International Journal for Research in Applied Sciences and Biotechnology

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

www.ijrasb.com

https://doi.org/10.31033/ijrasb.9.1.15

Mapping of Environmental Pollution Risk Induced by Open Dumping Practice of Municipal Solid Waste in Karadiyana of Sri Lanka Using Geographic Information System

Thavarajah Vaigunthan[1] and B. G. N. Sewwandi[2]
[1]Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, SRI LANKA.
[2]Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, SRI LANKA.

[2]Corresponding Author: sewwandidh@kln.ac.lk

ABSTRACT

Quantification of environmental pollution risk (EPR) induced by open dumping practice of municipal solid waste (MSW) is important to improve MSW management practices and to provide effective countermeasures for mitigating EPR at the MSW open dumping site. This study targeted an open dumping site at Karadiyana, Western province of Sri Lanka and aimed to assess EPR by using geographical and hydrological information, water (landfill leachate and surface water) and soil quality monitoring for samples collected at the pollutant source (i.e., MSW dumping site) and its surrounding with monthly interval from June to December 2019 to cover both wet and dry periods. The maps of EPR induced by the pollutant source were visualized by analysing measured physicochemical parameters including heavy metals incorporating with interpolation and weighted overlay techniques of geographic information system (GIS). Results showed that the EPR map characterized well spatial distribution and seasonal variation of pollutants from the source. Especially, it was found that the pollutants flowed towards the Northwest and North from the pollutant source at the investigated site. It was also found that higher concentrations of phosphorous and heavy metals were observed from landfill leachate samples in dry season than those in wet season. The findings in this study raise the mapping of EPR would contribute to take actions for establishing environmental sound waste disposal and to promote sustainable MSW management practice in Sri Lanka.

Keywords- Municipal solid waste; Open dumping practice; Pollutant distribution; Environmental pollution risk; Geographic information system; Sri Lanka.

I. INTRODUCTION

Waste has become a crisis in the modern world. Knowingly or unknowingly each and every activity of human produces a vast amount of waste [1,2]. With the increase of population and industrial development, the amount of waste produced has also increased [2,3]. Urbanization has resulted in a significant increase in quantity and change in characteristics of MSW during last 30 years [4]. Further, annual waste generation is expected to grow by 70% in 2050 all over the world with the increasing urbanization and population growth [5].

In Sri Lanka, nearly 85 % of the waste collected all over the Island mainly in urban areas end up in open dump sites [6,7]. Although disorganized solid waste disposal has been identified to be one of the major causes for environmental degradation in the National Action Plan of Sri Lanka (1998-2011), still the most common method of municipal solid waste disposal is open dumping [8]. Open dump sites are mainly located in urban areas where large amount of waste that had been produced in the country. Meethotamulla and Karadiyana are two such open dump sites based in Colombo where most of the wastes generated in Colombo and suburbs are dumped.

Even after several years of stopping the dumping of wastes, the effects from the pollutants such as NO_3^-, SO_4^{2}, PO_4^{3-} and heavy metals which had been leached into the ground keep on contaminating groundwater and associated resources which cannot be remediated on a short-term basis. Therefore, dumping of municipal solid waste of varying composition in open dumpsites causes long term health and environmental impact. The studies have been conducted to study the pollutants released from open dumpsites [9-11], the composition of wastes dumped [11], effect of open dumpsites on the health of soil and nearby water sources [13,14] etc. However, no studies have been conducted to study the spatial distribution of pollutants once they are released to the environment and map the distribution of pollutants released from open dumpsites in Sri Lanka. Even though, mapping of hazard risk is common in disaster management, there is an emerging trend of using mapping techniques in waste management [9,10]. In this regard, GIS provides a flexible platform which integrates and analyses maps and waste management databases [12–14]. Mapping of EPR for open dumpsites/landfills is an ideal technology to identify the potential contaminants and their distribution pattern around a landfill which provides necessary information to help people to understand the risks of hazards caused by open dumping of MSW and to help proper mitigation measures. EPR map will provide details on contaminant levels, pattern of the movement of contaminants and risk areas according to the hazard levels which can be used by the governing body to apply remediation measures in these areas according to the contamination levels. Thus, this study aims to map environmental pollution risk caused by the pollutant

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

released by the biochemical reactions of wastes dumped in open dumpsites by considering the combined effect of all the pollutants released from the dumpsite, retained in the soil and pollutants added to the water bodies nearby.

II. MATERIALS AND METHODS

2.1. Study area

Karadiyana open dump site is located in the Karadiyana Grama Niladhari Division of Ratmalana Divisional Secretariat (6°48′56″ N, 79°54′16″E) in Western Province, Sri Lanka. Total area of the dumpsite is 25 acres and it consists of two sites (Site 1 and 2) where only Site 1 was used for waste dumping at the time of the study. The Karadiyana open dump site is located in a low-lying area very close to the Weras Ganga - Bolgoda Lake wetland system (Figure 1). The dump site receives 500-700 metric tons of MSW daily from 7 local authorities in Colombo District.

Only active Site (Site 1) of the dump site was selected for the study. Sampling points were selected on the periphery of the dump site (A1 to A6), 100 m away from the periphery of the dump site (B1 to B5) and 500 m away from the periphery of the dump site (C1 to C3), as shown in Figure 1.

Figure 1: Location of Sampling points at Karadiyana MSW open dumping site and its surrounding (Map data © 2021 Google)

2.2. Sample collection and analysis

Leachate and soil samples were collected from the sampling sites A1 - A6. The leachate is being discharged from the dumpsite to the nearby canal around the dumpsite and mixed with water. Therefore, water and soil samples were collected from sampling sites B1-B5 and C1 - C3 (Figure 1).

In each sampling event, 500 mL of leachate and water samples were collected from the points selected. At the same time, soil samples were collected at a depth of 50 cm from the soil surface in selected sampling sites. Samples were collected monthly from June to December 2019.

2.3. Analysis of physicochemical parameters

The collected samples were filtered through a 0.2 mm membrane and stored for chemical analysis. Temperature, pH, electrical conductivity (EC), dissolved oxygen (DO) and total dissolved solids (TDS), nitrate (NO_3^-), sulphate (SO_4^{2-}), phosphate (PO_4^{3-}), Cadmium (Cd^{2+}), and Chromium (Cr^{6+}) were measured using standard methods for collected leachate and water and soil samples [18].

2.4. Statistical analysis

The values for pH, temperature, DO, EC, TDS, nitrate, phosphate, sulphate, cadmium and chromium concentrations of each sampling point in each sampling event were subjected to two-way ANOVA in MINITAB version 14.0 software package after confining their conformity with normal distribution using Anderson Darling test and the data was transformed to log[x+1] form except pH to reduce variance. When the null hypotheses in the ANOVA were rejected, Turkey's pairwise comparisons were carried out.

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

2.5. Preparation environmental pollution risk map

The study area was extracted and digitized with the dumpsite, roads and surface water bodies from the Grama Niladhari Division map of Sri Lanka. Sampling points were placed on the study area using the coordinates obtained by GPS and all the results from the analysis were input for each sampling point under different categories of soil, water and leachate. Interpolation technique was applied by using kriging to interpolate the values of physicochemical parameters to whole study area (equation 1). Interpolated maps were reclassified into five categories of pollution risk as very low, low, moderate, high and very high for each physicochemical parameter. These reclassified maps were given weightages for each parameter in leachate, water and soil as mentioned in Table 1. Final weighted overlay map was produced with five categories of risk by considering the combined effect of all the pollutants as very low hazard, low hazard, moderately hazard, hazard and extreme hazard.

Table 1: Weightages given for parameters of water, leachate and soil for weighted overlay.

Parameter	Weightage % assigned for water and leachate	Weightage % assigned for soil
pH	6	1
Conductivity	5	2
Temperature	5	2
DO	5	-
TDS	5	-
Nitrate	8	5
Sulphate	8	5
Phosphate	8	5
Cadmium	10	6
Chromium	10	6
Total	**70**	**30**

$$\mathbf{Z(S°)} = \sum_{i=1}^{N} \lambda i Z(Si) \ldots\ldots\ldots\ldots\ldots\ldots Eq.1$$

Where:
$Z(s_i)$ = the measured value at the i^{th} location
λ_i = an unknown weight for the measured value at the i^{th} location
s_0 = the prediction location
N = the number of measured values

III. RESULTS AND DISCUSSION

3.1. Spatial variation of physio-chemical parameters of leachate samples collected at the Karadiyana Dump Site

Leachate samples were collected in the sampling locations from A1 to A6 at the periphery of the dumpsite. Spatial variation of water quality parameters pH, DO, Conductivity, temperature, TDS at sampling locations from A1-A6 is given in the Table 2. The relationship between pH and decomposition stages has been studied by several authors across the world [19, 20]. It has found in several studies that the pH of landfill leachate is increased from acidic to basic with the age of the landfill due to the biological decomposition of organic nitrogen into ammonium nitrogen [21–23]. In this study, all leachate samples collected at the periphery of the Karadiyana dump site showed a mean pH value of 7.48 which is a suitable range for methanogenic bacteria. This result tally with the findings of Joseph et al. [24] who studied about the leachate quality of Karadiyana dump site. Similar results were obtained by Tränkler et al. [25] who found that leachate samples had a slightly high pH and remained in the range of 7 - 8 during the operations which indicates the early methanogenic phase. Major landfill sites under the same climatic conditions in Sri Lanka show methanogenic conditions [26]. On the other hand, Bahaa-eldin et al. [27] found that the average value of pH was 6.7 for the municipal landfill leachate in Malaysia indicating the young leachate and the waste degradation was at its late stage of acidic phase.

EC of leachate samples ranged from 3.45 to 29.30 ms/cm indicating the presence of higher content of dissolved solids. This is further verified by the amount of TDS in leachate where it exceeds the WHO standard. According to Joseph et al. [24], high organic and inorganic solids contributed to high TSS concentration and the metal salts to high EC. High of EC is attributable to high levels of anions and cations in the landfill leachate.

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

Also, the high values TSS indicate that leachates in this study could be undergoing biodegradation, thereby increasing the solids.

Dissolved oxygen concentrations were very low around the dump site. Very low concentrations of DO in the leachate indicates that the high concentrations of biodegradable organic matter in leachate released from the dump site [22]. This is due to DO demands by the organic matter in leachate for the degradation process, which results an anaerobic condition in leachate [19].

Table 2: The spatial variation of physio-chemical parameters of leachate at the periphery of the dumpsite.

Parameter	Sampling Locations					
	A1	A2	A3	A4	A5	A6
pH	7.55 ± 0.24[a]	7.47 ± 0.18[a]	7.33 ± 0.17[a]	7.66 ± 0.21[a]	7.65 ± 0.22[a]	7.24 ± 0.30[a]
*DO (mg/L)	0.34 ± 0.06[a]	0.37[a]	0.36 ±0.050[a]	0.43 ±0.07[a]	0.42 ±0.08[a]	0.49±0.08[a]
EC (ms/cm)	22.98 ± 1.59[a]	17.79 ± 2.55[ab]	14.09 ± 3.31[ab]	9.30 ± 2.29[b]	8.02 ± 2.11[b]	18.81 ± 2.55[ab]
Temp. (°C)	29.68 ± 0.46[a]	29.45 ± 0.55[a]	29.37 ± 0.45[a]	29.18 ± 0.41[a]	29.37 ± 0.37[a]	29.17 ± 0.48[a]
TDS (g/L)	11.74 ± 0.56[a]	8.51 ± 1.18[ab]	5.46 ± 1.32[b]	5.52 ± 9.81[b]	4.83 ± 1.22[b]	11.61 ± 1.01[a]

*For each parameter, mean values indicated by different superscript letters at each row are significantly different from each other ($p<0.05$)

Figure 2 shows the variation of NO_3-N and PO_4-P variation at the periphery of the open dump site. NO_3-N content in leachate were below the standard concentration of ambient water quality for aquatic life and were not significantly different among sampling sites. Nitrate in the leachate samples were relatively low and it may be due to the anaerobic conditions prevailing which impairs the oxidization of ammonium nitrogen. However, nitrates are conservative contaminants as they are not affected by biochemical processes and natural de-contamination processes taking place inside the landfill as well as their infiltration into the unsaturated zone [24]. Therefore, the concern is still there even at low concentrations of nitrate below the standard value is capable of causing potential threat to water pollution.

As shown in Figure 2, PO_4-P content in leachate were very much higher than the standard value of ambient water quality for aquatic life [28] during the study period and the concentrations among the sampling sites were not significantly different. The high phosphate concentrations in leachate may be due to the organic load of the refuse that contains phosphorus [29]. The phosphorous containing organic material (mainly phospholipids and phosphoproteins) releases phosphorus during its biodegradation and eventually increases phosphate concentrations [30]. The presence of high PO_4-P in leachate and its presence in water increases eutrophication and correspondingly promotes the growth of algae [24]. The presence of high P in leachate implies the importance of having a treatment facility for leachate before discharging it to the environment.

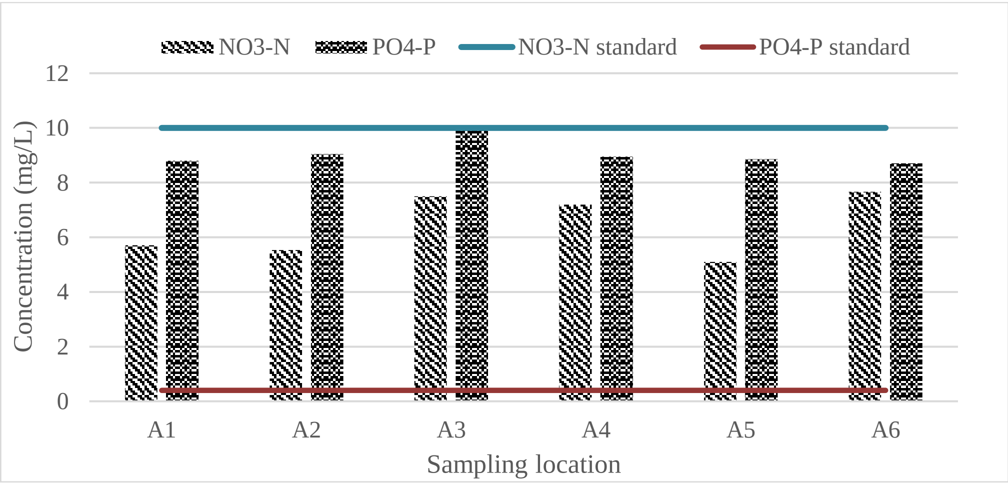


Figure 2: Spatial variation NO_3-N, PO_4-P in leachate at sampling locations A1 - A6 and respective ambient water quality standards for aquatic life

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

Cadmium concentration in leachate ranged from 13.13 to 28.36 µg/L and concentration of Cd^{2+} were significantly different ($p<0.05$) among sampling sites (Figure 3). Cadmium concentrations in all sampling sites at the periphery of the dump site (A1 – A6) are very much higher than the ambient water quality standard of 5 µg/L for aquatic life [28]. Cd is a highly toxic heavy metal for the aquatic ecosystem and the studies have shown that Cd is toxic to the aquatic organisms even when the concentration is lower than the permissible levels [31]. This shows the negative impact that can cause to the environment by continuous discharge of leachate from open dump to the nearby water canals.

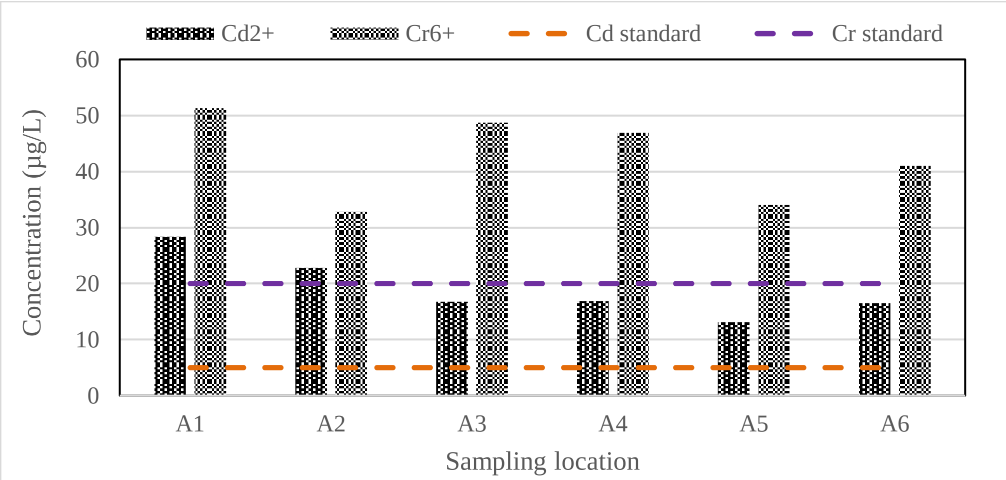


Figure 3: Spatial variation of Cd^{2+} and Cr^{6+} concentrations of leachate at sampling locations A1 to A6.

As shown in Figure 3, Cr^{6+} concentrations of leachate from sites A1-A6 are very much higher than the ambient water quality standard of 20 µg/L for aquatic life [28]. The highest Cr^{6+} concentration was observed in site A1 while lowest at site A2. The dumping of mixed MSW from different sources on the dump site may increase the concentration of Cr6+ in leachate and it is important to note that the above standard is for the total Cr. In this study, Cr^{6+} concentration was measured and even that is higher than the total Cr standard. Therefore, total Cr in leachate has to be further high in leachate discharged from the dump site.

Heavy metal concentration in all sampling locations from A1-A6 was observed as $Cr^{6+} > Cd^{2+}$(Figure 3). Concentrations of Cr^{6+} and Cd^{2+} in leachate are higher than the maximum permissible levels of ambient water quality for aquatic life [28]. Direct toxicity and biomagnification of high concentrations of heavy metals may result a worst impact on the aquatic species in the nearby surface water bodies as they are directly discharged into the surface water body that has been created around the dumpsite and will be flowing to the nearby environment.

3.2. Spatial variation of physio-chemical parameters of water samples collected at Karadiyana Dump Site

The characteristics of water samples collected at 100 m and 500 m distance from the dumpsite are shown in Table 3. Accordingly, most of the parameters show favorable condition for the environment. Very low concentrations DO of leachate have been increased with the increase in the distance from the dump site which could be due to the effect of dilution of discharged leachate to the nearby water canal surrounding the dump site. The dilution of organic matter in leachate results in less microbial activities which results in high DO in the water body.

Table 3: Spatial variation of physio-chemical parameters of water at 100 m and 500 m away from the dumpsite

Location	Sampling site	pH	DO (mg/L)	EC (ms/cm)	Temperature (°C)	TDS (mg/L)
100 m away from the dumpsite	B1	7.46 ±0.14^{a}	2.2 9± 0.26^{b}	0.42 ± 0.11^{a}	28.50 ± 0.48^{a}	153.0 ± 35.20^{ab}
	B2	7.36 ± 0.20^{a}	3.11 ± 0.34^{ab}	0.59 ± 0.10^{a}	28.23 ± 0.37^{a}	143.5 ± 45.10^{ab}
	B3	7.33 ± 0.30^{a}	3.19 ± 0.44^{ab}	0.52 ± 0.02^{a}	28.20 ± 0.60^{a}	125.1 ± 20.60^{ab}

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)
https://doi.org/10.31033/ijrasb.9.1.15

	B4	7.10 ± 0.31[a]	4.02 ± 0.49[ab]	0.40 ± 0.03[a]	28.13 ± 0.48[a]	200.6 ± 22.90[a]
	B5	7.16 ± 0.28[a]	4.29 ± 0.54[ab]	0.43 ± 0.02[a]	28.15 ± 0.47[a]	63.60 ± 20.10[bc]
500 m away from the dumpsite	C1	7.21 ± 0.29[a]	5.91 ± 1.07[a]	0.48 ± 0.05[a]	27.67 ± 0.65[a]	0.48 ± 0.03[c]
	C2	7.26 ± 0.28[a]	5.06 ± 1.08[ab]	0.45 ± 0.06[a]	27.60 ± 0.52[a]	0.51 ± 0.07[c]
	C3	7.18 ± 0.30[a]	6.47 ± 1.38[a]	0.41 ± 0.09[a]	27.12 ± 0.53[a]	0.52 ± 0.07[c]

For each parameter, mean values indicated by different superscript letters at each row are significantly different from each other ($p<0.05$)

The variation of NO_3-N and PO_4-P concentrations in water samples collected from sites B1-B5 and C1-C3 along with the respective maximum permissible levels of ambient water quality for aquatic life [28] are shown in Figure 4. Accordingly, NO_3-N concentration in sampling points at 100 m and 500 m away from the dump site are well below the standards for ambient water quality for aquatic life. However, PO_4-P concentrations at all the sampling sites were higher than the standard and decreased with increase in distance from the dump site. Low concentrations of anions near the sampling locations C1, C2 and C3 shows the effect of dilution of leachate effectiveness of an artificial water body around a dumpsite in effluent management. showed a very low concentration towards the South, West and Northwest directions. The high concentration of PO_4^{3-} released to the environment can be one of the major factors for dense growth of aquatic plants in the nearby water bodies.

Sulphate concentrations in water samples ranged from 1.01 to 65.12 mg/L and the mean values of the sampling locations 100 m away from the dumpsite (B1-B3) were higher the sampling locations 500 m away from the dumpsite (C1-C3). Although sulphate concentrations of the leachate leaching from the waste at the periphery of the dumpsite was high; moderate concentrations of Sulphate were observed around 100 m away from the dumpsite due to the dispersion and dilution effect of water.

Cadmium concentration of water samples from B1-C3 ranged from 0.88 to 19.22 µg/L and the concentrations from C1-C3 were low compared to B1-B5 ($p<0.05$). Cd^{2+}concentrations in sites B3 and B5 were significantly higher than the other sites and the ambient water quality standard for aquatic life. Cd^{2+} concentration around the dump site was high and it showed a decreasing trend with the distance. Similarly, the Cr^{6+} concentration of water samples ranged from 2.3 to 32.25 µg/L. Only Cr^{6+} concentration in site B5 were significantly higher than other sampling locations and ambient water quality standard for aquatic life. Therefore, site B5 can be identified as a critical point where most of the pollutants are accumulated and a suitable location for a treatment unit to treat landfill leachate in the Karadiyana open dumpsite.

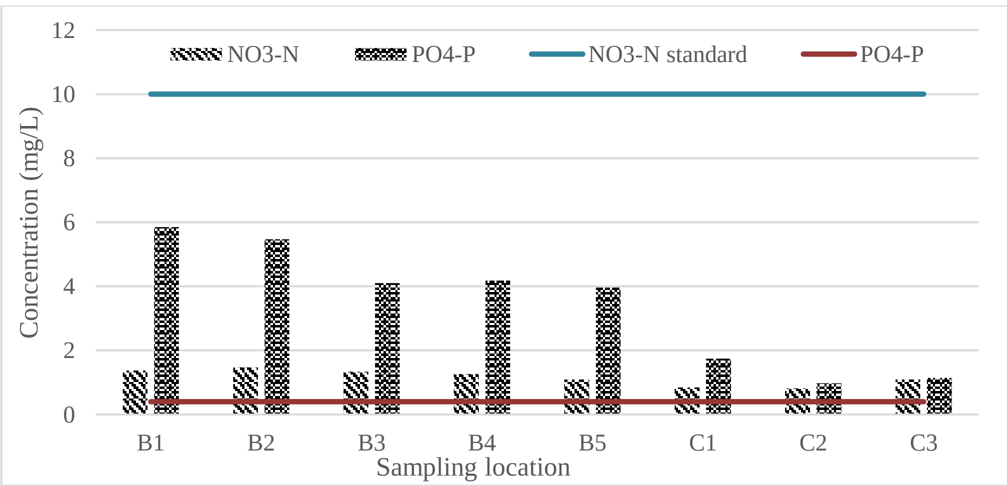


Figure 4: Spatial variation of anion concentrations in water samples from B1 – B5 and C1 - C3

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)
https://doi.org/10.31033/ijrasb.9.1.15

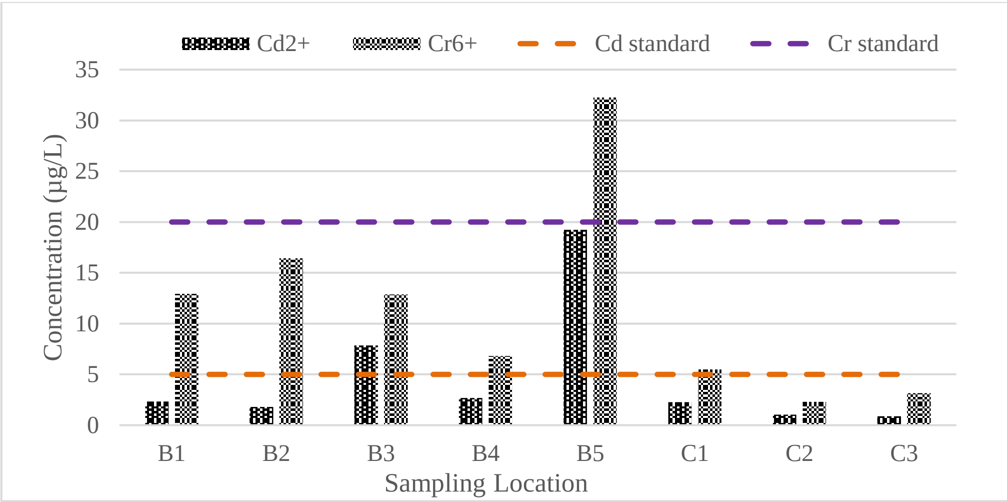
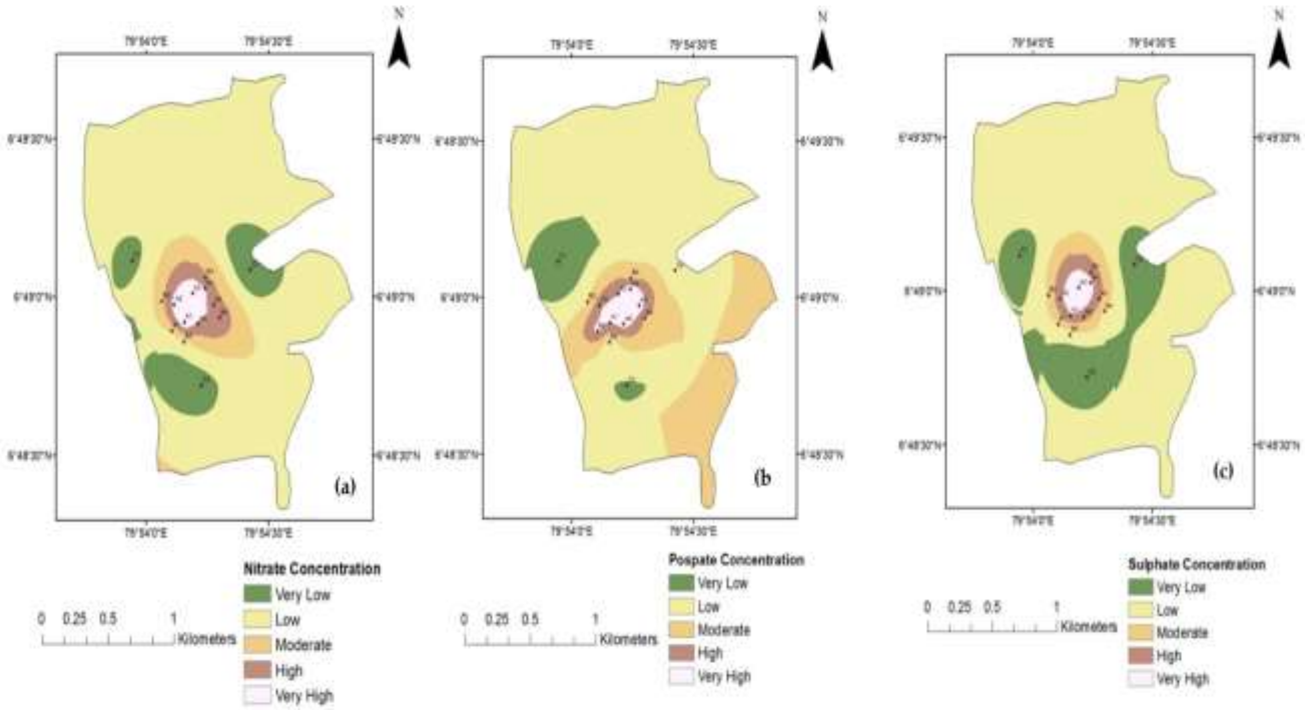


Figure 5: Spatial variation of Cd^{2+} and Cr^{6+} concentrations of sampling locations from B1 to C3.

3.3. Spatial variation of physio-chemical parameters of soil samples collected at Karadiyana Dump Site.

The leachate generated in the landfill carries numerous contaminants to the soil surface and to adjacent areas. During percolation of leachate through the soil, leachate undergoes various processes such as physicochemical decomposition process, ion exchange reactions, chemical alterations, oxidation, hydrolysis, adsorption of contaminants by the soil components etc. These reactions alter the properties of soil [32] and contaminants are get in contact with the soil at and near the landfill site [33]. Most of the pollutants will be remained in the soil while other pollutants are transported to air, ground and surface water by evaporation, erosion, and infiltration, and therefore soil must be monitored frequently. Characterization of soils collected at the dumpsite shows the importance of continuous monitoring of soil samples to control environmental pollution.

The distribution of NO_3^-, PO_4^{3-}, Cd^{2+} and Cr^{6+} are shown in Figure 6. Accordingly, all the parameters showed significant differences with distances in which a high concentration values were observed at the periphery of the dumpsite (A1-A6) and showed a decreasing trend with the increase in distance. The difference in movement of different pollutants in the soil can be due to the differences in soil characteristics and pollutant characteristics.



ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

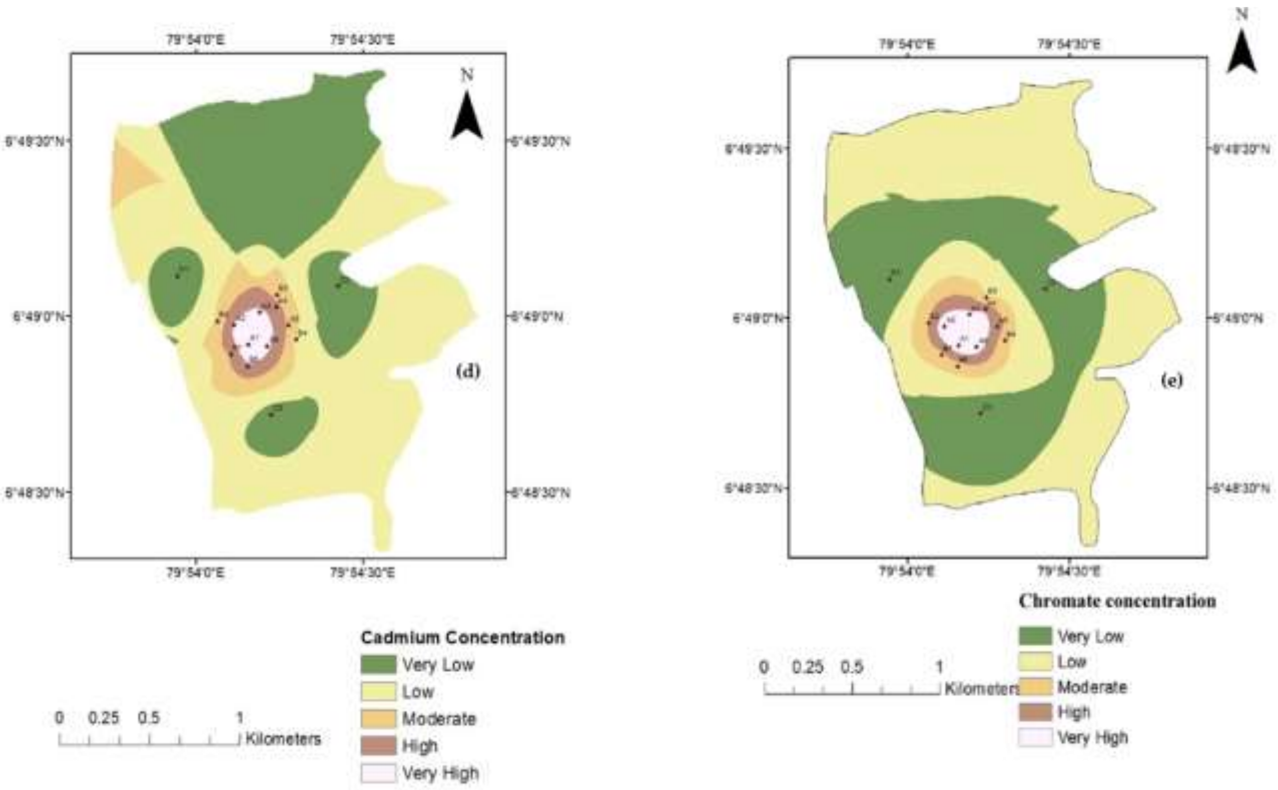


Figure 6: Spatial variation of NO_3^-, PO_4^{3-}, Cd^{2+} and Cr^{6+} in soil at the dumpsite

Nitrate concentration in soil at the periphery of the dumpsite is high (28.86 mg/kg) and the flow of Nitrate ion in soil is more towards the North and Southeast directions of the dump site (Figure 6). Moreover, the distribution of Phosphate ion showed a different trend from other anions as the flow of Phosphate ion is more towards the Southeast and Southwest sides of the dumpsite. The flow of Cadmium ion was found towards the North side of the dumpsite.

The flow pattern of Chromium is very much similar to the flow pattern of sulphate ions in the soil samples. It is not limited towards only one side of the dumpsite. Tumuklu et al. [34] have found that the leachate drained from the dumpsite due to physical, chemical and biological activities helps accumulation of heavy metals in the soil. Therefore, this shows the importance of recycling of all the possible materials without just dumping which will reduce the health and environmental risk. The developed map can be used by authorities as a tool for applying pollutant remediation measures near the dumpsite as it will help for them to apply the remediation measures only in the places where necessary.

3.4. The temporal variation of anions and heavy metals in leachate samples

Landfill leachate quality is influenced by the waste composition, the age of landfill, waste amount, rain intensity as well as the composition of municipal solid wastes [35]. Therefore, it is clear that temporal variation plays an important role in the amount of leachate that is being generated and the quality of leachate. Joseph et al. [25] has found that the leachate discharge varies from 2.4 L/s to 0.02 L/s in rainy to dry period, respectively and accordingly the composition of leachate varies. Kalčíková et al. [36] has found that there is a strong seasonal variation in the amount and composition of leachate generated in a dumpsite [36].

Figure 7 shows the temporal variation of leachate quality parameters along with the weather data (rainfall and temperature) for the sampling period. The content of NO_3^-, and Cr^{6+} in dry months was significantly higher than that of in the wet months ($p<0.05$). The sulphate and phosphate concentrations in wet and in dry months were significantly different ($p<0.05$). Depending on the category of contaminants, they end up either in water held in the soil or leached into the ground water [37]. Therefore, identifying the pollutant level in leachate is important to protect the adjacent water body and soil around the dump site.

Similar temporal variation was observed for the water samples collected at the dumpsite with a low concentration than the leachate. The reduced concentration in the water than that of the leachate can be due to the effect of dilution after leachate mixed with the water nearby the dumpsite which further proves by the lowest concentrations for all the parameters were observed in August where the highest rainfall received in the study area.

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

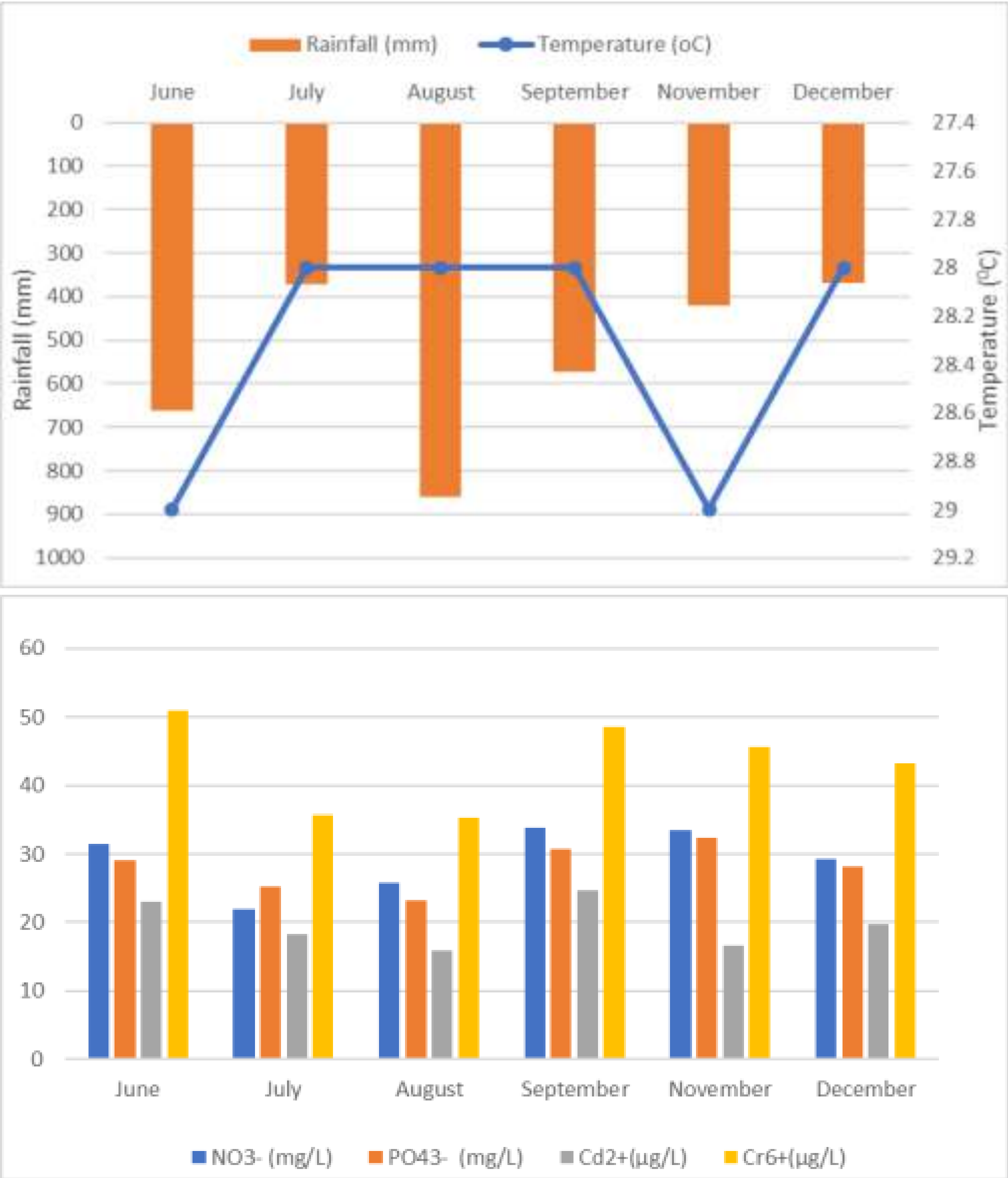


Figure 7: Temporal variation of anions and heavy metals in leachate and weather parameters (rainfall and temperature) during the study period

3.5. The temporal variation of anions and heavy metals in soil samples

Temporal variation of anions and heavy metals of soil samples and the weather data throughout the study period are shown in Figure 8. The temporal variation of the mean value for pH in dry months was significantly different and low from the mean value for pH in wet months ($p<0.05$). The temporal variation of the mean value for conductivity, temperature, Nitrate concentration in dry months was significantly different and higher than that of in wet months ($p<0.05$). There was no any significant difference among the concentrations for sulphate and cadmium in wet as well as in dry months ($p>0.05$). However, there was a significant difference among the phosphate concentration and chromium concentration values in wet and dry months ($p<0.05$).

Heavy metal concentrations were lower in soil in wet months with compared to the dry months. The trace metals available in leachate/soil can be washed away into the water bodies during the rainy period thus reducing the concentrations in soil [38]. The comparison between the mean values of all the parameters in wet and dry months of the year shows the effect of dilution in the contaminant concentrations.

The variation of pollutants in soil during the dry and wet months clearly shows that the accumulated pollutants in soil washed off during the wet months with the runoff water. Therefore, this further emphasis the importance of taking all the measures to avoid pollution of soil and nearby water bodies.

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

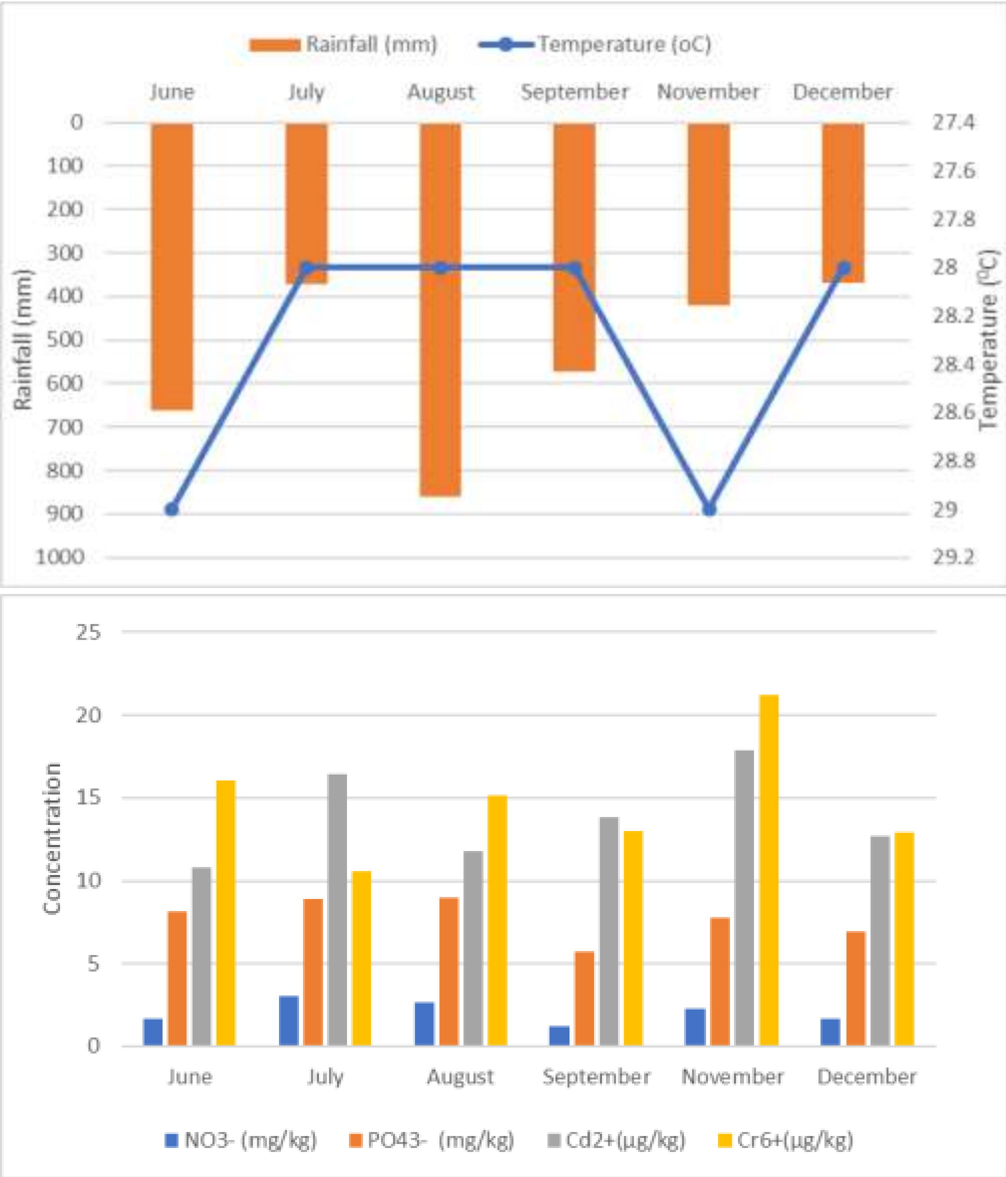


Figure 8: Temporal variation of anions and heavy metals in soil, and weather parameters (rainfall and temperature) during the study period

3.6. Environmental pollution risk map for Karadiyana dumpsite

Geographic Information System (GIS) has proven itself as a useful tool in identifying and mitigating the hazards [38,39]. Various thematic maps can be prepared by using remote sensing and GIS techniques [41]. The spatial analyst extension employs one of several interpolation tools to create surface grid in ArcGIS [42]. Kriging is a powerful statistical interpolation method used in several fields [43] in which the weights are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement of the measured points [44].

Interpolated maps were produced for individual parameters of soil, leachate and water can be used by other researchers or government bodies for any mitigatory actions on a particular parameter. For example, increasing concentration of nitrate may result in eutrophication of the surface water body. If any action is going to be implemented by government or any other responsible authority, particular mitigatory action can be concentrated on the high concentrated nitrate zones around the dumpsite.

Figure 9 shows the environmental pollution risk map developed for the Karadiyana open dumpsite by considering the important pollutant concentrations in the landfill leachate generated and soil and water collected nearby the dumpsite at varying distances from the dumpsite. Although the contaminant flow is observed in all the directions of the dumpsite, it is obvious that the contaminant flow is more towards the Northeast and North side of the dumpsite. Near the periphery on the

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

North side of the dumpsite, the pollutants have been concentrated more as the leachate infiltrated to the soil without flowing over the land resulting high concentrations of pollutants in soil in North area, resulting an extreme hazard zone near the sampling location A3. Contaminant concentration decreases drastically with a small distance variation from the dumpsite and the zone of diameter of about 150 m around the dumpsite is identified as moderately hazard zone. Surface water body around the dump site plays a major role in diluting the contaminant concentration and therefore the concentration in surface water body decreases drastically and the zone of diameter of 150 m - 500 m is characterized as low hazard zone.

Mapping of environmental pollution risk maps for individual and collective effect of pollutants will help not only the readers, but also the municipal authorities, engineers and regulatory bodies in decision making process for landfill design, operation and maintenance. Further studies have to be carried out to find out the toxicological effect of these containments from the dumpsite on the freshwater species such as fishes which are harvested from the nearby surface water bodies.

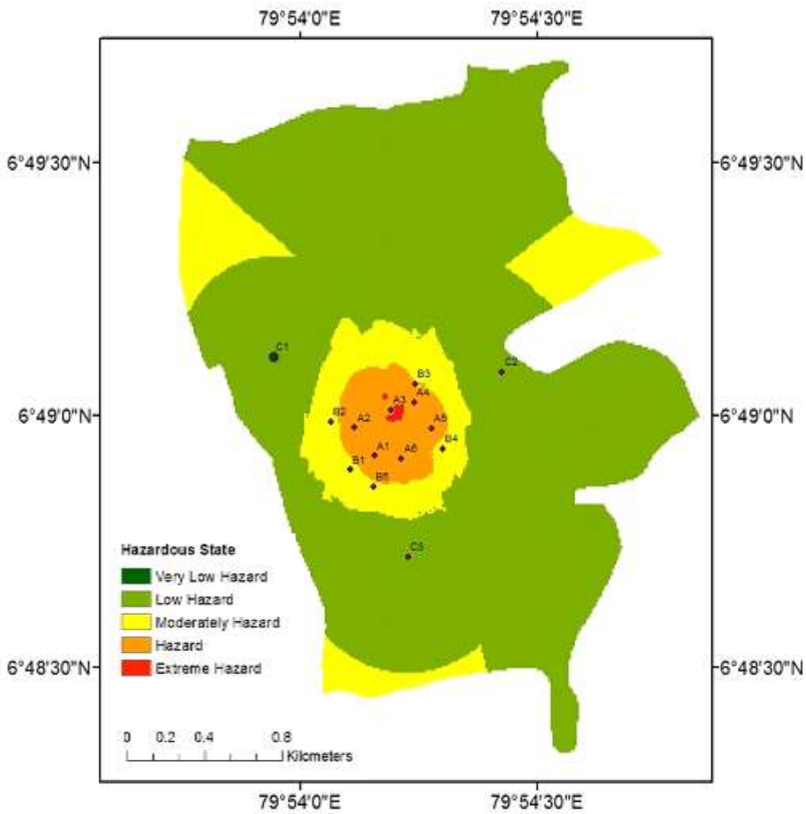


Figure 9: Environmental pollution risk map developed for Karadiyana open dumpsite based on pollutant concentrations in landfill leachate, water and soil nearby the site

IV. CONCLUSION

The study investigates the level of contaminants and the extent to which it has spread and the flow pattern of each and every contaminant in Karadiyana open dumpsite along the distance. Further, the study elevates the effects of open dumpsite on surface water as well as on soil. Conductivity, Total dissolved solids, and Phosphate concentrations of leachate samples were higher than the ambient water quality standards for aquatic life. Contaminant concentrations in the surface water around the dumpsite showed a decreasing trend with the distance from the dumpsite. Contaminant concentration is high in the surface water body near the dump site as leachate is added with the water without any treatment and the contaminant concentration shows a decreasing trend with the distance because of the dilution effect. Conductivity and nitrate concentrations in the soil samples were very much higher near the dumpsite than other parameters. Accumulation of contaminants directly affect the soil near the dumpsite. With the runoff trace metals and other contaminants are being washed away from the dumpsite into the nearby surface water body and dilution affected the contaminant concentration in rainy seasons of the year. Remote sensing and GIS technology is an efficient tool for delineating the flow pattern of contaminants and to identify different hazard zones around a dumpsite. Weighted overlay method is very useful for integration of thematic layer and mapping of contaminant's concentrations. According to the Environment pollution risk map developed, the area around the dumpsite have been classified into five groups as very low hazard, low hazard, moderately hazard, hazard and extremely hazard. The flow of contaminant concentration is more towards the Northwest and North side of the dump site and extreme hazard zone lies on that area. More priority should be given for extremely hazard and hazard zones when mitigation measures are being applied.

REFERENCES

[1] Amasuomo, E. and Baird, J. "The Concept of Waste and Waste Management," *Journal of Management and Sustainability*, vol. 6, no. 4, p. 88, Nov. 2016, doi: 10.5539/JMS.V6N4P88.

[2] Chandler, A. J., Eighmy, T. T., Hjelmar, O., Kosson, D. S., Sawell, S. E., Vehlow, J.,Sloot, H. A. "Municipal Solid Waste Incinerator Residues: The International Ash Working Group (IAWG)," Elsevier Science B.V.,Netherland, 1997, vol. 67, p. 974, ISBN 0-444-82563-0

[3] Hazra, T. and Goel, S. "Solid waste management in Kolkata, India: Practices and challenges," *Waste Management*, vol. 29, no. 1, pp. 470–478, Jan. 2009, doi: 10.1016/J.WASMAN.2008.01.023.

[4] Bandara, N.J.G.J., Hettiaratchi, J.P.A., Wirasinghe, S.C. and Pilapiiya, S. "Relation of waste generation and composition to socio-economic factors: A case study," *Environmental Monitoring and Assessment*, vol. 135, no. 1–3, pp. 31–39, Dec. 2007, doi: 10.1007/S10661-007-9705-3.

[5] Wowrzeczka, B. "City of Waste—Importance of Scale," *Sustainability, 2021*, Vol. 13, Page 3909, vol. 13, no. 7, p. 3909, Apr. 2021, doi: 10.3390/SU13073909.

[6] Bandara, N.J.G.J. "Municipal Solid Waste Management - The Sri Lankan Case," *Proceedings of International Forestry and Environment Symposium*, vol. 0, no. 0, Oct. 2011, doi: 10.31357/FESYMPO.V0I0.21.

[7] Karunarathne, H. M. L. P. "Municipal Solid Waste Management (MSWM) in Sri Lanka." 1st National Symposium on Real Estate Management and Valuation. pp 113-126

[8] Bandara, N.J.G.J. and Hettiaratchi, J.P.A. "Environmental impacts with waste disposal practices in a suburban municipality in Sri Lanka," *International Journal of Environment and Waste Management*, vol. 6, no. 1–2, pp. 107–116, 2010, doi: 10.1504/IJEWM.2010.033987.

[9] Bekti, R. D., Suryowati, K. and Tanty, H., "Mapping of Mn and Pb as Effect of Landfill Pollutant based on Ordinary Kriging Interpolation," *American Journal of Environmental Science*, vol. 13, no. 3, pp. 245–250, 2017, doi: 10.3844/ajessp.2017.245.250.

[10] Spokas, K., Graff, C., Morcet, M. and Aran, C., "Implications of the spatial variability of landfill emission rates on geospatial analyses," *Waste Managment*, vol. 23, no. 7, pp. 599–607, 2003, doi: 10.1016/S0956-053X(03)00102-8.

[11] Enkhtur, B., "Geostatistical Modelling and Mapping of Air Pollution," *ITC acedemic*, p.44,2013,[Online].Available:http://www.itc.nl/library/papers_2013/msc/gfm/enkhtur.pdf.

[12] Samarakoon, M. B., Suresh. K. and Amarawardana. D., "Reducing the Volume of Municipal Solid Waste in Karadiyana Dumpsite by Using Compaction Method," *Proceedings in Engineering, Built Environment and Spatial Sciences, 9th International Research Conference-KDU, Sri Lanka*, 2016,pp. 90–95.

[13] Amano, K. O. A., Danso-Boateng, E., Adom, E., Kwame Nkansah, D., Amoamah, E. S. and Appiah-Danquah, E. "Effect of waste landfill site on surface and ground water drinking quality," *Water Environment Journal*, vol. 35, no. 2, pp. 715–729, 2021, doi: 10.1111/wej.12664.

[14] Sharma, A., Gupta, A. K. and Ganguly, R. "Impact of open dumping of municipal solid waste on soil properties in mountainous region," *Journal of Rock Mechanics and Geotechnical Engineering*, vol. 10, no. 4, pp. 725–739, 2018, doi: 10.1016/j.jrmge.2017.12.009.

[15] Pandey, P. C., Sharma, L. K. and Nathawat, M. S. "Geospatial strategy for sustainable management of municipal solid waste for growing urban environment," *Environmental Monitoring Assessment, 2011*, vol. 184, no. 4, pp. 2419–2431, doi: 10.1007/S10661-011-2127-2.

[16] Kontos, T.D., Komilis, D.P. and Halvadakis, C.P. "Siting MSW landfills on Lesvos island with a GIS-based methodology," *Waste Management & Research*, 2003, vol. 21, no. 3, pp. 262–277, doi: 10.1177/0734242X0302100310.

[17] Zamorano, M., Molero, E., Hurtado, Á., Grindlay, A. and Ramos, Á. "Evaluation of a municipal landfill site in Southern Spain with GIS-aided methodology," *Journal of Hazardous Materials*, vol. 160, no. 2–3, pp. 473–481, Dec. 2008, doi: 10.1016/J.JHAZMAT.2008.03.023.

[18] APHA, (1998), Greenburg A.E., Rhodes T.R., and Lenore S.C. Standard Methods for the Examination of Water and Waste water, 20th edition, APHA/AWWA/WEF.

[19] Tumer, A.R., Karacaoglu, E., Namli, A., Keten, A., Farasat, S., Akcan, R., Sert, O. and Odabaşi, A.B. "Effects of different types of soil on decomposition: an experimental study," *Legal Medicine, Tokyo*, 2013 vol. 15, no. 3, pp. 149–156, , doi: 10.1016/J.LEGALMED.2012.11.003.

[20] Haslam, T.C.F. and Tibbett, M. "Soils of Contrasting pH Affect the Decomposition of Buried Mammalian (Ovis aries) Skeletal Muscle Tissue," *Journal of Forensic Sciences*, 2009, vol. 54, no. 4, pp. 900–904, doi: 10.1111/J.1556-4029.2009.01070.X.

[21] Sewwandi, B.G.N., Takahiro, K., Kawamoto, K., Hamamoto, S., Asamoto, S. and Sato, H. "Characterization of landfill leach ate from municipal

ISSN: 2349-8889
Volume-9, Issue-1 (January 2022)

https://doi.org/10.31033/ijrasb.9.1.15

solid wastes landfills in Sri Lanka," 2012. International Conference on Sustainable Built Environment.
[22] Samadder, S.R., Prabhakar, R., Khan, D., Kishan, D. and Chauhan, M.S. "Analysis of the contaminants released from municipal solid waste landfill site: A case study.," *Science of the Total Environment*, vol. 580, pp. 593–601, Dec. 2016, doi: 10.1016/J.SCITOTENV.2016.12.003.
[23] Omofunmi, O.E., Satimehin, A.A., Olasunkanmi, J.B. and Akinsorotan, A.M. "Evaluation of ground and surface waters around dumpsites in ado-ekiti, Nigeria", FUOYE Journal of Agriculture and human ecology, 2017, vol. 1, no.3, PP.47-58.
[24] Fatta, D., Papadopoulos, A. and Loizidou, M. "A study on the landfill leachate and its impact on the groundwater quality of the greater area", The journal of Environ. Geochem. Health, 1999, vol.21, pp.175- 190.
[25] Tränkler, J., Visvanathan, C., Kuruparan, P. and Tubtimthai, O. "Influence of tropical seasonal variations on landfill leachate characteristics--results from lysimeter studies," *Waste Managment*, 2005, vol. 25, no. 10, pp. 1013–1020, doi: 10.1016/J.WASMAN.2005.05.004.
[26] Wijesekara, S.S.R.M.D.H.R., Mayakaduwa, S.S., Siriwardana, A.R., de Silva, N., Basnayake, B.F.A., Kawamoto, K. and Vithanage, M. "Fate and transport of pollutants through a municipal solid waste landfill leachate in Sri Lanka," *Environmental Earth Sciences*, 2014, vol. 72, no. 5, pp. 1707–1719, doi: 10.1007/S12665-014-3075-2.
[27] Rahim, B.E.A., Yusoff, I., Samsudin, A.R., Yaacob, W.Z.W. and Rafek, A.G.M. "Deterioration of groundwater quality in the vicinity of an active open-tipping site in West Malaysia," *Hydrogeology Journal*, 2010, vol. 4, no. 18, pp. 997–1006, doi: 10.1007/S10040-009-0567-3.
[28] Akazemi, A., Habibollah, Y. and Bahramifar, N. "Assessment of the Variations in the Composition of the Leachate Generated in Open Dumps in Three Provinces of the Caspian Sea region, Iran", Iranian Journal of Toxicology, 2013, vol 7, pp. 22.
[29] Fatta, D. Papadopoulos, A. and Loizidou, M. "A study on the landfill leachate and its impact on the groundwater quality of the greater area," *Environmental Geochemistry and Health*, 1999, vol. 21, no. 2, pp. 175–190, doi: 10.1023/A:1006613530137.
[30] Central Environmental Authority (Sri Lanka), 2019. National Environmental Act No.47 of 1980. "Ambient water quality standards," *The Gazette of the Democratic Socialist Republic of Sri Lanka*, vol. 2017, no. I, p. 4.
[31] Okocha, R. C. and Adedeji, O. B. "Overview of cadmium toxicity in fish," *Jounal of Applied Sciences and Research*, 2011, vol. 7, no. 7, pp. 1195–1207.
[32] Pillai, S., Peter, A.E., Sunil, B.M. and Shrihari, S. "Soil Pollution near a Municipal Solid Waste Disposal Site in India," *In International Conference on Biological, Civil and Environmental Engineering (BCEE-2014)*, 2014, vol.1718, doi: 10.15242/IICBE.C0314080.
[33] Kanmani, S. and Gandhimathi, R. "Assessment of heavy metal contamination in soil due to leachate migration from an open dumping site," *Applied Water Science*, 2012, vol.3, no.1, doi: 10.1007/s13201-012-0072-z.
[34] Tumuklu, M. G. Yalcin, M. Sonmez. "Detection of Heavy Metal Concentrations in SoilCaused by Nigde City Garbage Dump," *Polish Journal of Environmental Studies*, 2007, vol. 16, no. 4, pp. 651–658.
[35] Farhana Zakaria, S.N. and Abdul Aziz, H. "Characteristic of leachate at Alor Pongsu Landfill Site, Perak, Malaysia: A comparative study," *IOP Conference Series: Earth and Environmental Science*, 2018, vol. 140, no. 1, p. 012013, doi: 10.1088/1755-1315/140/1/012013.
[36] Kalčíková, G., Vávrová, M., Zagorc-Končan, J. and Žgajnar Gotvajn, A. "Seasonal variations in municipal landfill leachate quality," *Management of Environmental Quality: An International Journal*, 2011, vol. 22, no. 5, pp. 612–619, doi: 10.1108/14777831111159734.
[37] Essienubong, I. A., Okechukwu, E. P. and Ejuvwedia, S. G. "Effects of waste dumpsites on geotechnical properties of the underlying soils in wet season," *Environmental Engineering Ressearch*, 2019, vol. 24, no. 2, pp. 289–297, doi: 10.4491/EER.2018.162.
[38] Osadchyy, V., Nabyvanets, B., Linnik, P., Osadcha, N. and Nabyvanets, Y. "Processes determining surface water chemistry," 1st Edition, Springer International Publishing, Switzerland, 2016, p. 265.
[39] "The Use of GIS in Natural Hazard Mitigation." Available at: http://www.edc.uri.edu/nrs/classes/nrs409509/509_2002/Crosby.htm [Accessed 24 Sep. 2021].
[40] N. P. Hapuarachchi, "The Usage of Geo-information and Technology in Disaster Management by Sub National Level Organizations Case Study-Ratnapura in Sri Lanka," 2008. Available at: https://webapps.itc.utwente.nl/librarywww/papers_2008/msc/gim/hapuarachchige.pdf [Accessed 24 Sep. 2021]
[41] Adeyinka K. Akanbi, Santosh Kumar, Uwaya Fidelis. "Application of Remote Sensing, GIS and GPS for efficient Urban Management Plan, A case study of part of Hyderabad city." 2013. Novus International Journal of Engineering & Technology, 2013, vol.2, no.(4), pp.14.
[42] "Comparing interpolation methods—ArcGIS Pro | Documentation." Available at: https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/comparing-interpolation-methods.htm [Accessed 24 Sep. 2021].
[43] B. C. Childs and E. E. Services, "Interpolating Surfaces in ArcGIS Spatial Analyst."
[44] "How Kriging works—Help | ArcGIS for Desktop." Available at: https://desktop.arcgis.com/en/arcmap/10.3/tools/3d-analyst-toolbox/how-kriging-works.htm [Accessed 24 Sep. 2021].