Drainage System and Settlement Pattern in the Yamuna-Hindon Doab: An Archaeological Perspective

Dr. Rewant Vikram Singh
Department of History,
Maharshi Dayanand College of Arts, Science, & Commerce,
Parel, Mumbai-12, Maharashtra, India
rewant@gmail.com

Abstract

The Yamuna-Hindon doab is a part of the greater Ganga-Yamuna doab, which provides vital geo-ecological settings for human settlements right from the prehistoric period. It has revealed several hundred sites associated with Pre-historic, Proto-historic, Painted Grey Ware (PGW), Northern Black Polished Ware (NBPW), early historic, Gupta, Post-Gupta and Medieval cultures. In the present work, a study of the drainage system of the Yamuna-Hindon Doab has been taken up in an attempt to study the settlement archaeology of the region.

Keywords: *Archaeology, Doab, Ecology, Ganga, Geology, Hindon, History, Settlement, Yamuna*

Introduction:

Generally, in ancient times, in their struggle for existence, within any region, people settled down in places that were close to sources of water and food, and as far as possible, that are safe and pleasant. However, there are exceptions to such generalizations. Makkhan Lal (1984 : 165) points towards Bylund's study in Central Lappland in North Sweden, to show that good land close to the established settlements and suitable for colonization may remain unsettled while other localities in remote districts and with inferior soils and poor resources may be colonized. Ancient Indian literature also does recognises the significance of rivers for humans. *Markandeya Purana* (LVII, 30) says, "All the rivers are sacred, all flow towards, the sea. All are like mothers to the world, all purge sins." It is not surprising that along the banks of the rivers and in close proximity to them we find the traces of ancient settlements, prosperous towns and fertile villages, religious shrines and peaceful hermitage. These rivers also constituted highways of trade and commerce.

The Yamuna-Hindon doab is a part of the larger Ganga-Yamuna

doab, and the region and its neighbourhood has revealed more than 500 sites associated with Pre-historic, Proto-historic, Painted Grey Ware (PGW), Northern Black Polished Ware (NBPW), early historic, Gupta, Post-Gupta and Medieval cultures. To understand the settlement history of the region, the author undertook a field survey of the Yamuna-Hindon doab in December, 2014 and May, 2015. In the present research paper, based on the findings of the field survey and study of primary and secondary sources, an investigation of the potential of the river bodies of the Yamuna-Hindon Doab to support human settlements has been taken up in an attempt to study the settlement history of the region.

The Yamuna-Hindon Doab:

The doab between the Yamuna river and the Hindon river is spread over an area of about 6,500 sq. km. It includes the districts of Saharanpur, Muzaffarnagar, Baghpat, Ghaziabad, east Delhi and Faridabad. To the west of the doab lie, Punjab, Haryana, and Delhi. Haryana is on the south-west of the doab. Saharanpur is on its north-west. To the east of the doab lie Muzaffamagar and Meerut. Bulandshahar is on the south-east of the doab. B.C. Law (1967 : 13) has pointed out that according to Kavyamimamsa the land between the confluence of the Yamuna and the Ganges (including the Yamuna-Hindon doab) was called Antarvedi. Further he (1967 : 13) points out that Taittiriya Aranyaka (II.20) states that those who dwelt between the Ganga and the Yamuna were privileged.

Geology

The Yamuna-Hindon doab is a part of the larger north Indian plain, which was a deep basin in Pre-Tertiary times that has been filled by the Tertiary rive-borne debris from the peninsular. The Upper and Post-Tertiary Himalayan debris known as alluvium later supplemented it. The deposition of alluvium started taking place during the last phase of the Siwalik formation and has continued all through the Pleistocene up to the present. The alluvial deposit is of two types: Bangar (older alluvium) and Khadar (younger alluvium). The bangar occupying the area above the existing flood plains (representing the present borders of the rivers) belongs to the Middle Pleistocene. Kankar (calcium carbonate nodules) are found in bangar land. The khadar occupies the flood plains. Its source lies partly in the fresh alluvium brought by the rivers and partly in the erosion of the bangar land. It is free from kankar and reh (alkaline soil).

Physical Features

The Yamuna-Hindon doab is a gently inclined alluvial plain dipping towards southeast. It is challenging to demarcate regional divisions in this featureless plain. The only reliefs seen are arms of river channels and existing rivers. The relief of the Yamuna- Hindon doab exhibits Bangar land rising upto 15-60 m above the adjoining floodplains, the Khadar. Bangar areas are beyond the floodplains and lie more upland, and compared to Khadar it consists of older alluvial soil which is higher in sandy loam content. Bangar areas are less prone to flooding but are usually more sandy and less fertile as well.

The Drainage System

The Yamuna, the Hindon and a number of their tributaries - the Katha Nala, the Krishni and the Kali Nadi, drain the Yamuna-Hindon doab. The archaeological significance of these streams and their catchment areas cannot be ignored, as a large number of sites, representing cultures from protohistoric to Medieval period have been located here. In the past, these streams were the main water sources for the settlements in the areas.

Yamuna

The Yamuna rises in the Himalayas; all other rivers and streams rise in the plains. The general direction of the drainage is from north to south, and the slope is very gradual throughout. The average gradient is less than 2 feet to a mile. This restricts the erosional capacity of the rivers and the streams.

On the western part of the doab, the Yamuna, one of the perennial watercourses of north India, forms the chief drainage channel. It rises from the slopes of the Himalayas below the mount Kamet. From Saharanpur down to Faridabad, it flows southwards parallel to the Hindon until it meets the Hindon at south of Surajpur village in Haryana. Its total length is 1,357 km. The total catchment area of the Yamuna is 3,71,870 km.

The Yamuna forms the Yamuna-Hindon doab starting from the west of Jatlana, Thaneshwar, Haryana. The areas that lie in the doab region include Nakur, Saharanpur, western Deoband, Kairana, Muzaffarnagar, Budhana, Baghpat, western Sardhana, and Ghaziabad. Out of these, Nakur, Kairana. Budhana, Baghpat, and Ghaziabad lie on the left bank of the Yamuna, while the Hindon transverses through the Saharanpur city, Deoband, Muzaffarnagar, Sardhana, Baghpat, and Ghaziabad.

The *Gazetteer of Meerut* (1922 :4-6) indicates that the bed of the Yamuna river in the study area lies so low that irrigation from it is impracticable, and its water is only used for melons, which grow on its sandy banks. Generally, the bank is much higher in the north than in the south, and in the study area steep and abrupt cliffs are frequently seen. In May, the melting of the snow within the drainage area of the Yamuna in the Himalayas causes considerable rise in the river; the stream is then very deep and strong, but it does little damage in the northern doab (upto Baghpat), where the small area of lowland on its banks is actually benefited by the alluvial deposits brought down by the stream. Towards the end of the cold weather, owing to the amount of water that is drained out by the canals, the Yamuna is fordable and there is generally only a couple of feet of water in the bed. However, further south, the absence of high bank causes frequent overflow and saturate a great portion of Pargana Loni, although the river is kept in place to a large extent by the training works of the Agra canal.

The Katha Nala

Katha Nala is an important tributary of the Yamuna-Hindon doab. It rises in Sangathera, Nakur, and after traversing through Nakur, it reaches Kairana. It meets the Yamuna at west of the city of Kairana. The Katha Nala follows a southwesterly course. The total length of the river is approximately 54 km

Yamuna Khadir

The *Gazetteer of Meerut* (1922 : 5) informs that the Yamuna Khadir is much wider in the south than in the north. The ridge that forms the high bank of the river disappears in the south of Baghpat. or rather bend inward towards the Hindon. Here the uplands terminate in a sandy fringe of ravines and undulating soil, a stretch of useless land in which nothing will grow except an inferior kind of thatching grass. Further south of Loni, the khadir sinks into a lowlying tract which contains a number of depressions which are nearly always covered with water to a depth of two or three feet. The southern Yamuna khadir can be divided into two, upper and lower khadir. The upper khadir is a khadir without water; a khadir that is safe from flooding now by reason of the numerous works that cross and enclose it - the Eastern Yamuna canal; the East Indian Railway, which rubs embankment the whole way from the Hindon to the Yamuna bridge; the Hindon cut, which carries the water of the Hindon across to the Yamuna to

feed the Agra canal; and the Okhla bund, which runs from the Yamuna railway bridge along the bank of the river: but a tract characterized by peculiarly infertile sandy soil, called by the people *dabkans-ki-zamin* and altogether of very inferior quality. The lower khadir is khadir proper, subject to floods, but resembling often in soils the upper khadir.

Hindon

The Hindon river forms the eastern border of the doab. It rises from the plains around north of Haraura in the Saharanpur district, closer to Dehradun. The Hindon runs southwards parallel to the Yamuna before emptying itself in the Yamuna, south of Surajpur village in Haryana. Its tributaries include the Kali Nadi on its east, and the Krishni (or Kirsani) Nadi on its west. The total length of the Hindon river is about 260 km. The river is very winding, has no defined banks and covers large areas. The land on its both sides is subject to flooding during monsoons. The river is only navigable in the rains. The land inundated by the river is occasionally cultivated for the *rabi* crops, and the harvests are of excellent quality. However, in times of heavy flood the khadir lands are liable to become saturated and affected by the saline efflorescence known as *reh.* The *Gazetteer of Meerut* (1922 :8) states, "of recent years there has in fact been a considerable development of *reh* in the Hindon khadir and large areas of land have not been ploughed for twenty years and more." The water from the river is used to irrigate the *rabi* crops and melons. The land east of the Hindon is "extraordinarily rich and uniform, fully irrigated and splendidly cultivated." Similar to the Yamuna river, the Hindon river also runs in a southeasterly direction in consonance with general slope of the region. Due to a gentle gradient, the erosion capacity of these rivers is restricted.

Kirsani or Krishni River

Between the Yamuna and the Hindon, the Kirsani River rises in the plains of south of Chilkana, the Saharanpur district. After traversing through Saharanpur, Deoband, Kairana, Budhana, it joins the Hindon just below the town of Barnawa at Sardhana. It follows a southwesterly course and takes a sudden turn towards east to join the Hindon. Its approximate length is 121 km. It is an unimportant stream, having no towns on its banks and being little used for the purpose of irrigation. It flows in a well-marked bed, the banks of which on both sides are broken by numerous ravines, and the land in its neighbourhood is of a sandy inferior quality.

Kali Nadi

The Kali Nadi rises in the plains of southwest of Badhai, Muzaffarnagar. After traversing through Muzaffamagar, it forms a natural boundary between Budhana on the west and Jansath on the east. It joins the Hindon from the east at Pitlokkhar village of Sardhana. Its approximate length is 110 km.

Hindon Khadir

The khadir of the Hindon varies in width: at Malahra it extends for a mile on each side of the stream, while at Bamawa it is little more than one-fourth of a mile in breadth. Further south, it widens out on the west to join the Yamuna khadir in the south of Baghpat, and then the khadirs of the two rivers unite to form the sandy tract already described. As the *Gazetteer of Meerut* (1922 : 8) informs, the land east of the Hindon is "extraordinarily rich and uniform, fully irrigated and splendidly cultivated."

Meanderings of the Yamuna

Caused by tectonic forces, the meanderings of the Yamuna through millenniums have left their deep imprint on the physiography of the plains in the region. The work of A.K. Grover and P.L. Bakliwal titled, *"River Migration and Floods -A Study of a Section of Yamuna River through Remote Sensing" (Man and Environment,* volume 9, 1985 :151-3) suggests that the Yamuna once flowed into the Saraswati (identified with the modem Ghaggar-Hakra). Over a period of time, the Yamuna moved more and more towards the easterly course. Consequently, it abandoned the Saraswati and joined the Ganga. The remains of at least six palaeochannels of the Yamuna have been identified through the study of Landsat imagery. Traces of old courses of the river can be seen in various lakes such as the Najafgarh, Surajkund and Badkhal lakes. The remote sensing studies show that the migration of the river ranged from 100 km in the area north and west of Delhi to 40 km in the area south of Delhi. However, the Yamuna seems to have remained more or less static in its present course around Delhi in a span of 4000 years. In this process of meandering towards the east, the Yamuna deposited rich deposits of alluvium on either bank. With an average height of about 700 ft. above the sea level, the plains are considerably wider, more fertile and populous in the north and almost lose themselves in the regions of the historic capitals of Siri and Tughluqabad. Further south, the terrain becomes flatter and more open. The soil in this

region is light sandy loam and is good for agriculture. The meanderings of the Yamuna, and deposition of alluvium in the process over a larger part of the plains had very significant bearings on the history of ancient settlements in the region. Many stone age sites have been found in the hilly areas that were once traversed by the Yamuna. Also, several ancient sites grew up along the older courses of the river. It is in this background, one needs to study the large number of ancient sites have been identified in the Yamuna-Hindon doab and its neighbourhood.

Agriculture

In the context of agro-climatic conditions, rains are a very lean source of supply as these are scanty and erratic in occurrence. Both the total rainfall and the total number of rainy days in a year show much variation. The major sources of irrigation in the doab are the Yamuna and the Hindon itself together with their streams. Wells are also important sources of irrigation. According to the *Delhi Gazetteer* (1976 : 215), in 1965-66 there were about 17,954 wells in the Delhi region, which were sources of irrigation, and were mostly in the trans-Yamuna area. This shows importance of a well in agriculture. Here it must be pointed out that during my exploration in the region, it was noticed that the Yamuna-Hindon doab is full of wells. It was also noticed that for irrigation, farmers considered well water superior to that of canal, which was built during the 18th century.

Crops

During my field survey in the region, I noticed that double cropping was widely practiced in the entire Yamuna-Hindon doab. People are proud of the fact that the soil is very fertile and any crop could be easily grown in the area. In contemporary times, the cultivators divide the agricultural year *(fasli)* into three seasons each of which has its own distinctive group of crops: *kharif* (rainy season), *rabi* (winter), and *zaid* (summer). The two main groups of crops are *kharif and rabi.* The *Gazetteer of Meerut* (1922 : 39-47) states that the *kharif* generally covers a greater area than that sown in the *rabi,* except in the Ghaziabad Tehsil and occasionally in Baghpat. The *kharif* crops are diversified. The main *kharif* crops are millets *(jowar* and *bajra),* pulses, and rice. *Bajra* is the major *kharif* crop grown in the area. *Rabi* crops consist mainly of wheat, barley, and gram. In the remaining area potatoes, vegetables, oilseeds, cotton, tobacco, sugarcane, chillies, fodder, and other non-food crops are grown. The other subsidiary crops include

mango, guava, grape, strawberry, tomato, brinjal, radish, watermelon, cauliflower, calibage, cabbage, and onion.

Assessment:

The geo-ecological settings of the Yamuna-Hindon doab and its neighbourhood made the region ideal for cultivation, and hence for human settlements in the period prior to industrialization in India. The rivers bodies not only drained the area but also provided alluvial deposits that made the soil fertile. The empires and the invaders of the past were aware of the fertile land of the doab and its prosperity, and hence since ancient times, this area witnessed frequent attempts by these forces to control the doab. The ancient settlements sites along the Yamuna river were bigger as compared to those along the Hindon and other tributaries as the topography was high and hence it was easy to found an urban (petty fort-like) settlement along the Yamuna. Also, Yamuna was suitable for long distance navigation, hence it could have facilitated trade and commerce. Therefore, it was more suitable to found an urban (petty fort-like) settlement along the Yamuna. On the contrary, the Hindon river was not suitable for long distance navigation and therefore, sites along this river remain a rural settlement. Also, it is to be noted that the floods in the Yamuna were more threatening to settlments than the floods in the Hindon. Therefore, while only high banks of the Yamuna were selected for settlements, along the Hindon, banks with even average heights were selected. The presence of the varied species of flora and fauna in the region and the fact that in the past the area had a much richer vegetation shows that the region, the Yamuna-Hindon doab, was easy attraction for human settlements. The rich vegetation together with rich agriculture (facilitated by the fertile alluvium soil and the perennial sources of water, the Yamuna and the Hindon) would have easily met the food requirements of the people. In fact, the vegetation of the area could provide at least the bare minimum subsistence to the people even when there were natural disasters, such as floods. Also, as the *Gazetteer of Meerut* (1922) highlights, the comparative vicinity of the mountains and the high altitude combine to render the region one of the healthiest parts of the plains of India. None of these factors worked in isolation, they together seem to create the ecological, social, economic and political bases determining the settlement pattern in the region.

At macro level, it appears that the Late Harappan settlements in the Yamuna-Hindon doab were established by way of migration from the adjoining Haryana and Punjab regions where the Harappan settlements had

been established from a much earlier period (Dikshit 1985 : 58). The Harappan culture complex at Alamgirpur and Baragaon were found more influenced by the material remains of Sutlej Valley, whereas Hulas appears to have its mooring in the Sraswati-Drishadvati complex of Haryana (Dikshit 1985 : 57). Thus, in the Yamuna-Hindon doab both these cultural waves are present and it appears that in the doab only late mature phase entered and survived. In the Yamuna-Hindon doab, the migration took place along the river system. The geo-ecological settings of the Yamuna-Hindon doab and its neighbourhood made the region ideal for human settlements and in this background one needs to evaluate the existence of large number of sites associated with Pre-historic, Proto-historic, Painted Grey Ware (PGW), Northern Black Polished Ware (NBPW), early historic, Gupta, Post-Gupta and Medieval cultures in the Yamuna-Hindon doab.

Bibliography:

A. Ghosh (ed.). "Excavations at Alamgirpur". *Indian Archaeology, A Review* (1958–1959). Delhi: Archaeological Survey of India. pp. 51–52.

Ansari, K.A.A. 1938, Exploration in the United Provinces, Archaeological Survey of India, Annual Report, 1935-36, pp. 44-50.

Babu, B.S.R 1996, Mandoli - A Late Harappan Settlement in Delhi, C. Margabandhu and K.S. Ramachandran (eds), Spectrum of Indian Culture (Professor S. B. Deo Felicitation Volume), Delhi, pp. 98-104.

Cautley, P.T. 1834, Discovery of an Ancient Town near Behat in the Doab, Journal of Asiatic Society of Bengal, Vol. III, pp. 43-44.

Cautley, P.T. 1834, Further Accounts of the Remains of an Ancient Town at Behat, Journal of Asiatic Society of Bengal, Vol. III, pp. 221-27.

Chakrabarti, Dilip K. 1995, The Archaeology of Ancient Indian Cities, Delhi.

Chakrabarti, Dilip K. 1988, A History of Indian Archaeology from the Beginning to 1947, Delhi.

Coningham, Robin; Young, Ruth (2015). *Archaeology of South Asia: From the Indus to Asoka, c.6500 BCE–200 CE*, Cambridge University Press

Dales, George F. (1962). "Harappan Outposts on the Makran Coast". *Antiquity*. 36 (142): 86–92.

Clark, Graham. 1979, Sir Mortimer and Indian Archaeology, New Delhi.

Cunningham, Alexander. 1963 (rep.), The Ancient Geography of India, Varanasi.

Cunningham, Alexander. 1969 (rep.), Archaeological Survey of India Reports, Vol. I to XXIV, Delhi.

Cunningham, A. 1848, Proposed Archaeological Investigation, Journal of Asiatic Society of Bengal, 17, pp. 535-36.

Cunningham, A. 1841, An account of the discovery of the ruins of the Buddhist city of Samkassa, JRAS, Vol. 7, pp. 240-49.

Dey, N.L. 1971 (rep.), A Geographical Dictionary of Ancient India, Delhi.

Dikshit, K.N. 1985, Late Harappan Cultures - A Reappraisal, Archaeological Perspective of India Since Independence, Delhi, pp. 55-61.

Dikshit, K. N. 1982, Harappan Civilization, Hulas and the Late Harappan Complex in Western Uttar Pradesh, Harappan Civilization, G. L. Possehl (ed.), Delhi, pp. 339-51.

Dikshit, K.N. 1981, Excavation at Hulas and Further Exploration of the Ganga-Yamuna Doab. Man and Environment, 5 : 70-76.

Dikshit, K.N. 1980, Distribution of Harappan Ware in the Gangetic Doab, R.K. Sharma (ed.) Indian Archaeology : New Perspectives, Delhi, pp. 113-23.

Dikshit, K.N. 1979, The Ochre Coloured Ware Settlements in the Ganga-Yamuna Doab. Agrawal,

D.P. and D.K. Chakrabarty (eds.) Essays in Indian Protohistory, Delhi, pp. 285-99.

Dikshit, K.N. 1979b, The Late Harappan Cultures in India. Agrawal, D.P. and D.K. Chakrabarty (eds.) Essays in Indian Protohistory, Delhi, pp. 123-33.

Dikshit, K.N. 1973, The Allahapur Evidence and the Painted Grey Ware Chronolgy, Radiocarbon and Indian Archaeology, Agrawal D. P. and A. Ghosh (eds.), Bombay, pp. 148-53.

Dikshit, K.N. 1970, Harappan Culture in Western Uttar Pradesh. Bulletin of National Museum, 2, pp. 21-28.

Dikshit, K.N. 1968, The Copper Hoards in the Light of Recent Discoveries, Bulletin of Ancient Indian History and Archaeology, 2 : 43-50.

District Gazetteer of the United Provinces of Agra and Oudh, Volume IV, Gazetteer of Meerut, 1922.

Dikshit, K. N. & Mani, B. R. (2012). Origin of Early Harappan Cultures: A Review. *In International Conference on Harappan Archaeology*, Chandigarh October, 27–29.

Dixit, Y., Hodell, D. A. & Petrie, C. A. (2014). Abrupt weakening of the summer monsoon in northwest India ~4100 yr ago. *Geology* 42, 339–342

Durrani, F. A. (1988). *Excavations in the Gomal valley: Rehman Dheri Excavation Report*, Issue 1 Peshawar: University of Peshawar.

Dyson, Tim (2018). *A Population History of India: From the First Modern People to the Present Day*. Oxford University Press

Enzel, Y. et al. (1999). High-resolution Holocene environmental changes in the Thar Desert northwestern India. *Science* 284, 125–128.

Erodsy, G. 1988, Urbanization in Early Historic India, BAR International Series, England.Gazetteer of Delhi District, 1912, Delhi.

Lal, B.B. 1954–55. Excavations at Hastinapura and other Explorations in the Upper Ganga and Sutlej Basins 1950–52: New light on the dark age between the end of the Harappa culture and the early historical period. *Ancient India* 10–11: 5–156.

Lal, B.B. 1975. In search of India's traditional past: lights from the excavations at Hastinapura and Ayodhya. *India International Centre Quarterly* 2 (4): 311–314

Lal, Makkhan. 1984, Settlement History and Rise of Civilization in Ganga-Yamuna Doab from 1500 B.C.-300 A.D., Delhi.

Law, B.C. 1967, Historical Geography of Ancient India, Paris.

Renfrew, Colin and Paul Bahn (2005), *Archaeology - The Key Concepts*, Routledge, London and New York

Singh, Upinder (2008). *A History of Ancient and Early Medieval India: From the Stone Age to the 12th Centur*y. Pearson Education India, Delhi

Waste Management in Sri Lanka: Challenges and Opportunities

Mervin Lal Dharmasiri
Professor, Department of Geography, University of Kelaniya
Mervin@kln.ac.lk

Abstract

It has been an unmitigated fact that in recent times, many developing countries have been faced with a critical issue in respect of the proper management of solid waste within their territories, due to increasing urbanization leading towards many a menace of disease, odour, nuisance, fire hazards, atmospheric and water pollution, aesthetic nuisance and so on and so forth thereby leading towards many social and economic losses. In 2012, cities world over, generated 1.3 billion tons of solid waste per year, amounting to a footprint of 1.2 kilograms per person, per day needless to say that with the rapid population growth and urbanization, municipal waste generation is expected to rise up to 2.2 billion tons (MT) by 2025. Inadvertently with the current trends continuing, it is likely to rise from 3.5 MTs to 6 MTs per day, each person generating around 0.64 kg waste per day in Sri Lanka with an estimated 4.8 billion MT of waste collected per annum in the country.

The main objective of this study is to examine the present situation of solid waste management in Sri Lanka in determining the nature and extent of the problem, thereby identifying the challenges and opportunities towards maintaining a sustainable waste management system in the country. as a result, the respective study has identified that, several challenges such as the absence of waste segregation, poor waste collection mechanisms and lack of public commitment on waste management etc. to be the underlying causes of the prevailing issue. Thus the prevailing system on waste collection, transportation and disposal aspects is nevertheless believed to be an issue yet to be resolved, due to the lack of education and awareness of the public on waste management, the lack of technical knowledge and the absence of applying 3R principles and so forth.

In this context, awareness through educating and changing the attitude of the public can be specified as precautionary methods towards maintaining a sustainable waste management system in terms of which, the participation of the public is to be quoted as essential and it should be borne in mind, that this is not something that can be accomplished via a limited operation and soon be forgotten, but rather one which needs to be

continued and maintained by ongoing continual efforts in keeping the menace at a minimum. Thus, a new model for waste management is required for collection, transportation and the disposal of waste, which should not be harmful to the society nor to the environment. The existing waste management policy of the country should be further developed by considering the concept of zero waste, alternative waste management approaches like waste to energy, sanitary landfills and the acceleration of composting methodology etc. thereby leading the pathway towards more sustainability.

Keywords: *Waste management, segregation, zero waste and sustainabi*lity.

Introduction

Solid Waste Management (SWM) has been becoming a major issue of economies and priority should be given to overcome the issue due to the rapid growth of the population as well as the increases of waste quantities in the Developing countries. Although the quantity and quality of solid waste generated by urban areas in developing countries are low compared to Western developed and industrialized countries, the municipal solid waste management still remains inadequate (Ilic and Nikolic, 2016). However, developed countries have already been applying different approaches such as composting, land filling and waste to energy etc. to overcome the issues. In this respect, it is appropriate to examine the strategies that they have applied to overcome the issue.

Waste is any subsistence materials derived from primary use or a useless defective. Solid Waste (SW) or garbage comprises of unwanted and discarded materials from houses, street sweeping, and commercial and industrial operations. The increase in the urban population and changing life styles lead to the generation of solid waste. Generally, solid waste is heterogeneous in nature such as the mixture of vegetables, food items, paper, plastics, rags, glass etc. If solid waste is disposed of on land in open areas, then it causes a negative impact on the environment, ground water and on health (Mundhe, Jaybhaye & Dorik, 2014). On one hand 'waste' has a value for someone while it doesn't for another. If it is possible to convert 'waste' into a valuable thing then no more would the 'waste problem' persist in the world.

Most of the countries in the world, in particular, developing countries, face the problem of proper management of solid waste within their territories. It has been creating different issues such as diseases, odor nuisance, fire hazards, atmospheric and water pollution, aesthetic nuisance,

social and economic losses. There have been many turgidity stories on collapsing waste dumps in several countries including Ethiopia and Sri Lanka. Many have pointed out, that, the developing countries haven't appropriate technology, with the lack of proper management and lack of leadership being the major defects of SW management of these countries.

Around the world, waste generation is being raised. The amount of waste generated by a country is proportional to its population and the mean living standards of the people (Grossmann et al., 1974). Further, Medina (1997) indicated that the waste generation rates have a close relationship with the income levels of people. In addition socio economic factors such as persons per dwelling, cultural patterns, education, and personal attitudes also play a role (Nilanthi Bandara, 2008). In 2012, the worlds' cities generated 1.3 billion tons of SW per year, amounting to a footprint of 1.2 kilograms per person per day. With rapid population growth and urbanization, municipal waste generation is expected to rise to 2.2 billion tones (BT) by 2025. If current trends continue, we are likely to go from 3.5 MTs to 6 MTs per day by that point. In South Asia, approximately 70 BT of waste is generated per year, with per capita values ranging from 0.12 to 5.1 kg per person per day and an average of 0.45 kg/capita/day (World Bank). The continuous indiscriminate disposal of SW is accelerating and is linked to poverty, poor governance, urbanization, population growth, poor standards of living, low level of environmental awareness (Rachel et al., 2009; Ogu, 2000) and inadequate management of environmental knowledge. However the waste generation rates will more than double over the next twenty years in lower income countries.

Even though human health and safety have been major concerns over waste management in the past at present, the society demands more than expected as in the past. society expects sustainable waste management which incorporates feedback loops, is focused on processes, embodies adaptability and diverts wastes from disposal. At a policy level decision making process, environmental consideration has played a major role in this sustainable system. Transitioning from a traditional unsustainable system to a sustainable waste management requires to identify and apply of leverage points which effect change (Jeffrey K. Seadon, 2010). Failure to do so may lead to ill-designed solutions that may not be effective enough to give any productive and sustainable results in waste management. Therefore, a system is required to control generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health,

conservation, economic, aesthetic, engineering, and other environmental considerations.

Objectives

The major objective of this paper is to examine the present situation of the SW management in Sri Lanka and identify the challenges and opportunities for maintaining a sustainable SWM system in Sri Lanka. In addition, alternative strategies will be identified for better SWM in the country.

Waste Issue of Sri Lanka

Wastes have been an issue when an absence of or a weak management system for collection, transporting and disposal. Mostly, it generates at a household level while the rest from industries or other. The Waste problem is not a big issue in rural and sub-urban areas where space is available to dispose waste unlike urban areas of the country. It is a significant issue in the urban areas especially in the western province of the country.

A survey on Waste amount and Composition Surveys (WACS) done by the University of Peradeniya in 2014 revealed that nearly three fourth of total waste is generated from kitchens. It is a noted feature that, more than 85 percent of the total waste is degradable at the source (Table 01).

Table No. 01 shows the composition of the waste collection at the point of waste generation of Sri Lanka. However, the figures differ with the study conducted by the Central Environmental Authority (CEA) in 2014. Figure 01 shows the waste composition of Sri Lanka.

A Similar study done by the CEA also pointed out that, the waste composition of the source at the generated point is more or less comparable with the study done by the WACS. According to Fig. 01 about 62 percent of the waste is categorized as bio-degradable, while 7 and 6 percent belong to paper and wooden items which also come under bio-degradable waste respectively. Altogether three fourth of waste could be categorized as bio-degradable which is capable of being decomposed by the action of microorganisms. This study further identified that about 6

Category	% in wet basis
Kitchen wastes	74.6
Garden wastes	4.8
Paper and cardboard	7.8
Soft plastics	4.2

Hard plastics	0.9
Textiles	1.0
Rubber and leather	0.4
Metal	0.9
Glass	1.7
Ceramics	0.5
Hazardous wastes	0.4
E wastes	0.2
Miscellaneous	2.7

Table 01: Waste amount and Composition in Sri Lanka
Source; Waste amount and Composition Surveys (WACS), 2014

and 2 per cent of waste are polythene & plastics and glass items which fall under non-degradables respectively. Non-degradable waste like polythene and plastic do not break down for several decades, if not centuries, and have a general tendency to poison the ecosystem, as they are petroleum based.

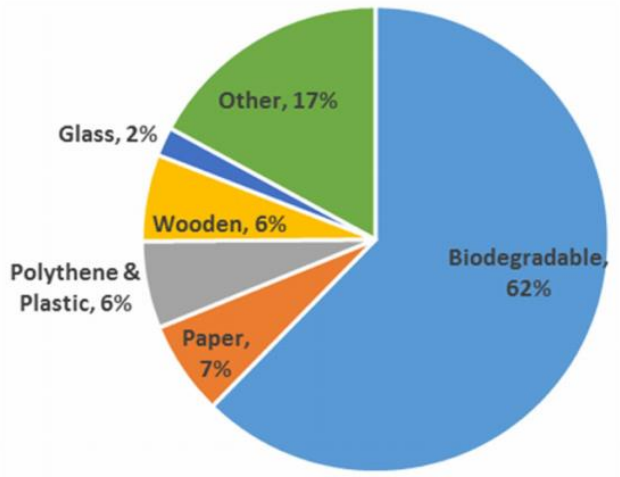

Fig. 01: Waste composition in Sri Lanka
Source; Central Environmental Authority (2014)

Sri Lanka has 309 local authorities of which 15 are Municipal Councils, 37 are Urban Councils and 257 are Pradeshiya Sabas. Approximately Sri Lanka generates 7,000 MT of solid waste per day. Most of the waste generated at the Colombo Municipal Council which is the largest local government authority in Sri Lanka covers a resident population of over 600,000. The Following table shows the waste generation by different local authorities of the country.

Provinces	Kg's p/p
Colombo Municipal Council	0.80
Municipal Councils	0.75
Urban Councils	0.60
Pradeshiya Sabas	0.40
Average	0.64

Table 02: Daily waste collection
Source; Central Environmental Authority (2014)

According to table 02, each person generates about 0.64 kg's per day in Sri Lanka. It is higher in urban areas such as Colombo and Gampaha. Most PS do not collect all the waste generated from their territories but part of it is collected. It may be estimated that about 4.8 billion MT of waste is collected per annum in Sri Lanka. However, the actual figure may be higher than the given figure. Table 03 shows the waste collection of the country by provinces.

Provinces	Generation amounts (ton/day)		Collection amounts (ton/day)		Collection rates	Number of final disposal sites
1. Northern	566	5%	178	5%	31%	16
2. Eastern	785	7%	347	10%	44%	40
3. North-central	616	6%	91	3%	15%	35
4. North-western	1,134	11%	187	5%	16%	45
5. Central	1,585	15%	304	9%	19%	47
6. Sabaragamuwa	835	8%	178	5%	21%	30
7. Uva	587	6%	116	3%	20%	24
8. Western	3,502	33%	1,793	52%	51%	52
9. Southern	1,158	11%	264	8%	23%	60
Total	10,768	100%	3,458	100%	32%	349

Source: Moratuwa University and NSWMSC, 2013

Table 03: Provincial level waste collection and Disposal sites

Table 03 shows the provincial level waste generation, collection and the final disposal sites of Sri Lanka. Accordingly, more than half of the total waste is collected by the Western province. Even though the Western province generates 33% of the total waste it collects more than 52% of the total waste of the country. All other provinces contribute less than 10% each. The Uva province occupies the lowest share of waste generation amounting to 6% while the Eastern, Central, North central and Southern Provinces produce more than 7% each of the total waste of the country.

According to table 03, it was estimated by the University of Moratuwa and the NSWMSC that 3,458 tons of SW are collected from the island per day. About 1,800 tons of SW are collected from the Western province per day. However, another study done by the CEA, revealed that, the total collection of solid waste by local authorities in Sri Lanka is around 2900 tons per day (CEA, 2014). Another study done by Hikkaduwa, and others of University of Moratuwa (2016), "Sustainable Approaches to the

Municipal Solid Waste Management in Sri Lanka" the collection of solid waste by all local bodies amounts to 3423 mt per day. Approximately 60% (1663 tones) of the total waste is collected in the Western Province which has about 30 percent of total population in Sri Lanka.

It is an interesting factor that a total of 349 sites have been selected for the final disposal of waste. Most of the sites do not provide a total solution for waste. Some of them have recycling facilities but it does not function in a proper manner.

Responsibilities of Waste Management in Sri Lanka

The Responsibility of waste collection from generated point to disposal sites are vested in local government authorizes such as Pradeshiya Sabha (PS), Town Councils (TC) and Municipal councils (MC). In Sri Lanka 111 local authorities have been functioning by the elected members of the particular area. These authorities are responsible for the collection, transport and the disposal of solid waste in a proper manner. The following table shows the range of waste collect by a number of local authorities.

It is clearly indicated in the Municipal council ordinance in 1947, the Unban council ordinance in 1939 and the PS Act in 1987. In addition, all disposal activities should be handled according to the national Environment Act no 47. However, several Ministries are also responsible for waste management in the country. They are Local Government and Provincial councils, Mahaweli Development and Environment, and Megapolis and Western Development. The Western province has a separate arm to handle solid waste within their province. Apart from the Ministries, several authorities are also responsible for different stages such as giving environmental concern by the Central Environmental Authority and providing approval by the Urban Development Authority and so on.

Ranges [Tones/ Day]	Number of local authorities
Up to 1	111
1-2	48
2-5	76
5-10	26
10-20	23
20-50	19
50-100	5
110-150	2
>150	1
Total number of local authorities	111

Table 04: Different Ranges of Daily SW Collection [tones/day]
Source; Central Environmental Authority (2014)

Further, the relevant Ministry of the Provincial Councils have the overall responsibility for the enforcement of rules and regulations in the Provinces. Further they are also responsible to regulate the operation of and the transportation and processing of Municipal Solid Waste and the management of final waste disposal facilities of waste without being a nuisance to the general public and/or to the flora and fauna of the Province.

Several waste management steps have been already identified by the Waste management Authority, of the Western Provincial Council (See; Municipal Solid Waste Management Rules-2005) for better handling and cleaning the environment of their area. They are as follows;

A. Properly Manage the SW at Source i.e. segregation, reduction, reusing and recycling and prohibiting the dumping of solid waste on streets or public places and open burning of wastes are being considered,
B. Proper Collection/Acceptance of MSW from the Source of Generation,
C. Cleaning of Streets and Public Places,
D. Abolition of Open MSW Storage Bins Abolishing of open storage waste bins from main roads, public places and introducing of close type appropriate waste receptacles are considered,
E. Improving a System for Mass Transportation of MSW Under this step prohibition of waste transportation in open vehicles and optimizing the efficiency of the vehicle usage for waste transportation are considered,
F. Treat the Collected MSW as a "Resource" Under this step encourage recovering of resources from collected MSW through re-using of MSW for composting, Power generation, production of biogas, bio-fuel, electricity, bio-gas and use of state of- the- art technologies for this purpose and also recycling are considered,
G. Improving a System for the Final Disposal of MSW Under this step establishing of engineered and/or sanitary landfills and use of the state- of- the- art technologies for such events at zonal and/or regional level are considered.

Challengers of Waste Management in Sri Lanka

One of the biggest problems in Sri Lanka is to manage the MSW in a sustainable manner. The prevailing system on waste collection, transport and disposal are yet to be resolved. It is possible to identify these issues which are discussed below as the challenges of WM in Sri Lanka.

a. **Waste segregation**: Segregation is the systematic process that waste is separated into different types. It can be done manually at the household level or mechanically. Basically, waste could be divided as dry and wet waste. Then it could be further divided into solid waste, bio-degradable, non-biodegradable, toxic waste and recyclable waste. Thus far we do not have a proper system or proper practice of segregation at the generation or collection points. Every individual has the responsibility to practice such a segregation system but only a few are practicing it

b. **Waste collection and transport**: Waste collection, storage and transport are essential elements of any WM system and can be major challenges in towns and cities. As mentioned above, the collection of SW are done by the PS, TC and MCs. All 111 local bodies have been collecting waste to keep clean on their territories. The Waste management Authority (WMA) of the Western Province is responsible for more than 60% of the total waste collection of the country. The Collection of waste from House to house and entire industries, commercial areas and public areas have to be transported and unloaded either into processing sites or sanitary landfills by the above authorities. However it has not been done in a proper and sustainable manner.

c. **Waste disposal:** The Absence of a proper arrangement for the disposal of garbage in towns and cities create many more challenges in the face of financial, technical and administrative incapacities of the relevant local bodies. From an individual to the top level institutions or Ministries related to WM should pay a good role in this regard. A few sanitary landfills and organic compose yards are available for the sustainable disposal of garbage. Unfortunately at present, solid waste is collected in a mixed scale and disposed in environmentally sensitive areas such as abundant arable land, marshy land, forests, wild life habitats, near water bodies, isolated hilly areas and so on. Most of the local bodies collect garbage and dump it at open lands which create many problems.

d. **Pollution:** Different types of pollution arises when the waste collected in dumping sites keeps rotting, spreading odour, water and soil pollution, health related problems and aesthetic pollution is caused in the surrounding areas. Most of the dumping sites are located in open

spaces. They are burnt sometimes and cause the emission of toxic gases like carbon dioxide and carbon monoxide which create health issues.

Garbage from household and other sources fall into rivers and water bodies. It makes the water of the water bodies polluted. The Blocking of the drainage system in towns and cities create breeding sites for mosquitoes and other vectors which spread diseases such as Malaria, Dengue, Filarial and other health problems. In addition, the improper garbage spreading from place to place and dumping it could increase the population of flies and rats which create many more health issues.

Increasing garbage at households and outside or water bodies has become a serious problem to air, water and soil. Accordingly, physical properties of the soil could be changed, and thereby the growth of plants and other factors affect soil nutrition and could be badly affected.

Inappropriate and unsustainable waste dumping would also destroy or reduce the worth of the aesthetic value and the scenery and beauty of the surrounding areas.

e. **Institutional set-up**: Several authorities i.e. Local government authorities, Waste Management Authority, Central Environment Authority, Ministry of Environment, Ministry of Megapolis and Western Development etc. have been dealing with the SWM in the country. In addition, several projects were also set up to support and to manage the WM issue in Sri Lanka. The Lack of coordination between institutions, the lack of Institutional capability with technical expertise and the lack of adequate funds etc. may beloop wholes.

f. **Public commitment**: The Literacy of the Sri Lankans are much higher than other developing countries. It means that the literate people should work in a systematic manner in WM. Beginning, at the school level all students were being given training in systematic practice in WM in their surrounding environment. Unfortunately, when they became adults, most of them do not follow the principles of WM. It has become a serious issue in the country.

g. **Political arena**: The lack of commitment of most of parties that involve in WM in the country. There are many obstacles arising when the

ruling party of a particular local body work on the waste issue. Simultaneously, the same in a different way will arise when the opposition takes over the next time in the same local body. Ultimately issues of WM will be stagnated in most of the local bodies.

The challenges would be able to be overcome by the commitment of the collaborative attendance of the public and private sector, government interference and the mindset change of the people of the country. The Following opportunities may be useful to overcome the identified challenges of WM in Sri Lanka.

Opportunities of Waste Management of Sri Lanka

a. **Education and awareness**: Knowledge from education and awareness has been seen as a key factor affecting environmental action. It is a vital fact that, the environmentally relevant knowledge plays a significant role in changing environmental activities and human behaviour. A Change in habits, behavior and the participation of the people on 'what do you/ people think about waste' is a significantly important aspect of SWM. As all knew, most information and practices about WM start at school and influence their households. The WM process at a school level is focused to keeping the environment clean and recycling the bio-degradable items. This process would help to increase awareness and attitudes towards solid WM among children and their parents.

b. **Improvement of technical knowledge**: The adoption and transfer of the technologies of WM either from developed countries or some others to the local level authorities and the people who are responsible for WM at the grass root level would be immensely useful for better practice. Technical aspects for a WM would have to be taken into account in many points from bottom to top, for planning and the implementation of different activities. Provisions of better technical knowledge would be directly supporting for sustainable WM practice in the country.

c. **Apply 3R principles:** The principles of 3R i.e. reduce, reuse and recycle can be applied in an acceptable manner to cut down on the amount of waste people throw away. The simple logic behind the principle is easy to understand, if there is less waste, then there is less waste to recycle or reuse. Any items that can be used again for another purpose or in a different way is called 'reuse'. The people can reuse most items such as plastic bags, furniture, toys and repair some broken items that they

used. On the other hand they can sell or give to others for charity. Recycling is a process which will be transformed again into raw materials that could be shaped into a new product. All materials could be recycled or transformed except for a few items in the world. About 38% of the waste such as glass, paper, wood items and so on could be transformed into recyclable items in Sri Lanka.

d. **Waste segregation**: Waste segregation is essential as the amount of waste being generated day today causes many more problems. Most of the bio-degradable waste could be transformed into fertilizers and only a small proportion of the waste has to be discarded. Unfortunately, the bulk of waste is not being segregated yet by the responsible people and the quantity of waste would be much higher. In particular, household waste can be separated into different baskets for the different categories of waste such as degradable and non-degradable which should be disposed separately.

e. **Attitudinal changers:** Waste could be identified as 'two sides of a coin', which highlight the idea of the environment as a gift and a responsibility. People were open minded on the environmental impact on improper waste management.. Everybody should understand that waste is from nobody, it belongs to everybody. Therefore all have a responsibility to manage waste in a proper manner.

f. **Independent Authority**: At present, there are many institutions which deal with WM in Sri Lanka. Therefore, a strong and independent authority is required to regulate WM if WM is to improve and be kept in a sustainable manner in the country. The Absence of clear regulation and enforcement will make improvement not activated in a timely and in a proper manner. The WM sector needs to include attractive and profitable businesses models with clear performance requirements imposed, with financial penalties applied when WM services are not working effectively.

g. **Adequate funds:** Finance for WM authorities and funding for other WM activities should be raised through Waste Management Tax (WMT) which comes through Polluter Pay Principle (PPP). All polluters must be paid for, keeping the environment clean and fair. An average WMT of 1 Rupee per any transaction of non-degradable wrapped items sold by merchants to buyers would generate huge amount of money and

the collected funds could be used for proper waste management in Sri Lanka. In addition, PPT policy could be applied for the person who violates the waste management system of a particular city.

h. **Alternative strategies:** Several alternative strategies are being implemented by the respective authority in the country. Zero waste, Waste to Energy, sanitary landfills and large scale composting. At present there are several landfills being constructed at Aruwakkaru, Keeramale, Medirigiriya and Keerakkulama. In addition, two waste to energy project plants of 10 megawatts each, to incinerate, were started in the Western province. The Ministry of local government is also establishing several mega composting machines in selected districts.

Alternative Strategies for better WM practice

It is an important fact that the education on WM should be further expanded for all the sectors which start at the kindergarten schools. The role and responsibilities of WM of each individual should be communicated and instructed in a proper way. It may be one way of forming responsible citizens who manage waste as resources and also applying 3R principles and creating a zero waste or waste less society in the future.

It is a vital requirement that WM must involve waste segregation at sources such as households, market or industries to allow more efficient value extraction and recycling. It should be separated into dry/ wet or bio degradable/ non-degradable etc. Then the waste would have significant benefits for waste collectors and the people who are involved in the WM field.

Innovative and practical waste management regulations could be imposed. The WM sector needs to include attractive and profitable models with financial penalties from polluters and WM discipline breakers. Then the WM services include collection, transport and disposal which will be sustained effectively and efficiently.

Short term and long term comprehensive WM planning requires to overcome the WM issues in the country. The private sector involvement should be strengthened for most of the WM activities. Local level Provincial councils and the Ministry of Local Government could monitor and evaluate the WM practices. To achieve the targets, training and capacity building is required from the grass root to the top level people who are engaged in WM.

Conclusion and recommendations

The quantity of waste has been generating continuously due to the growing population and increase in development. The Modern way of life has led to serious waste problems in the country. Easy products require more packaging and habits of the people are also associated with generating larger quantities of waste, discarded wrappers from the inevitable fast foods, and the modern day waste contains a higher proportion of non-degradable materials which have caused an acute waste issue. The problem has been further worsened due to the extensive use of plastic products such as plastic bottles.

Despite the huge amounts of waste produced, the standards of waste management in the country are still poor. These include outdated and the poor management of waste and, the inefficient handling, and collection, transportation systems, disposal of hospital wastes and hazardous waste and also disposal or dumping of wastes. Waste at the roadside, drains blocked up with garbage and plastic items and rivers filled with filthy garbage indicate that solid waste is a major environmental problem in Sri Lanka.

This situation has been diminishing our environmental quality to sustain life. If the present rate of solid-waste production goes on without a proper waste management system, there will be significant negative impacts on the quality of our environment. In addition, the inadequate awareness and knowledge about solid waste management issues, and being ignorant about the effect that improper SWM has definitely worsened the problem.

Sri Lanka needs a long-term goal to establish a sustainable and effective SWM that are cost effective, economically viable and environmentally sound. Strategies that have been recommended for waste minimization are part of the waste management hierarchy and involve 3R principles such as reduce, reuse and recycle.

The situation could be managed in a sustainable manner through several implications. Providing awareness from schools up to the higher education level in different scales and standards would be ideal. It may be able to change the attitude and awareness of the masses through formal and informal education. Finally, everybody should think and understand that waste is from nobody, it belongs to everybody.

The Appropriate technical knowledge and equipment should be provided to the local government institutes. Technical training is also an essential component for the people who practically engage in SWM at the field. WM requires not only technological knowledge but also public

participation, consultation and stakeholder mutual understanding and dialogue on activities.

Waste segregation is a vital part of SWM and attention should be paid to impart all stakeholders to follow the principles of waste segregation. It should be practiced from the household level to top level institutions of the country.

It is necessary to establish an apex independent institution to regulate SWM in the country. The institution should control all other institutions which deal with SWM. The institution could apply a good market model for managing SW in a profitable manner. The Legal framework should also be established to raise the required additional funds for the efficient management of the institution and also the PPP would be an ideal concept to strengthen SWM.

The Available WM policy of the country should be further developed by considering the concept of zero waste, alternative WM approaches like waste to energy, sanitary landfills and accelerating composting methodology etc. which is required to manage the waste in a sustainable manner. Finally, making responsible citizens who regard waste as 'our waste' and 'our resources' would easily manage the waste and achieve the sustainability of the country.

References;

Central Environmental Authority (2014) 'Present status of solid waste management and challengers for change' [Online Web: Accessed on 20th April, 2019], http://www.cea.lk/web/images/REEB/Present_Status_of_SWM_2.pdf

Daniel Hoornweg and Perinaz Bhada-Tata WHAT A WASTE: A Global Review of Solid Waste Management . The World Bank. March 2012, No. 15, [Online Web: Accessed on 13th March, 2019], https://openknowledge.worldbank.org/handle/10986/17388

Data Collection Survey on Solid Waste Management in Democratic Socialist Republic of Sri Lanka Final Report. Japan International Cooperation Agency (JICA) Kokusai Kogyo Co., Ltd. [Online Web: Accessed on 2nd March, 2019], http://open_jicareport.jica.go.jp/pdf/12250213.pdf

Hikkaduwa, HN; Gunawardana, KW; Halwatura, RU; Hee, H "Sustainable Approaches to the Municipal Solid Waste Management in Sri Lanka" [Online Web: Accessed on 20th March, 2019], **URI:** http://dl.lib.mrt.ac.lk/handle/123/11569

Grossmann, D., Hudson, J. F., & Marks, D. H. (1974). Waste generation models for solid waste collection. Journal of the Environmental Engineering Division, 100, 1219–1230.

Jeffrey K. Seadon, (2010), Sustainable waste management systems, November Journal of Cleaner Production 18(16):1639-1651, [online Accessed on 12nd November, 2019], https://www.researchgate.net/publication/245168221_Sustainable_waste_management_systems

Ilic, M., and M. Nikolic. (2016), Waste management benchmarking: A case study of Serbia. *Habitat Int*. 53:453–460. doi: 10.1016/j.habitatint [online Accessed on 02nd November, 2019], https://www.tandfonline.com/doi/full/10.1080/10962247.2016.1229700

Medina, M. (1997). The effect of income on municipal solid waste generation rates for countries of varying levels of economic development: A model. Journal of Resource Management and Technology, 24(3), 149–155, 1997.

Mundhe, Jaybhaye & Dorik (2014), Assessment of Municipal Solid Waste Management of Pune City using Geospatial Tools, International Journal of Computer Applications (0975 – 8887) Volume 100– No.10, August 2014

Nilanthi J.G.J. Bandara ,(2008), 'Municipal Solid Waste Management – The Sri Lankan Case' Paper Presented at Conference on Developments in Forestry and Environment Management in Sri Lanka. [Online Web: Accessed on 20th March, 2019], http://journals.sjp.ac.lk/index.php/fesympo/article/view/21/17

Ogu, V.I., (2000), Private sector participation and municipal waste management in Benin City, Nigeria. Environ. Urban. 12 (2), 103–117.

Rachel, O.A., Komine, H., Yasuhara, K., & Murakami, S., (2009), Municipal solid waste management in developed and developing countries-Japan and Nigeria as case studies. [Online Web: Accessed on 03th March, 2019], http://wwwgeo.civil.ibaraki.ac.jp/komine/mypapers/JGSPaper/2009/JGS2009(973)Rachel.pdf

Waste Amount and Composition Surveys (WACS) implemented in the Central and Southern Provinces of Sri Lanka, SATREPS report (May 2014)

Waste Management Authority (Western Province) (2015), Municipal Solid Waste Management Rules-2005, Joint programme of the Government of Sri Lanka, Western Provincial Council & USAID/USAEP

World Bank. Solid Waste management [Online Web: Accessed on 12th May, 2019], http://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management