Spatial Distribution of pH & Cd in Surface Water around an Open Landfill

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Abstract

Open dumping of municipal solid waste (MSW) is the most common way of handling solid waste in Sri Lanka due to the high cost involved with advanced technologies for handling, lack of technical capacity, lack of knowledge-how to manage landfill sites, and so on. The Kelaniya provincial council also operates an open waste dumping site at Manelgama area in Kelaniya. This garbage dumping has been carried out continuously several years in this property without any sort of proper management. And this landfill is surrounded with a channel. So, in this situation, this area and water of this channel has been polluted. So I decided to do a research for the surface water of this channel with the rainfall to find out the effect of this landfill to the water of the channel. The objective of this study is to find out the distribution of pH & Cd in surface water of this channel. For that collected water samples from this channel in rainfall & dry events after 1hr, 5hrs and next day because of the differentia of the leachate with the environmental conditions (Dry & Wet events). For the collected samples, general water quality parameter pH and heavy metal Cd were measured. With the coordinates of this sample points, measured values was plotted using ArcGIS to represent the distribution of pH & Cd. From the final result we can deduce that after a rainfall event pH value is increased and in dry event pH value is decreased. That is in a wet event water is to be base and in a dry event water is to be acid. With the final maps & graphs further we can say that most of the points are in acidity in every events. That is directly we can say that the water in that channel is always in acidity and polluted due to the landfill. When considering Cd we can deduce in a low rainfall intensity the pollution is little bit. And then in a medium rainfall intensity, it was high because not only the amount of rain, specially the time to be taken for the rainy that is rainfall speed causes for the pollution. But in high rainfall intensity, when I observed it wasn't much polluted. Because with the high speed of rainfall and the flowing speed of water in the channel, the contaminants was added to the water and flowed to the downward of the channel passing considering points. Finally we can say with the rainfall, the water of this channel is more polluted and by flowing the contaminants are spread to the downward of the channel network.

Keywords: cadmium, landfill, pH, rainfall intensity, spatial distribution

Introduction

In Sri Lanka, much of the drinking water comes from surface water bodies such as lakes and rivers. It is crucial for public health that these water sources remain clean and free from pollution. Surface waters are susceptible to contamination from surrounding environments, necessitating regional efforts for their protection. Pollution can arise from both point sources and non-point sources, the latter being more challenging to identify and regulate. Non-point source pollution typically results from runoff traveling over various land uses within a watershed. Public agencies must monitor water quality to locate and mitigate these pollution sources.

The Kelaniya provincial council operates an open waste dumping site near a water channel, which acts as a pollution source, especially during rainfall when leachate can enter the channel. This channel is a tributary of the Kelani River, and pollution issues have persisted for some time. This study examines the pollution problem in the channel due to the landfill, focusing on rainfall intensity and its impact on water quality. Physical measurements included rainfall intensity and climate change, while chemical assessments focused on pH and dissolved cadmium (Cd). Water quality parameters were monitored at seven locations in the channel over one month, encompassing various meteorological conditions (wet and dry events) with different rainfall intensities. The data analysis aimed to identify contamination sources affecting the water quality in the channel.

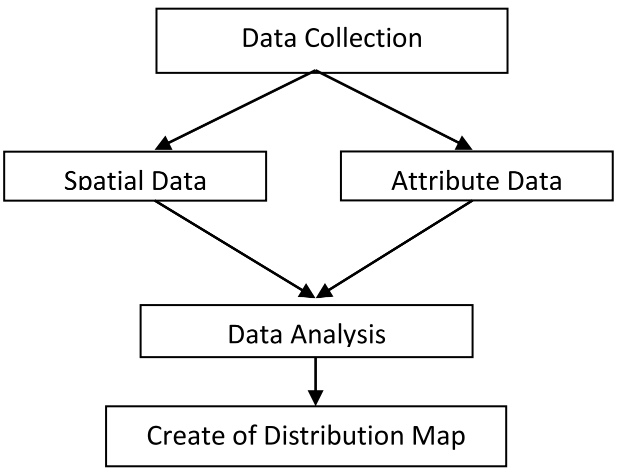


Figure 1: Sketch of the Methology.

Source Water Management

Source water is untreated water from streams, rivers, lakes, or underground aquifers which is used to supply private wells and public drinking water systems. Source water management consists of protecting and treating source water to obtain adequate drinking water for a population. Source waters are protected from pollution as much as possible to reduce risks to public health. In addition, protecting a source water can be more economical than treating unprotected waters to obtain clean drinking water. Source water protection programs also protect valuable ecosystems for fish, other aquatic species, and wildlife, as well as preserve the natural environment for some recreational activities.

Surface Water Pollution

Surface water sources should be protected as much as possible from contamination by harmful pollutants. Potential pollutants include microorganisms, inorganic chemicals, organic chemicals, and radio nuclides. Completely protecting source water may not be possible because pollutants from the atmosphere can enter a surface water through precipitation, and contaminated ground water can introduce pollutants through recharge. However, limitations on land use around a surface water can reduce contamination of surface waters from the watershed itself. Surface waters can be polluted by industrial and municipal discharges which may cause runoff of pollutants. Both direct discharges and runoff can include human and animal waste.

Point Source Pollution

Point source pollution, such as pipe discharges, industrial outflows, tributaries, or waste water treatment plant outflows are relatively easy to define and regulate. So direct discharges from a landfill is a point source pollution. There is no any Pollution Discharge Elimination System in Sri Lanka to eliminate waste water. In this systems, should not take into account the amount of pollutant that can safely be added to a specific water body without degrading that water. Therefore, the amount of pollutant that is allowed from a discharger is not dependent upon the size of the water body or the number of other dischargers to the water body and Total Maximum Daily Load can be calculated such that surface water can receive from all sources of Pollution and still meet water quality standards.

Non-point Source Pollution

Non-point source pollution occurs when rainfall moves over or through the ground, collecting natural and human pollutants that enter surface waters. Common pollutants include fertilizers, herbicides, and insecticides from agriculture; oil and toxic chemicals from urban runoff; sediment from poorly managed construction sites; salt from irrigation; and bacteria from livestock waste and faulty septic systems. In landfills, many of these pollutants can be found.

Non-point source pollution poses significant challenges for surface waters, primarily because identifying the pollution source is often difficult. Control measures for non-point sources are problematic, as land use surveys and water quality sampling are typically the only methods to pinpoint potential sources. Rainfall exacerbates non-point source pollution, and there is no systematic approach to effectively protect water from these sources.

Water Regulations

There are different water types in source waters based on uses. That is drinking water, waste water, etc. For that types have different regulations and limitations. Values of parameters in different waters is vary according to the contaminants and contained constituent. These limitations is provided the protection of water.

Drinking Water

Source water protection involves assessing and safeguarding drinking water sources, groundwater wells, and surface water collection systems. The safety and accessibility of drinking water are critical global concerns, as contaminated water can pose health risks from infectious agents, toxic chemicals, and radiological hazards. Enhancing access to safe drinking water significantly improves public health. The quality of drinking water is a key environmental determinant of health, and ensuring its safety is essential for preventing waterborne diseases. The World Health Organization’s Guidelines for Drinking-water Quality provide over 50 years of guidance that informs national regulations and standards for water safety. These guidelines recommend limits on harmful naturally occurring constituents, including a pH of 6.5-8.0 and cadmium (Cd) at 0.003 ppm, while the Environmental Protection Agency (EPA) sets the limit for Cd at 0.005 ppm.

Waste Water

Wastewater is water that has been used and contains dissolved or suspended solids, adversely affected by human activities. It can originate from domestic, industrial, commercial, or agricultural sources, as well as surface runoff and stormwater. Municipal wastewater, commonly referred to as sewage, is typically transported through combined or sanitary sewers and treated at wastewater treatment plants before being discharged into receiving waters via an effluent pipe. In areas lacking centralized sewer systems, on-site wastewater systems, including septic tanks and drain fields, are used for treatment. The management of wastewater falls under the broader category of sanitation, which also includes human excreta, solid waste, and stormwater management. Sewage specifically refers to domestic wastewater contaminated with feces or urine, while sewerage encompasses the physical infrastructure—pipes, pumps, and channels—used to transport sewage to treatment or disposal points.

Cadmium

Cadmium is used in the steel industry and in plastics, with cadmium compounds being common in batteries. It enters the environment through wastewater and diffuse pollution from fertilizers and air contamination. Drinking water can be contaminated by impurities in galvanized pipes, solders, and some metal fittings. Food is the primary source of daily cadmium exposure, with an oral intake estimated at 10–35 µg. Smoking also significantly contributes to cadmium exposure.

While elements like copper and zinc are essential for human health, cadmium is not; its ingestion primarily occurs through terrestrial foods, such as plants grown in contaminated soil and meat from animals that consume these plants. It's estimated that 98% of ingested cadmium comes from terrestrial sources, with only 1% from aquatic foods like fish and shellfish and another 1% from drinking water.

Chronic exposure to cadmium mainly affects the kidneys, lungs, and bones. A connection has been established between cadmium exposure and proteinuria, which indicates kidney dysfunction (WHO 1992, OECD 1994). Cadmium accumulates in the renal cortex, and studies suggest that urinary excretion increases when cadmium levels in this area reach about 200 to 250 µg/g (wet weight).

Landfill leachate

Leachate is the liquid that drains from a landfill, varying in composition based on the landfill's age and waste type. It contains both dissolved and suspended materials. The term "leachate" typically refers to landfill leachate, though it applies to any liquid produced by leaching, which occurs when water percolates through permeable materials.

In temperate and tropical climates, landfills inevitably produce leachate, regardless of efforts to minimize waste through reduction, reuse, recycling, and composting. As landfilling will continue for many years, managing leachate generation and ensuring its safe disposal to prevent pollution remains a significant challenge.

Water quality

Water quality refers to the chemical, physical, biological, and radiological characteristics of water, measuring its condition relative to the needs of various biotic species or human purposes. It is typically assessed against standards that address ecosystem health, human safety, and drinking water requirements. Agencies make political and technical decisions when setting these standards, considering different uses and the natural conditions of water bodies.

Environmental scientists study these systems to understand their function and identify contaminants, while lawyers and policymakers work to create legislation that ensures appropriate water quality for identified uses. Most surface water on Earth is neither potable nor toxic, particularly when excluding seawater, which is too salty to drink.

Water quality is often perceived simply as an indicator of pollution; however, it is a complex issue tied to Earth's ecology. Major causes of water pollution include industrial and commercial activities, agricultural runoff, urban runoff, and untreated sewage discharge. Collected data is analyzed to assess relationships between water quality parameters and rainfall intensity using tools like ArcGIS.

Literature Review

Landfill leachate

Municipal Solid Waste (MSW) is a global issue, generating vast amounts of waste each year. In many developing countries, MSW is often dumped without proper sanitary practices, leading to groundwater contamination. Leachate from these landfills accumulates and percolates through soil, carrying toxic substances and pathogens, with concentrations varying based on waste composition (Mor et al., 2006; Alker et al., 1995). Sugirtharan and Rajendran (2011) studied groundwater quality near a landfill in Thirupperumthurai, Batticaloa, analyzing 20 well water samples for parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), hardness, phosphate, nitrate, copper, lead, and coliform populations. The results indicated that all parameters, except for pH, exceeded acceptable limits for safe drinking water, highlighting the significant pollution caused by the landfill. This underscores the critical need for sustainable waste management practices to protect groundwater quality.

Surface water quality

Surface water bodies can be polluted by both point and nonpoint source pollution, with the latter being difficult to locate and regulate. Nonpoint source pollution arises from runoff traveling over various land uses within a watershed, making it challenging to pinpoint the origins (EPA, 2005g). Elbag (2005) assessed surface water quality by examining physical, chemical, and microbiological characteristics to evaluate the impact of surrounding land uses on the West Boylston Brook (WBB) watershed in Massachusetts, USA. The study aimed to identify water quality parameters indicative of pollution. Seven sampling locations were selected to represent different land uses in the watershed. The analysis included measures of organic matter, particles, and indicator organisms such as fecal coliforms and E. coli. Water quality was evaluated over four seasons, allowing for trend analysis by site and season, followed by correlation analysis among parameters. This research is vital as much of the U.S. drinking water comes from surface water bodies like lakes and rivers, necessitating the protection of these sources to ensure public health. The findings underscore the complexity of maintaining clean surface waters and highlight the need for regional protection efforts.

Spatial distribution of water quality

Water quality in rivers and lakes is essential for human existence, but population growth and urbanization significantly affect it (Sharma et al., 2004). This decline comes from increased pollutants from both point and non-point sources. Point sources involve direct discharges from residential, industrial, and commercial areas (Goonetilleke et al., 2005), while urban stormwater runoff is a major non-point source of pollution (Bannerman et al., 1993). A study by Athukorala et al. (2010) examined water quality variations in the Kelani River, analyzing nine parameters—pH, turbidity, electrical conductivity (EC), chloride (Cl-), chemical oxygen demand (COD), dissolved oxygen (DO), biochemical oxygen demand (BOD), total coliforms, and Escherichia coli (E. coli). Water samples were collected over a 7 km stretch from January 2010 to October 2012 at three sites representing different land uses. Principal Component Analysis (PCA) was used to explore correlations between parameters, revealing significant variations tied to land use types. The study recommended targeting non-point sources, such as stormwater runoff, in pollution mitigation strategies. It also identified EC as a reliable indicator of chloride concentration and suggested using PCA for future water quality studies in Sri Lanka.

Effect of weather condition to the leachate

Landfill emissions include gaseous volatile organic compounds, airborne particulate matter, and landfill leachate, with leachate generation posing significant environmental concerns, especially at open dumpsites (Slack et al., 2005). Landfill leachate is highly contaminated, and its composition varies over time and across sites due to factors such as waste composition, precipitation, moisture content, climatic changes, site hydrology, waste compaction, and environmental interactions (Kulikowska & Klimiuk, 2008; Umar et al., 2010). A study conducted by students at Saitama University and The University of Tokyo aimed to characterize landfill leachate from municipal solid waste landfills in Sri Lanka during wet and dry seasons. Samples were collected from 12 landfill sites in areas including Matale, Hambantota, and Galle. The analysis included general water quality parameters (pH, EC, DO, ORP, SS), organic pollutants (BOD5, COD, TOC, TN, TP), anions and cations (Cl-, $SO4^{2}$-, NH4+, etc.), and heavy metals (Cr, Mn, Fe, Pb, etc.). Results indicated that pollutants such as F-, Cl-, $PO4^{3}$-, NH4+, and BOD5 exceeded Sri Lankan standards. The BOD5/COD ratio ranged from 0.01 to 0.6, with the highest value observed in Kolonnawa. Electrical conductivity (EC) values were also high, suggesting that biological treatment alone may not effectively reduce heavy metal pollutants. The study highlighted the significance of precipitation in leachate generation during wet seasons and the contributions of groundwater inflow and biological decomposition.

Cd

Soil degradation is significantly influenced by the accumulation of heavy metals, defined as metal elements with an atomic mass greater than calcium and a density exceeding 5 g/cm^3 when present in toxic concentrations (Koc, 1994; Sanecki, 1995; Kabata-Pendias & Pendias, 1999; Rosik-Dulewska, 2007). While these metals are natural components of the environment, they pose a serious hazard to biological systems and human health. Metals like cadmium, lead, copper, and zinc present a high degree of risk, while arsenic poses a medium risk (Koc, 1994; Kabata-Pendias & Pendias, 1999; Gambu & Gorlach, 2001). Heavy metals tend to affect animal organisms before plants; the safe levels for plants can be toxic for human or animal consumption (Koc, 1994; Gambu & Gorlach, 2001; Zgnilicka, 2002). These metals are prone to bioaccumulation and can be absorbed by living organisms, potentially crossing biological barriers like the blood-brain barrier, binding to proteins, and damaging nucleic acids.

A major concern is evaluating various factors affecting soil quality. Adverse changes in soil properties can reduce fertility and render land unproductive (Biernacka & Małusznyski, 2007; Wiecki et al., 2007). The leaching of metals such as lead, cadmium, and mercury into groundwater is particularly alarming, threatening drinking water quality and posing health risks (Terelak et al., 1995; Gambu & Gorlach, 2001; Karwaczynska et al., 2005). Domska and Warechowska (2008) investigated the impact of a municipal waste landfill on heavy metal content in soil near Wgorzewo, Poland. Soil samples were collected at various distances from the landfill, and analyses revealed cadmium levels ranging from 0.12 to 0.15 mg/kg of dry matter, significantly exceeding WHO standards, indicating a high risk. This thesis further characterizes landfill leachate for cadmium, linking it to serious health issues such as lung cancer and damage to vital organs.

pH

The term pH measures the concentration of hydrogen ions in a solution, ranging from 0 to 14, with 7 being neutral. Water with a pH below 7 is acidic, while above 7 is alkaline. The health effects of pH in drinking water depend on its range. The U.S. Environmental Protection Agency classifies pH as a secondary drinking water standard, recommending a range of 6.5 to

8.5. Extreme pH levels can have pronounced health effects. Elevated pH above 11 can irritate the skin, eyes, and mucous membranes, while low pH values below 4 can cause corrosion and irritation. Acidic water can leach heavy metals from plumbing systems, leading to serious health issues. The Water Systems Council warns that these toxic metals, such as lead, pose neurological and reproductive risks, including seizures and miscarriages. Aquatic wildlife also suffers; fish die-offs occur when pH levels drop below 4.5 or rise above 10 (Northeastern Regional Aquaculture Centre, University of Maryland). External factors, including bedrock degradation, acid rain, and wastewater discharge, can cause pH fluctuations. Given that over 60% of public water supplies come from surface water sources (U.S. Geological Survey), low pH levels can exacerbate toxic effects, increasing ammonia levels and disease-causing bacteria. Therefore, characterizing pH is essential in water quality research, including the work presented in this thesis, which also examines pH in landfill leachate.

Methodology

Study Area

The study area is in Kelaniya, Gampaha district, Western province, Sri Lanka and 10 Km far from Colombo. The considering Landfill is very close to the Colombo - Kandy main road and this area is called as Manelgama. This area can be identified as urban area. The population density of that area is very high because of the small distance to Colombo. This landfill is spread out about 0.4 Km2 area and surrounded with a channel network as fig. 3.2. The water quality data for this study was collected from this channel. For that selected some special point in this channel according to the situation of landfill.

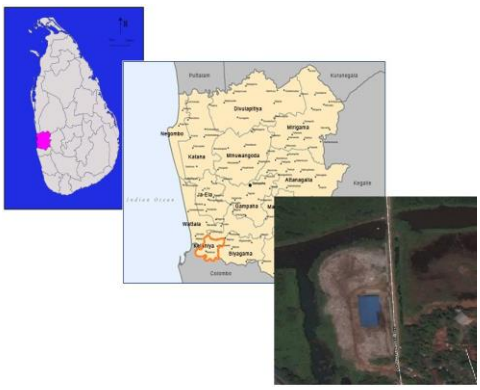


Figure 2: Map of Study Are

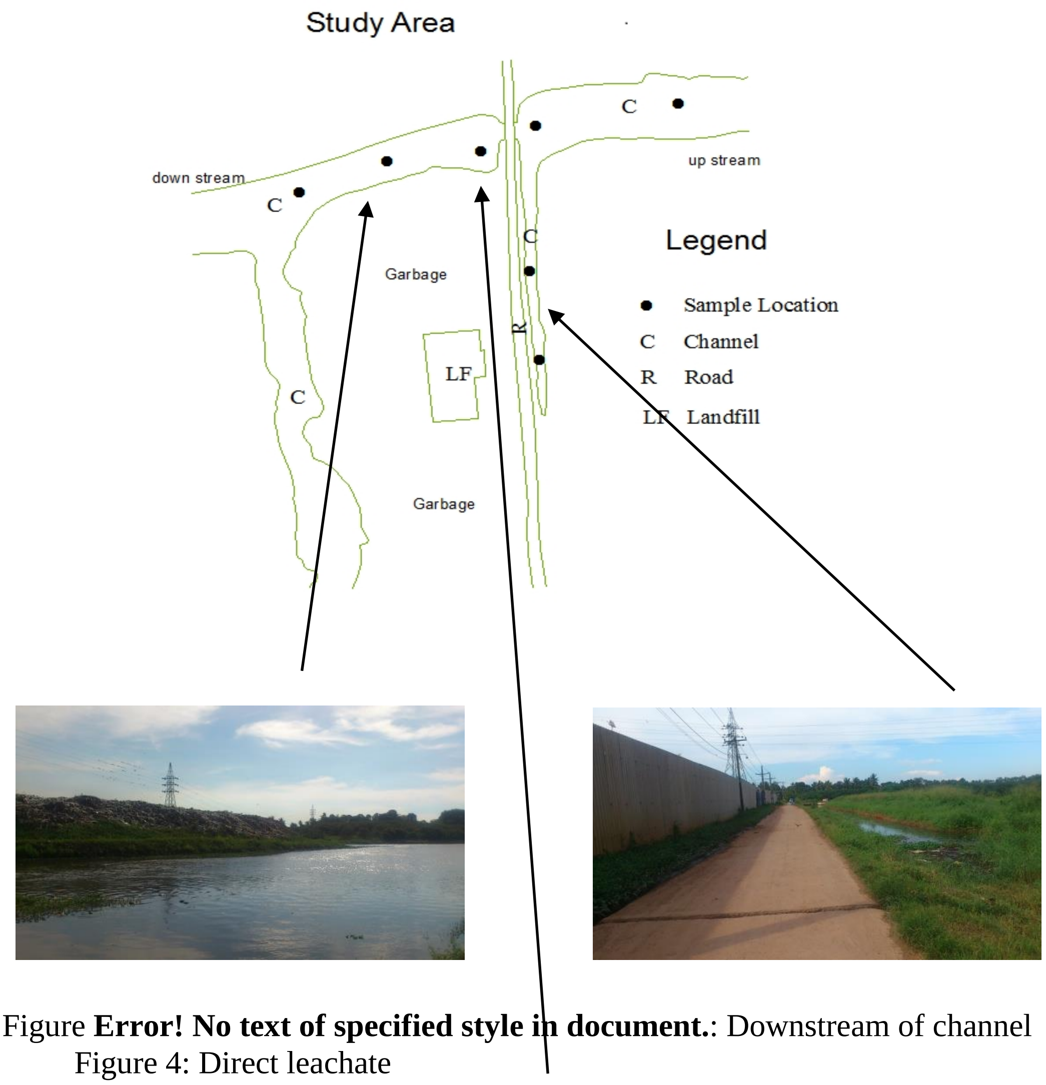


Figure **Error! No text of specified style in document.**: Downstream of channel
Figure 4: Direct leachate

Figure 5: Direct leachate to the channel

This figure shows the real pictures of the special locations as the area of two direct leachate points and the downstream of the channel in the study area.

Experimental Design

Pollutant leachate to the surface water of the channel is happened through the water which is passing through the landfill. So when considering that amount of water, the amount of pollutant which added to the channel is also can be increased. The only one source that passes the water to the channel through the landfill is rain. So this study is designed to analyze the water quality with the rainfall and the dry event which is as the comparison of the rainfall event. because of if the water is polluted in a rainy in a dry event the leachate is decrease and with the sunlight it is to be clean the waste water by flowing. There for in a rainy day after a rainfall took the samples and then in the dry event with the increasing of sunlight took samples. For the study these two events are defined as wet event and the dry event. In the rainfall event, the relevant rainfall intensity is measured. So the water samples were taken with three set of which is having different rainfall intensities. Then two sets of samples for adjacent dry events for that rainfall events are collected. That is the collecting of water samples for the water quality monitoring of the channel is done with the precipitation.

Sampling Locations

For the data collection, seven sample locations were selected along the channel branches which are covered by the landfill to determine the possible sources of pollution to the channel. Selected the first point as base point that it is in the very upward of the main channel of the channel network. because there should be a point without pollution from the landfill as the base point. Second point is selected as the point which passes the water to the downward of the main channel through the road. Third point is a special point that leachate the waste water to the channel directly. Fourth and the fifth point is selected towards the downward of the main channel. Sixth and the seventh points selected from another branch of the channel that feed in to the main channel and the seventh point is also the direct leachate point to this channel branch across the road from a drainage which is cut across the road.

The coordinates of sampling locations were taken using simple GPS display app using a smart phone.

Figure 6: Simple GPS Software.

Sampling dates

Sampling was done approximately once a month from 8th of July 2015 to 25th of July 2015. A total of five sampling events completed over the 18 days. Sampling events included both wet and dry weather conditions. Three of sampling events were done in rain event and the other two sampling events were done in dry events.

But water samples for the Next Day of Dry Event 1 could not collected.

According to the following table the sampling data is collected in wet event and the dry event.

Table 1: Sampling dates.

Event	Time	Day
Wet Event 1	1 hr	8^{th} July 2015
	5hrs	9^{th} July 2015
	Next day	
Dry Event 1	1 hr	10^{th} July 2015
	5hrs	
	Next day	11^{th} July 2015 (Null)
Wet Event 2	1 hr	11^{th} July 2015
	5hrs	
	Next day	12^{th} July 2015
Dry Event 2	1 hr	13^{th} July 2015
	5hrs	
	Next day	14^{th} July 2015
Wet Event 3	1 hr	24^{th} July 2015
	5hrs	
	Next day	25^{th} July 2015

Sampling Procedure

For storing the collected samples used new thick plastic bottles. The bottles is cleaned with liquid tea pole and distilled water and all the equipment used for water collecting is washed with distilled water. After cleaning, all were dried very well. Labelled these bottles according to the event and the time duration. Water samples were collected after a rainfall within 1hr, 5 hrs and next day and also same as in dry event also. In every time of sampling the water is collected for all the seven sampling locations. But in the 2nd dry event, water samples for the Next Day event could not be able to collect because of the rainy. So thence started the collection of water sampling related to the 2nd Wet Event.

Figure 7: Sampling Bottles.

Transporting and storing samples

Water samples were collected in to the 250 ml bottles and 98 water samples were transported to the laboratory. After collecting the water sampling bottles were stored in refrigerator till the samples was tested and When it transport from the study area to the laboratory of faculty of Applied Science, it is stored in the dry ice because to give the same conditions.

Figure 8: Storing in Dry Ice.

Laboratory Analytical Procedures

The water quality parameters that were measured at laboratory of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka. They provide the facility to measure pH and Cd water quality parameters for collected water samples. When the collected samples were carried to the laboratory, pH is measured promptly. First allow to the samples to became the room temperature at that time. Then using pH meter, pH values of the collected water samples were measured. Then 50 ml of the from all the water samples were filtered by using filter funnel, conical flask and filter paper and after filtering added the concentrated HNO3 (Ar) filtered water for the preservation of waste water till the Cd is measured. Finally after finishing measuring pH all the data is measured for the heavy metal Cd using AAS (Atomic Absorption Spectrophotometer).

pH standard method

The pH of the sample water was measured with a PC 700 pH meter in accordance with Standard Method 4500-H+(APHA et al.,1998). Sample water was poured into a small clean beaker from the 250 ml sample bottle after inverting several times. The pH meter was calibrated before use with 4, 7, and 10 pH buffers. The pH probe was then placed in the sample and the value read from the digital readout of the calibrated pH meter.

Figure 9: pH Meter.

Cd standard method

Figure 10: Atomic Absorption Spectrophotometer.

Before measuring Cd, about one litre of HNO3 (Ar) was added to the water samples. For that AA24FS instrument is used. For that 1000 ppm company standard is used. First create a standard series from 0.5, 1, 1.5, 2 and then found out the absorbance for these standards. Then using these values, the standard curve was created according to the given values in the following table.

Table 2: Standard Series for Absorption.

Standard	Absorbance	Concentration
CALZERO	-0.0011	0.00
Standard 1	0.2519	0.5
Standard 2	0.4147	1.0
Standard 3	0.4747	1.5
Standard 4	0.5354	2.0

Created curve for cadmium standard using above absorbance is as follows;.

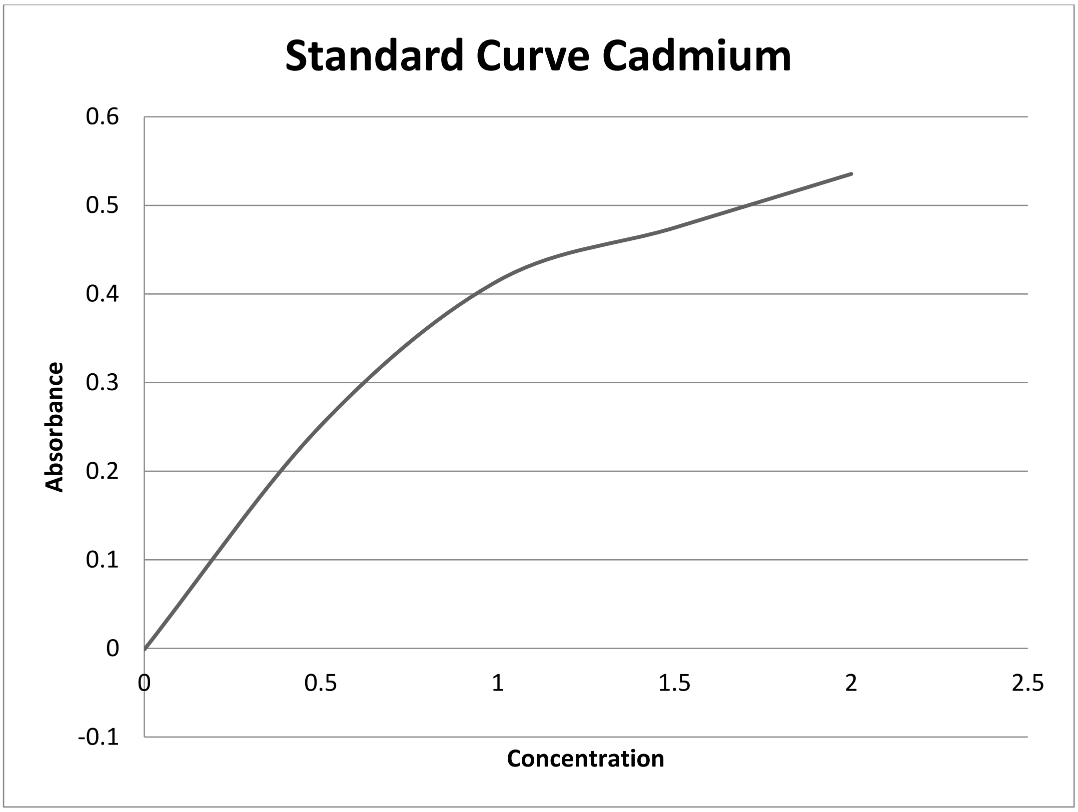


Figure 11: Standard Curve for Cadmium.

Then filtered 50 ml water samples were entered to the AAS for measuring Cd concentration. The absorbance for the entered sample was detected from the AAS and then according to the created standard curve the concentration was calculated for the relevant water sample from the computer.

Data analysis

First create the database for data which is to be analyzed. Collected coordinates of the sample points were save in the Excel sheet and they plotted on the Google Earth by using Excel to KML online . Then found out the corrected coordinates of the sample locations comparing plotted points using Google Earth. Then these corrected coordinates entered to the excel sheet. Importing this excel sheet to the ArcGIS create a point layer. After that digitizing to create KML files for the boundary of channel. Then create the polygon layer for the boundary also to the database which is going to be analyzed.

Then entering the pH and Cd values, two excel sheet were created. Then importing these created the database. Using this database created the distribution map within the boundary of channel for every sampling event by using IDW interpolation method in ArcGIS software. Produced 14 distribution maps for pH and 14 maps for Cd. Then mean values of points for pH and the Cd for the different three rainfall intensities were calculated. Then created the graphs for seven sampling points under rainfall intensity by using these mean values.

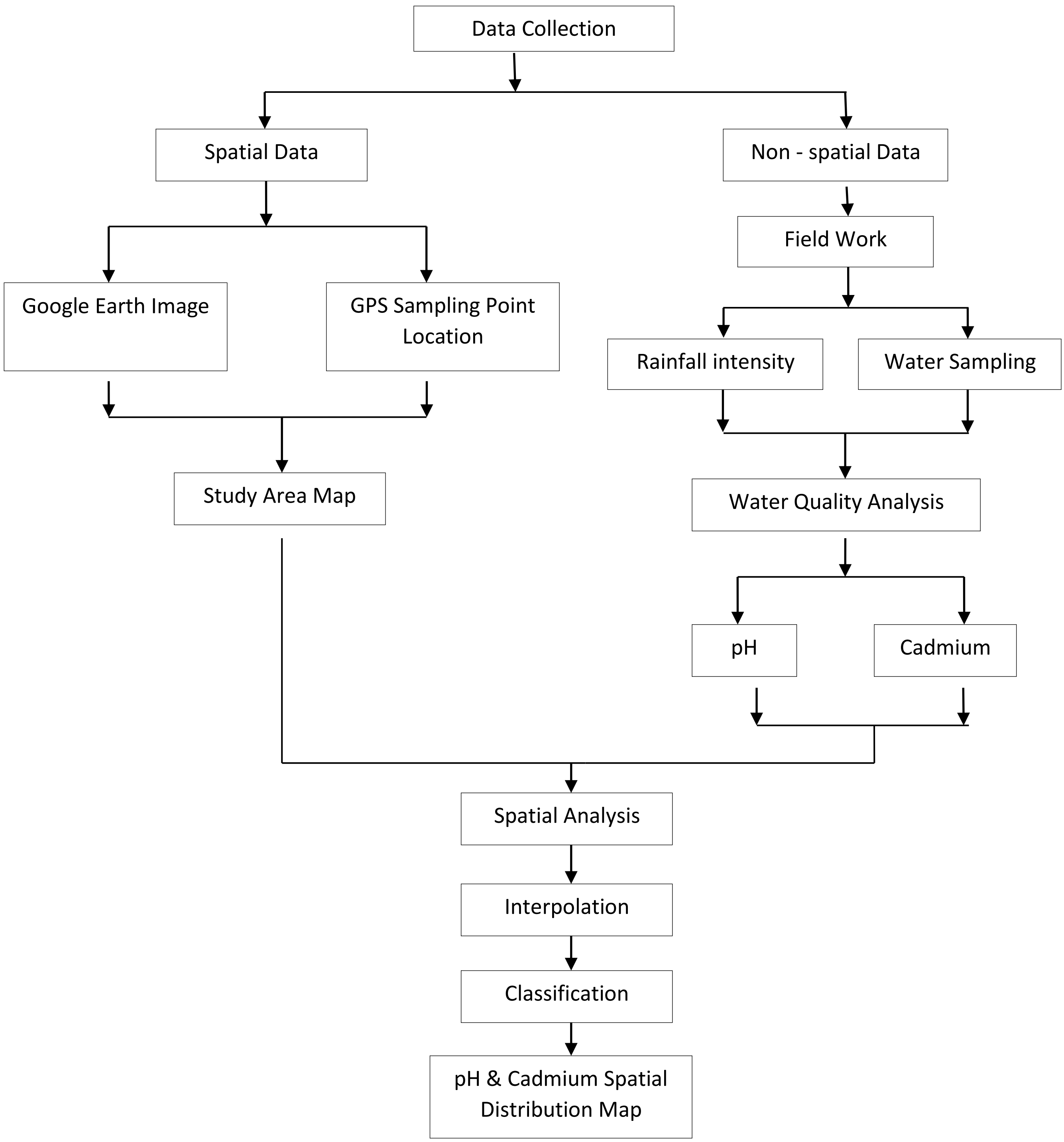


Figure 12: Data Analysis Diagram.

Results and Discussion

Water quality parameters pH and Cd were measured over wet and dry seasons at seven sampling locations in the channel network in Kelaniya. This channel feeds into the Kelani River, which serves as a drinking water source for the western province. This chapter presents information on the water quality at the different sampling locations and during different seasons are presented in the channel.

Following table shows the obtained values for Cd for all the collected water samples.

Table 3: Cd Values of Sampling.

Event	Time	point 1	point 2	point 3	point 4	point 5	point 6	point 7	RF Intensity
RF 1	1 hr	0.013	0.012	0.005	0.006	0.007	0.006	0.006	
RF 1	5 hrs	0.007	0.01	0.014	0.013	0.009	0.007	0.01	
RF 1	next day	0.013	0.008	0.008	0.011	0.007	0.009	0.011	1.5mm
DF 1	1 hr	0.008	0.006	0.005	0.005	0.005	0.008	0.011	
DF 1	5 hrs	0.01	0.009	0.008	0.007	0.006	0.002	0.006	
DF 1	next day								
RF 2	1 hr	0.012	0.007	0.016	0.013	0.01	0.008	0.014	
RF 2	5 hrs	0.011	0.014	0.012	0.011	0.009	0.014	0.011	10.9mm
RF 2	next day	0.017	0.011	0.011	0.017	0.01	0.016	0.013	
DF 2	1 hr	0	0.006	0.002	0.006	0.007	0.003	0.006	
DF 2	5 hrs	0.007	0.004	0	0.007	0.005	0.003	0.006	
DF 2	next day	0.006	0.004	0.007	0.005	0.004	0.002	0.007	
RF 3	1 hr	0.028	0.032	0.038	0.034	0.032	0.029	0.034	
RF 3	5 hrs	0.03	0.031	0.027	0.028	0.029	0.032	0.031	6.6mm
RF 3	next day	0.031	0.028	0.028	0.027	0.031	0.027	0.029	

Following table shows the obtained values for pH for all the collected water samples.

Table 4: pH Values of Sampling.

Event	Time	point 1	point 2	point 3	point 4	point 5	point 6	point 7	RF Intensity
RF 1	1 hr	6.14	6.22	6.36	6.37	6.37	6.68	6.67	
RF 1	5 hrs	6.36	6.35	6.43	6.48	6.64	6.79	6.7	1.5mm
RF 1	next day	6.34	6.42	6.55	6.53	6.74	6.82	6.96	
DF 1	1 hr	6.42	6.36	6.46	6.44	6.45	6.8	6.78	
DF 1	5 hrs	6.48	6.52	6.59	6.52	6.59	6.78	6.89	
DF 1	next day								
RF 2	1 hr	6.43	6.53	6.49	6.53	6.5	6.85	6.75	
RF 2	5 hrs	6.56	6.53	6.77	6.63	6.57	6.97	6.86	10.9mm
RF 2	next day	6.53	6.53	6.6	6.59	6.71	6.91	6.76	
DF 2	1 hr	6.49	6.54	6.54	6.57	6.59	6.76	6.7	
DF 2	5 hrs	6.65	6.58	6.6	6.64	6.61	6.86	6.77	
DF 2	next day	6.42	6.63	6.69	6.67	6.66	6.96	6.72	
RF 3	1 hr	6.57	6.63	6.65	6.61	6.6	7.08	7.11	
RF 3	5 hrs	6.46	6.52	6.78	6.61	6.59	7.19	7.26	6.6mm
RF 3	next day	6.53	6.47	6.55	6.6	6.56	7.32	7.29	

Final result:

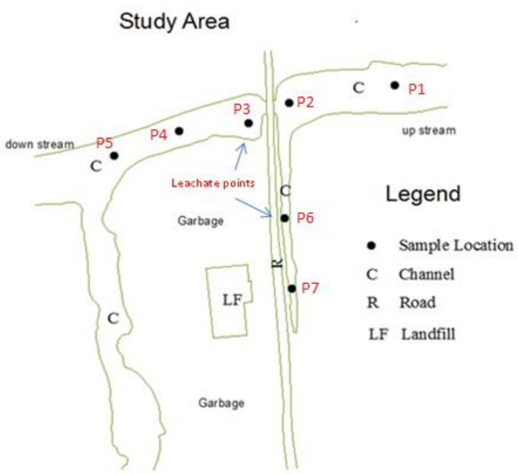


Figure 13: Map of Study Area.

For the following results P1 considered as point 1in the graphs below, same as for P2, P3, P4, P5, P6, P7 also.

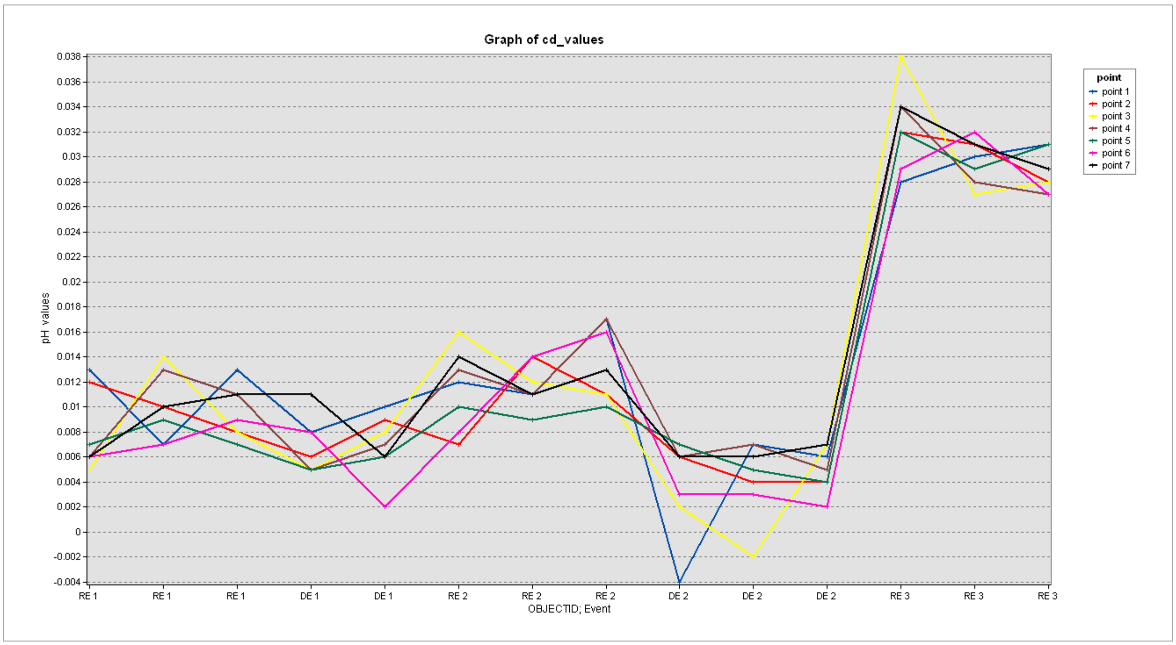


Figure 14: Graph of Cd values under different events.

When considering the mean Cd variation of points with respect to the rainfall intensity in,

Low rainfall intensity (1.5mm)	-It variants 0.004-0.014
Medium rainfall intensity (6.6mm)	-It variants 0.027-0.038
High rainfall intensity (10.9mm)	-It variants 0.007-0.017

According to that we can deduce that,

In low and high rainfall, considering points are not much polluted. But in medium rainfall the considering points are not most polluted with high Cd concentration. But in every dry event after the rainfall the Cd concentration is reduced. And also in every rainfall event the point 3 & 4 are the most polluted points.
Justification: Point 3 is direct leachate point & 4 is the adjacent point of 3 in the downward of the channel.

After a long period of rainy (after 5hrs) the point 6 & 7 somewhat polluted but less than 3 & 4. Justification: Point 7 is also direct leachate point which is in the upward of the channel and less closed to the dumping area than point 3.

Point 1 & 2 are also polluted after long period of the rainy (next day). Point 1 and 2 are the point which are in the upstream of the channel. So we can deduce that polluted water of point 6 & 7 is flowing to the area of point 2 and the contaminants which was in the upstream of the channel are flowed to the down. So point 1 and 2 are polluted. But because of the low speed of the flowing, the time consumed to be polluted is high.

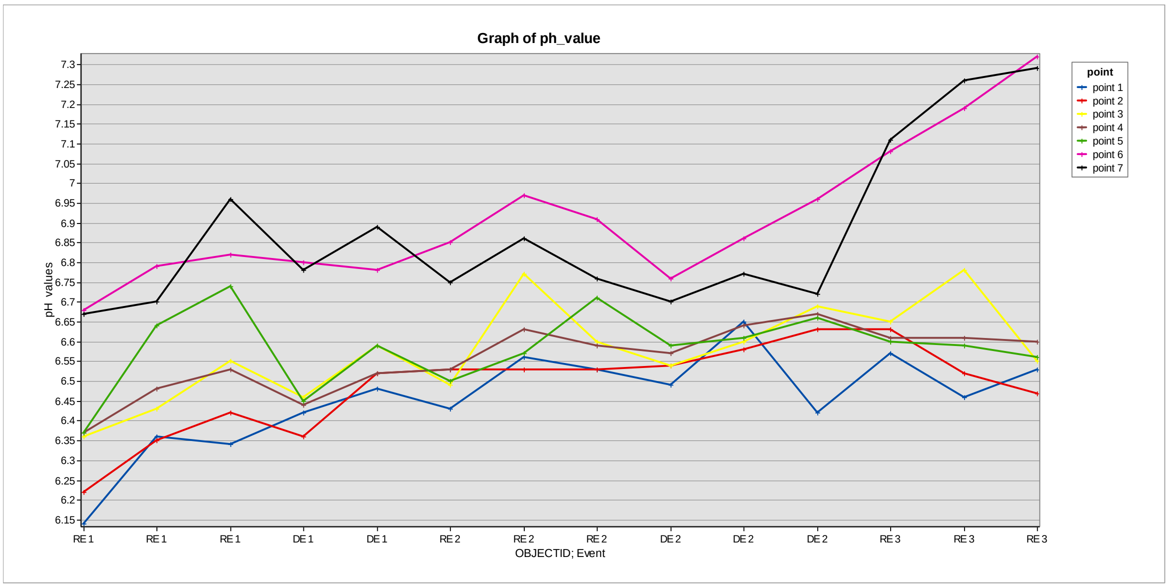


Figure 15: Graph of pH values under different events.

When considering the mean pH variation of points with respect to the rainfall intensity in,

Low rainfall intensity (1.5mm)	-It variants 6.35-6.8
Medium rainfall intensity (6.6mm)	-It variants 6.52-7.22
High rainfall intensity (10.9mm)	-It variants 6.5-6.75

According to that we can deduce that,

After a rainfall event pH value is increased and in dry event pH value is decreased. That is water is alkaline during a wet event and water acidic during a dry event. With the above graph it can be said that most of the points are acidic during every events. So it was observed that at all times, the water of the channel showed a certain level of acidity and have polluted. Only point 6 and 7 can reach to the neutral water (pH =7) in a dry event, but again in rainfall event the water is to be acidic .

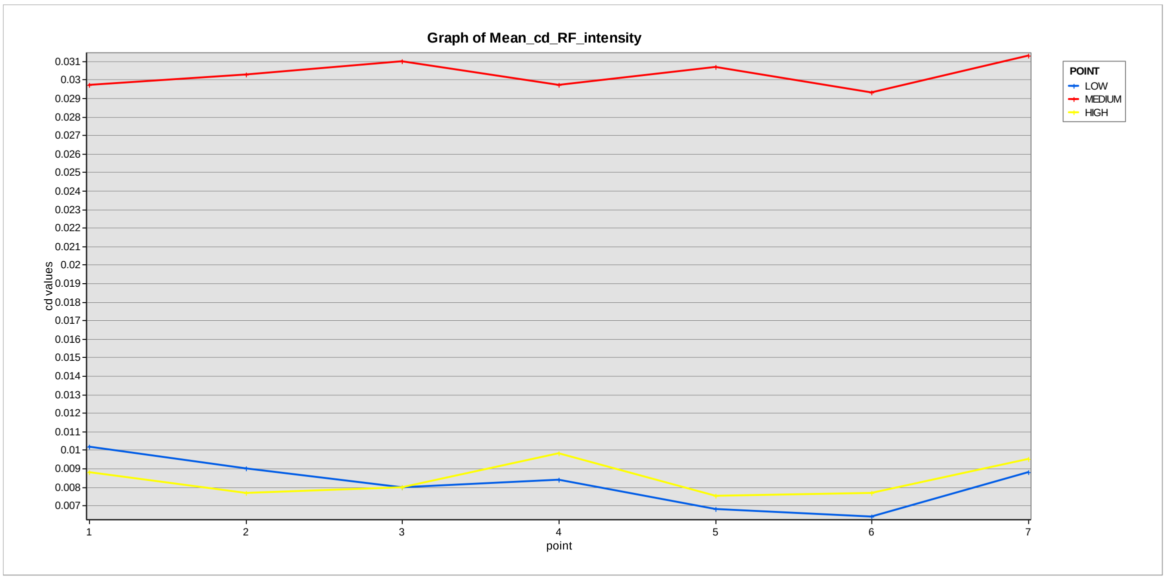
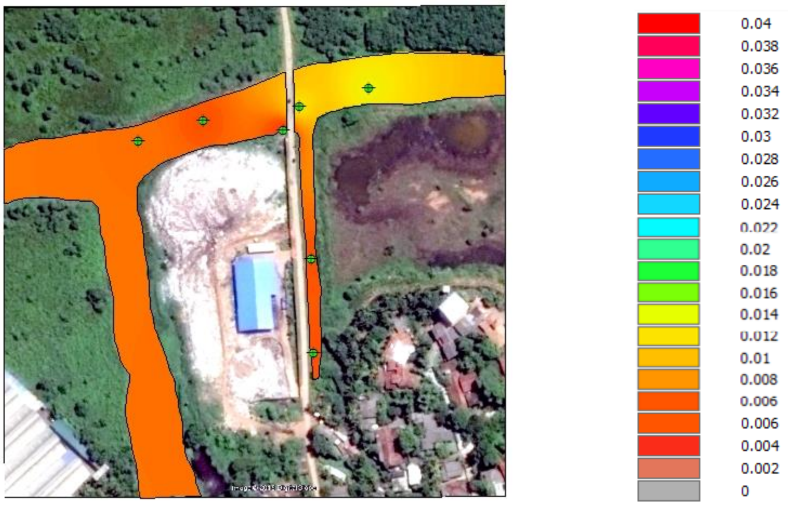


Figure 16: Graph of Cd values under rainfall intensity.

This graph shows mean Cd values under different three rainfall intensities. With this graph it can be deduce that during the low rainfall intensity (R1) the less amount of Cd was added to the water of the channel. But the mean Cd was observed to be 0.009 ppm on average during low rainfall intensity. That value also exceeded the Cd standard level of EPA for drinking water. And then during the medium rainfall intensity (R3), the amount of Cd released to the water of the channel was high. That mean Cd was observed to be 0.0325 ppm on average. That is a grievous situation for the water of the channel. The pollution is maximum in this rainfall intensity.

But during high rainfall intensity(R2), the mean Cd was to be 0.012 ppm on average. That Cd amount was less than to the amount that released to the water of the channel in the medium rainfall intensity. So it wasn't polluted much but greater than the amount during the low rainfall intensity. This was not due to the lack of pollutants in the channel water, but mainly caused by the pollutant being washed downstream with the increased speed of the water flow. So it can be deduce that in every rainfall intensities, the amount of Cd that released to the water source was increased gradually. But with speed of the rainfall the contaminants were washed to the downstream. So that is caused for the maximum amount of Cd that released during the medium rainfall intensity.

A brief idea can be get with following Cd distribution maps series created for different rainfall and the dry events about how the pollution of points are varied with the precipitation.



RF1

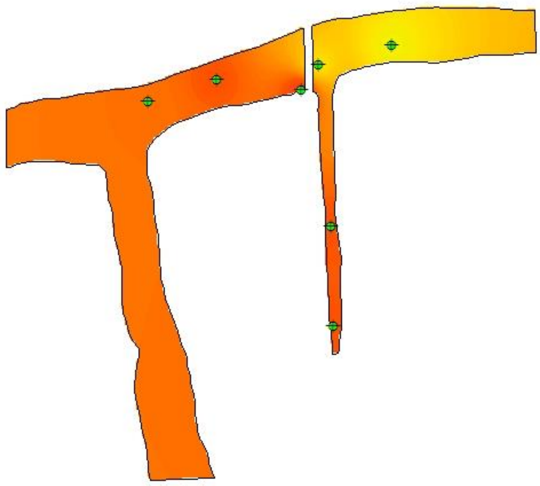


Figure 17: Map of 1 hr RF 1

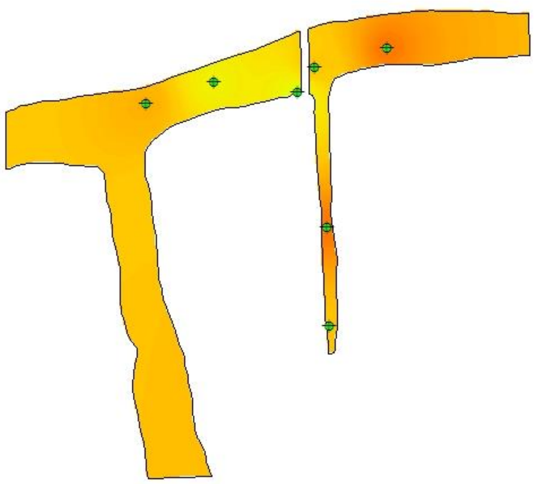


Figure 18: Map of 5 hrs RF 1

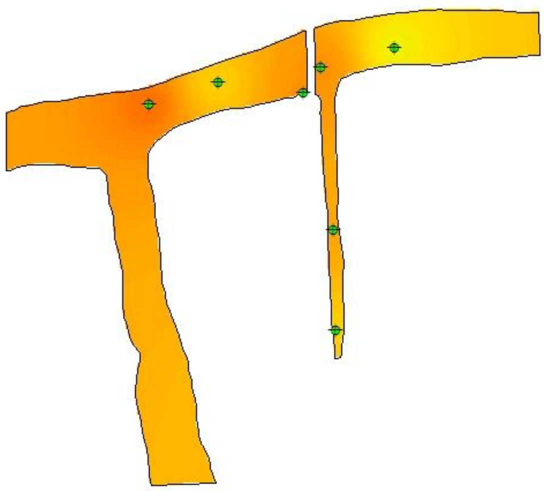
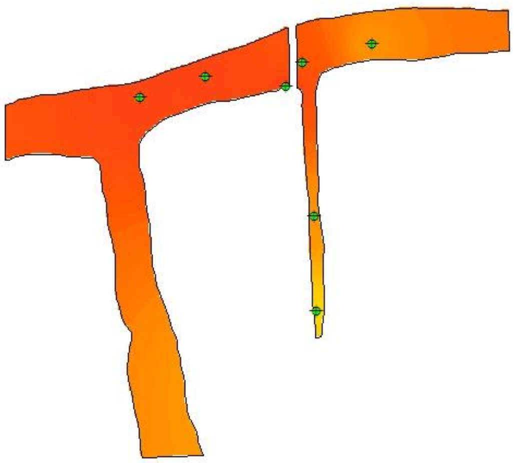


Figure 19: Map of Next day RF 1

These three maps represent the distribution maps related to the low rainfall intensity. By comparing with the legend, in this event the Cd is flowed to the downstream from 1 hr to 5 hrs and from the 5 hr to next day decreased the amount of Cd. But in the third map the Cd amount is increased in point 1 again. Therefore it can be said that the contaminant in the upstream is washed to the down.

DE1



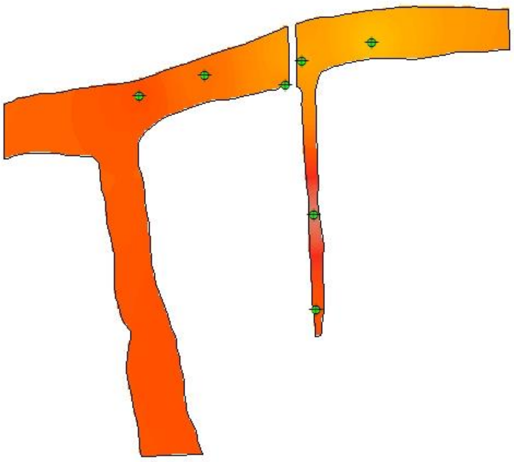


Figure 20: Map of 1 hr DE 1   Figure 21: Map of 5hrs DE 1

This distribution map series shows relevant to the dry event 1. By comparing with the legend it can be said that the amount of Cd is decreased than the rainfall event as in the above. With the time Cd is washed to the downstream and cleaned the channel. but in this also the second map (5 hrs) shows the increasing of Cd concentration with the time due to the flowing of water in the upstream. The map related to the next day is not there because of the rainy the water samples could not get for the dry event.

RF2

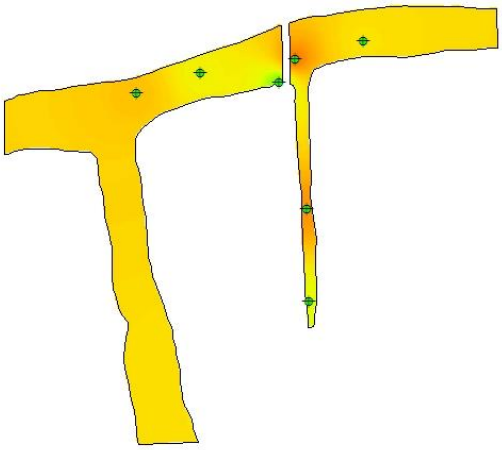


Figure 22: Map of 1 hr RF 2

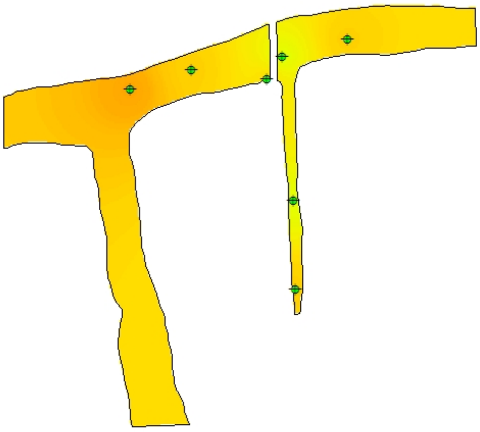


Figure 23: Map of 5 hrs RF 2

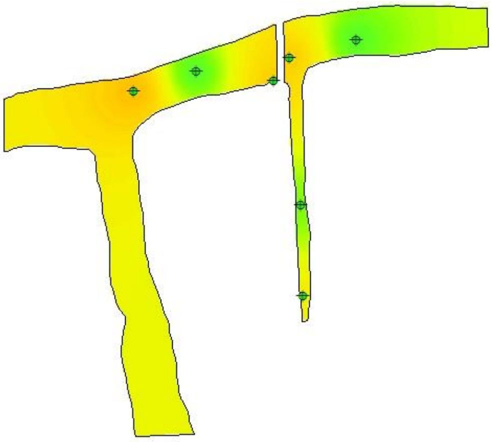


Figure 24: Map of Next day hr RF 2

When considering these map series with the legend it shows that a Cd concentration is more than the RF 1 event and with the time in Next day it increased more.

DE2

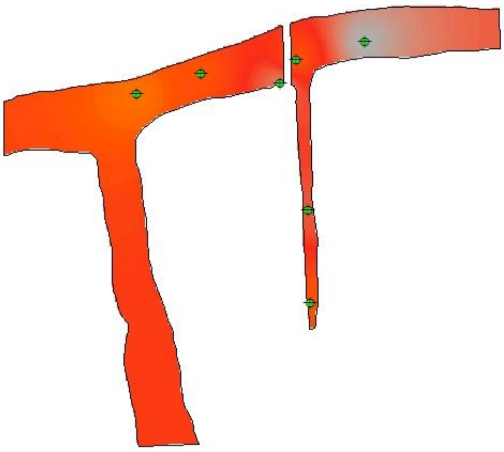


Figure 25: Map of 1 hr DE 2

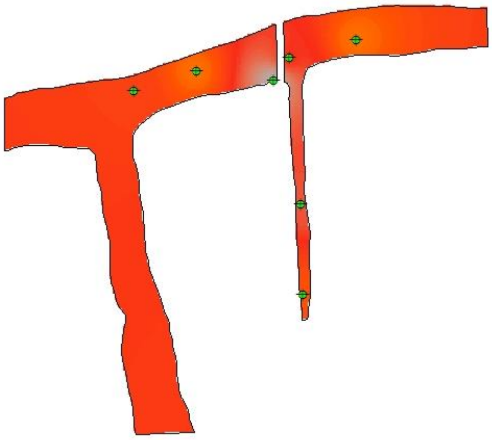


Figure 26: Map of 5 hrs DE 2

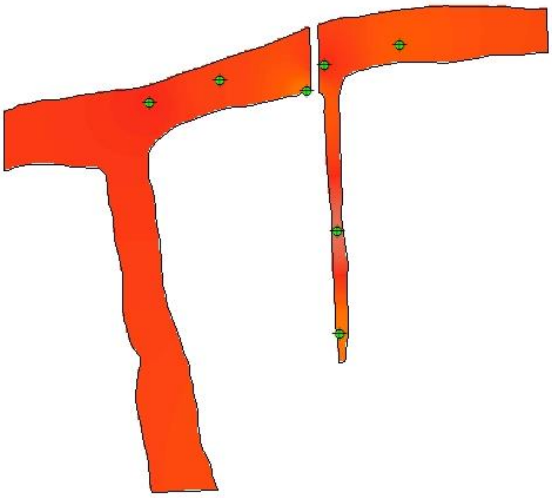


Figure 27: Map of Next day DE 2

When considering R 2 event, the Cd concentration is decreased more in this dry event. Some points were decreased to the 0 ppm level of Cd because of the sunlight. But with the time, small amount of Cd is flowed to the downstream.

RF3

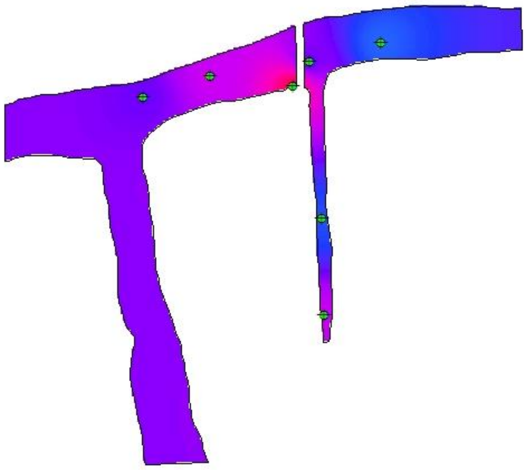


Figure 28: Map of 1 hr RF 3

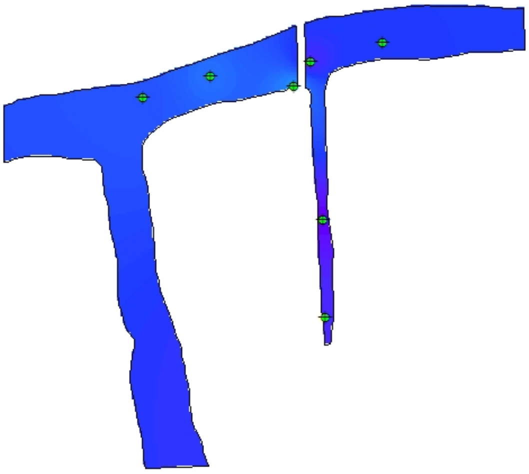


Figure 29: Map of 5 hrs RF 3

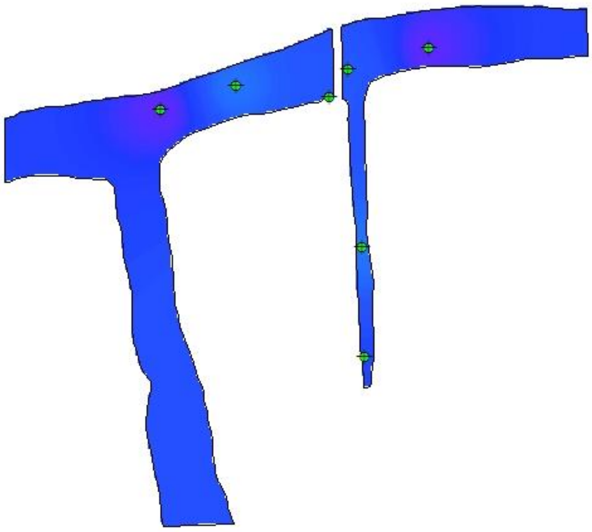


Figure 30: Map of Next day RF 3

In this event when considering these distribution maps with the legend it shows a large amount of Cd concentration released to the channel. With the time it has been flowed to the downstream but in the Next day also there is a huge amount of Cd in the water of the channel and shows small amount increasing of Cd concentration in the channel because of the flowing of the contaminents in the upstream.

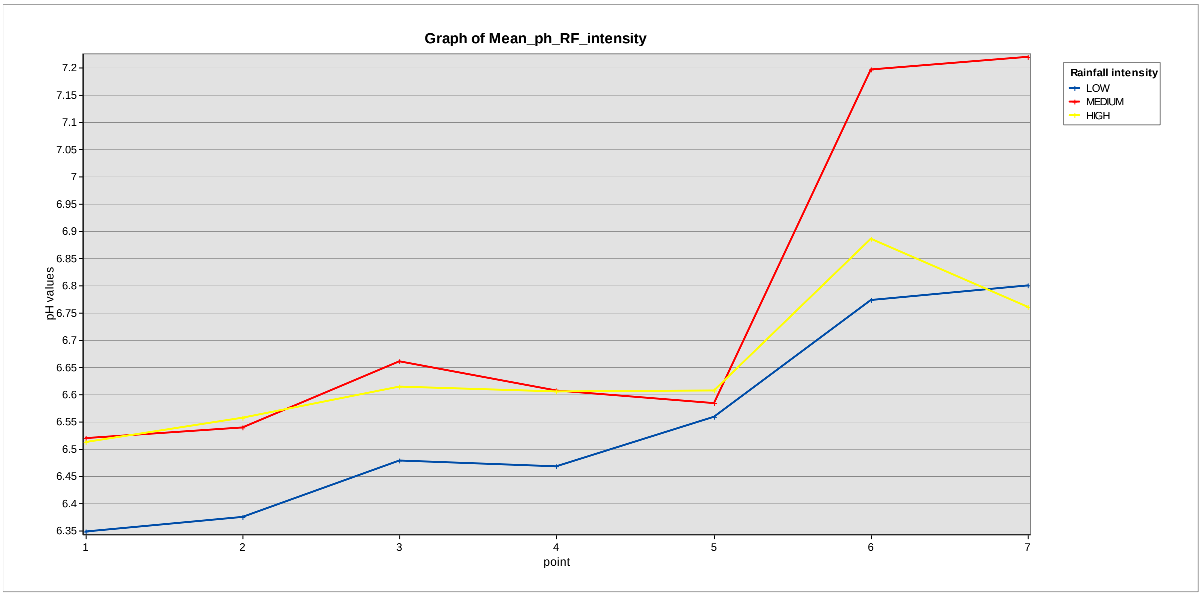
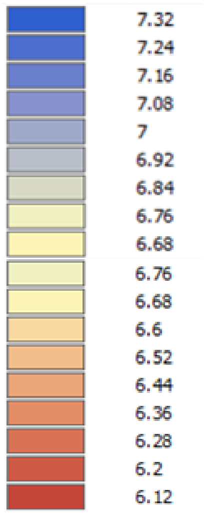


Figure 31: Graph of pH values under different rainfall intensities

In above proved that the water in this channel have a certain level of acidic at all times and with the rainfall it is alkaline.. But according to above graph the water in every locations are in the acidic level without 6 and 7 locations in the medium rainfall intensity. There is no water in anywhere in the channel which is closed pH value of 7. So it can be deduced that there is no clan water in that channel only the polluted water. Point 1 & 2 are more acidic. But in direct lechate points 3 & 6 were being alkaline in every rainfall event due to the direct pollutant discharge and the water near point 7 is more alkaline than the point 6 because of the accumulation of the water to the end of channel branch from the direct leachate. But due to the high rainfall it decrease little bit than the point 6 due to the flowing.

A brief idea can be get with following pH distribution maps series created for different rainfall and the dry events about how the pollution of points are varied with the precipitation.



RF1

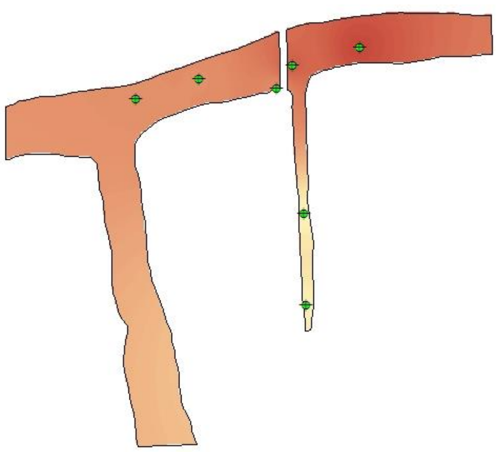


Figure 32: Map of 1 hr RF 1

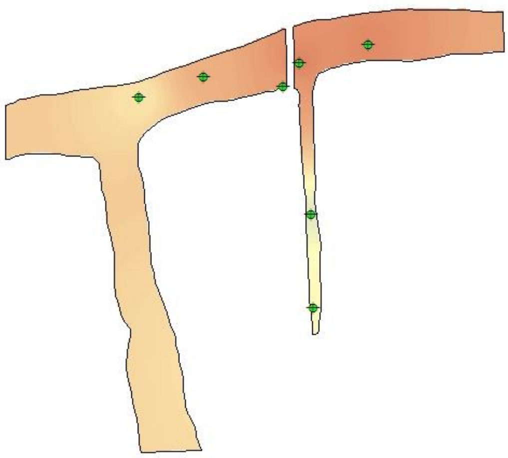


Figure 33: Map of 5 hrs RF 1

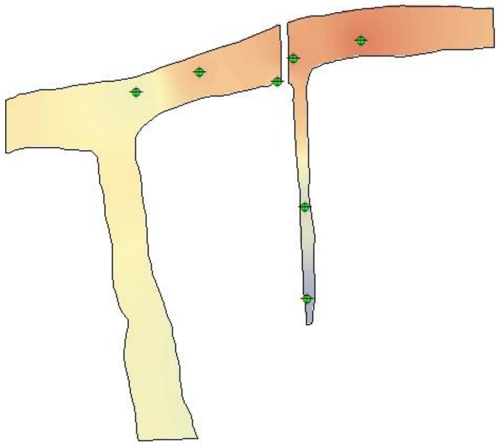


Figure 34: Map of Next day RF 1

In this map series it can be seen the water near the point 1 (base point) is more acidic because pH value is very low in this area. In every time of that event the water in the downstream of the channel is to be alkaline. So it can be deduce that the contaminants leachate by the channel is caused for that alkaline. in the third map related to the next day have a maximum alkalinity of water and the alkalinity of water near to the point 7 is maximum because it is a direct leachate point.

DE1

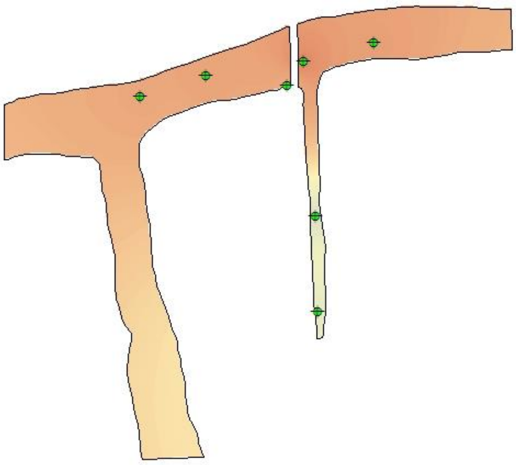


Figure 35: Map of 1 hr DE 1

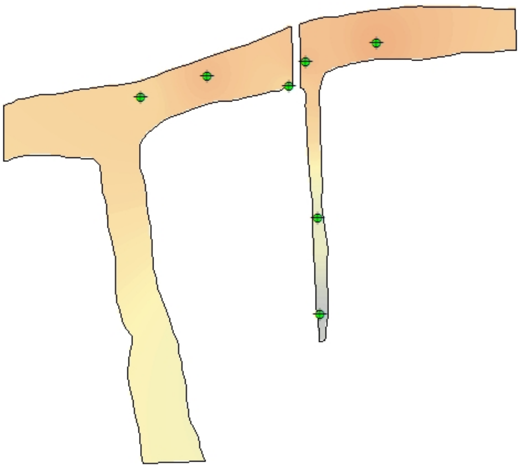


Figure 36: Map of 5 hrs DE 1

In this dry event also the contaminants are washed to the downstream with the time. So the pH value is decreased with time. But in point 7 the pH value is increased in the dry event also because this is the direct leachate point and in the low rainfall intensity, time is consumed to be leachate.

RF2

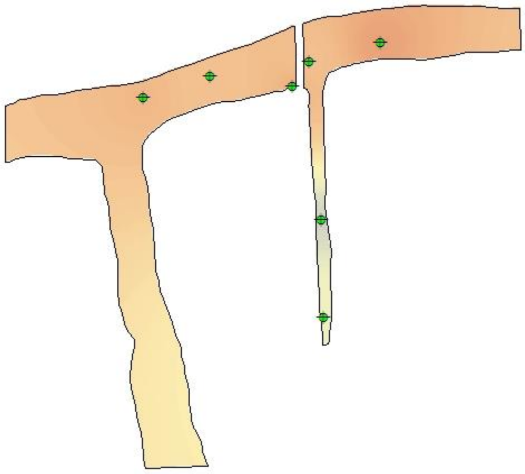


Figure 37: Map of 1 hr RF 2

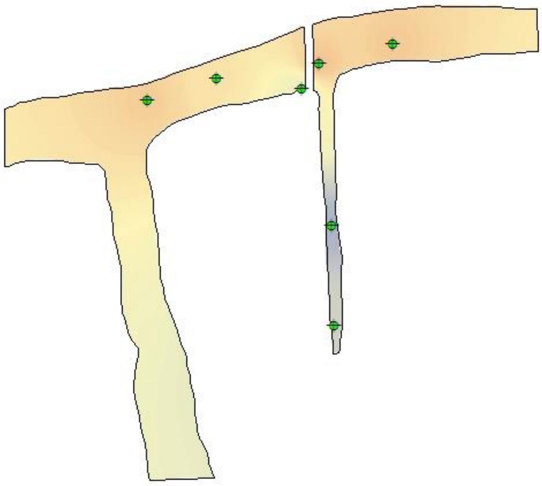


Figure 38: Map of 5 hr RF 2

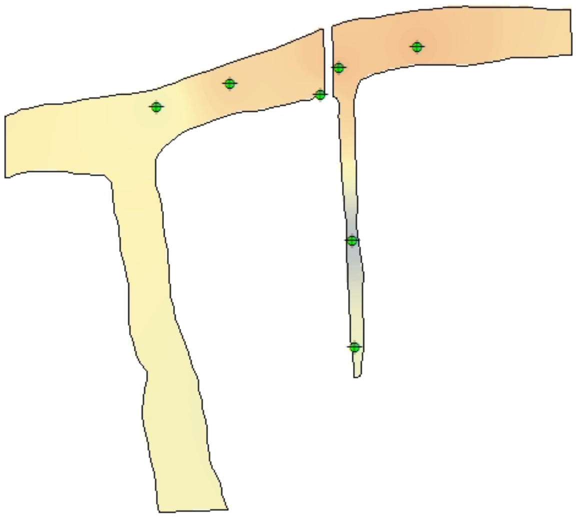


Figure 39: Map of Next day RF 2

In this event also the water of the channel is alkaline with the time. Specially the contaminants released to the leachate (point 7) point is washed and passed to the point 6 also within 1 hr and within 5 hrs it increased more. In the next day it decreased from a small amount.

DE2

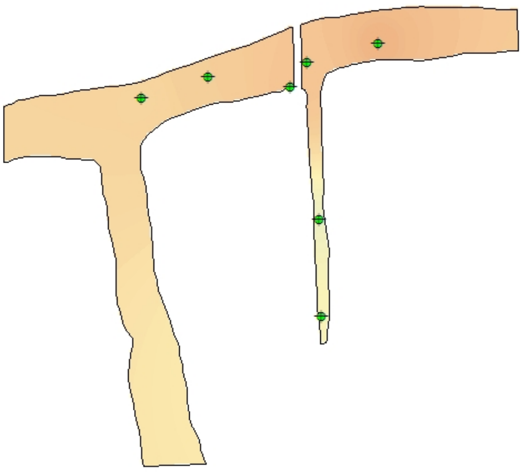


Figure 40: Map of 1 hr DE 2

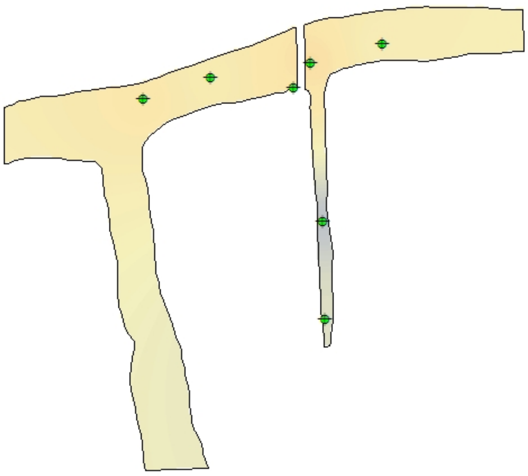


Figure 41: Map of 5 hrs DE 2

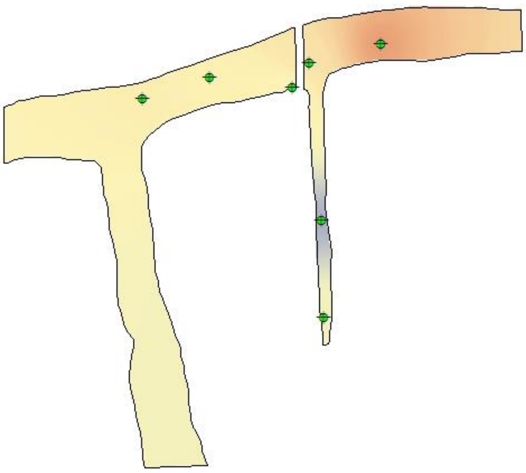


Figure 42: Map of Next day DE 2

In this dry event also pH value is decrased and reduce the alkalinity. but within the area of point 6 the pH value is not decreased because this leachate is from a high rainfal intesity. So the amont of leachate is large.

RF3

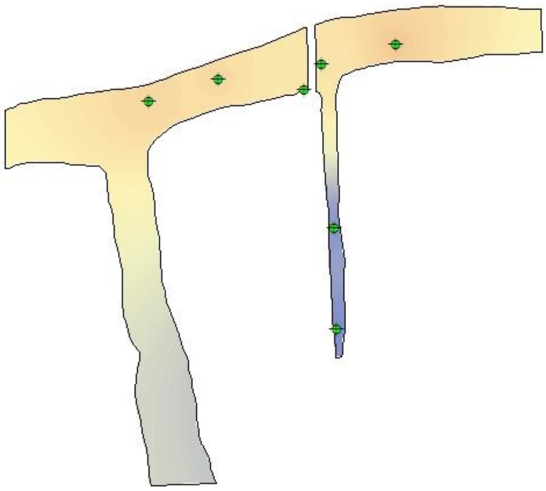


Figure 43: Map of 1 hr RF 3

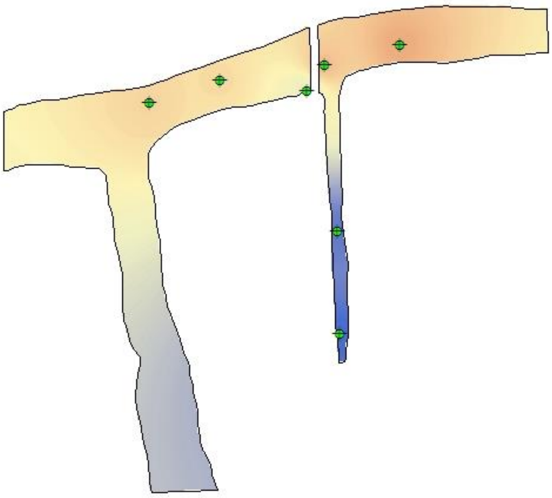


Figure 44: Map of 5 hrs RF 3

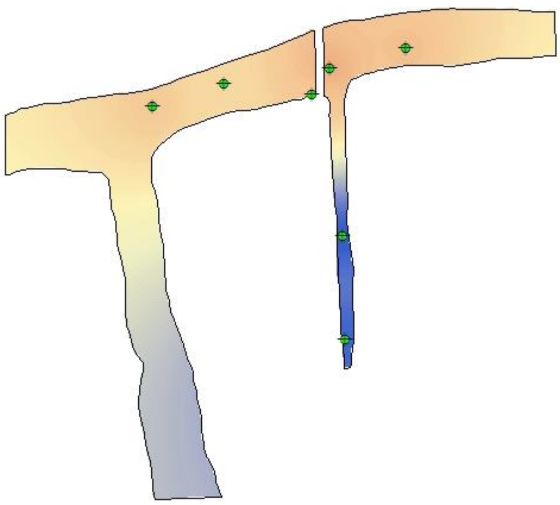


Figure **45**: Map of Next day RF 3

These distribution maps are related to the medium raifall intensity and the increasing of pH is very high. The huge amount of contaminents was leachated to the channel in the direct leachate point of point 7. The channel branch in the downstream also have a high pH value and the water is more alkaline. So the contaminants are accumulated to the end of the channel branches.

Finally we can say with the rainfall, the water of this channel is more polluted and by flowing the contaminants are spread to the downward of the channel network.

Conclusion and Recommendation

Conclusions and recommendations were made based on the culmination of the water quality parameters analyses. This chapter first presents conclusion on the water quality data, Secondly, the chapter provides recommendations for improving water quality and for future water quality monitoring in the channel.

Conclusions

The results of the study showed clearly the complex nature of landfill leachate from different locations due to the differences in climatic conditions.

The EPA standards for drinking water is as follows;

pH – 6.5-8

Cd – 5µg/l

In the study it is proved that the PH and Cd is exceeded the EPA standard limits for drinking water. So Cd is a contaminant and the normal water in the channel is alkaline. So it can be said that the water of the channel is polluted and not suitable for the healthy. From the direct leachate points, the maximum pollution of the water can be seen. With the rain fall intensity the pollution of water is increasing gradually. Similarly with the flowing speed of high rainfall intensity the contaminates are washed to the downstream quickly. That is with the high rainfall intensities, a huge area of the channel can be polluted within a small time period. So it can be said that in a rainfall the landfill pollutes the surrounding water sources by leachating. That statement further can be justified with the decreasing of amount of contaminant in a dry event because of the decreasing of leachating with the dry condition. With the time consuming a huge amount of contaminants are added to the water channel and all the other water sources situated in the downward of the cannel was polluted.

In some events the base points is also polluted. Therefore it can be deduce that with the time the contaminant of the upstream also flowed to the study area of the channel because this area is situated in the urban city. So in future the pollutant which is leachate by the landfill will spread a large area of the channel network and accumulate a large amount of Cd and there will be a very harmful effect for the health of living beings. Further there is a effect for the kidney diseases because of the Cd because this high concentration of Cd water feeds to the crops which are in the surrounded area and the fishes in this channel. So from that the large amount of Cd is intaken to the body.

By studying this area, the height of the terrain is neglected. Because the considering study area is very small and the sampling water is collected from surface water. And also the height of this small area variants within 1 feet from 10ft to 11ft is negligible. So the nature of the terrain does not effect for this study more.

In the preliminary checking of the first sampling the differences of the values of the parameters which was measured to the selected water samples among sampling locations was not high. So the distance among two sampling locations were 4m. It there are more variations among sampling locations, It should be got another points among these locations for the sampling.

When measuring the Cd by the AAS gave the minus values for some locations. That is impossible. those values which was having a minus values assumed 0 ppm in the analyzing. But we cannot deduce, that there was no any amount of Cd in that samples. Because the water samples were measured for the Cd in ppm level. But in ppb level it can be detected a value for the Cd in that sample.

After measuring the pH values the samples were again stored in the refrigerator because all the samples were measured at the same time due to the high cost of operating the AAS. For the preservation of the water samples added the high concentric HNO3 (Ar).

Samples were collected in thick plastic bottles and leachate was collected as to minimize the headspaces in the bottles to prevent aeration of the samples.

pH of landfill leachate is increased with the age of the landfill due to the biological decomposition of organic N into ammonium N. So that is why in a rainfall the pH value is increased highly.

Recommendations

It the time difference of that collected sampling was selected is short, in every speed of rainfall, the amount of contaminants which are leachated to the channel can be detected before flowing the pollutant to the downstream.

If it uses the GPS to get the coordinate of the sampling locations the maps should be more accurate than this.

This research is can be done for another parameters also. Thereby further more contaminants can be identified that caused for the pollution of the water in the channel.

If the study area of the channel can be extended to the downstream of the channel, can get more samples within that area and the changes of the pollution can be seen clearly and the variation of the terrain also can be considered for the analysis.

References

Sugirtharan, M., & Rajendran, M. (2015). Ground water quality near municipal solid waste dumping site at Thirupperumthurai, Batticaloa. *Journal of Agricultural Sciences – Sri Lanka*, *10*(1), 21-28. https://doi.org/10.4038/jas.v10i1.8044

National Primary Drinking Water Standards (MCL / MCLG) KnowYourH2O. (n.d.). https://www.knowyourh2o.com/indoor-4/primary-standards