Water Practice & Technology Vol 14 No 1
doi: 10.2166/wpt.2018.109

Community engagement and pollution mitigation at Kandy Lake, Sri Lanka

K. B. S. N. Jinadasa[a,*], S. K. Weragoda[b], E. Valencia[c], S. T. V. Sim[c] and W. J. Ng[d]

[a] Department of Civil Engineering, University of Peradeniya, Peradeniya, Sri Lanka

[b] National Water Supply and Drainage Board, Sri Lanka

[c] Nanyang Environment and Water Research Institute, Nanyang Technological University, Singapore

[d] Environmental Bio-innovations Group (EBiG), School of Civil & Environmental Engineering, Nanyang Technological University, Singapore

*Corresponding author. E-mail: shamj@pdn.ac.lk

Abstract

Kandy City is a UNESCO world heritage site. Being the second largest city in Sri Lanka and host to the annual Esala Perahara festival, it has a floating population two to three times its 120,000 permanent residents. Among the city's key landmarks is Kandy Lake, a culturally, environmentally, and economically significant ornamental lake. Nevertheless, inadequate urban development regulation has resulted in serious pollution of the lake. An integrated remedial measure was needed to improve the urban lake's water quality sustainably, for the Kandy community and their cultural heritage. A project was initiated by the University of Peradeniya (UOP), Sri Lanka, and the Nanyang Environment and Water Research Institute (NEWRI), Singapore. It started with modelling of Kandy Lake and community surveys, demonstrated implementation of wastewater management technologies (floating wetlands and an aerobic sequencing batch reactor (SBR)), and initiated community outreach with schools. The project also involved local authorities and government agencies in Kandy, and provided an informal cooperation platform. After project handover on July 10, 2014, further developments were observed in Kandy, including implementation of sewerage and centralised wastewater treatment, rehabilitation of Kandy Lake and the Mid-Canal, and integration of Kandy Lake into the city's development plan and regulations.

Key words: community involvement, multi-stakeholder engagement, urban lake remediation, wastewater infrastructure

KANDY CITY & KANDY LAKE

Kandy, the second largest city in Sri Lanka, is its heritage capital and capital of the hill country. It is 500 m above sea level and surrounded by forested hills. The latter, with Kandy's mild climate, has attracted residents and visitors alike. The city is active both as a commercial centre and a leisure destination. It has 120,000 permanent residents, but the daily floating population is the same size on average. The population can then further increase two- to three-fold during the Esala Perahara festival season in August each year.

The city is the site of the last Sri Lankan kingdom, and houses the sacred Temple of the Tooth Relic '*Sri Dalada Maligawa*', a national treasure and a major pilgrim destination of the Buddhist faith. The City is a UNESCO World Heritage Site. Kandy Lake occupies a depression in the city centre, ringed by a major road, and schools and hotels. This 0.25 km^2 lake is highly significant to Sri Lankans for several reasons:

Water Practice & Technology Vol 14 No 1
doi: 10.2166/wpt.2018.109

Culture & Heritage. The Lake was constructed between 1810 and 1812 by the last King of the Kingdom of Kandy, Sri Wickrama Rajasinghe, as an ornament and for water storage. It is also beside the prominent *Sri Dalada Maligawa.* Its banks are bounded by a characteristic low wall dubbed the 'cloud wall', where lanterns are placed during the festive season, and it is a key landmark in Kandy.

Economics. With its prominent location and natural beauty, the lake adds charm and livability to the heritage city, and hitherto is one of the top leisure destinations for the city's residents and visitors.

Environment. Kandy Lake is part of the Mahaweli River catchment, which covers 15% of Sri Lanka. The river is the country's longest and a major water source – e.g., for Kandy (Hewavisenthi 1997). The lake drains into the Mid-Canal and then the river. The water supply intake for Katugastota Water Treatment Plant is 4 km downstream of the canal's discharge.

Sri Lanka has historically practiced indirect water reuse, through its 'tank cascade system', with many manmade and natural lakes in its river basins, to divert and store water for drinking and irrigation. While efficient in distributing fresh water resources, such systems also pose contamination risks. It is still common for untreated sewage and agricultural runoff in Sri Lanka to be discharged close to intakes used by downstream communities.

KANDY LAKE POLLUTION & CHALLENGES

Severe algal blooms have occurred periodically on Kandy Lake (Pu *et al.* 2011). The first major incident occurred during the period of British rule, leading to construction of the Mahamaya Silt Trap in 1873 (Karunaratna 1999).

The lake's bed profile resembles that of an oil lamp – the deepest point is conical and approximately 14 metres deep, and it shallows gradually outward to 2 m. Substantial sediment deposits have collected over the years and, while it is dredged at intervals, dredging is costly and safe disposal of the bottom mud has posed challenges as urban lake deposits contain significant quantities of heavy metals and organic matter (Dissanayake *et al.* 1987; Silva 2003).

Following rapid economic growth, the pollution load into Kandy Lake has increased while space for remediation devices has become increasingly scarce. Unlike many cities, Kandy cannot expand, as it is surrounded by hills.

Economic growth, development, & pollution load to the lake

Five major and 15 minor drains empty from the city centre into the Lake. As visitor numbers increase, more houses have been converted into guesthouses and hotels, and small businesses such as restaurants and laundries flourish.

Economic & technical challenges in wastewater management options

Kandy has had neither sewerage nor centralised treatment, although sewers are now being constructed. Houses are connected to septic tanks and most businesses must build their own wastewater treatment plants. However, and often during the design stage, no space is allocated for wastewater treatment. This is because space is at a premium and wastewater management usually becomes a low priority for business/home owners. Wastewater treatment contractors are commonly required to provide maintenance-free and compact treatment systems, but this is difficult as some level of training and maintenance is required for even the simplest systems. Lack of maintenance is often cited as the reason for treatment plant failures in Kandy, although inappropriate design is also a possible cause. There is also then the

Water Practice & Technology Vol 14 No 1
doi: 10.2166/wpt.2018.109

mistaken but nonetheless widespread belief that there are no appropriate technologies that can manage Kandy's wastewater economically.

Regulatory challenges

While upkeep of Kandy Lake is in the custody of the Irrigation Department of the Kandy Region, the lake's condition depends on other stakeholders, resulting in complexity in coordinating protection efforts. For instance, the lake's immediate management is divided so that:

- the water is managed by the Irrigation Department;
- the fish by the National Aquatic Research Agency (NARA);
- the surrounding walls and the island in the lake by the Archaeological Department; and,
- the surrounding plants by Peradeniya Botanical Garden.

At catchment level, the municipal area (buildings, roads, and the Mid-Canal) is managed by Kandy Municipal Council (KMC), while the Central Environmental Authority (CEA) is responsible for regulating wastewater discharges into the lake. Enforcement had been difficult, partly due to the wastewater management challenge mentioned above, limited surveillance resources, and rapid property and land use changes (e.g., conversion of houses into small hotels or restaurants). Water quality in the lake has varied between eutrophic and hyper-eutrophic states, despite the existence of wastewater discharge regulations in Sri Lanka. In the absence of regular consultation among and coordinated action by stakeholders, an integrated water management approach has proved difficult to achieve.

Community behaviour & perceptions

Anecdotally, Kandy residents and visitors value the lake, and would wish to see it in a clean and pleasant state. The older generation, for instance, expects the lake's environs to be developed more towards fish-feeding and resting areas for pilgrims. The younger generation, however, views activities like swimming, boating, and birdwatching as more important.

Awareness of actions that may damage the lake may not be widespread. For instance, fish-feeding, which may enrich nitrogen and phosphorus levels in the lake, is common, especially close to the temple, as many believe this is a meritorious act. Kandy Lake is also informally (and illegally) a 'convenient' place for residents and businesses to empty the contents of septic tanks and other wastewaters (in the absence of adequate facilities), as the lake's perceived large volume makes such acts seem innocuous. Thus, lack of adequate awareness of the impact of their actions and of safe waste disposal methods has led to inappropriate actions on the part of the people.

SOLUTION DEVELOPMENT FOR THE LAKE

Kandy's local authorities recognise the need to manage wastewater at source and catchment level, if lake pollution is to be controlled in the long-term. However, this requires coordination and sustained effort among and between the agencies responsible, as many factors contribute to the lake's pollution (Matsubara *et al.* 2015). There was also a need to provide a working technical solution, to restore public confidence and raise awareness. In 2011, the University of Peradeniya (UOP) and the Nanyang Environment & Water Research Institute (NEWRI), Singapore, started a project to map and model Kandy Lake, and subsequently identified the technologies and designed the systems to be deployed in Kandy. The project was called 'Mitigation of Pollution in Kandy Lake and Mid-Canal, Sri Lanka'.

Water Practice & Technology Vol 14 No 1
doi: 10.2166/wpt.2018.109

Figure 1 | Completion of 1st phase of wetland installations.

Floating wetlands were designed by the project team, tested, and installed at major inlets to the lake, as a passive water treatment and protection system (Figure 1). Installation was preceded by hydraulic modelling of the lake to enable strategic wetland module placements (Pu *et al.* 2011). A local wetland plant (*Canna iridiflora*) was selected, considering both growth rates and aesthetics (Weragoda *et al.* 2012). Floating wetlands were selected because these: (1) take up excess nutrients and reduce sedimentation of larger particles without consuming energy; (2) require virtually no land space, which is scarce in Kandy; (3) are easy to control and maintain, as the plants will not grow outside the float, and the floats can be anchored at the most effective locations, and (4) integrate naturally into and beautify the surroundings (Vymazal 2007).

Prior to the project, Kandy Lake was cleaned only by periodic desilting and, to some extent, water lilies growing in its fore-bay. Desilting, however, poses a challenge. The lake's sediments have accumulated significant nutrient and heavy metal content over many years. If not properly disposed, these contaminants may end up polluting waters elsewhere. Similarly, while water lilies help to remove nutrients, they grow fast in nutrient-rich water and, having spread, become difficult to control.

It will be impossible to clean Kandy Lake, if sewage continues to flow into it, so pollution must be controlled at source. Construction of the wastewater treatment plant for the Temple of the Tooth Relic was carried out as an example for other institutions. The temple is a major pilgrimage site beside Kandy Lake. A sequencing batch reactor (SBR) system was designed to treat wastewater from the kitchens and toilets in the temple complex (Figure 2). It has been maintained by the temple since handover.

An SBR system was selected as it can be compact and yet handle large load fluctuations. These factors are critical for the temple because the number of visitors varies greatly. Once a month, on poya (full moon) days, there are many visitors. The peak numbers arrive in July and August, when hundreds of thousands of pilgrims and tourists visit the city and the Sri Dalada Maligawa, to celebrate and observe the Perahara festival.

Most parts of Sri Lanka still depend on septic tanks. Institutions and commercial establishments like temples, hospitals, and hotels are typically required to treat their wastewater prior to discharge. However, many wastewater facilities are often in poor working condition, due to inappropriate design or insufficient operator training. For instance, prior to this project, the Dalada Maligawa had a non-functioning wastewater treatment plant. Gully bowsers were hired to remove its wastewater. When there are no treatment facilities nearby, as is often the case, wastewater and septic tank sludge is taken by bowsers for disposal at unsanitary dumpsites. These are often open grounds and may be close to rivers and streams, and therefore pose public health hazards through direct and indirect

Water Practice & Technology Vol 14 No 1
doi: 10.2166/wpt.2018.109

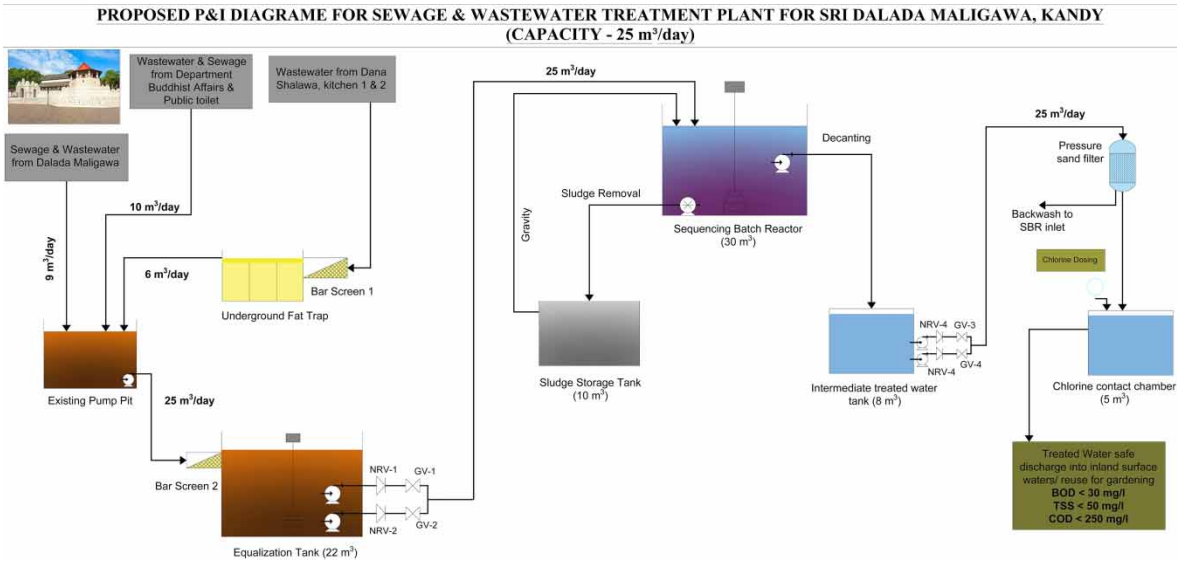

Figure 2 | Process diagram for the Dalada Maligawa WWTP (Drawing by Enviromec Pvt. Ltd. for Sri Dalada Maligawa, Project: 'Sewage Treatment Plant for Sri Dalada Maligawa', 13 September 2013).

contamination of ground- and/or surface-water. Waterborne disease is still a major cause of hospitalisation in Sri Lanka.

Skilled human resources and a sense of ownership are required, to support and sustain facilities and technology. Polluting habits, such as littering and feeding lake fish, must also be phased out. An education programme was designed to cultivate environmental stewardship among the young, as the future custodians of Kandy City. An example is the Wetland Education Programme at the Mahamaya Girls' College, a premier school beside the lake in Kandy. The students conduct hands-on activities such as water quality monitoring and organise regular events to promote water management awareness (Figures 3 and 4).

The project 'Mitigation of Pollution in Kandy Lake and Mid-Canal, Sri Lanka' was officially handed over to Kandy stakeholders and authorities on 10 July 2014. Since then, developments in Kandy's water and sanitation infrastructure have been continuing. The local authorities believe that the success of the Kandy Lake project helped trigger, and provide momentum and support for the ongoing developments.

Figure 3 | L-R: Creating floating wetland models at the Mahamaya Girls' College; a student demonstrating water quality checks using a World Water Day kit.

Water Practice & Technology Vol 14 No 1
doi: 10.2166/wpt.2018.109

Figure 4 | UOP undergraduate demonstrating how constructed wetlands work.

FURTHER DEVELOPMENTS IN KANDY

Centralised water treatment and rehabilitation of Kandy Lake

The project's success helped push confidence towards large-scale wastewater management for Kandy City. While the initiative for sewerage and a centralised wastewater treatment plant (WWTP) – i.e. Kandy City Wastewater Management Project (KCWMP) – has been planned since 2002, progress was halted due to difficulties finding a suitable WWTP site. KCWMP is now being implemented by the National Water Supply and Drainage Board (NWSDB) with the support of the Japan International Cooperation Agency (JICA). The project will provide a wastewater collection system and a 14,000 m^3/d WWTP at Gonnoruwa. Construction of the treatment plant started in 2015, and is expected to finish at the end of 2018, when the facilities will be handed over to KMC.

Great emphasis has also since been given to protecting Kandy Lake. With World Bank assistance, rehabilitation of the lake, its silt traps and the Mid-Canal was proposed, in 2015, by the Strategic Cities Development Project, under the Sri Lankan Ministry of Megapolis and Western Development. Work started in 2016.

Kandy lake monitoring by local authorities & increased awareness

After the project, Kandy Lake's water quality is monitored more regularly, and with better facilities. Kandy Irrigation Department received approval to set up a laboratory for regular lake water quality checks. This was a break from the 'tradition' as the department was equipped only to oversee water volumes and the lake's general upkeep. Drawing on the Kandy Lake example, the CEA is now setting up inland surface water quality standards.

Low fencing and signboards have now been erected around Kandy Lake to prevent people from standing too close to the water and thus discourage fish feeding.

Role of the university & use of full-scale technology as a learning platform

The Dalada Maligawa SBR and the floating wetlands in the lake are open to the public for use as models, and two hotels have opted to use the same SBR technology. The facilities are also

Water Practice & Technology Vol 14 No 1
doi: 10.2166/wpt.2018.109

open to staff and students of UOP for educational purposes and, hence, improves their learning experience.

Expansion of lake remediation efforts

The project team, using experience from remediating Kandy Lake, is now working on other lakes in Sri Lanka, starting with Kurunegala Lake.

CONCLUSION

Kandy Lake is a key Sri Lankan tourist attractions and recognised by UNESCO as a world heritage site. Maintaining its water quality has become a significant duty for all its stakeholders. Although there is sufficient legislation in place, managing the lake's water quality has been challenging, with water quality deterioration to eutrophic and hyper-eutrophic levels. An integrated approach involving both technology and community engagement was therefore implemented, for the first time in Sri Lanka, as a novel method of addressing lake remediation. An SBR wastewater treatment facility was implemented as an example to highlight the need for and feasibility of controlling inputs to the lake. Public awareness was raised successfully by involving school students around the lake. The project, led by a neutral/ non-partisan consortium of scientists and engineers from inside and outside Sri Lanka, helped foster consultation among the various parties. The Kandy Lake project has not only served local needs, but also made it a potential model solution for policy makers and planners elsewhere, because of its success.

ACKNOWLEDGEMENTS

The project was supported through the Lien Environmental Fellowship (LEF) program funded by the Lien Foundation and administered by NEWRI Community Development.

REFERENCES

Dissanayake, C. B., Bandara, A. M. R. & Weerasooriya, S. V. R. 1987 Heavy metal abundances in the Kandy Lake – an environmental case study from Sri Lanka. *Environmental Geology* **10**, 81–88.

Hewavisenthi, A. C. D. S. 1997 Management of the Mahaweli, a river in Sri Lanka. *Water International* **22**(2), 98–107.

Karunaratna, N. 1999 *Kandy, Past and Present, 1474–1998 A.D*. Central Cultural Fund, Ministry of Religious and Cultural Affairs, Colombo, Sri Lanka.

Matsubara, K., Tobe, T., Murata, M., Adachi, R., Ishikura, S., Wada, Y., Weragoda, S. K., Ramawickrama, U. & Jinadasa, K. B. S. N. 2015 Application of Water Quality Simulation for Water Safety Plan at Mahaweli River Basin. In: *Proc. of the 6th International Conference on Structural Engineering and Construction Management*, 11–13 December 2015, Kandy.

Pu, J. H., Jinadasa, K. B. S. N., Ng, W. J., Weragoda, S. K., Devendra, C. & Tan, S. K. 2011 Numerical Modelling of Kandy Lake, Sri Lanka in Preparation for Water Quality Improvement. In: *Proc. of the Sixth International Conference on Asian and Pacific Coasts (APAC 2011)*, 14–16 November 2011, Hong Kong.

Silva, E. I. L. 2003 Emergence of a Microcystis bloom in an urban water body, Kandy Lake, Sri Lanka. *Current Science* **85**(6), 723–725.

Vymazal, J. 2007 Removal of nutrients in various types of constructed wetlands. *Science of Total Environment* **380**(1–3), 48–65.

Weragoda, S. K., Jinadasa, K. B. S. N., Zhang, D. Q., Gersberg, R. M., Tan, S. K., Tanaka, N. & Ng, W. J. 2012 'Tropical application of floating treatment wetlands. *Wetlands* **32**(5), 955–961.