# Assessment of the Effect of Aruwakkalu Waste Dump on Surrounding Water Resources

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**Abstract**

In developing countries like Sri Lanka, waste management is a vital necessity. Solid waste dumps play a major role in handling waste in most countries. These solid waste dumps can cause severe environmental pollution via leachate generation and transport of toxic material along with both surface and underground water flows. The Aruwakkalu waste dump, which is the subject of the study, is a sanitary landfill situated in Puttalam district, Sri Lanka. The landfill is planned to receive and store municipal solid waste (MSW) from Colombo metropolitan area. Locations for these waste dumps must be selected strategically to minimise the risk of contamination of the surrounding environment. A distributed hydrological model was used to determine the effect of rainfall, evapotranspiration, and surface runoff on the site. It identified the direction of the water flow through the waste dump. The analyses have illustrated that the area receives lesser rainfall and a higher rate of evapotranspiration. The hydrological analysis illustrates the water flow direction from the waste dump to the outside is towards the West and away from the nearby settlement areas. The results were used to assess the effect of the waste dumpsite on the surrounding water resources.

**Keywords:** Evapotranspiration, Flow direction, Hydrology, Landfill, Rainfall

## 1. Introduction

Solid waste is one of the leading undisputable problems in most developing countries. With increasing population and urbanisation, the management of solid waste is getting complicated day by day [1].

Solid waste is considered as any non-flowing/non-fluidic substance which has no use or no immediate economic demand. Municipal solid waste (MSW) can be generated via various human aspects such as domestic, hospital, industrial and agricultural activities [1]. The quality and the quantity of the MSW depends on many factors such as population, lifestyle, food habits, standards of living, the extent of industrial and commercial activities, cultural practices, and climate. The collection, transportation, and disposal of MSW in unscientific ways caused chaotic results in many countries [2].

One of the main means of waste disposal is by sanitary landfills, where waste materials are spread over the land surface and covered and compressed by soil. These landfilling sites can cause surface water as well as groundwater pollution unless proper management and monitoring are done [3].

Solid waste in these landfills causes environmental pollution as well as water pollution both on the surface and underground. Direct precipitation on the site and surface runoff through the site can carry the waste unless the dumpsites are properly designed [4]. Precipitated water can be easily mixed with waste materials in the dumpsite and produce a mixture called leachate. This mixture can access nearby surface water flows and groundwater aquifers unless proper controlling measures are implemented [5].

In Sri Lanka, the Aruwakkalu sanitary landfill located in Puttalam district is one of the recently designed MSW dumpsites, which is at the final stages of completion. The people living in the vicinity of the dumpsite consume well water as their primary water source. The location of the dumpsite and the effect of surface water runoffs are critical factors which determine the degree of impact on waste dump contaminants on these settlement areas.

Runoff modelling and hydrological analyses are commonly used to determine the effect of precipitation, evapotranspiration, and water flow direction in an area. These methods can illustrate the nature of the water flow and the potential changes of the hydrology of a site utilising key factors like precipitation, temperature, elevation, and surface water flow.

This research study is mainly intended to determine the nature of the surface flow along the waste dump area and to determine the possibility of water contamination of the nearby settlements via surface runoff.


***Figure 1: Study area location map.***

## 2. Methodology

### 2.1 Study Area

The Aruwakkalu sanitary landfill is situated in Puttalam District, Northwestern province of Sri Lanka. Upon completion, it is expected to receive 1600 metric tons of waste daily. The waste dump is planned to store more than 4.7 million $m^3$ solid waste in the coming ten years [6].

As illustrated in Figure 1, the waste dump location is in the proximity of the Puttalam lagoon, and there are several settlement areas like Sewarakkuli, Karaitive, Periyanaga Villu etc. The area receives a total average annual rainfall of 2500 mm, and the temperature ranges from 23° C to 34.4° C [6].

### 2.2 Project Flow

The flow of the project can be logged into four parts.

1. Data acquisition
2. Model setup
3. Hydrological analysis
4. Analysis of results

### 2.3 Data Acquisition

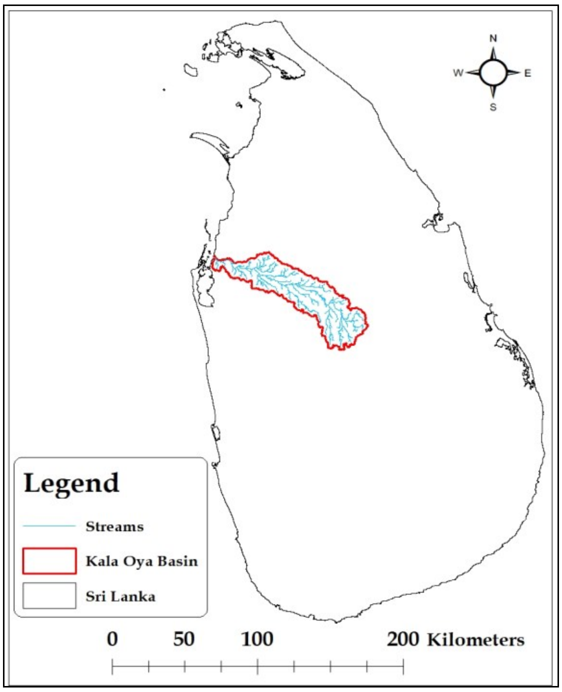


*Figure 2: Locations of the Kala Oya Basin in Sri Lanka.*

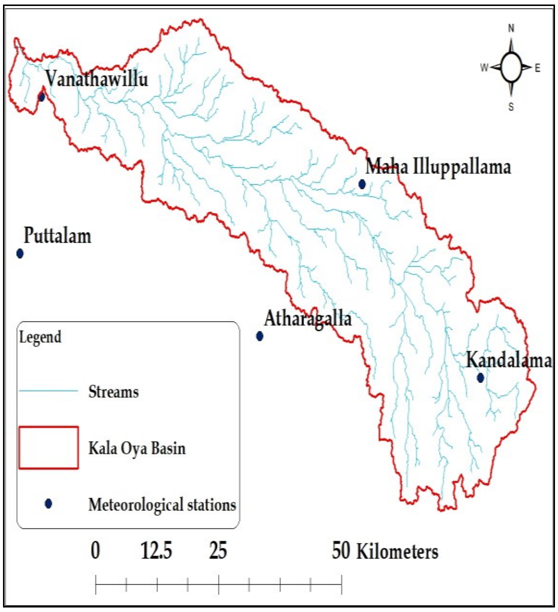


*Figure 3: Locations of meteorological stations relative to the Kala Oya basin.*

Data for the surface runoff model was collected as per the requirements from the Department of meteorology, Sri Lanka. As illustrated in Figure 3, daily rainfall data and maximum and minimum temperature data of 5 stations for the selected Kala Oya basin were acquired. The location of the Kala Oya basin in Sri Lanka is illustrated in Figure 2, and the selection of the Kala Oya basin was made considering the location of the Aruwakkalu waste dump.

Digital Elevation Model (DEM) files with 12.5 m resolution and 30 m resolution were acquired from the USGS and ASF archives.

### 2.4 Model Setup

The model setup consists of the preparation of the surface runoff model using rainfall and evapotranspiration maps, and the model inputs are given in Table 1.

The model is designed to determine the variations of precipitation and evapotranspiration of the Kala Oya basin.

The model is employed with a self-written Fortran program which consumes daily rainfall, daily maximum, and daily minimum temperature data as main inputs. Using the Hargreaves equation, the potential evapotranspiration is determined. 12.5 m resolution digital elevation file was obtained from ALOS PULSAR satellite. The DEM file was resampled into 100 m resolution.

***Table 1: Input data for the model***

| Required Data | Source(s) |
|---|---|
| Daily rainfall (2008-2010) | Department of meteorology |
| Daily maximum and minimum temperature data (2008-2010) | Department of meteorology |
| Elevation data (DEM) | USGS SRTM digital elevation model |
| Catchment boundary and terrain | SRTM and ALOS PULSAR digital elevation models |
| Soil data | World soil map and literature |
| Land use map | Sentinel 2 satellite image classification via Arc Map 10.5 |

Data from 5 meteorological stations from 2008 to 2010 were used to map the rainfall and evapotranspiration of the basin via the inverse distancing method. The location of each station with relative to the basin was given using a latitude grid of the same size (1063 columns and 701 rows).

All these above parameters and procedures were included in the self-written Fortran code. The outputs of precipitation and evapotranspiration were in binary format. They were visualised using Envi Classic 5.0 and ArcMap 10.5, and the variations were studied.

The location of the Aruwakkalu waste dump site is in the vicinity of the selected basin. Using the variations and trends observed within the basin, the impact of precipitation and evapotranspiration on the surface water flow along the waste dump was determined.

### 2.5 Hydrological Analysis

The hydrological analysis was carried out using the digital elevation models (DEM) via Arc Map hydrological Analysis tool. The DEM files were used to create flow accumulation of the area. Flow direction file was created using the flow accumulation to determine the direction of the water flow through the area.

A buffer zone of 1 km around the Aruwakkalu waste dump was extracted from the original flow direction file. A threshold value of 2000 was used to enhance the water flow paths of the area.

Together with the results of the hydrological analysis and the digitised location map of the surrounding settlements, the degree of water contamination of the nearby villages was determined.

The location of the dumpsite within the basins and the elevation of the dumpsite location relative to the surrounding areas were further analysed to determine the water flow direction and the effect of water flow on the location.

## 3. Results

### 3.1 Results of the Model

The model was created by the self-written Fortran code, and the resulted precipitation and evapotranspiration files were in binary format. They can be visualised via Envi classic 5.0 and Arc Map 10.5 software. Monthly variations of years from 2008 to 2010 were taken as outputs for analysis of the effect of surface running water along with the waste dump site.

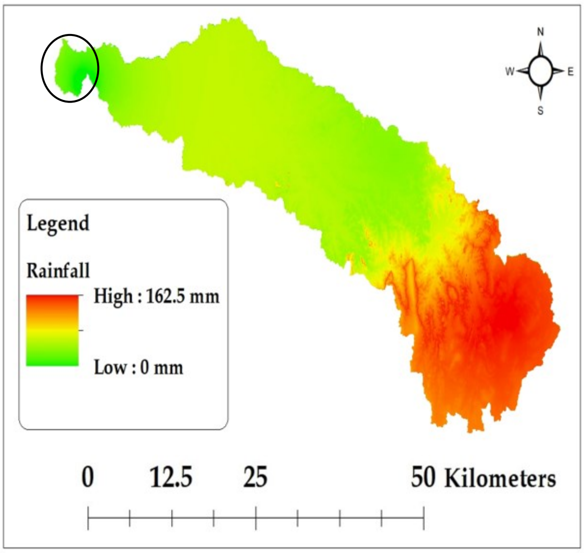


***Figure 4: Rainfall map for January 2008.***

The circled area of Figures 4 and 5 is the area extent where the waste dump is located within the basin.

Figure 4 and Figure 5 are the resultant rainfall and evapotranspiration maps generated from the Fortran code for the month of January 2008. A total of 72 files for precipitation and evapotranspiration were output by the model, and they can be visualised as GIF files to illustrate the variations.

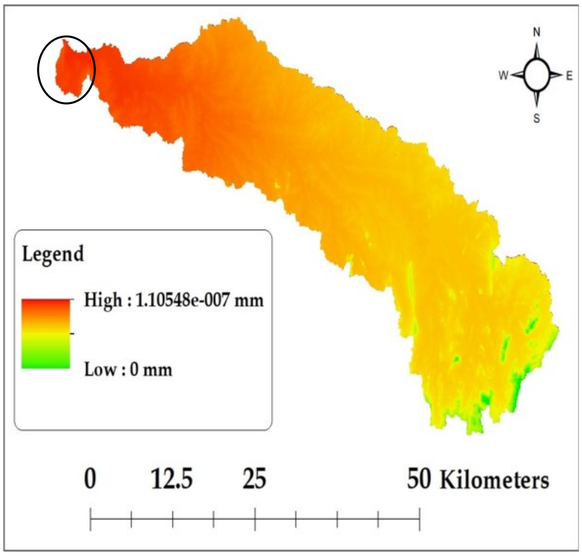


*Figure 5: Evapotranspiration map for January 2008.*

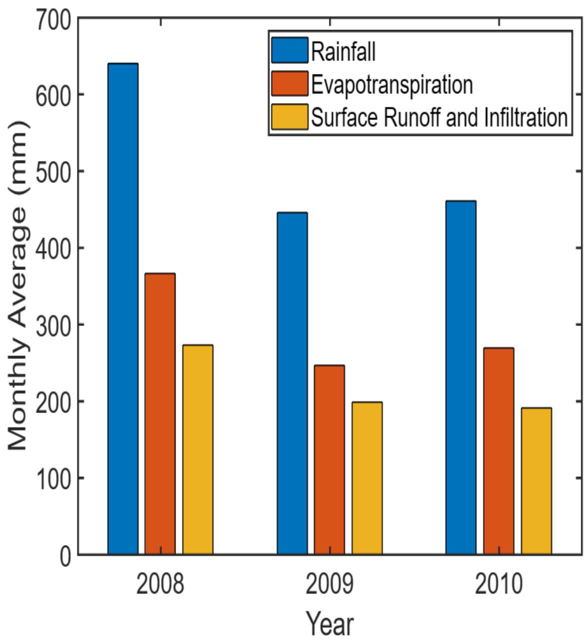


*Figure 6: Average monthly rainfall variations, evapotranspiration, surface runoff and infiltration.*

The average monthly precipitation, evapotranspiration, surface runoff and infiltration are graphically illustrated in Figure 6.

### 3.2 Results of Hydrological Analysis

The result of the hydrological analysis is illustrated in Figure 7.

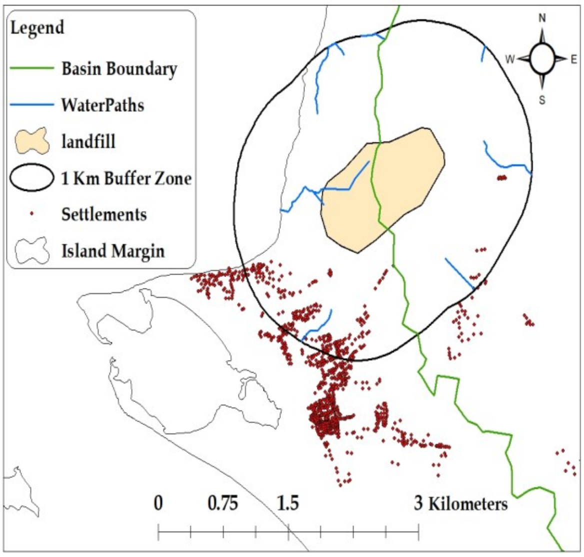


*Figure 7: Hydrological map of the Aruwakkalu waste dump area.*

## 4. Discussion

The modelling process was carried out to the Kala Oya basin, and it was observed that the location of the Aruwakkalu waste dump is in the boundary regions of the Kala Oya basin and the basin which is situated in the south of the Kala Oya basin.

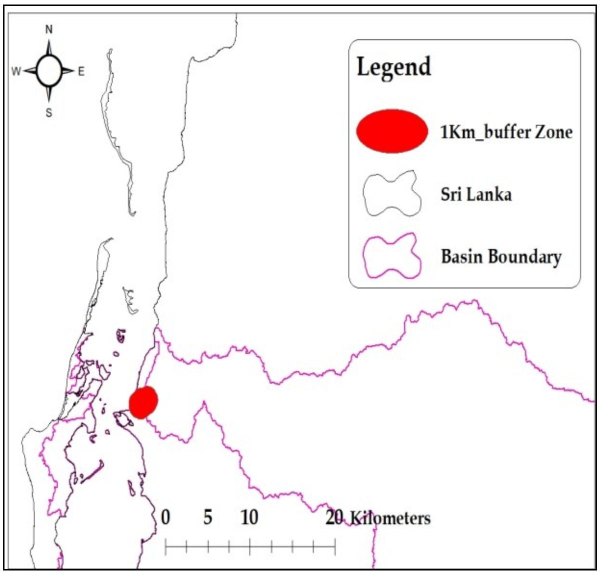


*Figure 8: Position of the waste dump and 1 km buffer zone on two basins.*

In the hydrological analysis illustrated in Figure 7, water paths through the waste dump area and the buffer zone were determined using a very low threshold value of 2000. This value was selected as there was no major or significant water flow through the area under higher threshold values which are commonly used to generate major water networks in basins.

The elevation of the waste dump area was also considered in the study to further determine the water flow direction and to analyse the position of the waste dump relative to the surrounding areas.

The precipitation and evapotranspiration models, which are created as stacks starting from Figure 4 and Figure 5 clearly indicate that the area that belongs to the Aruwakkalu waste dump (circled area) receives lesser precipitation and is subjected to higher evapotranspiration than the average values of the basin. Figure 6 also illustrates that more than 55% of the average annual rainfall is removed from the area as evapotranspiration. This affects the surface runoff of the area as the generation of runoff is lesser with low-intensity rainfall and high-intensity evapotranspiration.

As illustrated in Figure 8, the location of the Aruwakkalu waste dump is in the boundary areas of the two basins. Also, the location is in low elevation than the surrounding areas. The amount of running water through the area is minimum due to the location at basin boundaries, and as illustrated in Figure 7, the flow of the surface water is towards the lagoon and away from the nearby settlements.

The hydrology analysis clearly illustrates that the water flow gradient extends away from the surrounding settlements within the 1 km buffer zone. The effect of contamination of water sources through surface running water is minimum.

The EIA report [6] reveals that according to the boring tests carried out, the groundwater level fluctuates between –0.05 and -6.85 meters. Thus, the bottom foundation level of the sanitary landfill is higher than that of the groundwater. But in case of a rise in the groundwater table during the rainy season, a bottom liner system is placed to drain the groundwater from the site [6].

The development of the floor of the waste dump is carried out with layers of in situ soil and bentonite. Further, the HDPE sheet layer is used to reinforce the floor by reducing the permeability [6].

According to the EIA report, there is no history of major floods in the area. There were several minor flooding that occurred up to 3 MSL contour levels. Since the waste dump is located above 5 MSL, there will be a lesser impact from flooding in the future [6].

Accumulated drainage flows along minor undulations, and valleys in the area have formed rills causing erosion and fines washout in the sloping ground areas. These flows are finally diverted to the abandoned quarry pits in the North-west and Northside boundaries of the waste dump, and stagnant water is presumed to remain for a short duration after rainfall events before vanishing due to seepage losses and direct and soil evaporation. The average annual reference evapotranspiration and potential soil evaporation are relatively high in this arid region [6].

According to the borehole tests carried out, the groundwater levels were not encountered at any borehole pit, even though the bored pits were driven up to a maximum depth of 33.45 m and 58.00 m, respectively [6].

## 5. Conclusions

From the results of the model obtained from the hydrological model, it can be cognitively concluded that more than 55% of precipitation in the Kala Oya basin goes out as evaporation and transpiration. The rest is turned to surface runoff and infiltration.

Further, it can be concluded that the lagoon area is more vulnerable than the water sources in the settlement areas in case of a possible contaminant leakage from the waste dumpsite.

The findings of the EIA report of the Aruwakkalu waste dump conclude that the effect of pollution from the waste dump to the surrounding surface water as well as groundwater environment is less.

Following this study, further investigation of the groundwater profile of the area should be conducted to determine the groundwater flow trends of the area. Further, a detailed groundwater quality assessment should be conducted in both upstream and downstream areas of the waste dump, covering both the wet season and dry season of the year.

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