Geographical Measurements to Resolve Issues Associated with Municipal Solid Waste Disposal

Empirical evidences from wet and intermediate Agro-ecological zones of Sri Lanka

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ABSTRACT

The municipal solid waste (MSW) generation, collection and subsequent disposal has become an acute problem in Sri Lanka, since 80% of the waste are generated from the 24 Municipal Councils (MCs). The western province accounts for 60-65% of total waste collection per day. The common problems that are identified in the all most all the MC areas are high volume of waste generation, haphazard waste disposal, finding a geographically suitable disposal site and scarcity of land for some MCs within its MC limit. Accumulation of all these drawbacks create multifarious socio-environmental and health issues in the respective MC areas. Accordingly, the prime objective of this study is to identify such socio-environmental and health issues and to provide a possible solution in geographical point of view. Out of the existing three major agro-ecological zones (AEZs) of Sri Lanka, both wet and intermediate AEZs were selected for the present study, following the stratified random sampling method and considered the volume of the solid waste generation, waste related issues, dissimilarity of geographical features and different height of elevation ranges. Total of 867sample households were selected, following the random sampling technique, based on the ratio of population density. The structured and semi structured questionnaires were used to collect primary data. The collected primary data were analyzed, using the appropriate analytical tools. The results revealed the different patterns of socio-environmental ill effects and human health issues of solid waste disposal and its volume, types and risk level are varied, due to the uneven geographical features. 75% of socio-environmental and human health issues are almost same in the selected study locations and 25% of such issues are varied from one study area to another, due to their physical characteristics. Further, this study found that 56.7% of female populations have been victimized with different types of health issues, than the males (43.3%). Similarly, 65.5% of children population, 75% of waste pickers and 70% of waste collectors/vehicle drivers have also been affected by multiple health problems, due to the direct contact with waste dumpsite. This study recommends to establish a mechanism for managing, monitoring and controlling all steps of MSW management process with great participation of all stakeholders. The integrated solid waste management (ISWM) system is a viable option for addressing this issue with comprehensive policy and process reforms.

Keywords: **Municipal solid waste, waste generation, Agro-ecological zone, elevation ranges, and ill effects.**

1. Introduction

Municipal Solid Waste Management (MSWM) is one of the major socio-environmental challenge in Sri Lanka, since it is coupled with population density, urbanization, and development activities. Finding a suitable disposal site is a challenging issue in the most all the municipality areas. Moreover, the high magnitude of waste generations, availability of inadequate infrastructures with Municipal Authorities (MA), disposal of unsorted waste by households, public behaviors, daily floating population to the city, open dumping and open burning are recurring issues, commonly existed with majority of MCs. This has resulted negative impacts to the land, air and water in its territory creating multifarious socio-environmental and human health problems to the dwellers; however its volume, types and risk range are differed as per the geographical background of the area. Furthermore, the solid waste generation in Sri Lanka is 7,000MT/day and each person generates an average of 1.5 kg of waste per day. All municipality areas are responsible for 80% of the total waste generation and the western province accounts for 60-65% of total waste generation per day. The Municipal Authorities managed to collect approximately 50% only (CEA, 2011/12). The balance 50% solid waste are ended-up with

water bodies, cannels, low lying areas, bare lands, around the so-called disposal sites and also haphazardly scattered in the MC limit (Ruzaik, 2020).

2. Objectives of the study

Main objective

- To explore and compare the issues of municipal solid waste disposal in the wet and intermediary AEZs in Sri Lanka and to find possible solutions in terms of mitigation and management, through geographical approach.

Sub-objectives

- To identify and analyze the socio-environmental issues.
- To identify and analyze the human health issues.
- To assess its volume of diseases, diseases types, and risk level according to the geographical variations of the selected study sites of the wet and intermediary AEZs.
- To provide possible solution to overcome the identified issues in a geographical dimension.

3. Review of Literatures

The first geographical approach of waste management issue has been carried out in 1972 by Jean Gouhier in his study in Caen University, France. Another research was carried out in this direction by him in 1990. Thereafter, the geographers are attracted to this research direction and outlined the multiple research, connecting to each elements of solid waste management process. Tabeaud and Hamez (2000), Kah (2000), N'kounkou (2000), Perrin (2004), and Campan (2007) are a few of them. In general, geographical approach on waste management is performed in scientific and social approach, adhering quantitative and/or qualitative ways by Perrin, 2004. Geographical contributions are brought regarding methods for estimating the quantities of waste according to different demographic and socio-economic parameters by Kah in 2003 (Florin, 2012). Accordingly, the review of relevant literatures, collected from multiple sources provided an opportunity to endorse finding of this study. After a careful perusal, the information has been organized as depicted below in context of major terms, connected to the current research problem.

Geographical perspective: According to Meade and Melinda (2012), "geographical perspective is a lens one may use to analyze virtually any topic that has a spatial distribution". Brown (2006) further described that "geographical dimension offers a unique way to understand anything that is distributed across the earth, including the ever changing relationship between humans and the environments. Since, the earth is a large interrelated system; human and the environment have had an interactive relationship, each influencing the other in a complex way". Basically, the geographical dimension refers to spatial analysis (uniformity and variances) of any physical problem in terms of topography, elevations, climate and hydrology (Ruzaik, 2020).

Environmental issues: Purohit *et al*. (2007) expressed in his study, "an environmental pollution is the contamination of the environment from man-made substances that have adverse effects on living matter. Contamination of air, water and soil interferes with human health, the quality of life or the natural functioning of the ecosystems". Municipal solid waste has become a major threat to the health of general public, waste workers, animals and plants, due to the influences of bad odour, toxic gases, insects, fire, dust and pollution of air, water and land (Hester and Harrison, 2002).

Agro-Ecological Zone (AEZ): According to Punyawardena *et al*. (2003), "Sri Lanka has been classified into three AEZs; based on climate, vegetation, soil, elevation and topography for different purposes". The classification of ecological zones is one of them. Panabokke (1996) elaborates that "AEZs have been categorized with the combination of various characteristics; such as climate, soil, terrain and land". Thus, each zone represents some uniform conditions of agro climate, soil and terrain, which would best support a particular farming system, where a certain range of crops and farming practices find optimal expression. These three AEZs have been further sub-divided into 24 subzones (Survey Department, 2007).

Municipal solid waste was defined by Zhu *et al*. (2008) as "any discarded materials by the public each day in the cities and towns, supervised and controlled by elected local officials or county governments".

Municipal solid waste generation: Lin *et al.* (2007) defined that waste generation refers as "the quantity of materials or products that enter into the waste stream; before compositing, incinerating, land filling or recycling". According to Visvanathan and Glawe (2006), the municipal solid waste generation differs from place to place at a great extent. Its production and composition are influenced by consumption pattern, climate, seasons and cultural practice of the area.

Municipal solid waste disposal: Unscientific management of waste, such as open dumping and open burning are the present disposal methods, especially in developing countries, which create numerous environmental dilemmas; such as pollution of ground and surface water, widespread vector borne and other related diseases, emission of noxious gases and creation of social disparity in terms of people (MoE, 2012). Christian (2002) expressed, most of the municipal solid waste in developing countries is dumped on land in a more or less uncontrolled manner.

Municipal solid waste management: Xudong (2008), Visvanathan (2009) and Asase *et al*. (2009) discussed that the municipal waste management encompasses the functions of collection, transfer, treatment, recycling, resource recovery and disposal of solid waste by respective municipal authorities. MSWM techniques vary from country to country depending upon physical characteristics, demography and level of economic development. Site selection is also an important component in the MSWM.

Sustainable waste management is a middle level approach, balancing development, growing solid waste generations and inevitably increasing pressures on the environmental health, through the recovery, recycle and reuse of resources, and the minimization of waste streams. This includes the management of resources in an environmentally sound and economically effective manner (UNEP, 2011). The Rio Declaration on Sustainable Development in 1992 defined sustainable waste management as the application of the integrated life cycle management concept in waste management. In effect, as explained by Margaret (2006), above declaration suggests an approach to waste management that incorporates environmental, social and economic perspectives into environmental policy, planning and practices.

4. Location of the study area

Two MCs from aforesaid each AEZ were identified, according to its topographical variations. The Colombo MC from low-country and Kandy MC from mid-country wet AEZ and the Kurunegala MC from low-country and Badulla MC from mid-country intermediate AEZ have been selected for this study (figure-1). The brief profile of which are given in the table-1 below.

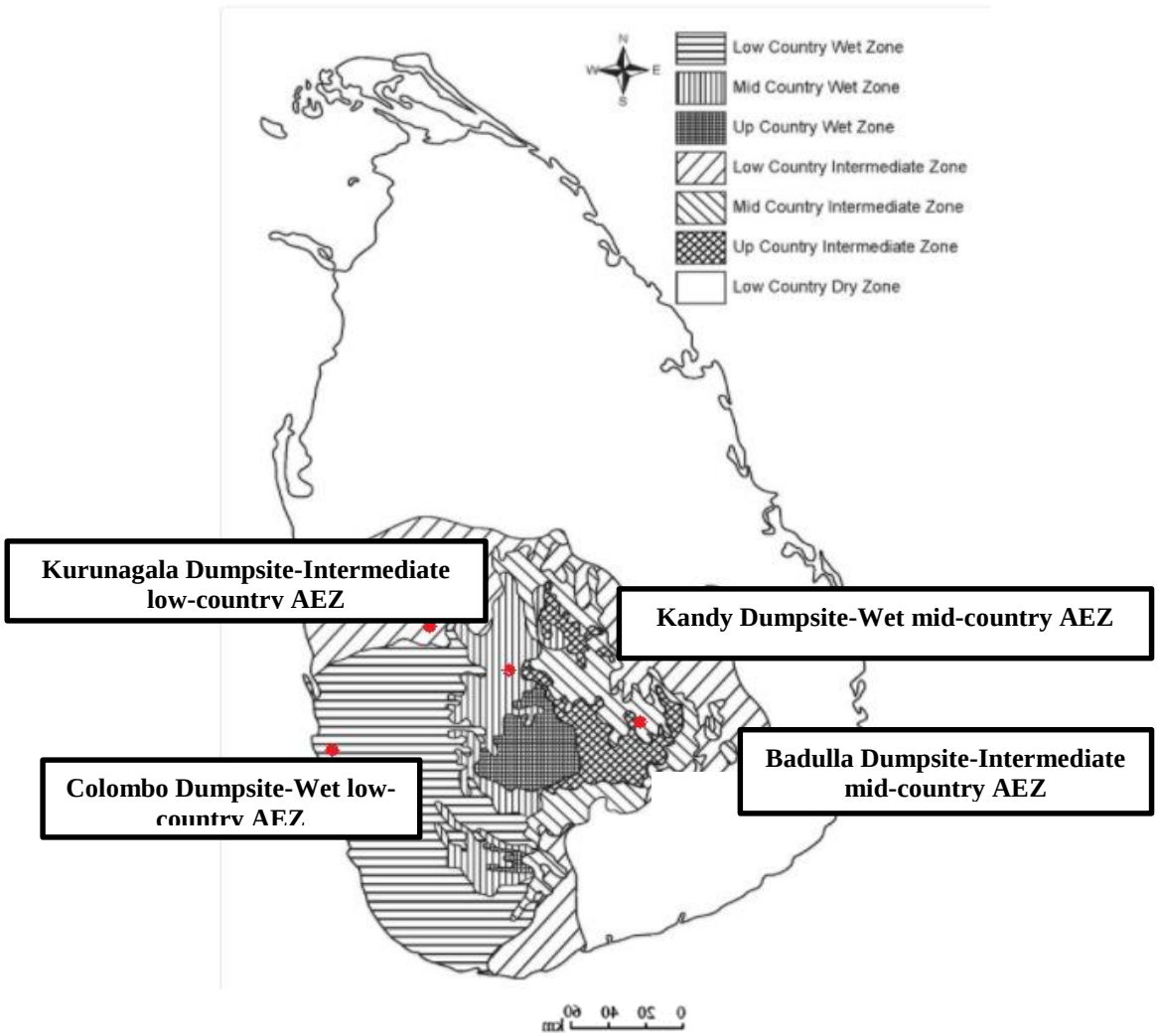
Table-1: Profile of study areas

Descriptions	Colombo MC	Kandy MC	Badulla MC	Kurunegala MC
Location	6º 55' N latitude and 79º 52' E longitude	7º18' N latitude and 80º43' E longitude	7º 30' N latitude and 80º 23' E longitude	7º 01' N latitude and 81º 07' E longitude
Area of MC	37.7km^2	28.53 km^2	10.36 km^2	11.34 km^2
No. of Wards/Zones	05 districts (zones) /47 Wards	05 Zones/23 Wards	03 Zones/ 13 Wards	06 Zones/12 Wards
75% expectancy value of annual rain fall	>1,525 mm	>1,250 mm	>1,400 mm	>1,020 mm
Annual avg. temperature	27.4 ^{0}C	23.8 ^{0}C	23.6 ^{0}C	27.2 ^{0}C
Tot. population(nearly)	1,000,000	165,000	47,587	30,700
Daily floating population	500,000<	150,000<	30,000<	200,000<
Avg. population density	17,254 Persons/ km^2	600 Persons/km^2	400 Persons/km^2	316 Persons/km^2
Waste collection (tonnes/day)	800- 850	150	25-35	45-75
Name of the dumping sites	Madampitiya/ Bloumendhal/ Pothuvikumbura,	Gohagoda	Badullupitiya	Sundarapola
Distance from the City (Km)	Within the city	3	Within the city	2
Area of the dumping site (acres)	16	31	8	12
Year of commencement	Since 1970	Since 1960	Since 1964	1970

Source: Prepared by the Researcher, extracting information from respective MCs, 2016/2017.

Solid waste dumpsite of Kurunegala is located at Sundarapola, which is 2 km away from the Kurunegala town and outside the Kurunegala MC area. Similarly, the Kandy site is located at Gohagoda, which is situated 3 km from Kandy town and outside the Kandy MC area. The dumping site of Colombo is located at Blumenthal/Madampitiya (previous sites) and is situated within the Colombo MC area. In addition, Badulla waste dumping site is also located within the Badulla MC area (table-1). The additional factors, which influenced for selecting above site areas are topography, vegetation, and hydrology and micro climatic conditions. Accordingly, two dumping sites beyond MC limits and two others within the MC limits were selected for the study (Figure-1). These four sites possess different geographical features, which strongly influence the impacts of the waste disposal on the areas concerned, resulted different magnitude of waste related issue.

Figure-1: Location of Dumpsites



5. Methodology

Accordingly to the objective, the methodology was develop to identify the both AEZs, dumpsites with topographical differences, demarcating a limit for household survey around the selected dumpsites (boundary line according to the distance from the dumpsite), prepare a sampling scheme and data collection process.

5.1. Rationale for selection of the study area

The investigator examined the current and actual situation of waste generation and the related issues of all twenty four (24) MC areas of the island, taken into consideration of volume of solid waste generation/disposal, nature of the issues, population density, location of dumping sites, representation of each AEZ and geographical features; such as topography, elevation, hydrology, climate and site location *etc*. and selected Colombo and Kandy MCs, representing wet AEZ and Kurunegala and Badulla MCs from intermediate AEZ. The elevation range of Colombo and Kurunegala is below 300m (low-country) from m.s.l. and Kandy and Badulla are located in between 300-900m (mid-country) elevation range. The Colombo and Kandy areas show similar natural characteristics, terrain (rolling), soil (red-yellow podzolic soils), annual rainfalls (below 1525 mm), since they are falling under the wet AEZ. Kurunegala and Badulla districts show similar natural characteristics like, terrain (rolling steep), soil (red-yellow podzolic soils and regosols soils) and annual rainfall below 1400 mm, which fall under the intermediate AEZ (Survey Department, 2007). The major differences between Colombo and Kandy (wet AEZ), as well as Kurunegala and Badulla (intermediate AEZ) is their elevation and topographical differences. These distinguished geographical features has a high influence on result of solid waste related, socio-environmental and health issues among the both AEZs. Dry AEZ with three MCs, namely Jaffna, Ampara and

Batticaloa was disregarded, since it has a 60% of the total land area of the island, with minimal waste related issues.

5.2.Sampling scheme and data collection

The selected municipality areas, Colombo-25.4 km^2, Kandy-37.3 km^2, Kurunegala-11.34 km^2 and Badulla-10.36 km^2 have different densities of population and solid waste related issues. Number of dwellers of all four identified dumpsites around the dumpsites were also accounted; drawing distance wise imaginary rings, considering dumping sites as the center point. This has assisted to mark a limit for household survey, maintain a uniformity and unbiased situation in data collection process. Accordingly, each study area was stratified into three rings as 0 to 500 m, 500 m to1000 m and 1000-1500 m from the respective dump site. Thereafter, the sample size was decided proportionately to the population density of study area and each imaginary rings. Total of 867 households were selected from the total population of 20,739 for data collection randomly from the each ring (strata), using structured questionnaire. A convenient sampling technique was used for collecting data from the waste collectors and drivers, through PRA survey using semi-structured questionnaire survey. More vital secondary data were also used for this study.

5.3. Data analytical techniques

Data processing and analysis were carried out, using the suitable statistical techniques and computer software. For an example: distance direction and location wise health issues from the dump site were processed, using two-way ANOVA and ANOVA Scheffes techniques. Similarly, Pearson correlation test was used to compare the health issues between the four different study areas. Further, socio-environmental data were processed by means of percentage analysis. Data collected by PRA were grouped into different headings and percentage analysis was applied. The same technique was followed to analyse the data collected from physical health officers and midwives. Apart from the above, the secondary data collected were listed and summarized into different topics, maintaining uniformity, whilst processing the data.

6. Analysis to explore applicability of Geographical approach in solid waste management

The prime objective of this study is to identify the geographical approach to resolve issues, associated with waste disposal. Accordingly, distinguishable geographically factors associated with solid waste related issues and management have been analyzed as per the following approaches.

1. Comparing chosen both AEZs (wet and intermediate).
2. Comparing chosen dumpsites of the same AEZs (eg. Colombo (low-country) with Kandy (mid-country) dumpsites of Wet AEZ and Kurunegala (low-country) with Badulla (mid-country) of intermediate AEZ.
3. Comparing chosen dumpsites of the different AEZs (eg. Colombo (Wet-AEZ & low-country) with Kurunegala (Wet AEZ & low-country); and Kandy (intermediate mid-country) dumpsites with Badulla (intermediate mid-country).
4. Comparing different imaginary rings of same dumpsites.

6.1: Background of Dumpsites

The correlations between the geography and location of the dumpsites determine the degree of the socio-environmental and health risk of the dwellers. The selection of a proper waste disposal site is more vital for reducing socio-environmental and human health damage. It was understood that the waste dumpsites of the selected study areas have been determined obviously, based on the availability of land area in its locality. The Colombo study area is densely populated and the Kelani River flows at the Northern boundary. However, Kandy site has less population, more hills and the Mahawelli River flows down the low lying area. The Kurunegala site has a rocky land area, along with many water bodies, agricultural lands and vegetation. The

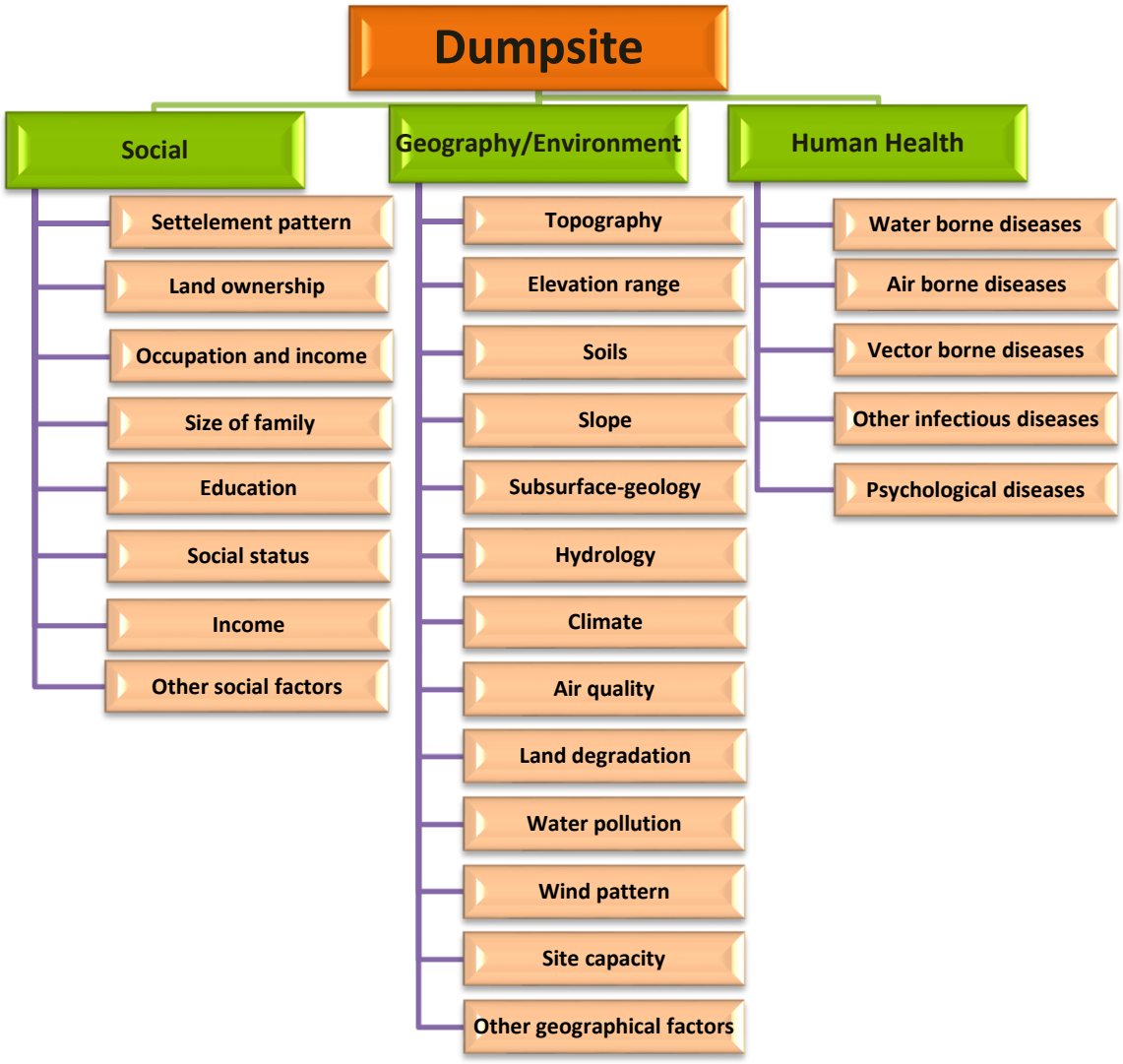
Badulla site consists of a highly populated area and water bodies. Therefore, it is clear that a systematic approach has not been adhered in selecting dumpsites in all the selected study areas.

The leachate can seep down, according to the structure and texture of land/soil and contaminate the hydrology of the area. High temperature emits toxic gases (greenhouse gases) from the waste site and induces warm conditions at the bottom of dumpsite, which would lead to fires and frequent explosions. Areas with very high rainfall should be avoided, when selecting a waste dumpsite. If it is a naturally high rainfall receiving area, MCs should adhere to remedial measures, such as waste reduction activities, compost preparation and recycling to minimize the adverse effect to environmental health. Depending on soil characteristics, leachate from a dumpsite is a threat to the groundwater quality (Brown, 1995). A dumpsite should be located, where the soils do not allow excessive seepage into the groundwater (Menikpura et al., 2012). Moreover, types of soil of the surface layer are important in selecting a waste disposal site. Clay soil is preferred to reduce the infiltration of leachate into the hydrology of the area. Therefore, soil structure should be evaluated carefully, before selecting a waste dumpsite. Hence, MCs should not select socio-environmentally sensitive areas to dump waste, which will cause heavy damage to the community around and the environment. Further, allowing this situation to continue indefinitely will increase the level of vulnerabilities; such as diminishing of biodiversity, soil degradation and contamination of water, loss of productivity of the land, forest pastures and health risks to the people.

The imaginary ring wise analysis shows that the most vulnerable group of the dwellers are those who live closer to the dumpsites (0-200m) and their socio-environmental backgrounds are also in very poor conditions. The selected study areas show different volumes and risk levels of health issues. Risk level too is different in each study area, within the same AEZ. *e.g.*, Kandy study area records more respiratory diseases, compared to Colombo. The major reason for this situation is lack of open space for the natural air purification process. Hilly areas surrounded the Kandy study area is obstructing the natural activities of the air purification process, whereas in Colombo there were more open spaces for this activity. The above facts clearly prove that elevation and location of the study area determine the health of the dwellers. Hence, a strategic approach is required to select any waste disposal site, considering both maximization of quality of the environment and minimization of environmental health risks, according to the geography of areas (figure-2). The background of all selected dumpsites show dissimilar, but sensitive geographical characteristics; which causes different types, nature, volume and risk level of socio-environmental and health damages.

A feasibility study carried out by an independent body, along with an Environmental Impact assessment (EIA), Health Impacts Risk Assessment (HIRA) and SWOT analysis, which is more important, prior to select any waste dumpsite and required to incorporate a separate section with regard to the Geography of the area: climatic factors (rainfall and temperature), topography (land structure), soil (Soil texture and composition), hydrology (surface and ground water), geology (geological features and bedrock level), wind (direction and velocity), land use pattern (human settlements, vegetation and crop cultivation), transportation (easy access), flood plain area, environmental sensitive area (rich bio-diversity), archaeological sites and public places (bus stand and market area); since the effect of the ill odour would reach more than 2 km from the dumpsite.

Figure-2: Strategic approach for selecting sustainable waste dump site
(Environmental quality maximization and risk minimization process)



Source: Prepared by the Researcher, 2016/2017

6.2: Social issues

This study has analyzed many elements of social factors of the selected study areas, comparing with its geographical contextual as described below.

Location of dumpsites: The Colombo and Badulla dumpsites were located within the municipality limits and Kurunegala and Kandy sites have been situated outside of the municipality limits with disparity in population density; directions and pattern of the households residential spreads, topography and other geographical factors, which caused significant difference in its results, among the study areas. The p-value of it was 0.097073738 (0.1% confidence level). That means, very close to the dumping site (First ring-0-500 m); it shows 84% of residential density in Colombo and 56.5% in Badulla, but in Kandy and Kurunegala study area, it was 36.4% and 39% respectively.

Landownership: The land areas around the dumpsites of 81.7% in Colombo, 91.7% in Kandy and 87.1% in Badulla are belonged to the government; whereas 100% around Kurunegala dumpsite is owned by the private sector/individuals. Therefore, the results show a significant p-value (0.009477914), which indicates a difference on land ownership pattern, among the study areas. However 100% of land areas, where dumpsite is situated, is possessed by the government. Hence, the 18.3% in the Colombo, 8.3% in Kandy and 12.9% in Badulla; but, 100% in Kurunegala community's residential land are owned by the private sector/individuals.

More land areas around the dumpsites have been encroached by low income earning dwellers in the Colombo and Kandy study areas.

Occupation/income avenue: The occupation/income avenue of the households were mainly deviated into four groups, such as state sector employee, private sector employee, overseas (middle-east countries) employment and other types, including self-employment). Accordingly, it was observed that 65-80% of the people were employed in the state sector in Badulla and Kurunegala study areas, since they are literate. However, dwellers of the Kandy study area also recorded a fairly high (48%) percentage in state sector employment, since most of them were employees of the Kandy MC. But in Colombo, a greater number of people were in self-employment (54%), which is also one of the important aspects of the Colombo dumping site.

Size of family: The number of members of a family shows a significant p-value (0.058860357), among the different study areas. The size of the family shows a significant p-value (0.000712787), in the same study area in between imaginary rings. The study considered a family with three members or less, as a small family and a large family with seven or more than seven members. 20.8% in Colombo and 14.7% at Badulla had large families within seven members. Further, this result clearly indicated that the Colombo and Badulla areas consisted of larger families, which therefore caused considerable amount of socio-environmental and health problems.

Education: The education levels of the household also varied, according to the distance from the dumping sites. A very low education level was seen in the first ring, closer to the dumping site. This could be observed in both at the Colombo and Kandy dumping sites. But, other two dumping sites (Kurunegala and Badulla) consisted of dwellers of with fairly good standard of education, since they were employees of state and private sectors and had a fairly good social-background as stated above. Generally, the education level around the dumping sites, of all the study areas showed a slight improvement in their second and third rings from the dumping sites. Accordingly, the statistical results evidenced that the p-value (0.014097317) is significant pertaining to the education level on different rings (distance wise education level) in dumpsites.

Schools: There were five schools in Colombo and three schools in Badulla, situated very close to the dumping sites. This situation gave rise to various problems involving the children, teachers and parents; in relation to their education, health and social equality. Based on the interviews and the collected data from the school principals, it was seen that more than 75% of the school children were suffering at least from one kind of ailment or other. As a result, it leads to poor school attendance with more than 50% of children marked absent daily. Especially, causes relating to polluted air, poor food, vector and water borne diseases were widespread affecting the school children, within the first ring of the dumping sites. In addition, headache, breathing difficulties, cough, skin rashes, fever and Phlegm ailments were some of the dominant diseases, which have afflicted them and made the day to day life of the school children as well as teachers difficult.

Flies and mosquitos: The havoc created by flies and mosquitoes has become much common and predictive danger to the general health of the people, around the selected dumpsites. Most of them use mosquito coils and mosquito nets as preventive methods but, some people do not have such preventive measures perhaps, because they cannot afford them.

Table-2: Use of mosquito bite prevention methods (%)

Study areas	Mosquito coils	Mosquito nets	None
Colombo	38.6	31.0	30.4
Badulla	34.3	48.6	17.1
Kandy	14.0	74.0	12.0
Kurunegala	20.3	71.6	8.1

Source: Field survey, 2016/2017

Above statistical table-2 explains the communities' socio-economic condition and the education level. Obviously, mosquito nets are the better option than the mosquito coils, which the people of Kurunegala, Badulla and Kandy have mostly used. The above statistics provide a message that the people with good educational background with affordable resources have taken precautionary measures to safeguard their lives from possible health risk.

Illegal activities: The vicinity of the dumping sites provide room for the various illegal activities (encroachment, trading floor for alcohol/drugs and theft), social crimes (sexual harassment, child abuse…*etc*.) and unconventional behavior (early marriage, early pregnancy, use of bad language words in their ordinary conversation, lack of kindness and encroachment). This situation is very common especially in the Colombo dumpsite. According to the study, 38.5% in Colombo, 34.6% in Kandy, 7.7% in Badulla, 19.2% in Kurunegala are involved in the at least one above stated illegal and social crimes. This situation has naturally arisen, due to the bad conditions of their living environment.

Other social issue:
The dwellers around the dumping sites are labelled by the derogatory name "KUNUGODA MINUSSU (the people garbage heap)" by the dwellers, who live in other areas and given scant respect. This is to be noticed among the school children too. Some school children are referred to pre-fixing "KUNU (garbage)" to his/her own name. This is a serious issue that the current study has identified. People and school children in the dump areas do not like to reveal their identity, as dwellers in the dump areas and are reluctant to provide their home address to the others. At the same time, people from other areas do not like to have any relationship with them (attending parties, marriage proposals and social cohesion). In addition, occupants of the sites cannot organize any special occasions; such as social parties, ceremonies, celebrations, religious activities, due to the limitations of housing (nuisances such as mosquitos, flies, scavengers, animals and bad odour). Always the doors of houses are kept closed, due to the bad smell blowing into the house carrying dust, flies and other insects. This situation has created lack of ventilation for the houses. Eventually, this type of environment will definitely will lead to extremely harmful consequences to socio-environmental and human health.

Above social factors revels that all selected dumping sites are located amidst residential areas, where almost all are low income earning poor people. The study ascertained that the sites have been selected without much consideration to the occupants of houses, around the site which is not a suitable method. A high level of social degradation in and environmental destruction is to be observed, where high population density is present. The topographical features of the area highly contributed in determining residential density. It was observed that in unsuitable land areas such hills and valleys; the population distribution is less. Thus, the population density is determined by the geographical factors of the sites. More social and environmental damage was to be seen in the residential areas, which were situated at the same level of dumpsites (eg: Colombo and Badulla) areas, due to the direct interaction of air circulation process, bad odour and direct contact with unpleasant dumpsite. Similarly, the houses close to the dumping sites were of poor conditions, which are temporary shacks. As a result, it was found that there are nearly 35-40% of occupants of such shanties in Colombo, 5% in Badulla, 15% in Kandy and 5% in Kurunegala. These statistics clearly show that in Colombo area, the housing condition was extremely poor, which leads to more social problems to the community, compared to the three other selected study areas. But, a considerable amount of environmental damage, such as soil, cultivated lands, water bodies, vegetation and biosphere, have taken place in the other three disposal sites, due to the destruction of the sensitive environment.

6.3. Environmental issues

The physical environment of the selected study areas have been contaminated, due to the open dumping and open burning of MSW. The environment thus obviously suffers from various negative effects; because of the various types of contaminations-air, soil and water; absorption of bad odour; spread of dust; emission of greenhouse and toxic gases; and escape of leachate. The existing waste disposal system is the root cause of degradation of both the environmental salinity and human health, poisoning the vicinity.

The study recorded the preferences, expressed by the occupants about their choice to live in, pertaining to the living interest in the particular areas. The level of satisfaction has been measured, based on their positive replies. Accordingly, 46% in Colombo, 87% in Badulla, 21% in Kandy and 36% in Kurunegala preferred to live in the dump area, due to various reasons. Further, the above statistics show that those in Kandy site are

the most dissatisfied (79%) with their living condition, since they are an educated, middle income earning groups of people and they prefer to live in another more healthy residential area. Again, dwellers on the Kurunegala dumping site also have similar opinions and 64% of the people do not like to live in the area, due to the pressure of the waste dumping site. Badulla site, it was recorded that a great majority of them (87%) were satisfied to live in the area, due to the low amount of waste disposed there, high value of land price and the fairly satisfactory socio-economic background. Further, availability of enough home lands to the citizen of Badulla reduces an amount waste generation, which makes the vicinity of the town more environmentally healthy. Similarly, attractive of the town area, like good surrounding environment, good climatic conditions, financial support from the funding agencies such as JICA/ Pilisaru of Central Environmental Authority (CEA) to recycle the solid waste, moderate/middle level income, fairly good housing conditions, easy accessibility to hospitals and schools and literate level and fairly good standard of living are some reasons to prefer that area to live.

Satisfactory level of dwellers of the Colombo study area are, approximately of a 1:1 basis with regard to their preference to live in this area. They do not have any option to change this accustomed location, since their income level is very low. They exist from day to day with no much on their future and the majority of the people have no long searching objectives in their lives. However, if the government offers an alternative settlement area, they will respond positively for such a move. The rest of the populations are willing to continue to live in the same area and they do not wish to shift their dwellings to other suitable areas, since they obtain income and various benefits from the dumping sites. Mostly, these dwellers are waste workers, waste pickers and drug addicts. The waste pickers get several benefits from the dumpsites; such as items of food, recyclable and reusable items and also use the dumping sites for feeding pigs, cows and goats. Accordingly, considerable benefits are enjoyed by the waste pickers at the Colombo site.

Living in this degraded environment, making use of short run benefits will definitely bring about health related problems. On the other hand, they have to spend money considerably to obtain medical treatment, which mostly provides temporary relief. Further, they have an opportunity cost, such as spending money for medicine, sacrificing their other needs like safety, nutrition, education…*etc*. Hence, open dumping of solid waste disposal create a situation for environmental terrorism to the other residents bordering these particular disposal sites. The above facts clearly indicate that the level of environmental factors enhance the probability of satisfactions to live in the relevant urban environment. Hence, the current study highlights the fact that the surrounding areas are not suitable for living and residential housing purpose and suggested maintain a gap (minimum 1.5 km) between dumpsites and residential areas and water bodies and other geographically sensitive areas.

Colombo site: During the field study, it was observed that the washed clothes, which have been put on the line for drying, are coated with brownish dust, black dots and gave out a bad odour. Flies settle on these clothes and lay eggs too. Further during rainy days, the dumpsites are flooded with dirty water, which directly inundate the houses and render the people homeless. It is pertinent to state that Rahula Vidiyalaya at Meethotamulla, Kolonnawa area is situated very close (not even 30 meters distance) to the dumping site, where the children and teachers very often fall sick owing to this very unhealthy environment. Poor attendance at the school children and teachers is also the result. The principal has to face a critical situation, due to poor attendance of both parties. The volume of environmental and health issues depend on the different physical and social backgrounds of the environment.

Kandy site: The Kandy waste dumping site, located very close to a branch of the Mahaweli River was previously used for vegetation, paddy field, homelands and coconut lands. After the commencement of municipal waste disposal (150 MT/day) in this area, the surrounding green nature was destroyed rapidly. It was observed that its leachate automatically seeping down to the branch of the Mahaweli River and to the wells in that vicinity. Due to the wet climatic conditions (annual rain fall >1250 mm), the amount of leachate seeping down to the water bodies is high, due to valley type topographical features. Finally, this process induces the movement of liquid waste. It is quite obvious that contamination of the Mahawelli river will be very detrimental, not only the citizen of Kandy, but also to the people who reside along the river bank of Mahaweli, until it reaches the Trincomalee Bay. Further, the waste mountain releases an unbearable ill odour to the surrounding environment, due to the molting in consequence of the moisture content. It is necessary to state that the age of the "Waste Mountain" is more than 50 years. The existing terrain with loamy type soil has a good capacity for absorption of the liquid waste. The contaminated water in the drinking well gives an

unpleasant taste, due to the leachate. Currently, the people do not use well water for drinking purposes. Vast acreages of paddy lands have been abandoned, due to contaminated soil. Therefore, the direct and indirect effect has changed the living livelihood pattern of the people, around the site.

Kurunegala: The dumping site-Sundarapola has Jack and Mahogany forest plantation in its North and a part of Northeast. Topographically, the Northern part of the site is slightly hilly and the Southern part is valley-like with fairly green environment. The existing terrain mostly consist of metamorphic rock, which leads to poor absorption of liquid and leachate from waste whereby all the leachate is released to the residential areas and water bodies downstream. Ultimately, this process leads to the destruction of the environmental condition. This was proved by the field investigations, as population density and water related diseases are gradually increasing, towards the town area situated to the South of the dumpsite. Further, water bodies; such as wells and lakes, the cultivated land area, home gardens and paddy fields are polluted, which might be a threat to many farmers' socio-economic conditions, especially depriving them of their livelihood/income generation avenues.

Badulla: The existing land and soil are fully saturated with leachate. The excess leachate has been continuously seeping downwards to the water bodies (Badulu-Oya and other water bodies) and the adjoining land area. Using contaminated water will lead to various socio-economic and environmental damages. On the other hand, Badulla has a fairly good climate and satisfactory level of greeneries in the vicinity. The amounts of waste accumulating is low per day (30-35 MT) and the moderate standard of living and fair literacy level are positive factors alleviating the rigors of waste related environmental problem, as compared to the other dumping sites.

6.4. Human health approach

The health issues were analyzed, taken in to consideration one independent/constant variable (dumpsite) and three dependent variables. In this analysis, the status of socio-environmental issues are also elaborated wherever applicable, since these variables have a direct relationship with the socio-environmental issues. These issues and the distance from the dumpsite have a very close relationship. However, this section discusses the status of issues available in the different imaginary rings (0-500 m, 500-1000 m and 1000-1500 m) of selected study areas. It was observed that more socio-environmental and health related issues have been observed in the first ring to the dumps site. It shows a gradually decreasing trend, when the distance increases. A greater amount of socio-environmental and health issues were observed in the first ring of the dumpsite, compared to the other two rings. However, it is observed that the various types of issues were noticeable, among the entire rings within the 0 to 1500 m distance. Further, the degree of such effects also depends on the population density, environmental background and topographical feature of the surrounding area. Moreover, this study identified 13 types of health issue during the survey among the dwellers, around the dumpsites, which were recorded as an average Colombo-45%, Kandy-21%, Badulla-19% and Kurunegala-15% (figure-3).

The distance from the dumpsite and health related issues have negative relationship, *i.e*. the lower the distance the higher the health risk and the higher the distance the lower the health risk. Between 0-500 m distance records an average of 53.8% health related issues. In the second ring from 500-1000 m, it was recorded as 32.1% of average affected people. The distance from 1000-1500 m records 14.1% health related issues. Similar observations have been found in terms of socio-environmental issue too.

The relationship between direction and health issues. Geographical factors (Wind direction, wind speed, hydrology, topography…*etc*.) and population pressures directly responsible for direction wise health issues of the area. More population could be seen in the northern direction of the Colombo site (45.5%), both Western and Eastern directions of the Badulla site (33.3%), Southern part of the Kandy dump site (41.2%) and Western direction of the Kurunegala site (48%). Obviously, health issues are more in these directions as stated below.

- Colombo: North-41.2%, South-14.4%, West- 22.3% and East- 22.1%.
- Badulla: North- 22.3%, South- 25.2%, West-15.0% and East-37.5%.
- Kandy: North- 20.7%, South-37.3%, West-27.0% and East-15.0%
- Kurunegala: North-0.0% (no health risk), South-45.8%, West-46.2% and East-8.0%.

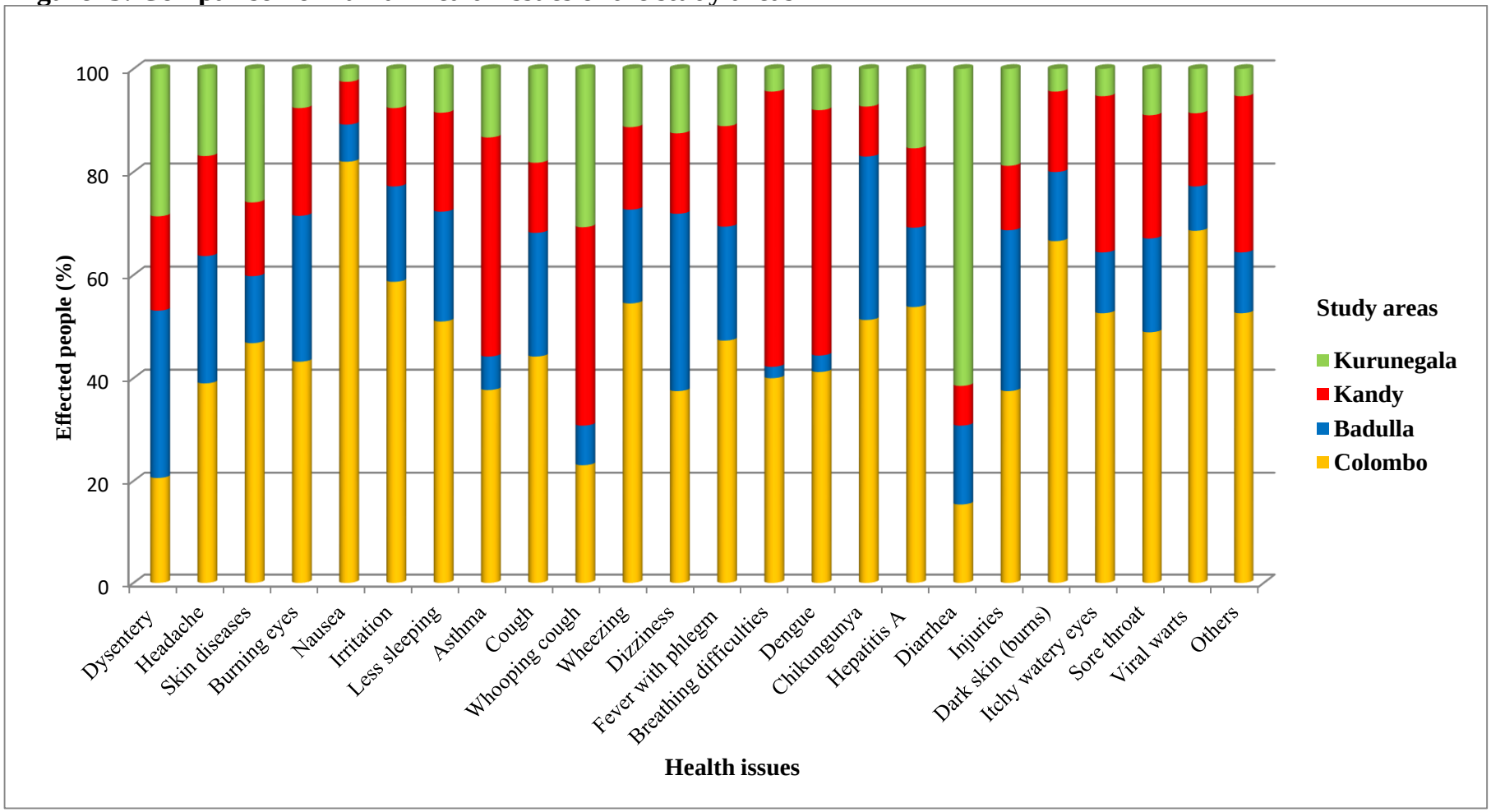
The relationship between dumpsite and the settlement patterns, whether human settlements are located in the same level of the dumpsite or below the level of dump site or above the level of waste dumpsite. Accordingly, the volume and risk level of health issues have recorded location wise variability. Location wise population distribution is summarized below.

- Colombo : Same level-55.0%, Level below-28.50%, Level above- 16.50%
- Badulla : Same level-61.6%, Level below-31.24%, Level above- 7.16%
- Kandy : Same level-22.5%, Level below-40.50%, Level above- 37.0%
- Kurunegala : Same level-24.20%, Level below-68.20%, Level above- 7.60%

More dwellings are situated at the same level of the dumpsites in Colombo and Badulla. As a result, more health issues also can be observed. The study areas of Kandy and Kurunegala recorded clear health issues in the area located, below the level of dumps sites. The dwellers, who live below the level of the dumpsites at Kandy and Kurunegala are the more vulnerable groups and have had a high volume of health damage, due to its geography and settlement pattern. Therefore, it is a fact that human and environmental health would be harmed by the geographical factors and the settlement pattern. Kandy and Kurunegala dumpsites recorded slightly high population in the area, above the level of dumpsite and there were upper flow apartments. An artificial elevation range is located above the level of dump site in Colombo. But, natural elevation range could be observed in Kandy as its topographical features.

The result of this study revealed that the solid waste related issues are very common, but some issues have the strongest compaction to the area, based on the geographical backgrounds

Figure -3: Comparison of human health issues of the study areas



Source: Prepared by the Researcher, 2016/17

7. Recommendations for implementing geographical approach in solid waste management

7.1 Concluding discussion

The waste management activities of MCs in Sri Lanka clearly prove that effective measures have not been taken so far, to manage waste related issues in a productive manner. The prime reason behind this is that all managerial activities had been concentrated merely on waste collection, transportation and disposal, rather than on modern method of waste management approaches. Due to the crucial spread of dengue in the past few years, the necessity and interest of effective waste management had been felt in the households and the policy makers. Further this study found that the uneven geographical distributions play a major role in the process of solid waste management hierarchy, since it has an undue influences on site selection, waste collection, transportation, disposal, post disposal site management and also in the solid waste related issues (nature, effects, size and volume). Hence, the policy reforms measures must be incorporated a comprehensive consideration on geographical dimensions in the decision making process of every stage of municipal solid waste management and find a sustainable and lasting solution to this recurring problem.

Majorly, the proper site selection has a liner correlation with waste related issues. Hence, the MCs are requested to choose a geographically suitable land area to dispose the collected waste from the purview of respective MCs. Colombo MC has difficulties in finding a disposal site in its purview, due to the lack of land (MC area 37.3 km^2-5.4% of the total land area of the Colombo district), compared to other sample study areas. This study found some MCs are geographically sensitive area, such MCs would find a land are out of its municipality limit, evaluating its environmental (EIA) and human health risk impact assessments (HRIA). Similar attention should be paid to other elements of municipal waste management hierarchy to minimize the ill effects of waste generation and disposal as much as possible.

In addition, the statistics revealed that the rate of discharge clearly indicates that the total waste has generated is not collected (100%) by the any of the MCs-Colombo, Kandy, Badulla or Kurunegala. Further, it was observed in the present study that an approximately 75% of the environmental and health issues are almost same in all four selected study locations and 25% vary from one study area to another, due to their physical characteristics. 80% of municipal wastes produced in Sri Lanka consist of organic waste, including food and garden waste. The balance, 15-20% consists of paper, plastics, glass, metal, and other inorganic materials. The organic fraction has a strong impact on the environment and can be hazardous (Perera, 2003). Further, the average age of the selected dumping sites for the study is more than 40 years (Ruzaik, 2020,). It is obvious that the decomposition process of solid waste over a considerable period of time has resulted in numerous ill-consequences, such as emission of toxic gases/other emissions and direct/indirect influence on nature and the health conditions of the residents around. This study found that although, the existing urban environmental issues are almost same in the selected study areas; the nature, effects, size and volume of the issues varied, due to uneven geographical distribution. Thus, the results show a clear variability in environmental and human health related issues, according to the distance, direction and location from the waste dumpsite. Variability in environmental and health issues have been observed in different rings of a study area and also amongst the four different selected study areas, as the geographical factors play an important role. Accordingly, this study highlighted a few areas to minimize and manage the solid waste related health issues by way of minimizing the waste at source, sorting, collections, transportation, disposal, encouragement of home compositing system, post disposal site management activities, stakeholders' participation, introducing a uniform practice of MSWM for all MCs.

Conducting public education and awareness change in public attitudes and behaviours, correct site selection following proper procedures, social and public acceptability of such sites, finding a solution to control imports with more packing materials are also included in the provided recommendations. Finally, the right solutions is to implement an Integrated system of Solid Waste Management (ISWM) process by each and every MCs, consolidating all the relevant resources including key stakeholders, who are responsible for waste management practices, under integrated mechanism. There has to be a systematic effort by the local governments, in the improvement of various factors, such as institutional arrangement, financial provisions, appropriate technology, operational management, human resources development, public participation and awareness and policy and legal framework though proposed integrated system of waste management.

7.2. Recommendations

The existing management measures should need to be regularized and strengthen to cope-up with increasing trend of solid waste generation, handling and disposal. Solid waste in Sri Lanka is largely disposed on the arbitrarily selected open dump sites, without any pre-treatment. Some of the main MCs in the country including; Colombo, Kandy, Kurunegala and Badulla are also following similar disposal methods to discharge their daily accumulations. Lack of awareness, low participation of the general public in segregating household waste and minimizing waste accumulation are becoming greater issues in the highly urbanized locations. Therefore, better disposal methods and the participation of the general public are vital for the purpose of risk reduction and efficient waste management system as depicted below.

- Suggested to extend a Health Impact Risk Assessment (HIRA), together with EIA for existing every disposal site and it is mandatory for selecting new dumpsites in the future.
- It is required to incorporate the "Geography" into account, when selecting disposal site and in the process of site management.
- Recommended to develop a paradigms for effective waste management; in terms of waste generation, sorting, collection, transportation and disposal of all MCs in Sri Lanka.
- Home composting is a way of reducing waste reaching the waste disposal site. Possible, MCs must consider household composting as an acceptable method of bio-degradable waste, if land space are available for residents. The public should be encouraged to maintain household composting units/bins, which should be distributed by the municipal authority at a concession rate.
- Environmental education and awareness is one of the most powerful, effective and less costly tool for MSWM, which will definitely produce sustainable results. A continuous awareness raising programme for stakeholders in order to obtain their active participation and support for implementing waste management programme is vital to share knowledge, value, skills, experience and the determination, which will enable them to act individually and collectively to resolve present and future solid waste related issues.
- Systematic rehabilitation process should be introduced to manage abandoned, poorly designed or improperly operated waste dumpsites. Frequent monitoring of all such waste dump sites is required to identify the possible health hazards to the environment and human lives and to convert them as a better standard site for reusing as a disposal spot in future. This study is clear that the potential for rehabilitation should be further pursued and continued by technically trained personnel of municipal engineering division, whose responsibility is to ensure a satisfactory operation of upgraded dump sites.
- The site selection is a complex procedure, which involves evaluating numerous factors, such as environmental, political, financial, economical, hydrological, topographical, geological, existing regulations and engineering/technical. Moreover, highly populated areas should be excluded from selection as dumpsites/landfill to safeguard the environment and human health. Further, dumpsites should not be located within 1500 m from rivers, lakes, flood plains (hydrological zone), densely populated and environmentally sensitive areas. Paying more attention to the related factors and selecting a proper waste disposal site will minimize the environmental destruction, ensure the aesthetic beauty of the area, maintain land values and reduce the health issues. EIA. HIRA and SWOT analysis should be applied to identify the suitability of the area as a disposal site. This is very essential tool to minimize environmental impacts, human health impacts and operational problems.
- The exiting legal framework, pertaining to the environment should be examined and amended, according to current requirements. The relevant amendments and addendums should be incorporated into the principal legislation. In addition, enforcement of separate waste management legislation, covering entire process of waste management is essential. Existing laws are strictly to be implemented, without any bias by proposed special
- A single person, a single institution or government alone cannot resolve solid waste related issues in sustainable manner. Combination of all stakeholders such as general public, MCs, private waste handlers, employees of MCs, provincial councils and the central government, NGOs, community based organizations, industries that generate waste, recycling industries, commercial establishments, waste pickers, scrap dealers, consultants, financial institutions, media, citizens, individual and waste processing and disposal organizations etc. should be consolidated to a focal point, under proposed integrated mechanism.

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