Socio-Environmental Impact of Water Pollution on the Mid-Canal (Meda Ela), Sri Lanka

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ABSTRACT

Unplanned urban population growth in developing countries such as Sri Lanka exert pressures on the sectors of water supply, sewage disposal, waste management, and surface drainage in the cities as well as their surrounding areas. The Mid-canal is considered the most polluted surface water body in the Kandy district of Sri Lanka and contributes significantly to pollution of the Mahaweli River. Health problems in the nearby population may well be associated with environmental degradation and related to deteriorated water quality. The overall objectives of this study were to identify the socio-economic status of the community settled along the Meda Ela banks, and to examine the current water quality status of the Meda Ela and possible impacts of the nearby residents on water quality. Additionally, we propose remedial measures concerning wastewater and solid waste disposal to improve environmental conditions in this area.

Keywords: Meda Ela; Sri Lanka; Environment; Pollution; Water Quality

1. Introduction

One of the most important demographic trends in the world today is urbanization, with particularly rapid growth in developing countries which is believed to be an important cause of the degradation of natural water resources. In future decades, almost the entire population growth in the world is likely to be in the urban population, primarily in Asia [1]. With rural-urban migration, it has been estimated that by the year 2025, approximately fifty percent of the population will live in the growing cities of less developed countries [2]. Unplanned urban population growth exerts pressures on water resources, and water pollution has emerged as one of the most critical environmental problems in Asia. Such growth has major impacts on water supply, sewage disposal, waste management, surface drainage, and can cause environment health problems.

Kandy is recognized as a world heritage city by the United Nations Educational, Scientific and Cultural Organization (UNESCO) on account of its long and venerable history and its many cultural treasures. A canal (called Mid-canal or “Meda Ela”) originates from the overflow sluice of the Kandy Lake, runs through the densely populated city, and thereafter drains into the Mahaweli, which is the largest river basin in Sri Lanka, draining about 16% (10,327 km²) of Sri Lanka’s land surface. Urbanization and population growth in Kandy city has rapidly increased in the volumes of wastewater generated in the region to about 20,000 m³·day⁻¹ [3]. Since there is no proper wastewater disposal system, untreated domestic sewage is released directly into the Mid-canal [4].

In addition, Mid-canal receives wastewaters from small scale industries such as commercial laundries, textile dyeing operations, various workshops, a hospital, the city’s main slaughterhouse, and miscellaneous dischargers such as petroleum and other oily waste from motor vehicle workshops. Furthermore, since the canal is topographically situated at a low elevation, a large number of side canals drain into the Mid-canal with their heavy pollutant loads. In addition, large water volumes from Kandy Lake spill over to the Mid-canal, especially during the rainy season. Therefore, polluted water in the Mid-canal is a potentially health hazard not only to the people living nearby, but also to persons the communities downstream.

Previous studies reported on some of the socio-economic implications of water pollution in the Meda Ela catchment and found that the awareness on water...
pollution issues of the community that lived next to the Mid-canal was high, although “discharge of gray water as well as black water by people who live close to the canal was evident” [3]. However, to date, there has been no comprehensive socio-economic survey on the urban population living adjacent to the Mid-canal. The overall objectives of this study were to: 1) identify the socio-economic status of the community settled along the Mid-canal banks; 2) identify the current water quality status of the Mid-canal and possible impacts of the community on water quality; and 3) propose remedial measures concerning wastewater and solid waste disposal to improve environmental conditions in this area.

2. Materials and Methods

Figure 1 shows a map of the study area. Mid-canal begins from Kandy Lake (on the top right hand corner of Figure 1) and flows through the city with a 5 km stretch running parallel to the William Gopallawa road. The confluence with Mahaweli River is at Getembe (on the bottom left hand corner of Figure 1).

2.1. Socio-Environmental Survey

The target group for the socio-environmental survey were the residents living along the canal bank of the Mid-canal. Nearly 350 houses are located along the canal bank. A questionnaire survey was conducted in Oct of 2010 with the help of Mid-canal community organizations and postgraduates from University of Peradeniya, Sri Lanka, through interviews with the 67 households. In addition, 15 businesses, commercial and public establishments were surveyed to collect necessary data for the identification of major types of pollutants. The open area of Mid-canal was divided into 5 segments according to topography and population density. Three focused group discussions and key information interviews were conducted to collect socio-economic information. The data were analyzed using MS Excel and SPSS statistical programmes.

2.2. Maintaining the Integrity of the Specifications

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A water quality assessment was carried out at 11 locations along the Mid-canal to analyse 16 physical, chemical and biological parameters for both the wet and dry seasons. Additionally, the 11 selected locations included five wastewater point sources—Kandy hospital, Peradeniya hospital, Kandy new courts complex, Kandy sudhuumpola slaughter house, and Kandy hospital private laundry. These were considered to encompass the significant point sources in this region. Sampling was conducted at approximately equal distances along the length of the canal. Table 1 shows 11 sampling locations along the Mid-canal.

Effluent samples were collected on the same day and at the same time, and were refrigerated (4°C) and transported to the laboratory. Temperature, pH, dissolved oxygen (DO) and electrical conductivity (EC) were measured using a Multi-Parameter Digital Meter (HACH-HQ40d, USA) on site. Turbidity was measured using an ESD-800 Digital Nephelometric Turbidity Meter. Total suspended solids (TSS) were determined gravimetrically using Standard Methods [5]. In addition, the samples were immediately analyzed to determine the concentration of the parameters: COD, BOD5, ammonia-N (NH4-N), nitrate (NO3-N), and total phosphorus (TP). These conventional parameters were analyzed colorimetrically using a spectrophotometer (HACH-DR3800, USA) in accordance with standard methods [5]. Faecal coliform densities were determined by the membrane filtration technique [5] using a Millipore type HA 0.45 μm pore size membrane filter and enumerated on M-FC medium. This test was carried out within 24 hours of sampling.

3. Results and Discussion

3.1. Socio-Environmental Survey

The survey indicated that urban population along the Mid-canal has steadily increased over the past few years and has produced a rapid increase in the volumes of wastewater generated. The total population of Kandy District was 1,279,028 and the urbanisation rate is 2.5%
Table 1. Sampling locations along the Mid-canal.

| Location—Along Mid-canal | Point sources | Distance from the Mid-canal starting point (km) |
|--------------------------|---------------|-----------------------------------------------|
| 1 Outlet of the Kandy Lake |               | 0.00                                          |
| 2 Atupattiya (The point it reappears through a tunnel close to Mallika Studio) |               | 0.50                                          |
| 3 Goods shed (The point it goes underground close to Goods shed Bus stand) |               | 0.80                                          |
| 4* Hospital treatment Plant effluent—I | √ | 1.90                                          |
| 5* Wastewater from cloth washing tanks | √ | 1.95                                          |
| 6 Upstream to Suduhumpola Junction |               | 2.00                                          |
| 7* Slaughter house effluent |               | 2.20                                          |
| 8 Downstream to Heeressagala Junction |               | 3.25                                          |
| 9* Effluent of court complex | √ | 4.30                                          |
| 10* Hospital treatment plant effluent—I | √ | 5.25                                          |
| 11 End of Mid-canal |               | 5.30                                          |

per annum [3]. Our survey showed that Sinhalese and Muslims comprise about 48% and 45%, respectively, of the population along the Meda Ela. The majority of people are at a medium income level for Sri Lanka and the Gross Domestic Product (GDP) per capita was estimated to be approximately US $2400. The survey revealed that there is a direct relationship between income and the quantum of wastewater generated (i.e., increasing as income increases). The education level is relatively good and 94% of the respondents in the sample had taken for the Ordinary Level Examination. Results of a Spearman’s correlation analysis showed that there is a significant correlation (p < 0.01) between education and legal awareness of waste disposal into water bodies.

Figure 2 shows the sources of drinking water and the types of bathing & washing waters used along the Mid-canal. Approximately 87% of people have pipes connected for potable water to their houses. However, some of residents still use unprotected wells on the canal bank for domestic purpose. Average family size was five and average consumption of water per family was 995 L·day⁻¹. About 91% of the families surveyed used piped water for bathing and only 4% of the people use common bathing places. However, survey results also showed quite clearly that residents did not use water from the Mid-canal for their drinking, bathing or washing purposes.

The survey also revealed that either most households along the Mid-canal dispose of their sewerage directly into the Mid-canal or else there is no well-maintained effective wastewater disposal mechanism. Figure 3 shows wastewater and municipal solid waste disposal. According to the survey, the average amount of wastewater generated by a family was approximately 798 L·day⁻¹. Approximately 64% of generated wastewater is discharged directly into the Mid-canal, and a secondary method of wastewater disposal is soakage pits (29% of generated wastewater) that are used to infiltrate septic tank effluent into the surrounding soil and enable surrounding soil to treat the effluent before entering the ground water table or water body. Wastewater from sources such as open drainage channels, pipe lines, and covered drains were also discharged to the Mid-canal. The survey also indicated that a majority (91%) of the households surveyed had toilet facilities and 9% used common toilets. The Japanese International Cooperation Agency (JICA) estimated that approximately 1000 m³·day⁻¹ of sewerage or blackwater flows into Meda Ela [6].

With respect to municipal solid waste disposal, nearly 100 tonnes·day⁻¹ of solid waste is generated within Kandy city [7] and average household solid waste generation was 1.5 kg·day⁻¹ [3]. The previous study also concluded that waste generation pattern could be related to the income levels and consumption patterns of the people [3]. Our survey indicated that 71% of the Mid-canal community disposed of their waste in municipal waste bins or collecting carts, but 29% of them disposed of their waste into the Mid-canal (Figure 3). The survey also revealed that even some people who reside outside the Meda Ela catchment also dispose of solid waste into the canal. In contrast, the residents who live near the canal oppose dumping the solid waste into the canal since these wastes block the water course and create problems for them.

3.2. Water Quality Assessment along the Mid-Canal

Overall, results of the water quality assessment showed an obvious increase in the water quality deterioration towards the end of the Mid-canal (Tables 2-5). The water quality analysis indicated the pollution level during the wet season was high. The increased levels of several parameters (e.g., colour, turbidity, BOD₅, COD, NH₄⁺-
Figure 2. Drinking water sources and distribution of bathing and washing water.

![Drinking water sources and distribution of bathing and washing water](image)

Figure 3. Wastewater and municipal solid waste disposal.

![Wastewater and municipal solid waste disposal](image)

Table 2. Water quality variation along the canal (physical parameter).

| Location | 1   | 2    | 3    | 4   | 5    | 6   | 7    | 8    | 9    | 10   | 11   |
|----------|-----|------|------|-----|------|-----|------|------|------|------|------|
| EC (µS·cm⁻¹) | Wet | 240  | 328  | 316 | 572  | 350 | 325  | 200  | 234  | 380  | 367  |
|          | Dry | 276  | 378  | 370 | 691  | 604 | 429  | -    | 330  | 579  | 320  | 317  |
| Colour (PtCo) | Wet | 22   | 76   | 68  | 230  | 1620| 108  | 858  | 207  | 87   | 339  | 135  |
|          | Dry | 75   | 69   | 95  | 375  | 1655| 85   | -    | 41   | 40   | 42   | 92   |
| Turbidity (NTU) | Wet | 4.3  | 10.1 | 12.7| 16.2 | 97.6| 16.5 | 892  | 37.5 | 4.3  | 40.2 | 55   |
|          | Dry | 3.8  | 5.1  | 1.4 | 14.3 | 84.5| 4    | -    | 0.5  | 2.4  | 2.1  | 3.3  |
| TSS (mg·L⁻¹) | Wet | 48   | 108  | 40  | 36   | 122 | 91   | 3073 | 122  | 91   | 584  | 273  |
|          | Dry | 94   | 106  | 123 | 198  | 532 | 148  | -    | 49   | 27   | 32   | 145  |

Table 3. Water quality variation along the canal (organic matter).

| Location | 1   | 2    | 3    | 4   | 5    | 6   | 7    | 8    | 9    | 10   | 11   |
|----------|-----|------|------|-----|------|-----|------|------|------|------|------|
| DO (mg·L⁻¹) | Wet | 5.14 | 4.24 | 3.47| 1.18 | 3.80| 3.50 | 3.43 | 3.68 | 4.49 | 5.05 | 2.00 |
|          | Dry | 5.34 | 3.67 | 3.89| 2.29 | 3.81| 1.37 | -    | 4.24 | 3.97 | 2.7  | 3.15 |
| BOD₅ (mg·L⁻¹) | Wet | 4.83 | 15.5 | 3.96| 62   | 430 | 8.7  | 2646 | 37   | 4.26 | 407  | 111  |
|          | Dry | 1.5  | 27   | 44  | 70.5 | 520 | 29   | -    | 23   | 27   | 88   | 44   |
| COD (mg·L⁻¹) | Wet | 5    | 17   | 4   | 88   | 600 | 10   | 2766 | 46   | 8    | 610  | 153  |
|          | Dry | 19   | 32   | 52  | 81   | 741 | 32   | -    | 28   | 68   | 104  | 56   |

Table 4. Water quality variation along the canal (coliforms: count 100 mL⁻¹).

| Location | 1   | 2    | 3    | 4   | 5    | 6   | 7    | 8    | 9    | 10   | 11   |
|----------|-----|------|------|-----|------|-----|------|------|------|------|------|
| Total coliform | Wet | 144  | 300  | 300 | 6500 | 1000| 400  | 3600 | 300  | 40   | 300  | 500  |
|          | Dry | 200  | 400  | 300 | 4200 | 800 | 500  | -    | 500  | 200  | 5800 | 800  |
| Faecal coliform | Wet | 58   | 100  | 100 | 5400 | 200 | 200  | 2500 | 100  | 0    | 200  | 200  |
|          | Dry | 100  | 200  | 200 | 3400 | 200 | 300  | -    | 100  | 0    | 4700 | 400  |

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N and phosphorus) in downstream segments of the Mid-
canal indicated the likelihood of deteriorating water quality in wet weather (Figure 4).

In this study, the pH values varied in the range 6.6 -
7.2 and water temperature was around 25°C - 26°C dur-
ding the study period (not presented in the table). For
electrical conductivity (EC), the highest EC value (430
µS·cm−1) along the canal was at Suduhumpola junction
(Figure 4(a)) in the dry season. The EC would likely
have originated from the upstream Kandy Hospital be-
cause of the fabric effluents which comprise of high load
of sodium ion [8]. Table 2 shows the level of colour wet
up markedly in wet weather. One of the main reasons for
higher level of colour during rain could be that some
factories or cottage industries discharge their waste into
the Mid-canal during rainy days. As for turbidity (as well
as colour), both parameters increased at the downstream
end of the canal also during the wet season. All the sam-
ple points showed the turbidity above the standard during
the wet season (Figure 4(c)) and most of the sample
points exceed the Ambient Water Quality Standards for
Inland Waters in Sri Lanka: 50 NTU (Table 2).

Dissolved oxygen (DO) was low at the end of the ca-
nal, especially in the wet season (Figure 4(e)). Previous
studies had reported the DO concentration was 5.78 and
2.68 mg·L−1 at the lake-outlet and end of the canal, re-
spectively [9]. That study also reported DO values were
6.03 and 5.40 mg·L−1 at 50 m upstream and 50 m down-
stream of the confluence with the Mid-canal. In the pre-
sent study, DO levels were 3.15 mg·L−1 in dry season and
2.00 mg·L−1 in wet season just before the confluence of
the Mahaweli River.

BOD5 and COD concentrations increased towards the
end of the Mid-canal (Figures 4(f) and 4(g)) and the
change was larger at the last few hundred metres before the
confluence of the Mahaweli River. The BOD5 and
COD values were 111 and 153 mg·L−1 in the wet season
at the end of the canal (Table 3), which are 3 - 5 fold
higher than the effluent BOD5 discharge limit (30 mg·L−1)
in Sri Lanka. The main sources are the Kandy and Peran-
deniya hospitals, along with the toilet discharges from the
Mid-canal residences. Other substantial BOD5 and
COD sources are the slaughter house and hospital laun-
dry. An earlier water quality analysis programme had
been conducted in March 2001 under the Greater Kandy
Water Supply Augmentation Project showed BOD5 to be
from 0.7 to 7.6 mg·L−1 at 500 m downstream of the con-
fluence of the Mid-canal with the Mahaweli River [6]. A
subsequent study was conducted via the Kandy City
Wastewater Management Project [10] and a higher BOD5
ranging from 2.13 to 10.5 mg·L−1 was noted. Compared to
previous investigation, the concentration of BOD5 that
we measured of 111 mg·L−1 suggests a progressively de-
terorizing water quality along the Mid-canal since 2005.

In the present study, the faecal and total coliform levels
varied from 58 and 144 MPN per 100 mL to 400 and 800
MPN per 100 mL, respectively in dry and wet weather (Ta-
ble 4). The total coliform values near the hospital
discharge point were very high, at 5800 and 4200 per 100
ml for wet and dry weather respectively (Figures 4(l)
and 4(m)).

(NH4+ -N) concentrations were also relatively high in
the wet season (Figure 4(j)). No fish were observed in
the canal. NH4+ -N levels were extremely elevated at down-
stream site 11 showing levels of 16.9 mg·L−1 during dry
weather and 39.6 mg·L−1 during wet weather. Table 5
also presents nitrate (NO3−-N) concentrations in the Mid-
canal, which can be largely attributed to biogenic waste
such as human and animal excreta as well as subsequent
nitrification. Nitrification will occur at dissolved oxygen
levels as low as 0.3 mg·L−1 [11], and since it exerts an
oxygen demand and can potentially result in some of the
oxygen depletion that we observed.

Phosphorus is commonly the limiting factor in fresh-
water bodies in Sri Lanka [6]. The concentrations of total
phosphorus and dissolved phosphate were high espe-
cially towards the end of the canal (Table 5). This sug-
gested substantial contamination from human, animal
excreta and organic waste discharged not only into the
canal but also into Kandy Lake. Phytoplankton in Kandy

| Location | Wet | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|----------|-----|---|---|---|---|---|---|---|---|---|----|----|
| NO3−     |     |   |   |   |   |   |   |   |   |   |    |    |
| (mg·L−1) | Wet | 1.8| 1 | 1.4| 0.5|   | 0.7| 1.9| 3.6| 1.8| 4.3 | 43  |
|          | Dry | 2.5| 1.6| 0.7| 28.7| 1.6| 0.6| -  | 1.5| 2.8 | 17  | 14 |
| NH4+     |     |   |   |   |   |   |   |   |   |   |    |    |
| (mg·L−1) | Wet | 3.9| 2.6 | 4.7| 5.1| 2.3| 5.2| 7.1 | 5.4| 4.7 | 47.3| 39.6|
|          | Dry | 3.9| 2.8 | 6.4| 26 | 2.6| 5.9| -  | 8.7 | 3.1 | 19.4| 16.9|
| PO43−    |     |   |   |   |   |   |   |   |   |   |    |    |
| (mg·L−1) | Wet | 0.4| 0.3 | 0.7| 3.2| 0.6| 0.9| 4.1 | 1.7| 0.4 | 9   | 5.1 |
|          | Dry | 0.5| 0.2 | 0.5| 7.5 | 0.4| 2.1| -  | 1.9 | 0.4 | 7   | 3.4 |
| TP       |     |   |   |   |   |   |   |   |   |   |    |    |
| (mg·L−1) | Wet | 0.2| 0.1 | 0.3| 2.5 | 0.3| 0.4| 3.6 | 0.6 | 0.1 | 7.1 | 2.9 |
|          | Dry | 0.2| 0.1 | 0.2| 2.5 | 0.1| 0.6| -  | 0.6 | 0.1 | 4.9 | 1.1 |
Lake, an urban and manmade water body, was examined for two consecutive years to determine species abundance and composition, and the lake was categorized as eutrophic due to nutrient discharge [12].

Access to safe drinking water and sanitation is recognized as a human right [13] and provision of clean water and safe disposal of wastewater should remain a basic necessity for daily survival and for all economic activities. Access to adequate sanitation and sewerage systems in the Kandy urban area, as well as access to appropriate
on-site sanitation facilities for those not connected to a sewerage system, is a long-term strategy for the Kandy Municipal Council. In order to address this strategy, there is a need to develop wastewater treatment facilities for Kandy city and the Mid-canal catchment. JICA has funded the Kandy City Wastewater Management Project (KCWMP), which covers the Mid-canal catchment in their centralised wastewater treatment project and it shall be commissioned by 2016. This project is aimed at reducing the current adverse impact on the Mid-canal catchment due to wastewater discharges. The technological appropriateness, economic viability, social acceptance, political feasibility and the overall sustainability of the project shall be subject to scrutiny in the future.

There is no doubt that with the continuing urban sprawl along Mid-canal, the provision of adequate levels of drinking water and safe disposal of wastewater shall become increasingly complex and expensive. This then is an increasing challenge in coming years and implies that large financial investments will be required for the water sector in this area. As a matter of fact, centralized wastewater management is a very costly part of infrastructure and its elaborate systems of pipes, pumps and treatment plants, as well as its institutional and managerial requirements are unaffordable in many of developing countries [14]. Decentralized wastewater treatment is not a new technology and was in the past decades prevailing in rural areas worldwide. Nowadays the concept of decentralized wastewater management is far beyond traditional thinking and solution. It focuses not only on community-based wastewater collection, treatment, disposal, but also on rainwater harvesting, groundwater protection and surface water conservation. Raw material flow, energy generation and resource management can also be integrated into new decentralized water approach. Decentralized technological alternatives like (a combination of appropriately constructed) individual septic tanks integrated with constructed wetlands at the mini/micro watershed level and managed by community-based institutions [15] may be a viable alternative in the Kandy city area.

4. Conclusions

Urban water bodies are susceptible to high anthropogenic pressures and water quality conditions attributes are influenced by hygienic and economic conditions of the riparian communities. Management of these water bodies have been largely neglected in developing countries due possibly to inadequate environmental awareness and financial constrains. Mid-canal is a typical example of such a water body. Flowing through a densely populated area in the second largest city in Sri Lanka, it receives a variety of untreated effluents from point and non point sources. Urban water bodies like the Mid-canal have lost their aesthetic value and have instead gradually become seen by the community as a nuisance and health hazard.

This water quality analysis along Mid-canal indicated the pollution level in the wet season was high. Dissolved oxygen was low at the end of the canal and especially so in wet season. Total suspended solids values had exceeded the discharge limits at all locations along the canal. The concentration of BOD5 and COD increased towards the end of the Mid-canal, and the highest BOD5 values were much higher than the effluent BOD5 discharge limit in Sri Lanka. Ammonia concentrations were above the inhibitory limit for fish and no fish were observed in the canal. Total phosphorus and phosphate concentrations were high towards the end of the canal. The results highlighted the need to generate awareness on protecting the environment and developing proper practices of wastewater and solid waste disposal to reduce nutrient levels in the canal water. Promoting waste reduction, reuse, recycling and final disposal in an environmentally sound manner are recommended from this study. Decentralized technological alternatives may be a vital, sustainable and cost-effective alternative. In addition to wastewater treatment and sanitation, systematic approaches and integrated remedial measures within the urban development sector have to be taken to develop a sustainable socio-environmental improvement plan to mitigate pollution in the Mid-canal of Sri Lanka.

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