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Smart Water Networks

Big data, software reveal utility challenges

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Greening the planet

Wastewater Gardens – a high-diversity approach to constructed wetlands – offer a solution to water supply and wastewater treatment challenges worldwide. Mark Nelson and Florence Cattin report on successful applications of the sustainable system in Algeria, Australia, and Iraq.

Constructed wetlands are gaining favor as an affordable and sustainable treatment in wastewater for reuse in many countries – developed and developing – facing the challenges of water shortages and climate change. A high-diversity approach to constructed wetlands, the Wastewater Garden System, has been implemented in 11 countries in varying climates. Several applications illustrate the wide range of conditions and scales in which the system can function effectively, including Algeria and Australia. Under development in southern Iraq is a project to install wastewater gardens to treat sewage from Marsh Arab towns.

The wastewater garden approach, which creates productive and beautiful landscapes, is founded on two fundamentals. The first, that residential wastewater contains very valuable nutrients and fresh water – the reverse of the current dominating paradigm to detoxify and dispose. The second, that untreated sewage causes human disease and sometimes death, as well as major environmental degradation, if it is allowed to impact surface and ground waters. Therefore, it is imperative to find cost-effective treatments for wastewater, while fully integrating and recycling its valuable elements. Constructed wetlands, like the wastewater garden, use sewage safely for creating greenery and potentially highly productive crops, rather than using potable water and chemical fertilizers (which are contributors to greenhouse gases and major water pollutants). This strategy is especially valuable in a world facing the challenges of water shortages and climate change.

According to the World Health Organization's 1992 estimates, on average each individual's annual waste contains more than five kilograms of nitrogen, a half kilogram of phosphorus, and one kilogram of potassium. According to Drangert's 1998 article in *GeoJournal*, these amounts would be sufficient to grow the 250 kilograms of food crops each individual needs annually. Depending on toilet type, approximately one to ten tons of water are used to dispose of the waste (flush it away).

The global situation is critical. According to a 2009 technology review by the German Agency for Technical Cooperation (GTZ), an estimated five to 10 percent of total wastewater worldwide is being treated (among which about 50 percent is insufficiently treated), while the remaining sewage pollutes aquifers, rivers, lakes, and the oceans.

Wastewater Garden System

The Wastewater Garden System had its genesis in Biosphere 2 – the materially sealed experimental facility in Arizona – where the lead author was in charge of managing and researching the constructed wetlands. The wetlands treated human and domestic animal wastewater as well as wastewater from laboratories and workshops. The system was created with the technical help of B.C. Wolverton, a NASA scientist who was a pioneer of constructed wetlands in the United States. During the research phase, the wetlands performed excellently and produced foliage, which was harvested for animal fodder or composted. The wetlands were beautiful, with 14 species of emergent and floating wetland plants, and provided habitat for beneficial insects. Remaining nutrients in the treated wastewater were sent back to the irrigation supply for the Biosphere 2 farm, thus helping maintain soil fertility.

After Biosphere 2, with the support of the Biosphere Foundation and later the Institute of Ecotechnics, the approach was further refined to use subsurface-flow constructed wetlands with gravel media. This refinement achieved good secondary treatment with a robust final stage of subsoil irrigation with the treated water. Almost total reuse of the sewage's nutrients and water is reached through the drainfield, where the green landscape continues using the treated wastewater.

The typical system has three stages that include primary sedimentation using washable filters, septic tanks, Imhoff tanks, fecal bags (which separate solids from liquids), the constructed wetland itself, and the final use for subsoil irrigation – where plants do not need to be wetland-tolerant, thus opening the way for inclusion of a wider array of high-value fruit, fiber, timber, or other attractive and culturally valued plants.

With a network of regional representatives, more than 200 systems have been implemented in 11 countries with varying climates from wet tropical, temperate, and Mediterranean to desert-arid. Overall, Wastewater Gardens International's plant catalogue includes approximately 200 species and local availability.

Several examples of the approach include gardens installed in Temacine, Algeria; Pandanas Park Aboriginal Community, Derby, West Australia; and Eden in Iraq, with planned projects for Marsh Arab towns in southern Iraq.

Algeria

The Temacine area of southern Algeria is one of the country's date plantation centers. Drainage water from the increasingly saline irrigation has caused the creation of a 150-kilometer canal, which has progressively been deteriorated by the addition of the growing population's raw sewage. In 2007, Wastewater Gardens International was invited by the Algerian government to create a demonstration sewage effluent treatment plant through a constructed wetland. The demonstration plant had to provide secondary treatment levels for the equivalent of 150 habitants and the local mosque for a total of 15 cubic meters per day. A 400-square-meter wastewater garden was designed using a crescent moon shape, culturally resonant for the region.

Because of low labor costs, the contractors preferred to make the wetland using concrete (in this case using sulfate resistant cement because of the soil's high salinity), which takes much longer than waterproofing in membrane but allows easier construction of desired shapes. Choice of plants and construction materials reflected the near desert climate (70 millimeters of annual rainfall) with cold winters that included short periods of freeze, along with the ability to manage the highly saline water supply.

Maurice Levy, an agronomist and landscaper from Earth and Water in Portugal, assisted in choosing the plants. Twenty-three species were chosen, specifically to increase plant productivity in terms of local use or market value relevance. The most successful were canna lily (Canna indica), hibiscus (Hibiscus rosa sinensis), oleander (Nerium oleander), papyrus family (Cyperus spp.), pomegranate (Punica granatum), silk cotton palm (Washingtonia robusta), lemon grass (Cymbopogon citratus), rush (Juncus spp.), and the Damascus or Syrian rose (Rosa damascene).

The crescent moon-shaped Wastewater Garden in Temacine, Algeria after six years of operation.

Table 1. Comparison of water quality tests at the Temacine, Algeria, pilot subsurface horizontal flow constructed wetland of Wastewater Garden design (July 2007 to November 2013), and comparison with a nearby activated-sludge sewage plant and Algerian regulatory standards.

Amount of water treated: 15 m³/day	Treatment levels of the sewage effluent of the WWG constructed wetland treatment plant of the Old Ksar, Temacine, Algeria									Conventional treatment plant Touggourt (Activated Sludge)			Local legislation
	25 September 2007			June 2008			Average between the results for months of August, September, October and November 2013						
Parameters	Exit septic tank	Outlet WWG	Reduction rate (%)	Exit septic tank	Outlet WWG	Reduction rate (%)	Exit septic tank	Outlet WWG	Reduction rate (%)	Entry TP	Exit TP	Reduction rate (%)	Maximal value of release into the environment
Salinity							1.65	2.15	-30%				
Temperature (°C)	35.6	32.3	9%				28.69	27.19	5%				
pH	7.33	7.48	-2%				7.105	6.92	3%				
BOD5 (mg/l)	450	25	94%	372.75	60.12	83.872	310.6	27.13	91%	312	10.83	96.528	40
COD (mg/l)	563	35	94%	481.75	75.63	84.3	352.6	35.38	90%	421.5	16	96.215	120
DO – Dissolved Oxygen	0.31	0.94	-203%										
SS (Suspended Solids) (mg/l)	837	49.5	94%	501.7	22.43	95.528	383.8	21.75	94%	803.59	21.8	97.282	30
N - Kjeldahl nitrogen													40
N-NO3 (mg/l)	35	20.2	42%	35	29.29	16.314	35.45	7.938	78%	35	7.9	77.428	
N-NO2 (mg/l)	1.27	0.29	77%										
P-PT (mg/l)				31.71	23.57	25.67				30.88	5.66	81.67	2
PO4 (mg/l)	31	15.5	50%										
PO4 (mg/l)				110000	3233	97.06				110000	9300	91.545	-

Table 2. Summary of Water Quality Tests at Emu Creek (Gulgagulganeng) Aboriginal Community, Kununurra, West Australia; and Birdwood Downs station, Derby, West Australia, 2000 to 2004.

Parameter	BOD-5 (Biochemical Oxygen Demand) mg/l	Total Suspended Solids (TSS) mg/l	Total Nitrogen mg/l	Total Phosphorus mg/l	Total Coliforms Cfu/100 ml
Average in Septic Tank	228	219	140	14	6,285,000
Average Wastewater Gardens discharge	18	14	47	7.5	116,000
Percent Reduction	92%	94%	66%	46%	98.2%

Since installation in 2007, the wastewater garden has produced high-level treatment.

Since the pilot installation performed well, and because of its aesthetics and plant productivity, the unit attracted visits by numerous public health officials. Currently, the Algerian government is expanding use of constructed wetlands for treating towns of 3,000 to 10,000 people throughout the country.

Western Australia

In the Kimberley region of northwest Australia, the climate is tropical savannah – with a four-month wet season that includes very heavy rain events, while the rest of the year remains quite dry. Rainfall averages 675 millimeters per year, but with high variability ranging from 185 millimeters to 1, 250 millimeters, and sometimes substantial single-day rainfalls like one of the region's tropical cyclone's that dropped 290 millimeters of rain. So, it is important that constructed wetlands have sufficient berms, adequate size piping, and robustly designed subsoil leach drain trenches to prevent any overflow, facilitate rapid movement of water, and prevent surfacing of wastewater during heavy direct rainfall events.

The Kimberley region is remote with a small population and widely separated towns and communities. Fifteen wastewater gardens have been implemented, including in three Aboriginal communities. The five systems at Pandanas Park Aboriginal Community treat wastewater from a school and many homes. The systems prevent pollution of the nearby river and save potable water. Using treated wastewater in constructed wetland and subsoil irrigation areas created substantial community landscaping.

Plants used in the Kimberley installations, including the Pandanas Park Aboriginal Community, are: banana (Musa spp.) and plantain, papaya (Carica papaya), coconut (Cocos spp.), sea grape (Cocoloba uvifera), Heliconia (Heliconia spp.), fantail palm, pandanas palm (Pandanas pandan), canna lilly (Canna edulis), elephant ear (Xanthosema roseum and Alocassia macrorhiza), wetland fern (Acrostichum sp.), Leichardt pine (a native Ficus species), snake's tongue (Sanseverria spp.), papyrus (Cyperus spp.), Ixora, oleander (Nerium oleander), Alimander spp., native paperbark species (Melaleuca spp.), mint, hibiscus (Hibiscus rosa), vetiver grass, crotons, Darwin palm, ginger, and cardamom. The subsoil irrigation areas used more than two-dozen native shrubs and trees including traditional indigenous food crops.

Treatment results from two pilot wastewater garden projects in the Kimberley region show high performance, including reduction of Coliform bacteria without disinfection. Remaining nutrients are used by the plants in the leach drains.

Southern Iraq

Currently, a project to install wastewater gardens to treat the sewage from Marsh Arab towns in southern Iraq is in development – in cooperation with Nature Iraq, an Iraqi environmental non-governmental organization (NGO), as well as the head of the NGO's Al Chibaish office, Jassim Al-Asadi. The project director Meridel Rubenstein, from Singapore's Nanyang Technological University (NTU), conceived of an art-and-ecology project symbolizing the restoration of the historic marshes and Marsh Arab culture. With the backing of the governate of Thi-Qar province and the area's Ministries of Water and the Environment, sewage from pumping stations serving 5,000 to 20,000 people, which currently goes completely untreated into the marshes and Euphrates River, will be treated by wastewater gardens covering one to three hectares with a similar area for subsoil irrigation. The system will include vertical and horizontal flow constructed wetlands to minimize size and maximize treatment levels. The design team includes Dr. Davide Tocchetto of Wastewater Gardens International, Professor Peer Satikh of NTU, Professor Sander van der Leeuw of Arizona State University, as well as Rubenstein and Nelson.

Green evidence

These applications illustrate the wide range of conditions and scales in which constructed wetlands function successfully. Systems that require a highly technological infrastructure are neither sustainable nor affordable and would be difficult to maintain. This opinion is increasing in developing countries. The Wastewater Garden System's cost-effectiveness and attractiveness add to its appeal. More natural systems, which make use of the principles of ecological engineering that Jorgensen and Mitsch classified in 1991, are increasingly gaining favor since they utilize time-tested ecological mechanisms.

Constructed wetland approaches, like waste-water gardens, rely much more on local resources and natural elements and far less on imported and mechanical equipment and chemicals than

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Events 2014

September

7-10 Dallas, Texas, USA
29th Annual WateReuse Symposium
www.watereuse.org

7-11 Kuching, Sarawak, Malaysia
13 International Conference on Urban Drainage 2014
www.13icud2014.com

10-12 New Delhi, India
Pollutech India 2014
Organized by Messe Frankfurt India and held concurrently with Wastetech India, Cleantech India, and Watertech India
www.pollutech-india.in

17-19 Santa Marta, Colombia
57th Annual ACODAL Congress and Exhibition, organized by the Colombian Association of Sanitary and Environmental Engineering. Includes WEF International Pavilion
www.acodal.com

21-26 Lisbon, Portugal
IWA World Water Congress & Exhibition
Organized by International Water Association
www.iwa2014lisbon.org

September

24-26 Rotterdam, The Netherlands
Deltas in Times of Climate Change Conference
www.climatedeltaconference2014.com

27- October 1 New Orleans, Louisiana, USA
WEFTEC® 2014, Water Environment Federation's Annual Technical Exhibition and Conference, WEF Stormwater Congress
www.weftec.org

October

5-10 Pacific Grove, California, USA
Ninth International Symposium on Subsurface Microbiology
Organized by the International Society for Subsurface Microbiology, National Water Research Institute
www.2014issm.com

8-10 Charleston, South Carolina, USA
SESWA Ninth Annual Regional Stormwater Conference, organized by Southeast Stormwater Association
www.seswa.org

9-11 Mumbai, India
IFAT India 2014
Organized by Messe München International
www.ifat-india.com

October

9-11 Mumbai, India
IFAT India 2014
Organized by Messe München International
www.ifat-india.com

13-17 Adelaide, Australia
Stormwater14: 3rd National Stormwater Industry Conference "New Ways of Thinking," organized by Stormwater Australia
www.stormwater.asn.au

20-22 Muscat, Oman
WSTA 11th Gulf Water Conference "Water in the GCC... Towards Efficient Management"
www.wstagcc.org

22-24 Chongqing, China
Water & Gas Metering China 2014: Moving Towards SMART
www.meteringchina.com

29-November 1 Hong Kong, China
Eco Expo Asia, International Trade Fair on Environmental Protection
Organized by Messe Frankfurt (HK) Ltd., Hong Kong Trade Development Council, Environment Bureau of Government of Hong Kong Special Administrative Region
www.ecoexpoasia.com
www.messefrankfurt.com.hk

November

11-14 Mérida, Mexico
28th Annual ANEAS Convention and Exhibition, Organized by National Association of Water and Sanitation Utilities of Mexico. Includes WEF International Pavilion
www.aneas.com.mx

12-15 Nashville, Tennessee, USA
Cities Alive 12th Annual Green Roof & Wall Conference
www.citiesalive.org

Upcoming WEF Webcasts COMPLIMENTARY

August 27 Innovative Stormwater Finance

September 3 Water Innovation Showcase Partners, Part 3

September 4 Sensors and Monitors Used by the Global Water Industry (Joint WERF)

September 10 Force Main Condition Assessment, Part 3

For more information, email webcasts@wef.org

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while renting can be a convenient option for short-term deployments, the current price of water-level loggers has decreased enough that purchasing is more cost-effective for many applications today. For example, hydrology or groundwater services companies may now find that owning their own inventory of water-level loggers may give them a competitive edge, since they'll be able to waive additional equipment rental fees for clients.

Choose the right computer interface

When choosing a water-level logger, the instrument should be able to be quickly and easily hooked up to a laptop or office computer. A logger with a direct universal serial bus (USB) interface enables plug-and-play ease-of-use – which can be particularly helpful when offloading data in the field. Direct USB also enables data to be offloaded in a matter of seconds, compared to the minutes it takes via serial communications.

Loggers that rely on mechanical plug-in connectors can be damaged by water in the field and cause logger failures. Water-level loggers with an optical interface completely sealed within the housing eliminate the possibility of water-related damage or failures.

As hydrologists, engineers, and others continue to rely on water level logging instrumentation as a means to collect level information, they need to be sure they are choosing the right tool for the job. Evaluating water-level data loggers with these five key factors in mind can result in a successful product selection process that leads to the best choice for the user's specific application.

Onset Computer Corporation is based on Cape Cod, Massachusetts, United States. A leading supplier of data loggers, Onset offers the HOBO data logger and weather station products for applications including water resources management.

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conventional sewage treatment approaches. Rather than becoming a net contributor to energy use and excess carbon dioxide production, constructed wetlands add additional green zones that can help in sequestering carbon and producing oxygen through the increase of plant biomass. High-diversity systems provide ancillary benefits such as harvestable and decorative plants and attractive landscape greening, which is especially valuable in harsh environments.

These approaches offer significant value additives to their primary purpose to prevent the impairment of potable water sources, which prevents pollution overall and greatly impacts human health. As water resources are increasingly in scarce supply and high demand, the value of water conservation also increases – in substituting recycled water in place of higher-quality water specifically for use in irrigation and greening the environment.

Authors' Note

Mark Nelson is an environmental engineer and founder of Wastewater Gardens International, headquartered in Santa Fe, New Mexico, United States. He is also the chairman of the Institute of Ecotechnics, an international non-profit organization consulting on ecological research and development based in London, United Kingdom. He is the author of The Wastewater Gardener: Preserving the Planet One Flush at a Time *(Synergetic Press, June 30, 2014).*

Florence Cattin is a constructed wetlands designer, builder, and international educator. She serves as a regional director and international liaison, design and implementation officer with Wastewater Gardens International and the Institute of Ecotechnics. She has directed Wastewater Garden International's office in Vejer de la Frontera, Spain, and is now based in Indonesia and the Southeast Asian region.