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The need for proper management leading to the sustainability of the Kelani River and its lower basin

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Abstract

The Kelani River is the second largest watershed in Sri Lanka and the main water-supply intake point for the Greater Colombo. The present study focuses to identify the sources of pollutants of the meandering zone of the Kelani River, particularly due to the absence of more recent information. Accordingly, a survey was conducted to obtain information on industrial discharges, anthropological, and social activities within the area of 15 m from left and right banks of the river. The high contaminations (total and faecal coliform – 1100 MPN·(100 cm^3)$^{-1}$; COD – 10 mg·dm^{-3}; BOD – 4 mg·dm^{-3}) of surface and groundwater are corroborated with the results obtained via the demographic and land usage statistics. Industrial pollutant sources and harmful anthropological practices were identified as major threats to the river basin. In this survey, agriculture and land degradation were identified as issues due to improper land use management. As policy recommendations based on the results of the study, it was identified that the awareness for Kelani River protection should be increased; monitoring and evaluation of the Kelani River basin under a management plan should be implemented; and stakeholder and private partnerships contribution to the sustainability of the Kelani River basin should be established.

Key words: *the Kelani River basin, lower river basin, pollution sources, proper management, strategic plan, sustainability*

INTRODUCTION

Population growth, industrial setting, and higher living standards will cause ever increasing demands for good quality municipal, irrigation, and industrial water, and ever-increasing sewage flows. Also, more and more water will be required for environmental concerns such as aquatic life, wildlife refuges, recreation, scenic values, and riparian habitats. This will require intensive management and sustainability of surface and groundwater as depletion and contamination, especially from non-point sources and point sources have occurred [BOUWER 2000]. Over the past five decades, the prevention of waste disposal into natural aquatic ecosystems has been a real research issue in the environmental sciences. Indeed, the continual discharge of chemical substances in aquatic ecosystems can bring about changes in the structure and functioning of the biotic community, i.e. on biotic integrity [KARR 1991]. The physico-chemical aggressions undergone by surface water and groundwater due to contact with pollutants contained

in liquid discharges lead, among other things, to a profound deterioration in the quality of the resource and constitute in itself a real health hazard for consumers. The need to set up a monitoring system for the quality of surface water and groundwater is becoming a real object of research with a view to achieve integrated management of resources and maintain the sustainability of water points and their watershed.

The Kelani River is one of the main rivers in Sri Lanka and it is starting from Nallathanniya (about 2200 m above mean sea level) which locates in the central highlands in the country and flows via Kithulgala, Avissawella through flood plains ending with the Colombo at Mattakkuliya into the Indian Ocean. However, since the river flows through the urban centers, farmlands, and industrial zones, it is more vulnerable to water pollution [MAHAGAMAGE *et al.* 2016a; MAHAGAMAGE, MANAGE 2014; 2015].

The Kelani River basin is home for more than 20% of the Sri Lankan population and among them, 60% rural, 32% urban, and 8% are estate communities, and the river provides around 80% of water required to greater Colombo as well [MAHAGAMAGE, MANAGE 2018]. The urban population in the Kelani River basin is the highest among the other river basins considered [DHI 1999]. Further, the Kelani River basin supports socio-economic activities such as agriculture, hydropower generation, sand mining, and gem mining, urban development, industrial development, tourism and power generation, recreational, fisheries, transportation, etc. [MAHAGAMAGE, MANAGE 2014]. Therefore, the Kelani River is known for its increasing pollution as a result of industrial discharges, poor local authority service delivery, weak environment management, and governance [AREWGODA 1986; CEA 2015; ILLEPERUMA 2000] coupled with inadequate awareness and education [MALLAWATANTRI *et al*. 2016].

In the lower part of the Kelani River basin (hereafter referred as the meandering zone), the Biyagama export promotion zone and Seethawaka industrial zone the considerable number of major wastewater generating industries; raw rubber factories, rubber latex factories, textile industries, food and beverage industries, steel manufacturing factories, fertilizer manufacturing factories, and industries are located [DHI 1999; MAHAGAMAGE, MANAGE 2014; 2015].

However, it is noted that limited recent information is available on the catchment's characteristics, land-use practices and anthropological activities on quality of groundwater in the Kelani River basin and its meandering zone, despite some studies performed during past three decades [DISSANAYAKE, GUNATILAKA (eds.) 1985; MAHAGAMAGE, MANAGE 2014; MAHAGAMAGE *et al*. 2020]. Thus, the objectives of the present study are to ascertain the levels of water pollution of the meandering zone of the Kelani River and to identify the causes for such water pollution. The findings are expected to make significant policy implications on policymakers including related regulators in ensuring the sustainability of the meandering zone of the Kelani River and provision of water with adequate quality for consumption.

MATERIAL AND METHODS

STUDY SITE

The Kelani River basin is located in Sri Lanka between 6°47' to 7°05' N and 79°52' to 80°13' E with the basin area of 2230 km^2. The basin receives about 2400 mm of average annual rainfall and the river carries a peak flow of about 800–1500 m$^3 \cdot$s^{-1} during the monsoon periods [DE SILVA *et al*. 2012]. The Kelani River basin has been divided into three regions; the Head region: Nallathanniya to Thaligama, Transitional region: Thaligama to Hanwella, Meandering region: Hanwella to Mattakkuliya (Fig. 1). In the present study, sampling was carried out in the meandering zone from Awissawella to Mattakkuliya to fill the data gap.

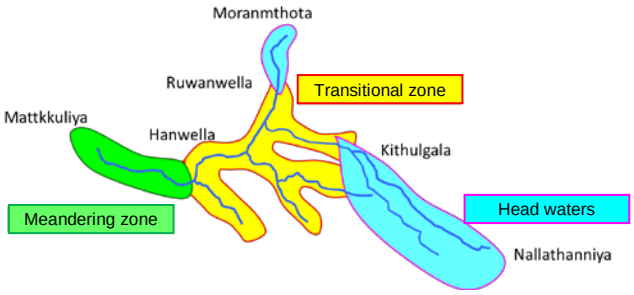

Fig. 1. Major zones of the Kelani River basin; source: own elaboration

POPULATION AND HOUSING

It is noted that the population and housing density increases towards the downstream direction of the Kelani River basin, except the plantation areas in the upper reaches where the working population resides (Fig. 2). Along with high population density, the provisions of service deliveries including waste and sewerage management are significant.

Table 1 depicts the population density of Colombo and Gampaha districts from 2012 to 2016. It is observed that there is a gradual increase of population in the two districts which enhance the increase tendency of housing units of the meandering zone of the Kelani River basin. Figure 2 illustrates the distribution pattern of housing units of the catchment of the Kelani River basin and it was clear that the density of housing units was concentrated towards to the meandering zone of the Kelani River basin.

LAND USE

Two-thirds of the Colombo and Gampaha districts belong to the meandering zone of the Kelani River basin. Therefore, agricultural and land-use practices of the stakeholders of each district directly impact on the surface and groundwater quality of the Kelani River basin. The land-use patterns on agricultural activities of the meandering zone of the Kelani River basin are illustrated in Figure 3.

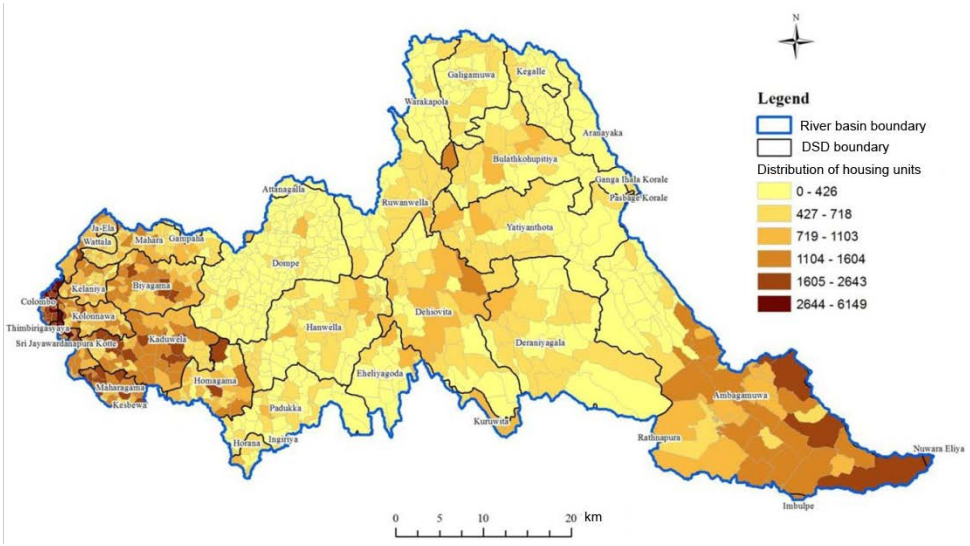

Fig. 2. Distribution housing units within the Kelani River basin; source: MALLAWATANTRI *et al.* [2016]

Table 1. Population in Gampaha and Colombo districts from 2012 to 2016

District	Population in year									
	2012		2013		2014		2015		2016	
	thous.	%	thous.	%	thous.	%	thous.	%	thous.	%
Colombo	2,330	11.4	2,339	11.3	2,357	11.3	2,375	11.3	2,395	11.2
Gampaha	2,310	11.3	2,324	11.2	2,338	11.2	2,354	11.2	2,372	11.1

Source: Department of Census and Statistics [2017].

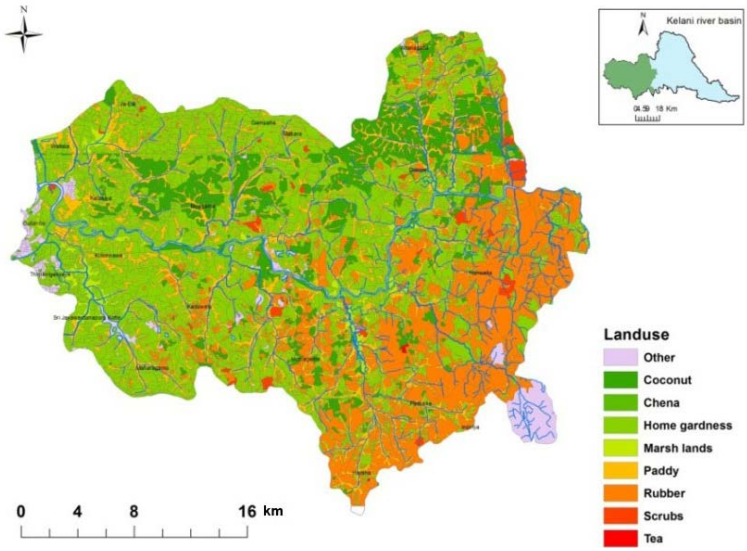

Fig. 3. Land use practice in the meandering zone of the Kelani River basin;
source: own elaboration based on data of Sri Lanka Survey Department [undated]

DATA COLLECTION

A questionnaire was prepared to obtain information on population, land-use practices, industries, garbage dumping sites, buildings, farms, direction of toilets to waterways, drinking water sources, tributaries, sand mining, and gem mining places, natural vegetation, etc., which were located 15 m from left and right banks of the river. The Google Earth and Arc GIS 10.0 software were used to prepare site maps for the 15 m zone from the Kelani riverbanks. It also should be noted that in some circumstances, information was gathered even up to 60 m depending on riverbank characteristics. Field surveys on both left and right bank of the river basin were conducted from 20th April to 25th June 2017. Additional information such as new constructions, houses, and land-use practices, etc. was added to the data sheet while conducting the survey. Collected information and marked site map sheets were cross-checked with relevant Google Map sheets. Then the information on confirmed site maps to a MS Excel sheet to filter the required data.

RESULTS AND DISCUSSION

LAND USE MANAGEMENT FOR SOURCE WATER PROTECTION

More than 55% of land areas covered under the Kelani River basin is adversely influenced by present land-use practices. Furthermore, the present study revealed that 34% of location sites recorded coconut cultivations and around 3% sites marked as rubber cultivations, especially in the Dompe DS Division within 15 m margin in the right bank of the river basin. It was noted that 13% of sites recorded as coconut trees and 3.4% for rubber cultivation in the left bank of the river. Several issues were noted in terms of watershed management with agricultural activities in the lower part of the river basin. Land fragmentation, soil degradation, and water pollution due to extra use of fertilizers and agro-chemicals are major issues with the agricultural lands in the basin. Further, these lands contributed to the large volume of water flow with a load of silt and sand in waterways even after a short period of rain. 11.5% sites in the left bank and 28% sites in the right bank had bamboo trees particularly in Kaduwela, Seethawaka, Kolonnawa, Homagama in the left bank, and Kelaniya, Biyagama and Dompe in the right bank of the river basin. It was observed that bamboo trees on the riverbanks reduced the riverbank erosion and increased the aesthetic value of the river.

During the survey, a considerable amount of baseline data such as updated land use, sub-basin characteristics, climate information, industrial categories, and infrastructure, and pollution information was gathered within 15 m of the riverbanks.

INDUSTRIAL POLLUTION AND OTHER ACTIVITIES

Industrial waste discharges, storm water, and sewerage related pollution were identified as major issues due to industrial pollution during the survey. Industry types and distribution in the Kelani River sub-basins are given in Table 2. Accordingly, the total number of 2,842 industries were located in the river basin. Out of 2,842 industries, 862 industries have been categorized as 'A' type where 1,220 and 760 are belonging to category 'B' and 'C', respectively. Around 75% of industries contribute directly or indirectly to the Kelani River basin pollution MANAGE and WIJESINGHE [2009]. During the survey, industrial pollution-related information, river pollution levels at different scales including tributaries, main river, surface water, and groundwater sources in the river basin, municipal solid and liquid waste and sewerage related information, and the technology adapted were collected by visiting the sites and filling the questionnaire survey. These collected data revealed that 14% of site locations recorded industries in the left bank and 6.5% sites examined recorded in the right bank, both within 15 m margin. 34% of industries among the above indicated that they release their effluent water directly to the river and the highest number was recorded in the left bank of the river basin. MAHAGAMAGE and MANAGE [2015] documented that there is an increasing tendency of some chemical compounds in the water towards the downstream of the Kelani River basin. Hence, a CCME indexed based assessment was performed by MAHAGAMAGE and MANAGE [2014] and the results indicated that the water in the lower part of the Kelani River basin is not good for drinking and recreational activities without some treatment.

Table 2. Industry types and distribution in sub-basins

Kelani River sub-basins	A	B	C	Total	%
Ambalanpiti Oya/Gonmala Oya	6	9	9	24	0.8
Biyagama	14	58	1	73	2.6
Getahetta Oya	10	14	31	55	1.9
Gurugoda Oya	34	62	1 18	214	7.5
Kolonnawa Ela	180	296	47	523	18.4
Lower Kelani Ganga	190	183	66	439	15.4
Lower Middle Kelani Ganga	50	43	30	123	4.3
Magal Ganga	0	0	2	2	0.1
Maha Oya/Seethawaka Ganga	18	34	50	102	3.6
Pallewela Oya/ Maha Ela	161	230	67	458	16.1
Panapura Oya	0	0	3	3	0.1
Pugoda Oya	7	7	5	19	0.7
Pusseli Oya	148	173	184	505	17.8
Ritigaha Oya	5	27	24	56	2
Upper Kelani Ganga	2	8	21	31	1.1
Upper Middle Kelani Ganga	28	61	78 9	167	5.9
Wak Oya/Kalatuwawa	7	4	12	23	0.8
Walihel Oya	2	11	12	25	0.9
Total	**862**	**1,220**	**760**	**2,842**	**100**
%	**30.3**	**42.9**	**26.7**	**100.0**	

Explanations: A = significantly high polluting industrial activities, B = medium level polluting activities, C = low polluting industrial activities
Source: MALLAWATANTRI *et al.* [2016].

Further, it was noted that riverbank characteristics have been worsened by adverse human activities due to urbanization in the lower part of the basin. Invading natural wetlands including marshy lands and mangroves and removal of riverine vegetation in the most vulnerable lower riverbanks were observed in this study. Occupying the riverine land for human habitats and industries are reducing the water retention capacity and increase the susceptible to seasonal flooding of both sides of riverbanks.

WATER AND SANITATION FACILITIES

MAHAGAMAGE and MANAGE [2015] documented that spatial distribution showed the meandering region of the Kelani River basin is contaminated with total and faecal coliform bacteria. Where the lower part of the meandering zone of the river basin showed high values (MPN value > 1100) of total and faecal coliform contamination, and it indicates that the microbial contamination of water is due to poor sanitary conditions in the vicinity of the area.

Further, the findings of the present study revealed that most of the inhabitants in the 15 m area in the later part of the meandering region had pit latrines instead of septic tanks and most of them were directed to the riverside. Around five percent of people had no toilet facilities and they used the river for their defecation purposes. MANAGE *et al.* [2017] and MAHAGAMAGE *et al.* [2016b] documented

that the Kelani River basin is in a risk of contamination of pathogenic bacteria in drinking and recreational water sources. Thus, above-mentioned issues could be considered as the reason for the pathogenic contamination in drinking water bodies within the basin. Therefore, these observations indicate that water and sanitation facilities that are highly important for human life are in danger.

CONCLUSIONS

In this survey, agriculture and land degradation related pollution including sedimentation, fertilizer and pesticide applications, illegal sand and gem mining, encroachments of lands and unplanned development, deforestation and forest degradation, inappropriate land-use practices were identified as issues due to improper land use management. Further, direct discharging of sewage and household garbage to the river, as well as some toilet pits being directly opened to the river by some residents were noted.

In terms of the impact of industries, it was identified that industrial waste discharges, storm water, and sewerage related pollution are major issues related to industrial pollution. Although some industries should not have been located within the prescribed distance from the tributaries, the main river, surface water and, groundwater sources in the river basin, in the survey breaches to this regulation were noted contributing to direct or indirect pollution of the river basin.

Thus, the high population, inadvertent human living practices on garbage and sewage disposal, agriculture and land degradation related pollution including sedimentation, fertilizer and pesticide applications, inadvertent industrial practices, encroachments of lands and unplanned development, deforestation and forest degradation, inappropriate land-use practices surrounding the meandering zone of Kalani River is noted to be directly contributing to the high levels of both ground and surface water.

Accordingly, to protect and ensure the sustainability of the meandering zone of the Kelani River, an integrated strategic development and restructuring plan should be formulated and implemented. In this integrated plan, it is proposed to review the current status of each industry including the locations and details of the treatment process available to facilitate the industrial environmental management, as well as address the issues pertaining to the high population, residents, and their activities. Also, this plan should address the advancement of the capacities of operational personnel, in-house testing facilities, record-keeping, and continuous monitoring of water quality should be implemented. Accordingly, within this integrative plan, the following policy recommendations could be suggested.

Awareness for the Kelani River protection**.** Published data and other media information revealed that over 55% stakeholders are aware of the scientific aspects of management and conservation of the Kelani River basin. Thus, to generate, share and usage of scientific knowledge and best management practices to support the Kelani River conservation should be included in a future strategic plan.

Monitoring and evaluation of the Kelani River basin for management plan. Lack of a multi-sector integrated approach for sustainable river basin management and pollution control, deteriorating land, deteriorating river water quality, deteriorating ecosystem values posing threats to humans and environment, minimal monitoring and evaluation capacity, lack of initiatives that link development initiatives in the basin with resilience, were identified as major issues. Accordingly, it is suggested to monitor continuously the quality of water of the Kelani River.

Stakeholder and private partnerships contribution to the sustainability of the Kelani River basin. Baseline data on water quality information at sub-watershed levels, health and pollution relationships; investments by private sector within the Kelani River basin was limited and required a significant database to analyse stakeholder and private partnership contribution to the sustainability of Kelani River basin. Thus, deployment of sustainability concepts and partnerships with active participation by private sector is needed to sustainable management of Kelani River basin.

A comprehensive, integrative and strategic action plan was noted to be a very urgent contemporary requirement in order to ensure the protection and sustainability of the Kelani River and avoid any dire consequences.

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