrigation threshold would be used as a reference point from which to determine the need for supplemental irrigation. To better understand this concept it becomes important to have a basic understanding of soil. The following information helped to clarify my confusion.

Soil is typically a mixture of inorganic and organic particles. The inorganic particles are mineral based and come from rocks that have been weathered and broken down into smaller pieces over a long period of time. The organic particles contain carbon compounds and they come from anything that was once living and has since died and decayed, including plants, microbes, insects and animals.

Soil texture is determined by the relative amounts of sand, silt and clay.

Soil structure refers to the arrangement of the sand, silt and clay particles joined together into larger aggregates of different sizes and shapes and the pore spaces that are left between them. It is in these spaces that root hairs grow and take in water and nutrients from the soil.

In heavier textured soils, soil structure favorable to turf growth is one that has stable aggregates. These aggregates result in a network of both small and large soil pores that has good aeration and drainage and allows for efficient exchange of air, water and nutrients. In sandy soils, typically having more than 85% sand, adequate pore space is primarily a product of particle size rather than soil aggregation.

The processes of root penetration, wetting and drying cycles, freezing and thawing, and microbial activity combined with inorganic and organic cementing agents produce soil structure. Soil structure can be severely compromised in many ways such as by compaction, playing on a field when it is too wet or by over tilling during construction or repairs.

After rain or irrigation, the pore space in soil typically fills with water. **Saturation** occurs when all the pores are full of water and the soil can hold no more water. This is the time when playing surfaces are generally most unstable and most vulnerable to damage caused by traffic. As moisture drains from the soil, the soil will typically become more stable. For this reason, it makes sense for the turf manager to manage soil moisture at a level favorable to turf survival yet providing a root zone stable enough to resistant damage by traffic.

Not all of the water will drain due to gravity. Some water will stay in the soil. Moisture will remain in the smaller pore spaces and as a thin coating on the outside of the soil particles. This remaining moisture held in the soil against the force of gravity is known as **capillary moisture**.

After the gravitational water has drained away, the soil is said to be at **field capacity**. At field capacity water in the pores is typically easy for the plant roots to use. Once the pore water is used up, there is normally a thin coating of moisture remaining around the soil particles. The **permanent wilting point** is defined as the point at which remaining soil moisture is held so tightly that it is unavailable to plants. Plants subjected to this level of soil moisture will not typically recover. Turf will usually exhibit signs of drought stress before the soil reaches the permanent wilting point. The amount of water held in the soil between field capacity and the permanent wilting point is called the **plant available water**. A sandy soil will typically hold less water at field capacity than a heavy textured clay soil but a larger percentage of that water is plant available water.

There are two means of identifying soil moisture content in the field. Volumetric soil moisture is measured as a percentage of the total soil volume. Soil moisture tension is a measure of how tightly water is held in the soil.

Volumetric soil moisture is a method of measurement used by many moisture meters to measure moisture in the soil and can be used as a means of monitoring irrigation requirements. Each location should be evaluated individually and the volumetric soil moisture compared to turf quality and soil conditions at the time the reading is taken. The accumulation of volumetric soil moisture data for a given location, over time, can give the turf manager the ability to correlate soil moisture readings, predict turf needs and irrigate accordingly.

Soil moisture tension is a phenomenon caused by the capillarity of water. **Capillarity** is the combined effect of cohesion and adhesion. **Cohesion** is the attraction water has to itself. It is the reason water beads up on a sheet of glass. **Adhesion** is the attraction water has to another surface; in this case it is the attraction to the soil particles. Moisture adhesion to the soil is typically the stronger of these two properties. Capillarity causes some water to remain in the soil after gravitational water has drained away. Capillarity also allows for water movement thru the turf plant against the force of gravity. This movement of water against the force of gravity is called **capillary motion**. Soil moisture tension increases as the volume of soil moisture decreases. Soil moisture tension can increase to a point where moisture remaining in the soil is held so strongly, it is unavailable to the turf. This is the permanent wilting point as previously described.

Kilopascals (kPa) are units of pressure measurement used to measure soil moisture tension. Suction is a negative pressure or tension and is therefore referred to by negative numbers. Soil moisture tension is a measure of suction, and the correct way to refer to it is minus or negative X kPa. Numbers closer to zero refer to less suction and therefore wetter soils. As a soil dries out the kPa value becomes larger (and more negative).

One benefit to measuring soil moisture tension as opposed to volumetric soil moisture is that soil texture is largely irrelevant. -25kPa in clay is the same as -25kPa in sand. Turf in either of these soils is basically working the same to extract moisture.

A **tensiometer** is a hand-held device that is forced into the ground for the purpose of measuring soil moisture tension. The hollow ceramic tip of a tensiometer is porous, allowing water to move into and out of a sealed water storage 'reservoir' or tube inside the tensiometer shaft. As the soil dries out, water is sucked out of the tensiometer through the porous ceramic tip. This creates a partial vacuum inside of the tube, which is registered by a vacuum gauge. Tensiometers usually operate accurately over a range of 0 kPa to -80kPa. **Gypsum block** sensors are also available for measuring soil moisture tension and can be buried in different locations of a field to allow for soil moisture tension measurements. Gypsum is a naturally occurring porous mineral. When shaped into a block and buried in the soil, water from the surrounding soil moves into and out of the gypsum block as though it were soil.

A gypsum block sensor consists of two electrodes embedded in a block, 'tablet' or cylinder of gypsum. When water moves into the gypsum block some of that gypsum dissolves, allowing a current to move between the electrodes. As the amount of water in the block changes so does the resistance to current flow.

As the soil dries out, water leaves the gypsum block and the resistance between the electrodes increases. Conversely, as the soil wets, soil water is drawn back into the gypsum block and the resistance decreases. These resistance values are then translated into soil moisture tension readings by a meter connected to the two electrodes, which displays the soil moisture tension as units of kilopascals (kPa).

The level of soil moisture tension required to sustain turf can vary by turfgrass species, region of the country and other environmental factors. -50kPa to -80kPa may represent an approximate irrigation threshold for cool season turf above which the sports field manager could anticipate draught stress and a decline in turf quality. As always, it is the responsibility of the sports field manager to evaluate soil moisture tension readings as they compare to turf quality and use good judgment when establishing an irrigation threshold from which to initiate irrigation.

Dielectric Constant or Dielectric Permittivity Sensors use electric fields to monitor a dynamic of soil called its 'dielectric constant'. Water greatly changes a soil's dielectric constant. Dry soil has a dielectric constant of between 2 and 5. Pure water has a dielectric constant of 80. Consequently, as the moisture level in the soil changes, the dielectric constant changes accordingly.

This class of sensors uses the dielectric permittivity as a means of reporting soil moisture content. A key advantage of these sensors is that mineral particles such as salt barely affect the dielectric constant of soil so the soil moisture readings are largely unaffected.

Although each employs a different technology, thetaprobes, capacitance or frequency domain reflectometry (FDR) probes and time domain reflectometry (TDR) devices all rely on the dielectric permittivity of soil for their soil moisture measurements.

In addition to soil moisture monitoring being available as a manual method of establishing and maintaining an irrigation threshold, manufacturers of automated irrigation systems have integrated similar methods of soil moisture monitoring as means of controlling supplemental irrigation. Whether you choose to monitor soil moisture yourself or incorporate it into an automated irrigation system, your choice becomes another tool in your sports field manager's tool box.

The methods of monitoring soil moisture mentioned in this article should not be considered the only options available to the sports field manager. This article is intended only to suggest the benefits that can be realized through soil moisture monitoring and the tools mentioned are used only as examples to help better understand the principles provided.

In the past 25 years, I have attended many classes and read a lot of books and articles on the topic of soil. However, I had not seriously considered the interrelationship between soil dynamics and effective irrigation management. The positive or negative influences that in sum total contribute to an improvement or decline in turf quality warrant understanding and consideration. Knowledge acquired thru success is far less expensive than wisdom acquired thru failure.

As for the field I mentioned at the beginning of the article; a basic review of these few principles concerning soil and soil moisture gave me the ability to comprehend why and how the compacted soil I had previously identified as having 18% moisture could conceivably measure less moisture, and exhibit a higher level of saturation than other areas of the field. We look forward to having the irrigation system repairs completed in the spring and hope to be able to establish an effective irrigation threshold from which to program the supplemental irrigation needs of the turf. We will also be working to further relieve compaction across the board. ■

Jim Hermann, CSFM, is President of Total Control Inc. Athletic Field Management.


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NICKEL AND TURFGRASS GROWTH: ALL YOU NEED TO KNOW

▲ **These two photos** show reduced growth with increasing Ni treatments from Clemson's toxicity study. Each one shows four representative plots of either Diamond zoysiagrass or TifEagle bermudagrass under Control, 400, 800, and 1600 uM Ni treatments. The reduction in clipping yield is significant and easy to see.

Turfgrass managers are always trying to leverage acceptable conditions with minimal inputs (water, nutrients, and pesticides). Maintaining optimal plant nutrition is the foundation of sustaining healthy turfgrasses that require fewer inputs. Liebig's Law of the Minimum states that plant growth is controlled not by the total amount of resources (nutrients) available, but by the most scarce resource (limiting factor). Due to the fertilization of macro and most micronutrients, this principle isn't usually a problem. However, there are trace micronutrients that play critical roles in the plant that we should consider, such as nickel (Ni). Nickel constitutes approximately 3% of the earth's crust and is the 24th most abundant element. Nickel is a trace micronutrient that was discovered to be essential for plants in the 1980s. Typical ranges of Ni in soils range from 5-500 ppm; however, measuring bioavailability in soils is difficult because the plant available form Ni2+ readily oxidizes in the soil rendering it unavailable. Nickel is commonly forgotten in the world of turfgrass nutrition because of the low concentration found in plants (0.05-10 ppm) which is thought to be adequately provided by the soil. However, Liebig should not be disregarded when it comes to Ni and turfgrass.

NICKEL BIOAVAILABILITY

Sports turf grasses are commonly grown in conditions conducive to reduced bioavailability of Ni:

• Dry and/or cool soils in early spring, (Common throughout the Carolinas)

• Soil pH > 7, (Limestone based calcareous sands, which are commonly used for turfgrass root zones typically have pH values in the 8.2 range

• Sandy and or low CEC soils (Putting greens, tees, and frequently top-dressed playing surfaces)

In addition, the following management factors influence Ni bioavailability:

• The presence of root-knot nematodes (Meloidogyne sp.) (Root-knot nematodes are not as damaging to turfgrass as sting or lance nematodes but are still commonly found in soils and can contribute to reduced Ni bioavailability)

•Exceedingly high concentrations of Zn, Cu, Mn, Fe, Ca, and Mg, (Rooney et al., 2007; Wood et al., 2006) (Many constructed root zones are derived from calcareous sands. Additionally, liming materials and other Ca sources (gypsum) are commonly applied in turfgrass management increasing Ca in the root zone)

• Ni deficiency was triggered in pecan with foliar applications of Fe, and heavy early spring application of N. (Turfgrass managers commonly fertilize with both of these nutrients to correct deficiencies and improve turf color.)

Ni TOXICITY, DEFICIENCY, HYPERACCUMULATION, AND PLANT DEFENSE

Minimal information exists on Ni toxicity and deficiency for turfgrasses. However, by way of other plant research, we can make some conclusions about Ni. One of the most well documented Ni deficiency cases has been in pecan trees, in which the deficiency caused a disruption in carbon metabolism resulting in stunted growth leaves termed "mouse ear." Foliar sprays of Ni corrected the deficiency, but only in newly emerged leaf tissue. The diagnosis and management has brought to surface the importance of Ni in plant health and suggests the possibility that many horticulture crops may possess a "hidden hunger" for Ni.

Plants found growing on serpentine soils containing elevated levels of metals (Zn, Cu, Co, Fe, Cr, Mg, and Ni) can hyperaccumulate Ni without deleterious effects. Nickel hyperaccumulator species have been studied for their potential in the phytoremediation of soils contami-