MULTI PATHWAY HUMAN HEALTH RISK ASSESSMENT FOR PERUNGUDI DUMPSITE

Submitted by

JOHN PAUL MANDAPAKA

CE16B106

Under the guidance of

Professor Dr. INDUMATHI M NAMBI

ENVIRONMENTAL AND WATER RESOURCES ENGINEERING

CIVIL ENGINEERING DEPARTMENT

INDIAN INSTITUTE OF TECHNOLOGY MADRAS

ACKNOWLEDGEMENT

When I started the Dual Degree Project, I had no experience writing on the research paper, I expected that project would be just like a course that continues for two semesters, and I would not need to write an exam to pass. As I am writing down this acknowledgment, I have to say my Dual degree project is one of the most crucial parts of my Dual degree life in IIT Madras.

Firstly, I would like to thank my project guide Professor Dr. Indumathi M Nambi, and my mentor Bokam Rajasekhar. Thank you, professor Indumathi M Nambi for your valuable Inputs and guidance throughout the project. Thank you, Raja Sekhar, for your constant support and guidance throughout the project. I am grateful for having the opportunity to have worked with both of you.

Finally, I would like to thank my family and friends for the constant love, support, and encouragement they have given me during this period.

John Paul

June 2021

Table of Contents

List of Figures

List of Tables

ABSTRACT

The main objective of this study is to conduct the Human health risk assessment for the Perungudi dumpsite, which is in the south part of Chennai.
In this study, we mainly centered on the risk through heavy metals. We conducted a risk assessment on the Perungudi dumpsite and its surrounding areas. In this study, we studied both cancer and non-cancer risk. For that, we will be using the US EPA equations for risk calculations on various pathways. We conducted both deterministic and probabilistic methods. For the probabilistic approach, we used the Monte Carlo simulation.

We found that oral risk is present more than dermal risk. Adults were more prone to risk than children; cancer risk is present for both children and Adults in Perungudi dumpsite from both the oral and dermal pathways. Whereas for the nearby areas, we found that cancer risk comes through the oral path most of the time, we used the 95th percentile value as RME (reasonable maximum exposure estimate) as prescribed by the US EPA. We used the accepted exposure risk of hazard quotient less than 1 for non-cancer, whereas 1 in a million for the cancer risk

Keywords; Perungudi dumpsite, hazard quotient, municipal solid waste, heavy metals, cancer risk

INTRODUCTION

A municipal dump yard is a place where waste is dumped." It can be defined as a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the trash to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of the earth after each day's operation or at such more frequent intervals as may be necessary."(Raghab et al., 2013) The landfill is common in many emerging nations because it is the cheapest, most cost-effective way to dump waste. Although many ways to reduce the amount of waste that goes to landfills, like recycling, reuse, composting, etc., many emerging nations are underfunded. They do not have the resources to implement it.

Landfills have been identified as significant threats to groundwater resources (US EPA, 1984). Once waste comes to landfills, it undergoes many changes at both the physical and molecular levels. It leads to contamination of landfills and surrounding places. Among those, heavy metal contamination is a major one. Heavy metal contamination causes both cancer and non-cancer effects. It depends on the heavy metal concentration present in that place. According to US EPA, Arsenic (Ar), Nickel (Ni), Cadmium (Cd), Chromium (Cr), Beryllium (Be) is termed as carcinogenic heavy metal because of their toxic nature.

When waste is placed in a landfill due to rain or precipitation, water passes through that waste a dark brown liquid. As a result, water is formed, which is called leachate. "Leachate can be defined as a liquid that passes through a landfill and has extracted dissolved and suspended matter from it" (Raghab et al., 2013). Leachate thus formed contaminates the groundwater below when it percolates through the soil, contaminating the surrounding areas. Furthermore, when leachate mixes with groundwater, it creates a plume that spreads in the direction of flowing groundwater, contaminating the groundwater of the locality (Vasanthi et al., 2008). Upon which it affects the human health living there by different pathways.

We will be researching the Perungudi dumpsite located in the southern part of Chennai for this study. We will use the probabilistic method like Monte Carlo simulation for the risk assessment; the main pathways we focused on were the dermal and oral pathways. We exclude the inhalation pathway because the pallikaranai mangrove forest surrounds the landfill, due to which human exposure through inhalation is low. Also, (Ali et al., 2021) study shows that risk through the inhalation pathway is negligible compared to the oral or dermal pathway.

Study area

Chennai is a metropolitan city located in Tamilnadu, which is also its capital. With an 11.2 million population, it is spread over 426km2, and it is a coastal city located on a Bay of Bengal coastal line. It receives rainfall during the South-West monsoon because of sea-breeze-induced convections. Predominant winds in Chennai are usually south-westerly between April and October and north-easterly during the year. The maximum temperatures around 35–40 °C are recorded in March-early June, while December and January with minimum temperatures of 19–25 °C.

Being a metropolitan city, Chennai generates a daily waste of 5600 tonnes of waste every day (GCC), with a per capita waste of 0.7kg (tnenvis). Greater Chennai Corporation (GCC) has divided the city into three regions: North, Central, and South, with five zones each, making 15 zones for administrative purposes. The daily generated MSW is being dumped into two major dumpsites

–Kodungaiyur and Perungudi. MSW collected from zones 1 to 8 are being left at Kodungaiyur dumpsite in northern Chennai, whereas MSW from zones 9 to 15, dumped at Perungudi dumpsite in southern Chennai((Peter et al., 2019).

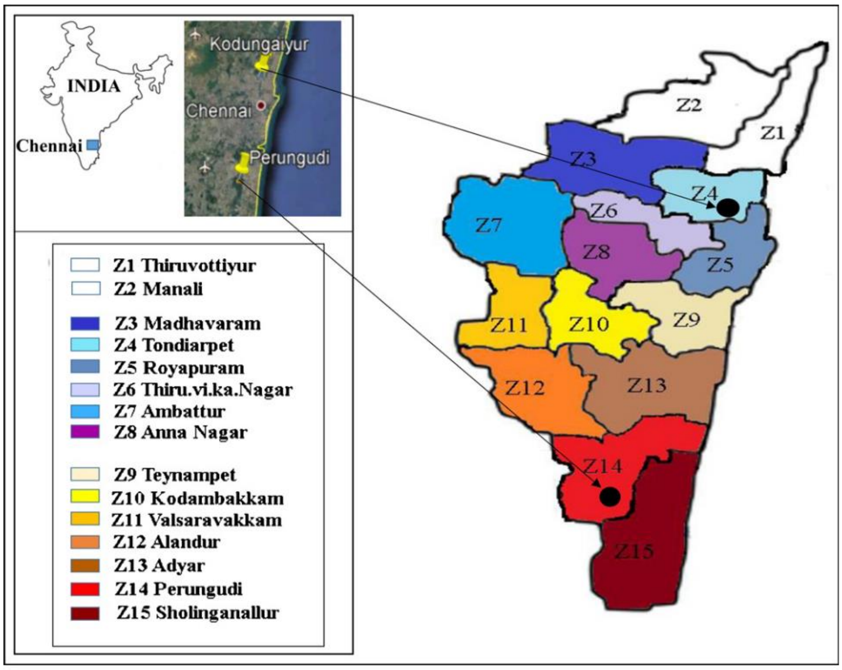

Figure 1 zonal distribution of Chennai for waste management

Perungudi dump yard is located in the southern part of Chennai, which is surrounded by pallikaranai marshland. Up until 1980, pallikaranai occupied 14,000 acres, but it is reduced to mere 1470 acres today(Sree Sharmila and Swathika, 2016) due to rapid urbanization. The dumpsite lies between 2 and 3 km west of the Buckingham Canal and is 3.5 to 4.5 km west of the Bay of Bengal coastline. Perungudi dump yard is in operation since 1987. (Vasanthi et al., 2008) This dumpsite is one of the oldest dumpsites in the city, with a disposal rate of approximately 2200–2400 tons per day. The height of the dumpsite is around 10–15 m. (Peter et al., 2019).

Figure 2 Perungudi and its surrounding location

The overall objective of the study

Human health risk assessment in the residential area around the dumpsite from the different pathways.

Scope of the study

- We will draw the CSM (conceptual site model) to identify the possible pathways for contamination.
- We will be looking at risk due to contaminated groundwater.
- We will be doing both deterministic and probabilistic methods.
- Develop a user-friendly excel spreadsheet where user can check their risk based on the input entered.
- Launch the website where users living surrounding that area can check their risk.

Literature review

(Ali et al., 2021) the study conducts the human health risk assessment for the dumpsite in khamees-mushait, Saudi Arabia. It states that Due to the lack of proper management of those sites in many countries, dumpsites appear as a significant source of pollution by various pollutants, particularly by heavy metals. It calculated the health risk assessment due to oral pathway by equations prescribed by the US EPA 2002. It calculates the HQ (hazard quotient) for the calculation for non-cancer risk. It also calculates the cancer risk due to the inhalation pathway by using the equations prescribed by the US EPA.

(Mor et al., 2006) study on the groundwater pollution near the gazipur landfill site. It states that "Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site." Heavy metals remain in the waste or at the waste–rock interface due to redox-controlled precipitation reactions. Further, the metal mobility is also controlled by physical sorptive mechanisms, and landfills have an inherent in situ capacity for minimizing the mobility of toxic heavy metals. This fixing of heavy metals reduces the risk of direct harmful effects due to ingestion of leachate contaminated groundwater. However, once the leachate leaves the site, the situation changes. The leachate is generally a strong reducing liquid formed under methanogenic conditions and, on coming into contact with an aquifer, materials can reduce sorbed heavy metals in the aquifer matrix. The most important reactions are the reduction of Fe and Mn to more soluble species. Hence the concentration of these components increases under favorable conditions close to a landfill and may lead to severe toxic risk.

This time we will review the US EPA 2004 document for the equations we need to calculate the risk assessment. We will calculate the risk assessment mainly due to heavy metals through the oral, dermal, inhalation pathway. Here are the findings

Dermal absorbed dosage through dermal contact.

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT}$$

Where

$$DA_{event} = k_p \times C_w \times t_{event}$$

Here

DAD = Dermal absorbed dosage (mg/kg-day)

DA_{event} = Absorbed dose per event (mg/cm^2-event)

EV = Event frequency (events/day)

ED = Exposure duration (years)

EF = Exposure frequency (days/year)

SA = Surface area (cm^2)

BW = Body Weight (kg)

AT = Averaging time (days)

t_{event} = Event duration (hr/event)

C_w = Chemical concentration in water (mg/lit)

k_p = Dermal permeability coefficient of a compound in water (cm/hr)

Dermal absorbed dosage through soil contact

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT}$$

Where

$$DA_{event} = ABS_d \times C_{soil} \times CF \times AF$$

Here

DAD = Dermal absorbed dosage (mg/kg-day)

DA_{event} = Absorbed dose per event (mg/cm^2-event)

EV = Event frequency (events/day)

ED = Exposure duration (years)

EF = Exposure frequency (days/year)

SA = Surface area (cm^2)

BW = Body Weight (kg)

AT = Averaging time (days)

ABS_d = Dermal absorption fraction

C_{soil} = Chemical concentration in soil (mg/kg)

CF = Conversion factor (10^{-6} kg/mg)

AF = Adherence factor (mg/cm^2-event)

For chronic daily intake

$$CDI = \frac{C_w \times IR \times ED \times EF}{BW \times AT}$$

CDI = Chronic Daily dosage (mg/kg-day)

IR = Ingestion rate (lit/day)

ED = Exposure duration (years)

EF = Exposure frequency (days/year)

C_w = Chemical concentration in water (mg/lit)

BW = Body Weight (kg)

AT = Averaging time (days)

(Mageswari et al., 2017) conducts study on groundwater quality due to Perungudi, it studies the water samples around the dump yard at 250m and 500m. Twenty-four groundwater samples are collected as twelve samples are located around 250m buffer distance, and another twelve samples are located around 500m buffer distance.

The sampling points are well distributed around the dump yard and are equidistant between adjacent points to obtain high accuracy. All the sampling points are reached by navigating to the noted coordinates using satellite maps. Groundwater samples are collected using polythene containers of two liters capacity, cleaned, and sterilized well before the sample collection. During sample collection, utmost care was taken to avoid any contamination.

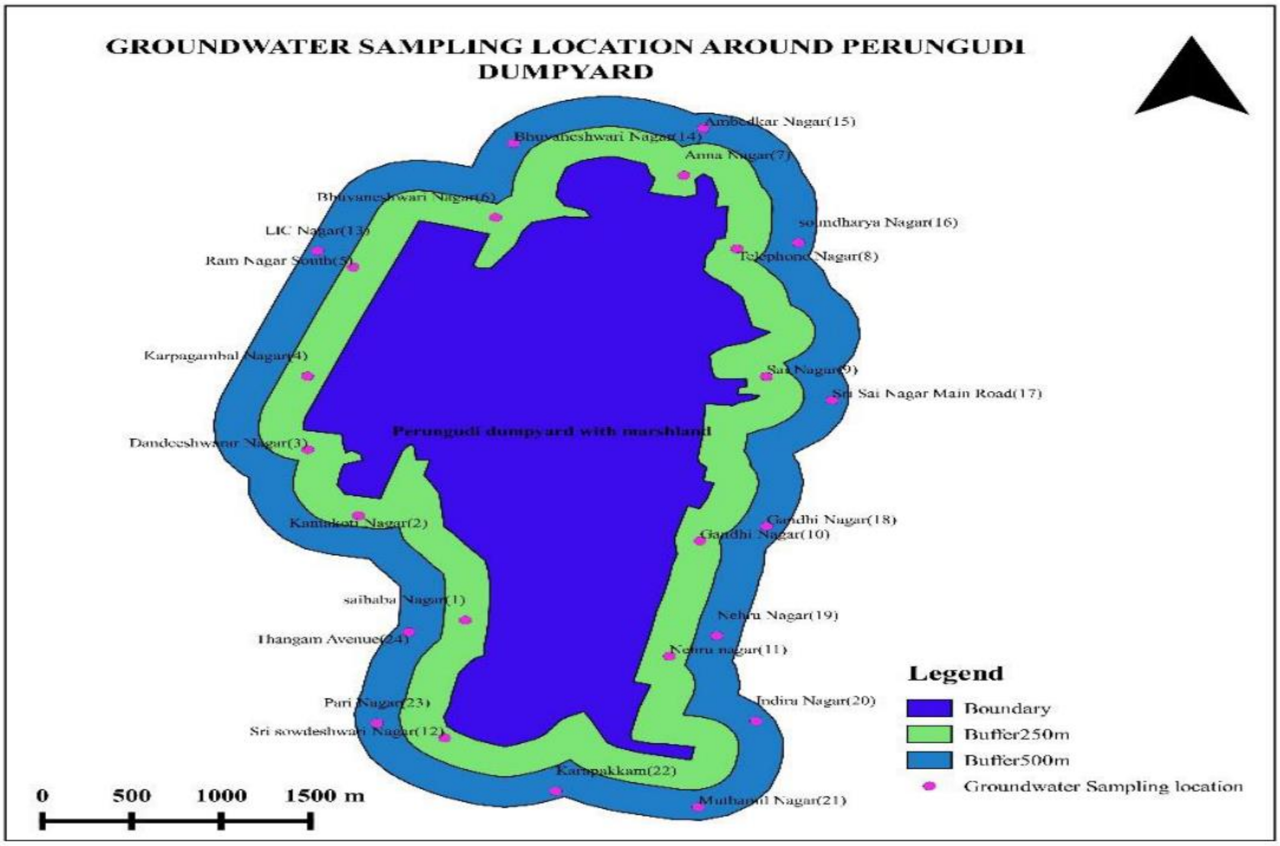

Figure 3 Groundwater sample location for the Mageswari 2017 study

Results here

component	Range
Turbidity	0.1-47(NTU)
Tds	665-5300(mg/l)
Iron(fe)	0-5(mg/l)
calcium	48-2400(mg/l)
Magnesium	19-3888(mg/l)
sulphates	60-14000(mg/l)
Fluorides	0.1-0.8(mg/l)

Table 1 List of heavy metals found in Mageswari 2017 study for groundwater around the dumpsite

(Parameswari et al., 2016) conducts socio-economic survey shows that 3% people depend on their groundwater, 6% people depend on piped water supply, 8% on purchased water 37% depends on the conjunctive use of well, piped and purchased water. 15% rely on well and piped water, whereas 21 % on well and purchased water and 10 % on piped and purchased water. The dependency on groundwater is mainly due to a lack of awareness regarding their contamination and affordability to go for other sources. The water was purchased even for domestic purposes only by the higher-economic group, whereas middle- and lower-economic groups purchased water only for drinking. From above shows that more than 70% of people are using groundwater.

(Parameswari et al., 2015) Conduct a study on soil contamination around the Perungudi dumpsite. They dig four borewells in the south-eastern direction of the dumpsite. They found that the concentration of copper, zinc, iron decreased with an increase in depth, which indicates their low mobility; the mobile nature of heavy metals depends on many other factors like ph., soil conditions, cation exchange capacity, etc. Heavy metals in soil indicate that leachate played a significant part, and the study recommends that dumping have to stop.

The soil concentration we found were

compound	Concentration(mg/kg)
Zinc (Zn)	0.6-4.5
Manganese (Mn)	2.4-9.3
Iron (Fe)	2.4-27.3
Copper(cu)	0.6-4.5

Table 2 List of heavy metals found in Parameswari 2015 study for soil

(Arthika and Maheswari, 2019) A study is conducted to assess the groundwater quality using the WQI (weighted athematic mean). The samples were collected around Perungudi Lake at different 11 locations and analyzed. This study happens to take the data for both pre-monsoon and post-monsoon. They concluded that 18% of the samples were of excellent quality, 36% were of good quality, and 45 % were of poor quality in pre-monsoon. On the other hand, 19% of the samples were of excellent quality, 27% were of good quality, and 54% were poor-quality post-monsoon. Thus, we can see that poor quality samples increased after the monsoon indicates contamination in surface water.

(Parameswari and Mudgal, 2015) conducted a study on leachate migration into groundwater by using contaminant transport modeling. This study assumed different scenarios. The first scenario was that if the same chloride concentration gets released from leachates. Then chloride concentration will rise to 300mg/l from 200mg/l within the next ten years. For the second scenario, if a recharge is increased by 10 %, then down the line, chloride concentration will get diluted. If chloride concentration is doubled for the third scenario, then concentrations in observatory wells doubled, making the water useless within ten years. This study predicts that water quality would improve if dumping stopped immediately within ten years due to the flushing and recharging of natural processes.

(Tripathy et al., 2019)conducted a study on the treatment for leachate using persulfate, hydrogen peroxide oxidation. They combine the Ultrasound system with the other treatment systems. The results show that the ultrasound system alone has an efficiency of 65% for COD removal. When combined with persulphate, its efficiency increased to 86%, whereas with hydrogen peroxide, the efficiency rose to 93%. However, more study has to do to comment on the energy and operational cost for the ultrasound system.

(Jayaprakash et al., 2010) conducts a study on how much total trace metals present on pallikaranai marshland. They study 36 samples collected from the wetland by going middle of them with a small fiber boat. Trace heavy metals were found using an X-ray fluorescence spectrometer. They conclude that the marshy region is more heavily contaminated with Cd, Hg, Cr, Cu, Ni, Pb, and Zn than other regions on the southeast coast of India.

(Parameswari and Mudgal, 2014)conducts a study in groundwater contamination in Perungudi dumpsite. The sample for the analysis was selected randomly from three locations for the survey in leachate. The groundwater was found to enter the Perungudi from north and west and flows towards the east and south directions. It was assumed that the leachate also follows the groundwater flow direction. The boreholes dig as shown below

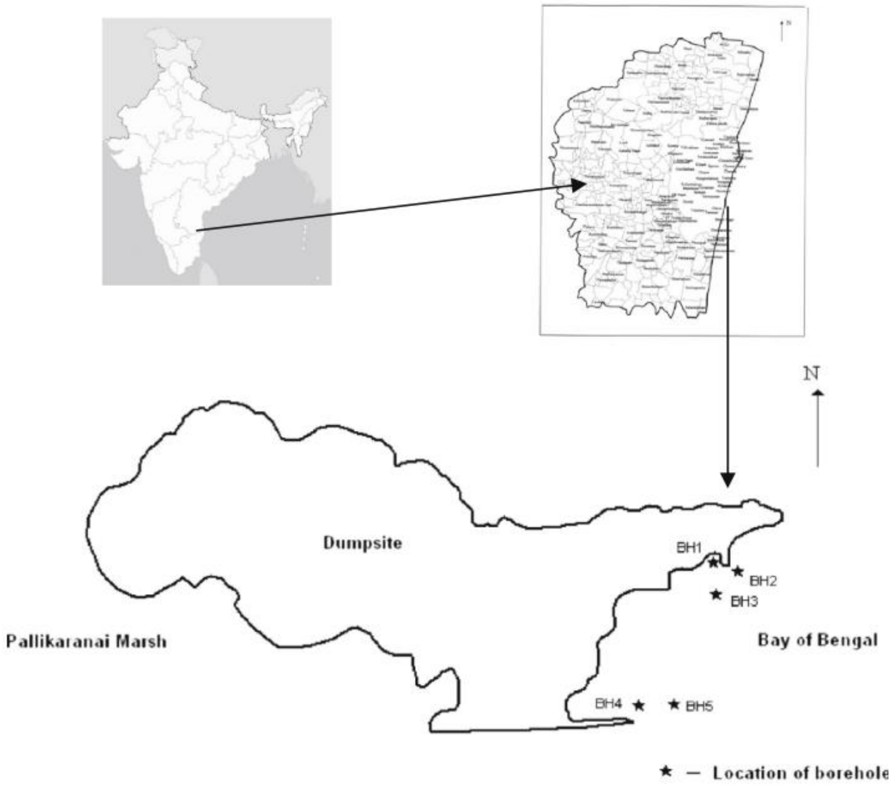

Figure 4 Borewell location for the Parameswari 2014 study

Five boreholes were drilled as shown above in **FIG (4),** each at 2, 4, 5.5, 9, 14-meter depths. The first three boreholes were used for the leachate characterization while remaining used to study contamination degree in groundwater. The results of the study were the

Component	Concentration reported range (mg/l)
Cadmium (Cd)	0.025-0.1095
Chromium (Cr)	0.682-1.021
Lead (Pb)	2.5-3.3
Iron (Fe)	0.25-0.62
Zinc (Zn)	0.06-0.09

Table 3 List of heavy metals found in Parameswari 2014 study for leachate

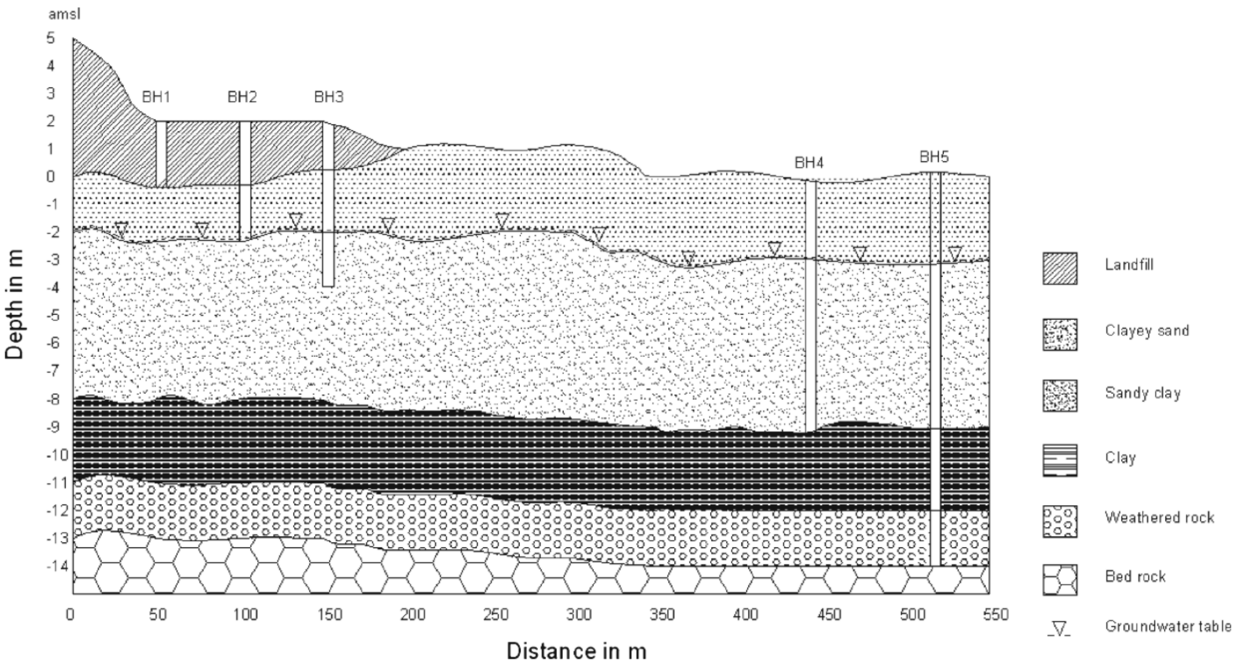

Figure 5 Distribution of soil across the depth Under Perungudi dumpsite

The dumpsite site has a geological profile, as shown in **FIG above** (5). We can see that sandy clay is the top layer of the ground below the dumpsite, which causes the water to hold there with less permeability. Below is the clay layer, which has low permeability, which reduces the whole ground permeability. Due to which there was significantly less space for the leachate due to which leachate goes out of dumpsite. Also, the dumpsite is surrounded by the marshland, which aids the leachate to reach nearby aquifers. This study also shows that deep, medium and Fine are best compared to coarse-textured material regarding contaminant removal.

(Swati et al., 2008) conducts a study on fresh and partially composted municipal solid waste in the Perungudi. They study for the hazardous organic compounds, toxicity characteristic leaching procedure (tclp) using a zero-headspace extractor, followed by further extraction by solvent separation using n-hexane containing 15% diethyl ether. They found dangerous organic compounds like diethyl phthalate, p-hydroquinone, etc. also, they found many phenolic. Among them, p-cresol is found abundantly.

(Vasanthi et al., 2008) conducts a study on the impacts of poor solid waste management of Perungudi dumpsite. In this study, the quality of groundwater around the dumpsite is studied. They collected the samples once in three months for three years at different distances. They observed that contamination concentration is decreased post-monsoon, then increases and reaches the peak during pre-monsoon. The quantity of leachate generated from the Perungudi dumping area is 348,000 m3/year, approximately 140 Olympic swimming pools. Sample for this study was collected from 30 open wells around the dumpsite at various locations, here are the findings

component	Concentration data found(mg/l)
Arsenic (Ar)	Below detection limit
Iron (Fe)	5.497
Manganese (Mn)	0.416

Lead (Pb)	0.038
Cadmium (Cd)	0.021
Copper (Cu)	0.219
Chromium (Cr)	0.200
Zinc (Zn)	7.448

Table 4 List of heavy metals found in vasanthi 2008 study for surrounding groundwater

This paper is published in 2008, which is 13 years old now. The report recommends the closure of the dumpsite to stop further contamination, but the landfill is still operational.

(Peter et al., 2019) Conducts the study on Perungudi dumpsite to study the nature of waste found in the Perungudi. Two locations were selected for the selection of sample based on the temperature profile, 50 kg of waste is collected from depth up to 7meters, fresh msw also ordered separately, they found the nature of waste is as below shown Fig (6)

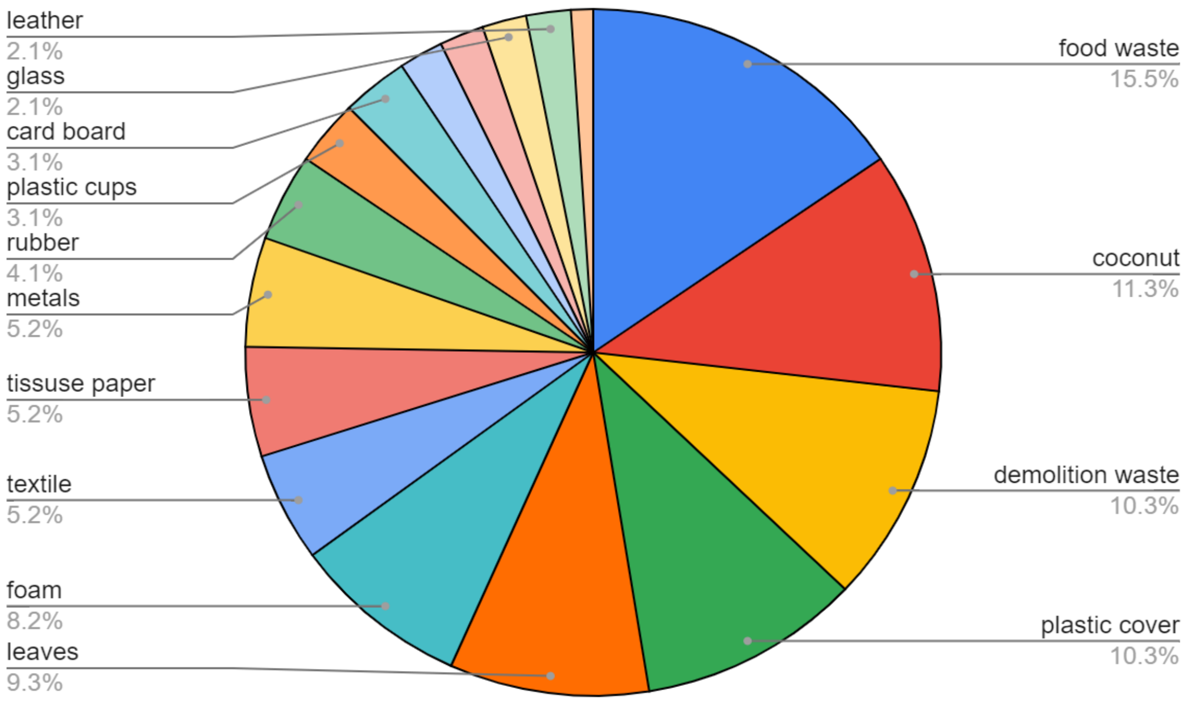

Figure 6 Distribution of waste from 2016 study

Here is the old nature of waste found in the Perungudi by the CMDA Chennai as shown in below Fig (7)

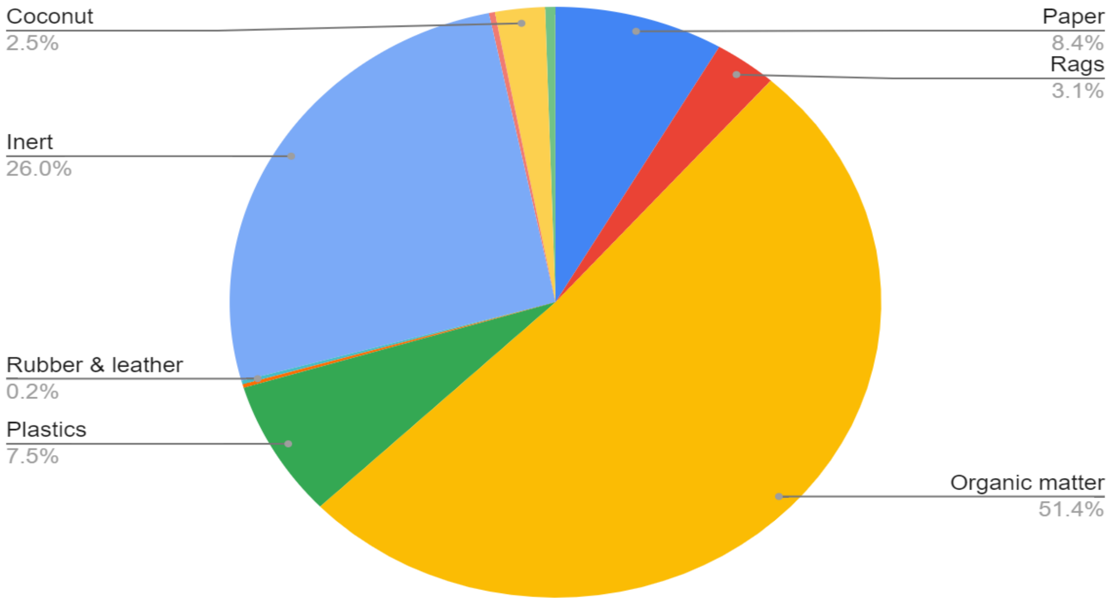

Figure 7 Distribution of water from 2006 study

We can see many changes like waste from the old one to the new one. For example, we can see that organic waste decreased to 24.8% from 51.4% due to installation for organic compost plants in the dumpsite where they try to compost it. Also, we can see that plastic waste was increased. Also, the new type of waste, i.e., foam, occupies 8.2% due to usage of package industries.

(Rajasekhar et al., 2018) conducts the study on human health assessment of contaminated groundwater from petroleum PAH using the Monte Carlo simulation. from this paper. We will be sourcing the input parameters as we will be doing the same as this paper for both oral and dermal pathways. here are the parameters

Parameter	symbol	Unit	For Child (0-5)	For the Adult (21-70)
Body Weight	BW	Kg	10.22	49.29
Exposure duration	ED.	Years	2.5	26
Exposure frequency	EF	Days/year	345	345
Permeability coefficient	k_p	Cm/hr	Compound specific	Compound specific
Lag time per event	t_{event}	Hr/event	0.484	0.484
Skin Surface Area	SA	cm^2	5837.77	19771.05
Ingestion Rate	IR	Lit/day	0.65	1.38
Averaging time (non cancer)	AT	Days	912.5	9490
Averaging time (cancer)	AT	Days	25550	25550

Table 5 Input data for the Deterministic method for both child and adult

Here we can see that this study has done the probability analysis using the Monte Carlo simulation using the Risk8 software. In this study, they found that cancer risk predicted using the single point values, i.e., the deterministic method was found to positioned greater than the median in risk distribution. However, by using the probabilistic method, we can address the uncertainties and variables in the study.

(Ali et al., 2021) conducts a study on human health risk assessment from Heavy metals for dumpsite located in Saudi Arabia. Risk assessment is calculated using the deterministic method. The pathways considered in this were ingestion, dermal, inhalation. The equation for each path was sourced from the US EPA document (USEPA 2002). The hazard quotient was calculated for the non-cancer risk. However, this study did not account for the uncertainties and variables in this study.

(Aram, 2016) conducts a study on groundwater quality in pallikaranai marshland. Five borewell samples were taken from the localities surrounding the Perungudi dumpsite named Anjugam Ammaiyar Nagar in the north, Re Nagar Extension in the east, Indira Nagar north, Re Nagar Extension in the east, Indira Nagar in the south, and Karapagambal Nagar in the west. Although the samples are surrounding the Perungudi, they have huge variations, here are data found

Component	Range
Sulphates (SO4) (mg/l)	71-350
Phosphates (PO4) (mg/l)	0.01-0.013
Iron (Fe) (mg/l)	0.17-1.15
F (mg/l)	0.25-0.38

Table 6 List heavy metal found in Aram 2016 study for surrounding dumpsite for groundwater

(Sijelmass, 2014) conducts a study on the effect of waste dumping on water quality. The six samples were taken around the dumpsite, as shown in table7. In the retrieved samples were examined for the heavy metals using the Coupled Plasma Optical Emission Spectrometry. here are the findings

Component	Concentration range (Mg/l)
Iron (Fe)	0.331-3.293
Manganese (Mn)	0.169-1.97
Cobalt (Co)	0.001-0.006
Lead(pb)	0.0005-0.095
Chromium (Cr)	0.004-0.014
Cadmium (Cd)	0.00006-0.001

Table 7 list heavy metal found in the sijelmass2014 study for surrounding dumpsite for groundwater

This study interviews people living in thorapakamm, and the findings are a severe mosquito problem, burning in landfills illegally. Also, some people dump the waste at night illegally. She was using the purchased water for drinking and cooking purposes which is costly to her lifestyle. They found that occasionally, the water from the tap even has a reddish or yellowish color. Other problems were during the rainy season, where there is a chance that dumpsite surface mix with rainwater comes to a residential place with bad smell.

(Peter et al., 2018)conducts on the health risk by the Perungudi dumpsite through the Inhalation pathway. Samples are collected from the rooftop of the building, which is located 0.6km away from the dumpsite during 2014-2015. they did a risk assessment for the heavy metals using the equation US EPA website.

$$ECR = \frac{C \times IUR \times ET \times ED \times EF}{AT}$$

Here

ECR = Excess Cancer Risk

C = concentration of pollutant

EF = Exposure Frequency, 180days per year

ED = Exposure Duration (6 years for Children and 24 years for adult)

ET = Exposure time (8h per day)

IUR = Inhalation unit risk (collected from USEPA website)

AT = Averaging time (70 Years for Cancer Risk)

$pm_{2.5}$ concentration was studied over the year. Here is the summary of 24 hr average over the season, 52.78 ± 23.22, 72.34 ± 24.90, 45.82 ± 13.91 μg/m3, respectively, during monsoon, winter, and summer seasons.

Heavy metal concentration was found in the PM of dumpsite samples, and they found heavy metals like Zinc, Cadmium, Chromium, Titanium, Manganese, Nickel, Lead, etc., because of open burning in the dumpsite led to release the heavy metals into the air. and also due to the leaching of these metals into the soil

The heavy metal analysis of PM2.5 samples showed that the 60-day average concentrations of THMs such as As (16.33 mg/m3), Cd (36.66 mg/m3), Cr (47.66 mg/m3), Ni (86.466 mg/m3), Mn (14.66 mg/m3) and Pb (16.55 mg/m3), which were very high than the concentrations found in the road. Therefore, the THM concentrations reported may be enough to cause cancer risk among the people who reside around the Perungudi site.

Inhalation Cancer Risk was calculated using the reported THM concentrations. The findings are that Chromium poses a risk of 10.4E-06, Cadmium poses a risk of 2.24E-06, Arsenic poses a risk of 1.34E-06 for the child. Chromium poses a risk of 42E-06, Cadmium poses a risk of 8.8E-06, Arsenic poses a risk of 5.4E-06. Therefore, we can see that all risks are above the limit of 1 in a million, i.e., 1E-06, but for the Nickel and Lead cancer risk, were within the limit.

They conclude the study that several THM is present in the air of MSW dumpsite due to the burning of scrap waste, electronics, plastics, etc. Also, frequent fires in the open dumpsite led to contamination of air. So, it is essential to avoid those fires.

Research Gaps

- Literacy study shows that no research has been done for Human health risk assessment from Heavy metals.
- A study calculates human health from the Inhalation pathway but did not find it from the oral and dermal pathways. So we will calculate that now.
- Our research found that risk was calculated using the deterministic method most of the time, i.e., using point values. However, the problem with the deterministic approach is that it does not account for the uncertainties and variables in the study.
- Hence, we will be using the probabilistic approach using the Monte Carlo simulation to address the uncertainty and variables in the study.
- We did find that there no many studies are conducted around the soil. Also, most of the data is 4-5 years old. We need the recent data to get the more approximate risk because 4-5 years is a very long time to see a change in risk.

METHODOLOGY

We will be following the methodology prescribed by the US EPA (2004)

According to US EPA, Human Health risk assessment have four steps

Hazard Identification

Exposure Assessment

Toxicity Assessment

Risk Characterization

Hazard Identification

The first step is Hazard Identification. In this step, we will identify the potential contaminants that pose a risk to human health. For this study, we Identify heavy metals contamination as a potential contaminant. Several (Vasanthi et al., 2008)studies we did in the literature review confirm the presence of heavy metals in the groundwater, soil, air details of their concentration from a different medium from different studies as shown below in tables.

Heavy metal Concentrations found in Perungudi dumpsite itself is shown below

Component	Range in Mg/l	References
Iron (Fe)	0-5	(Mageswari et al., 2017)
Zinc (Zn)	0.0153-10.375	(Parameswari and Mudgal, 2014)
Copper (Cu)	0.01 - 0.099	(Vasanthi et al., 2008)
Lead (Pb)	0.006-0.832	(Parameswari and Mudgal, 2014)
Cadmium (Cd)	0.025- 0.1095	(Parameswari and Mudgal, 2014)
Chromium (Cr)	0.682-1.021	(Parameswari and Mudgal, 2014)

Table 8 List of heavy metal concentration used for the deterministic and probabilistic method in dumpsite groundwater

In the literature review, we found the heavy metal concentration around the dumpsite in the residential here is reported values of heavy metal concentration in groundwater below table (9).

Component	Range (Mg/l)	References
Iron (Fe)	0.17-1.15	(Aram, 2016)
Manganese (Mn)	0.169-1.97	(Sijelmass, 2014)
Cobalt (Co)	0.001-0.006	(Sijelmass, 2014)
Lead (Pb)	0.0005-0.095	(Sijelmass, 2014)
Cadmium (Cd)	0.00006-0.001	(Sijelmass, 2014)
Chromium (Cr)	0.004-0.014	(Sijelmass, 2014)

Table 9 List of heavy metal concentration used for the deterministic and probabilistic method in surrounding groundwater

The literature review found the heavy metal concentration in the leachate reported values of heavy metal concentration below table (10).

Component	Range (Mg/l)	References
Zinc (Zn)	0.2	(Tripathy et al., 2019)
Copper (Cu)	0.61	(Tripathy et al., 2019)
Manganese (Mn)	2.31	(Tripathy et al., 2019)
Lead (Pb)	1.548	(Tripathy et al., 2019)
Chromium (Cr)	0.2	(Tripathy et al., 2019)

Table 10 List of heavy metal concentration used for the deterministic and probabilistic method in the leachate of the dumpsite

Another Medium where we find the heavy metal concentration as a potential hazard is a soil, where human health risk is involved. Here is the heavy metal concentration we saw in the ground.

Component	Range (Mg/Kg)	References
Zinc (Zn)	0.6-4.5	(Parameswari et al., 2015)
Manganese (Mn)	2.4-9.3	(Parameswari et al., 2015)
Iron (Fe)	2.4-27.3	(Parameswari et al., 2015)
Copper (Cu)	0.6-4.5	(Parameswari et al., 2015)

Table 11 List of heavy metal concentration used for the deterministic and probabilistic method in the soil of dumpsite

Also, we find heavy metal concentration in the air we are not going to explore because there was already a Human risk assessment done for that medium (Peter et al., 2018)for the Inhalation pathway in that study.

Exposure assessment

The primary exposure routes for the Heavy metals were identified using the Conceptual Site Model (CSM) here is the CSM (ignore my drawing skills)

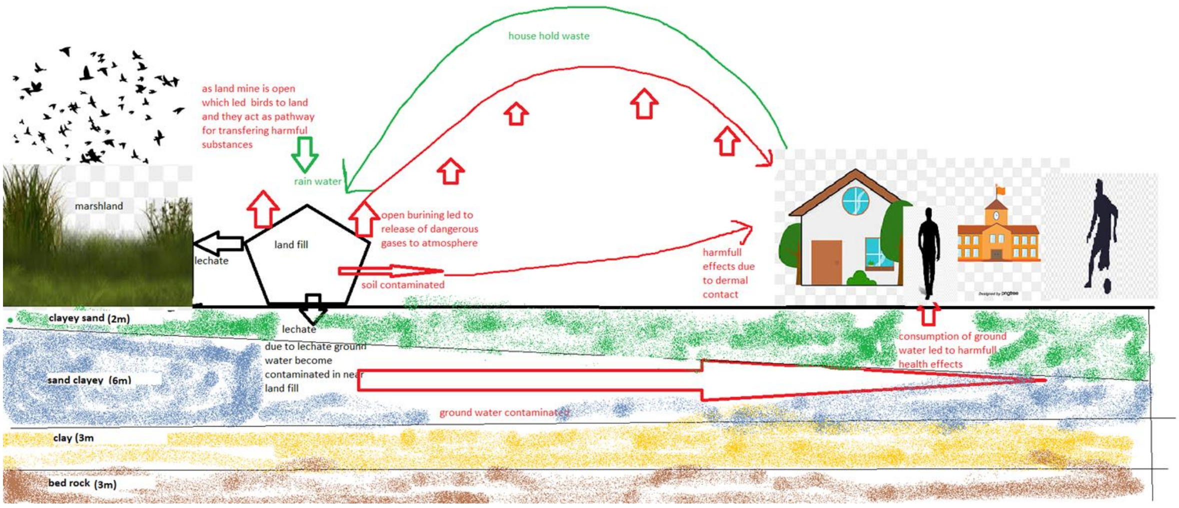

Figure 8 Conceptual site model for the Perungudi Dumpsite

The primary pathways Identified were through the

- Oral Pathway
- Dermal Pathway
- Inhalation Pathway

As the present study is around the residential area, the age groups considered are children (0-5) and Adults (18-70). These two groups are considered because to get a clear Distinction between results.

The dermal absorbed dose from the groundwater is calculated by using the USEPA equation

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT}$$

Where

$$DA_{event} = k_p \times C_w \times t_{event}$$

Here

DAD = Dermal absorbed dosage (mg/kg-day)

DA_{event} = Absorbed dose per event (mg/cm^2-event)

EV = Event frequency (events/day)

ED = Exposure duration (years)

EF = Exposure frequency (days/year)

SA = Surface area (cm^2)

BW = Body Weight (kg)

AT = Averaging time (days)

t_{event} = Event duration (hr/event)

C_w = Chemical concentration in water (mg/lit)

k_p = Dermal permeability coefficient of a compound in water (cm/hr)

The exposure due to oral pathway from consumption of contaminated groundwater was calculated using US EPA equation

$$CDI = \frac{C_w \times IR \times ED \times EF}{BW \times AT}$$

CDI = Chronic Daily dosage (mg/kg-day)

IR = Ingestion rate (lit/day)

ED = Exposure duration (years)

EF = Exposure frequency (days/year)

C_w = Chemical concentration in water (mg/lit)

BW = Body Weight (kg)

AT = Averaging time (days)

The exposure due to dermal pathway from the soil of contaminated soil was calculated using the US EPA equation

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times AT}$$

Where

$$DA_{event} = ABS_d \times C_{soil} \times CF \times AF$$

Here

DAD = Dermal absorbed dosage (mg/kg-day)

DA_{event} = Absorbed dose per event (mg/cm^2-event)

EV = Event frequency (events/day)

ED = Exposure duration (years)

EF = Exposure frequency (days/year)

SA = Surface area (cm^2)

BW = Body Weight (kg)

AT = Averaging time (days)

ABS_d = Dermal absorption fraction

C_{soil} = Chemical concentration in soil (mg/kg)

CF = Conversion factor (10^{-6} kg/mg)

AF = Adherence factor (mg/cm^2-event)

The exposure due to inhalation pathway is not calculated in this study because (Peter et al., 2018) has done the human health risk assessment for the Inhalation pathway and concluded that some of the heavy metal concentrations in the air had crossed the permitted limit of 1 in a million, i.e.(1.0E-06).

Toxicity Assessment

In this study, we identify that among the heavy metals, there are carcinogenic and non-carcinogenic. According to US EPA, among the heavy metals carcinogenic one is Arsenic (Ar), Nickel (Ni), Cadmium (Cd), Chromium (Cr), Beryllium (Be) is termed as carcinogenic heavy metal because of their toxic nature.

So, the carcinogenic heavy metal presence led to the calculation of both cancer and non-cancer risk. Carcinogenic heavy metal causes non-cancer and cancer risk, so they are calculated twice for cancer and non-cancer ones. Non-cancer heavy metal contributes only to non-cancer risk.

Risk Characterization

Risk for the cancer risk is calculated using the Slope factor (SF) for both oral and dermal pathway in which the dermal slope factor was calculated from the oral slope factor using the gastrointestinal absorption factor (ABS_{GI})

Where $SF_{dermal} = \frac{SF_{oral}}{ABS_{GI}}$ For the Non-cancer risk was calculated using the Hazard quotient where RFD (reference dosage) was used to calculate the Hazard quotient

Where $HQ = \frac{CDI}{RFD_{oral}}$ for calculating the hazard quotient through the oral pathway, $HQ = \frac{DAD}{RFD_{dermal}}$ For calculating the hazard quotient through the dermal pathway.

For the cancer risk, cancer risk is calculated as $CR_{oral} = CDI \times SF_{oral}$ for the oral pathway, where for the dermal pathway, cancer risk was calculated as $CR_{dermal} = DAD \times SF_{dermal}$.

The acceptable value for the cancer risk is 1.0E-06, i.e., I in a million, whereas for the Non-cancer risk acceptable Hazard quotient should be less than 1

Deterministic method Vs. probabilistic method

The deterministic method is when we have done the health assessment calculation using a single point value. It determines the risk. The problem with this method is that it does not account for the uncertainty and variables in the study. For example, we considered the Bodyweight for adults as 49 kg in the deterministic method. However, it does not satisfy all the population because bodyweights among the large population have many variations.

To address this uncertainty and variables in the study, the probabilistic method was introduced. We will be doing Monte Carlo simulation as the probabilistic method. In Monte Carlo simulation, any point value change to a statistical random variable is defined by its mean, std deviation, maximum and minimum values. We will be doing the 10,000 simulations to get the most accurate risk from the different variables.

Deterministic method	Probabilistic Method
Input is fixed values.	Input values were generated based on their mean and standard values.
It Does not address the uncertainty and variables in a study.	Addresses the uncertainty and variables in a study.
It considers only a single scenario.	It considers all the possible scenarios.
In this method, we know what input we are given, which is more proven and tangible.	Whereas in this method, we know what the result is and do not know what input entered.
The output of the model Is decided by the parameters entered.	In this method, we introduce randomness to the model.
It does not require more resources and expertise	It requires more resource and expertise
Simple models and equations	Complex models and equations

Table 12 Deterministic method vs. Probabilistic method differences

Results

Deterministic approach

The human health risk assessment was calculated in this study from both deterministic and probabilistic. Here are how results came for both.

The Input data for the Deterministic method was sourced from

(Rajasekhar et al., 2018), which was sourced from the US EPA website. Here are input data

parameter	Symbol	unit	Children	Adult
Bodyweight	BW.	Kg	10.22	49.29
Exposure duration	ED.	Year	2.5	26
Exposure frequency	EF	Days/year	345	345
Event duration	$\boldsymbol{t_{event}}$	Hr/event	0.484	0.484
Skin surface area	SA	Cm^2	5837.77	19771.05
Ingestion rate	IR	l/day	0.65	1.38
Average time (non-cancer)	AT	Days	912.5	9490
Average time (cancer)	AT	Days	25550	25550

Table 13 Input data for the deterministic method

The age groups we consider were child and adult. As we want to get more distinction among the results, we will be calculating both Cancer and Non-cancer risk. For calculating the risk, we need additional elemental specific data like k_p, RFD_{oral}, SF_{oral}, ABS_{gi} Etc.

For the additional Elemental data, we will be referring to RSL (Regional Screening Level) developed by the US EPA (the United States Environmental Protection Agency) and RAIS (Risk assessment Information system) developed by the US Department of Energy.

Component	k_p	RFD_{oral}	SF_{oral}	ABS_{gi}
Iron (Fe)	0.001	0.738	NA	1
Zinc (Zn)	0.0006	0.3	NA	1
Copper (Cu)	0.001	0.04	NA	1
Lead (Pb)	0.0001	0.0035	NA	1
Cadmium (Cd)	0.001	0.0005	0.38	1
Chromium (Cr)	0.002	0.003	0.5	1
Manganese (Mn)	0.001	0.024	NA	1
Cobalt (Co)	0.0004	0.0003	NA	1

Table 14 Input data of metal-specific data from rsl and rais

We will calculate both cancer and non-cancer risk for different pathways in each environmental medium by entering the above data. The ecological medium we are considered for this study is landfill groundwater, surrounding areas groundwater, Dump yard leachate, Dumpsite soil.

The pathways for each Environmental media were assumed as shown in the Fig below flow charts in FIG (9)

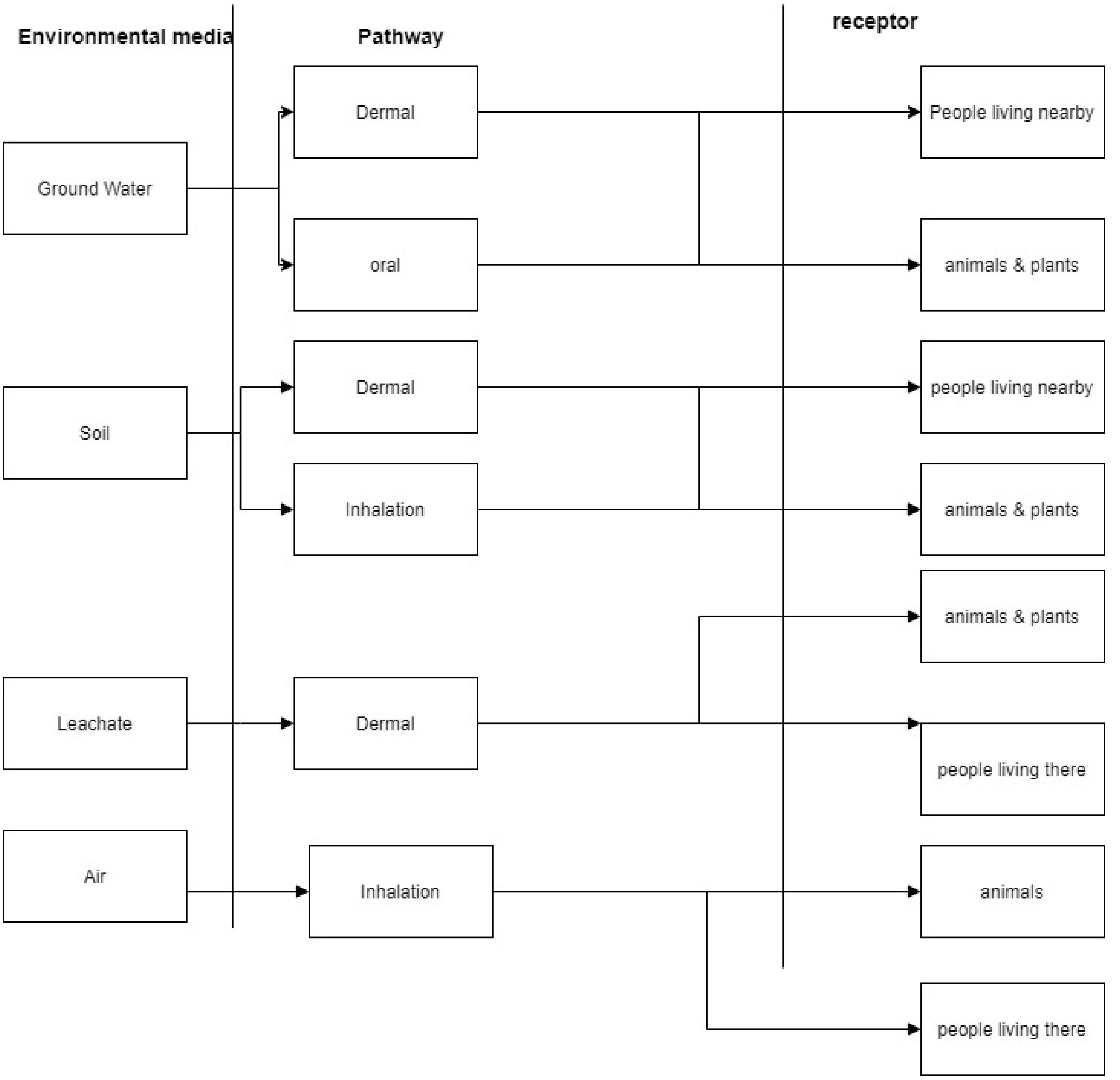

Figure 9 pathways for the different Environmental media

Now we will calculate both cancer and non-cancer risk for each pathway in each environmental medium.

For the Groundwater in Landfill

		children		adult	
	metal	oral	dermal	oral	dermal
non cancer	Iron	0.407289	1.77E-03	0.179292	1.24E-05
	Zinc	2.079005	5.42E-03	0.915194	3.81E-05
	copper	0.148787	0.000647	0.065497	4.54E-06
	lead	14.29039	0.006212	6.290741	4.36E-05
	cadmium	13.04513	0.056706	5.742569	0.0003982
	chromium	20.45941	0.17787	9.006395	0.001249
	total	50.43	0.24863	22.19969	0.001746
cancer	cadmium	8.85E-05	3.85E-07	0.000405	2.81E-06
	chromium	0.001096	9.53E-06	0.005018	6.96E-05
	total	1.18E-03	9.91E-06	0.005423	7.24E-05

Table 15 Deterministic method calculation for landfill groundwater

(*red colour indicates the risk value crosses the acceptable value)

For the groundwater in landfill risk calculation, we can see that both cancer and non-cancer Risk has crossed the acceptable value for both the children and adults, with the main contribution being the Cadmium and Chromium.

For the surrounding areas of Dumpsite from Groundwater

		Children		Adult	
	Metal	Oral	Dermal	Oral	Dermal
Non-Cancer	Iron	0.093676	0.000407	0.041237	0.000286
	Manganese	4.934506	0.02145	2.172208	0.015063
	Cobalt	1.202316	0.002091	0.529269	0.001468
	Lead	1.631715	0.000709	0.718294	0.000498
	Cadmium	0.120232	0.000523	0.052927	0.000367
	Chromium	0.28054	0.002439	0.123496	0.001713
	Total	8.262985	0.027618	3.637431	0.019394
Cancer	Cadmium	8.16E-07	3.55E-09	3.74E-06	2.59E-08
	Chromium	1.50E-05	1.31E-07	6.88E-05	9.54E-07
	Total	1.58E-05	1.35E-07	7.25E-05	9.80E-07

Table 16 Deterministic method calculation for surrounding areas of dumpsite groundwater

(*red colour indicates the risk value crosses the acceptable value)

For the groundwater in surrounding areas of landfill risk calculation, we can see that both cancer and non-cancer Risk has crossed the acceptable value for both the children and adults but only in an oral pathway, with the main contribution being the Manganese and Chromium.

For the leachate found in the dumpsite

in this environment, we consider only the dermal pathway because its oral pathway is not possible directly.

		Leachate	
		Children	Adult
	Metal	Dermal	Dermal
Non-Cancer	Manganese	0.002515	0.001766
	Zinc	0.000105	7.34E-05
	Copper	0.003985	0.002798
	Lead	0.011558	0.008116
	Chromium	0.034842	0.024467
	Total	0.05301	0.03722
Cancer			
	Chromium	1.87E-06	1.36E-05

Table 17 Deterministic method calculation for leachate of a dumpsite

(*red colour indicates the risk value crosses the acceptable value)

We can see that there was no non-cancer risk involved in our calculation but cancer risk there through the dermal pathway. It raises the question of the safety of people working inside the dumpsite. Our analysis used event time as 0.484h/event, which is time for the domestic time. Let us calculate the event time with no chance of cancer risk, i.e., calculating the event time for the Maximum Risk allowed. **Fifteen minutes** is the maximum time allowed per day to keep risk within the limit. However, people working inside the dumpsite may operate for more than 8 hours, so people inside the landfill must follow the safety precautions while working.

For the soil inside the dumpsite

	soil	
Non-Cancer	children	adult
Metal	dermal	dermal
Iron	3.99E-06	1.40E-05
Zinc	1.62E-05	5.69E-05
Copper	1.21E-05	4.27E-05
Manganese	4.18E-05	0.000147
total	7.42E-05	2.60E-04

Table 18 Deterministic method calculation for landfill soil

We did only the dermal pathway, while another pathway available to the analysis is inhalation. However, that pathway is already calculated in the (Peter et al., 2018), concludes that there are hazardous heavy metals in the air more than acceptable risk.

Probability Risk

We already did our study in the deterministic method. Let us do a probabilistic approach using Monte Carlo simulation. We will be considering the Bodyweight (BW), Ingestion rate (IR), Surface area (SA) as the variables. We will do the Monte Carlo simulation for those three variables using the mean, standard deviation, range derived from EFH (Exposure Handbook).

Property	Child (0-5)				Adult (19-70)			
	Mean	Std deviation	max	Min	mean	Std deviation	max	mini
Body weight(kg)	10.2	1.43	19.15	1.8	80	8.82	125	40
Ingestion Rate(lit/day)	0.65	0.39	0.95	0.325	1.38	0.71	2.9	1.04
Surface area(cm^2)	5838	920	9500	2400	19771	3373	25100	16100

Table 19 Input data for the probabilistic method

Using the above equation, we will develop the monte Carlo Simulation in excel using the equation (=norm.inv((rand (), mean, std deviation)), in this equation, we assigned the probability using rand() which random chance between 0-1, above equation generates the random value from the mean, std deviation using the random probability assigned to it, after that, we use the what-if analysis and generate the 10,000 simulations, with each unique value for the variable we calculated risk.

According to the US EPA, the 95th percentile value is considered the RME (reasonable maximum exposure estimate). So we will be using that 95th percentile value as the risk from that pathway.

Risk calculated using the probabilistic method in the groundwater in the dumpsite.

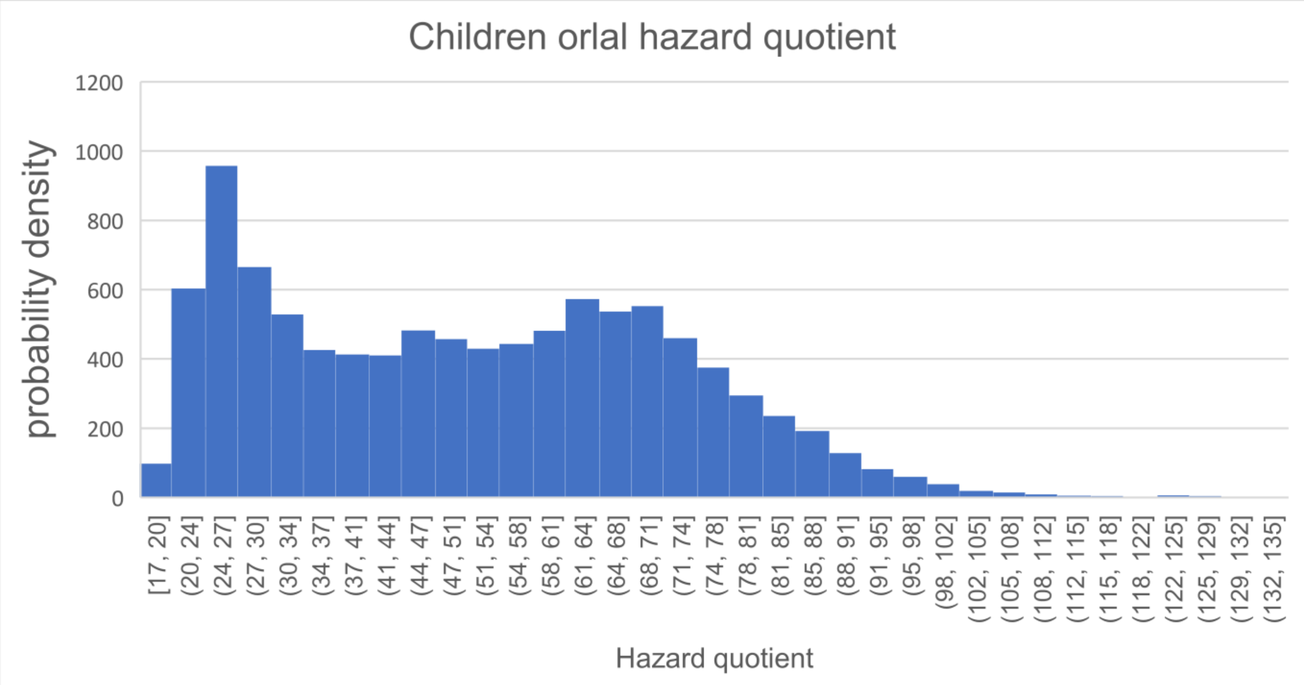

Figure 10 Probability distribution Vs. hazard quotient for child oral in groundwater of dumpsite

Properties	value
Mean	51.2034
Max	135.419
Min	16.866
5th percentile	22.82
50th percentile	50.353
95th percentile	85.87
99th percentile	98.97

Table 20 Non-cancer risk values from monte Carlo simulation for child oral for groundwater in a dumpsite

We can see 95th percentile is 85.87, which is more than the acceptable value

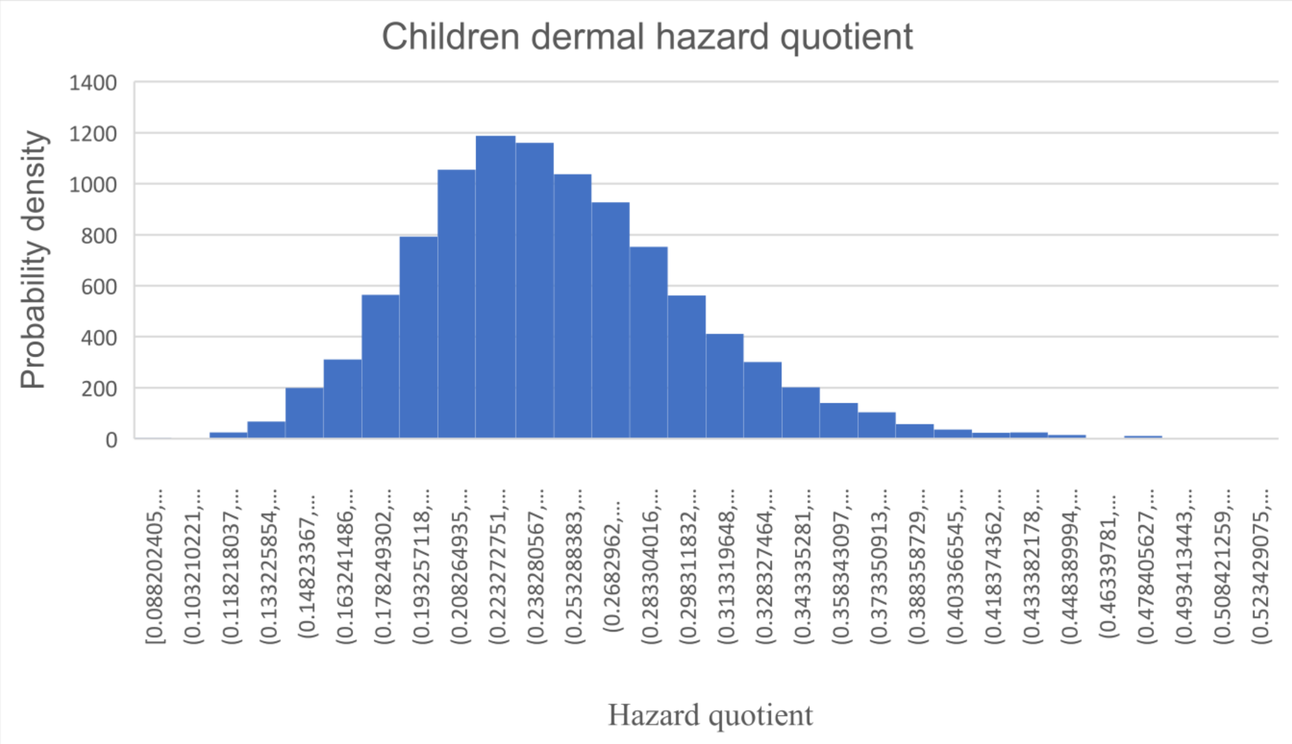

Figure 11 probability distribution Vs. hazard quotient for child dermal in groundwater of dumpsite

Properties	value
Mean	0.25398
Max	0.538
Min	0.0882
5th percentile	0.17396
50th percentile	0.24865
95th percentile	0.35265
99th percentile	0.412177

Table 21 Non-cancer risk values from monte Carlo simulation for child dermal for groundwater in a dumpsite

We can 95th percentile value is 0.35 is well within the limit

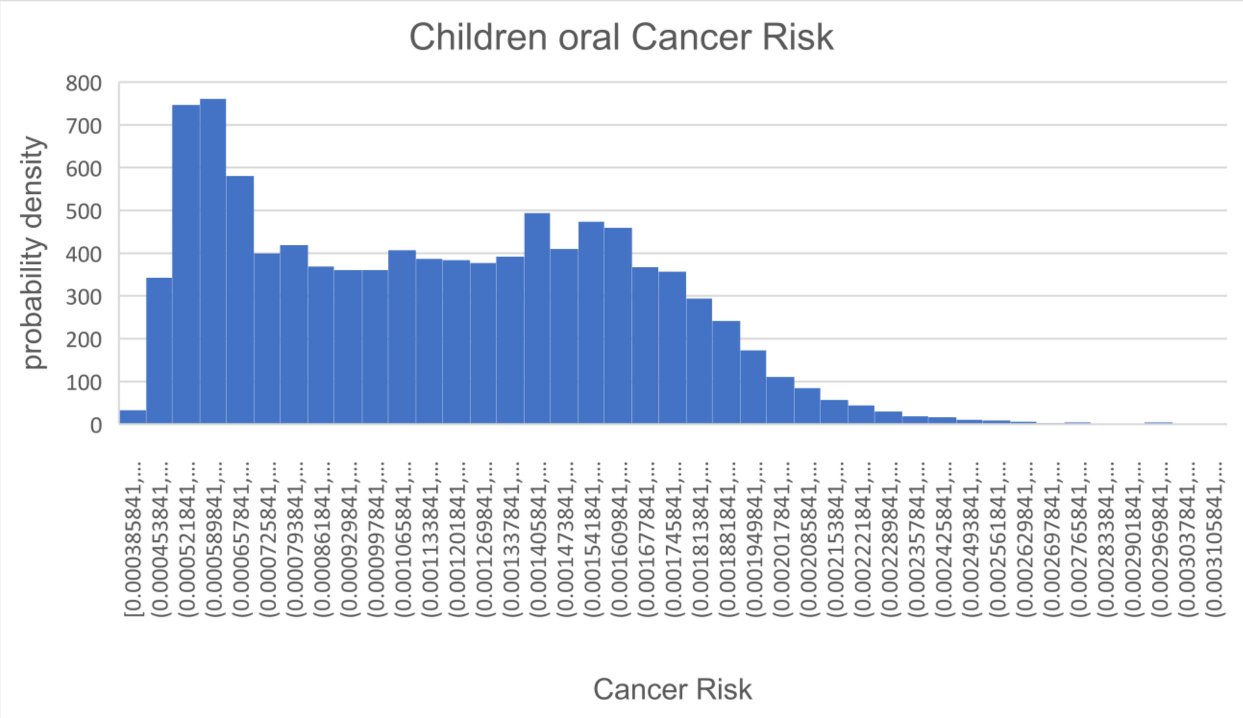

Figure 12 Probability distribution Vs. cancer risk for child oral in groundwater of dumpsite

Properties	Value
Mean	0.00119
Max	0.00311
Min	390.0E-06
5^{th} percentile	0.00053579
50^{th} percentile	0.001173273
95^{th} percentile	0.00198344
99^{th} percentile	0.002312984

Table 22 Cancer risk values from monte Carlo simulation for child oral for groundwater in a dumpsite

We can see that the 95^{th} percentile value is 1983.44E-06 which very high than the acceptable value

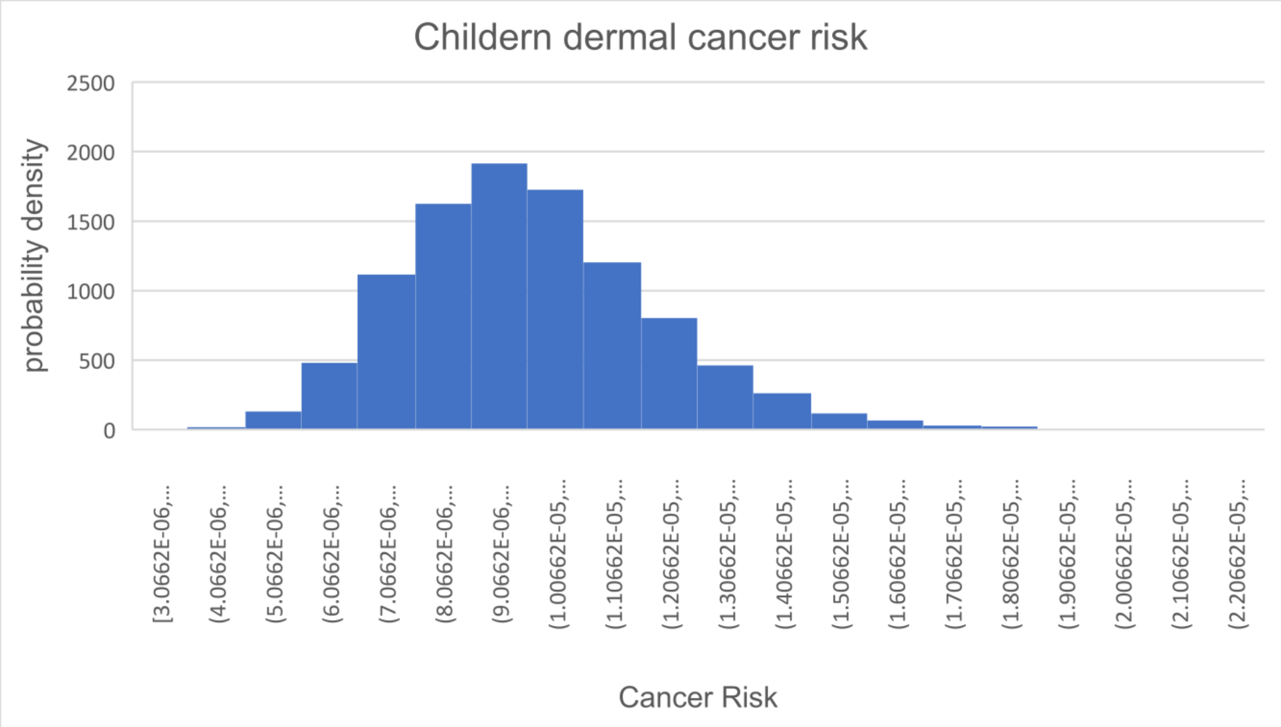

Figure 13 Probability distribution Vs. cancer risk for child dermal in groundwater of dumpsite

Properties	value
Mean	1.01E-05
Max	2.24E-05
Min	3.066E-06
5^{th} percentile	6.85E-06
50^{th} percentile	9.91E-06
95^{th} percentile	1.409E-05
99^{th} percentile	1.646E-05

Table 23 Cancer risk values from monte Carlo simulation for child dermal for groundwater in a dumpsite

We can see that the 95^{th} percentile value is 14.095E-06 which is more than the acceptable value.

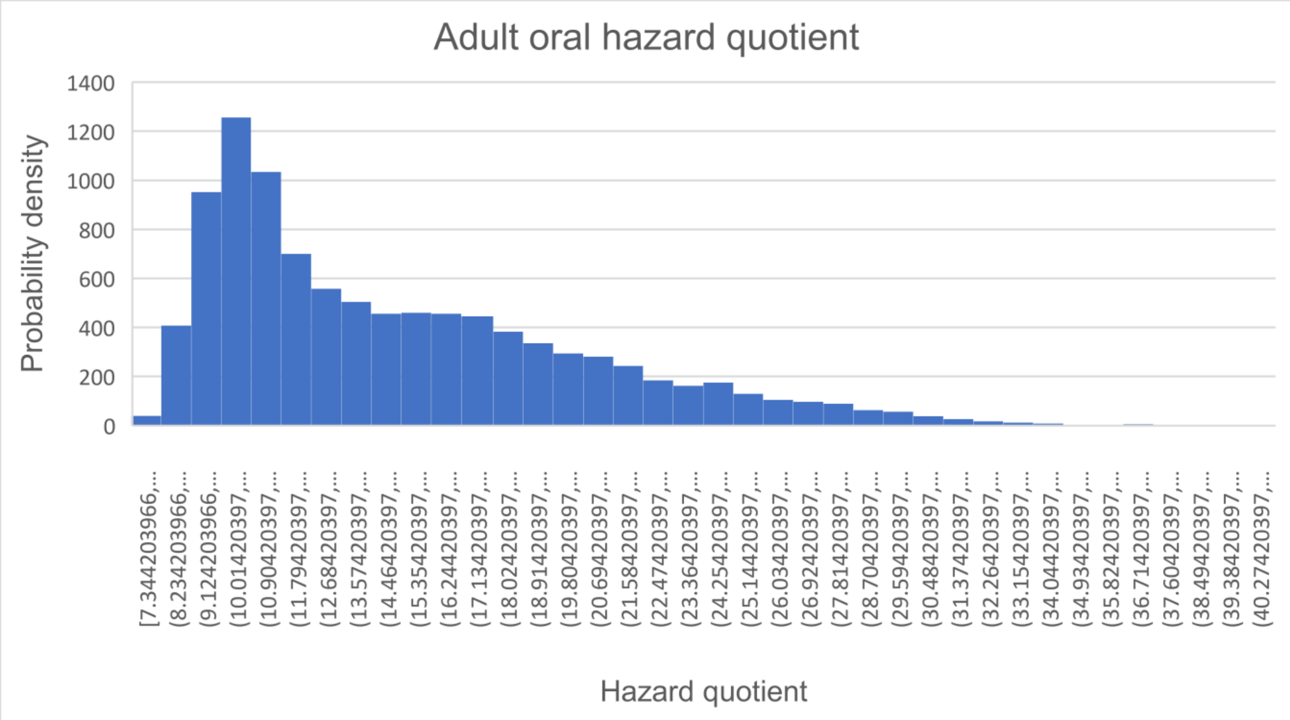

Figure 14 Probability distribution Vs. Hazard quotient for adult oral in groundwater of dumpsite

Properties	value
Mean	15.2466
Max	40
Min	7.34
5th percentile	9.19
50th percentile	13.640
95th percentile	26.299
99th percentile	30.92

Table 24 Non-cancer risk values from monte Carlo simulation for adult oral for groundwater in a dumpsite

We can see that the 95th percentile value is 26.299, which is more than the acceptable risk.

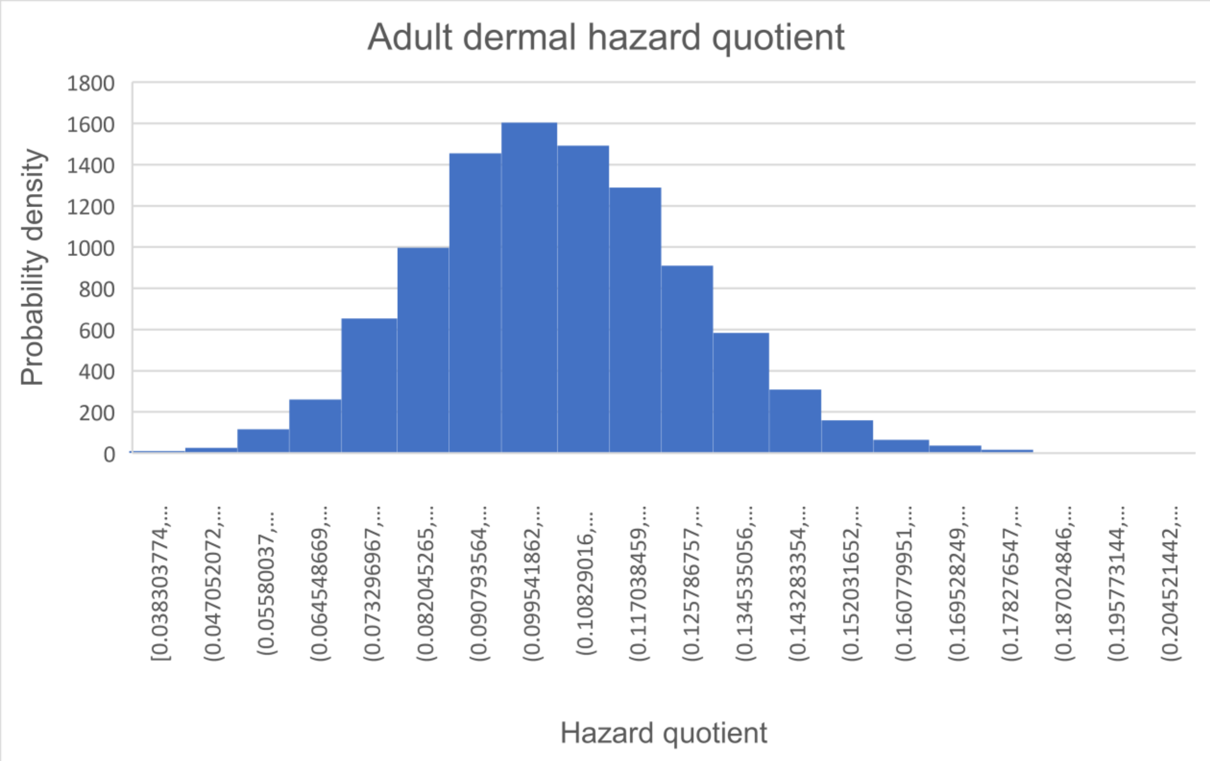

Figure 15 Probability distribution Vs. Hazard quotient for adult dermal in groundwater of dumpsite

Properties	Value
Mean	0.108567
Max	0.21327
Min	0.038304
5th percentile	0.07477
50th percentile	0.1075
95th percentile	0.1455
99th percentile	0.163

Table 25 Non-cancer risk values from monte Carlo simulation for adult dermal for groundwater in a dumpsite

We can see that the 95th percentile value is 0.1455, which is well within the limit

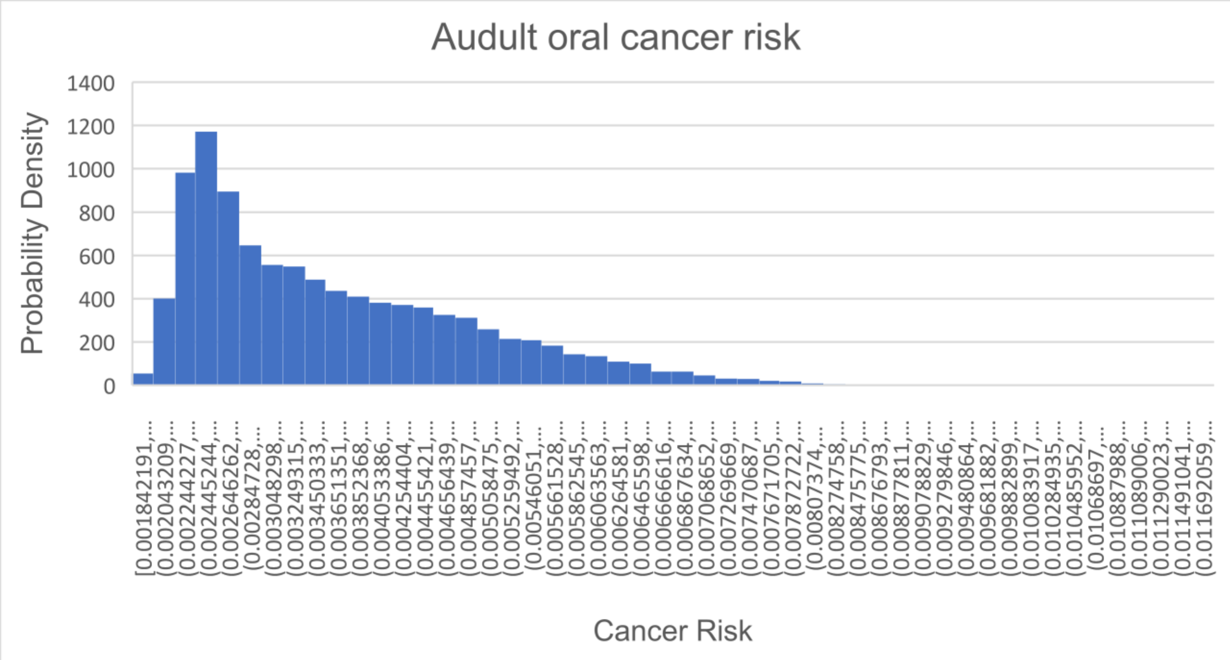

Figure 16 Probability distribution Vs. Cancer risk for adult oral in groundwater of dumpsite

Properties	Value
Mean	0.003711
Max	0.011893
Min	1842.0E-06
5th percentile	0.0022553
50th percentile	0.003349
95th percentile	0.006284
99th percentile	0.00746

Table 26 Cancer risk values from monte Carlo simulation for adult oral for groundwater in a dumpsite

We can see that the 95th percentile value is 6284E-06, which is very high than the acceptable risk value.

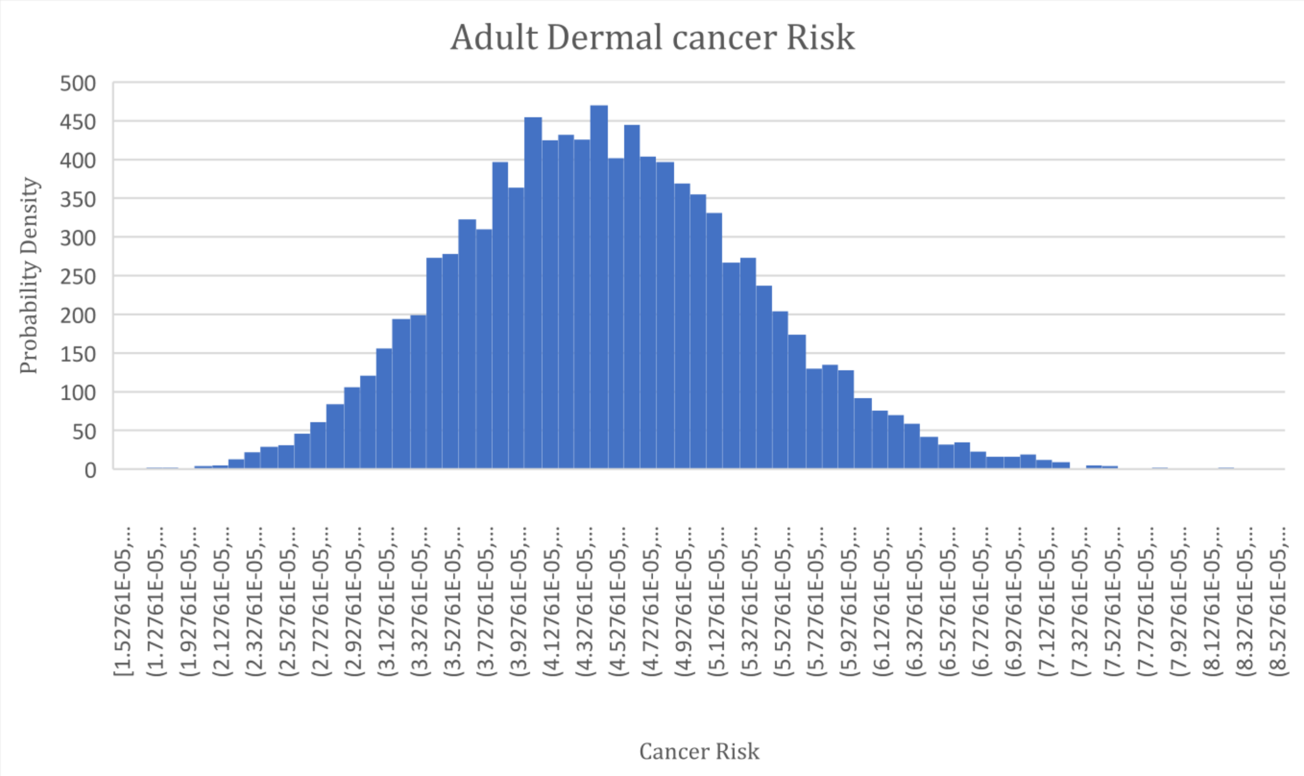

Figure 17 Probability distribution Vs. Cancer risk for adult dermal in groundwater of dumpsite

Properties	Value
Mean	4.5E-05
Max	8.55E-05
Min	1.52E-05
5th percentile	3.10E-05
50th percentile	4.48E-05
95th percentile	6.04E-05
99th percentile	6.79E-05

Table 27 Cancer risk values from monte Carlo simulation for adult dermal for groundwater in a dumpsite

We can see that the 95th percentile value is 60.4E-06 which is more than the acceptable value of risk.

For the groundwater of surrounding areas

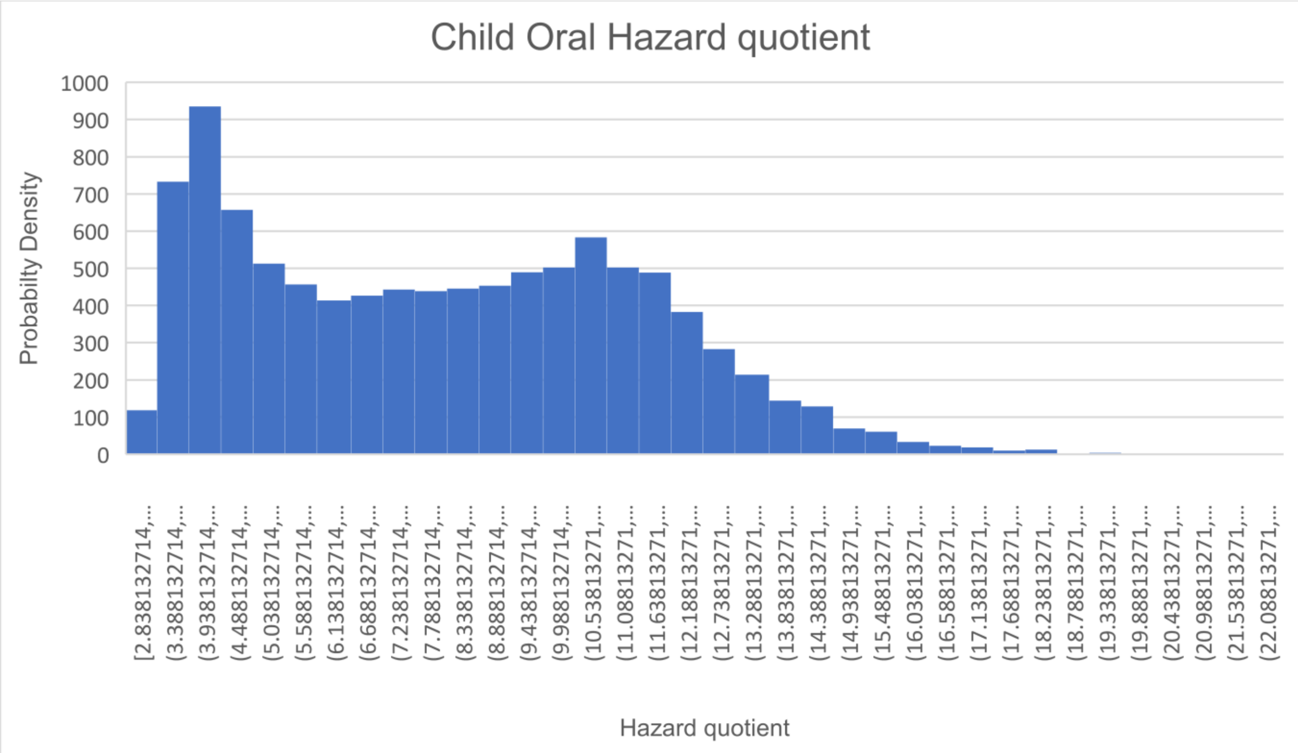

Figure 18 Probability distribution Vs. Hazard quotient for child oral in groundwater of dumpsite surroundings

Properties	Value
Mean	8.29
Max	22.399
Min	2.838
5th percentile	3.7298
50th percentile	8.165
95th percentile	13.869
99th percentile	16.109

Table 28 Non-cancer Risk values from monte Carlo simulation for child oral for groundwater in dumpsite surrounding areas

We can see that the 95th percentile value is 13.869, which is more than the acceptable risk.

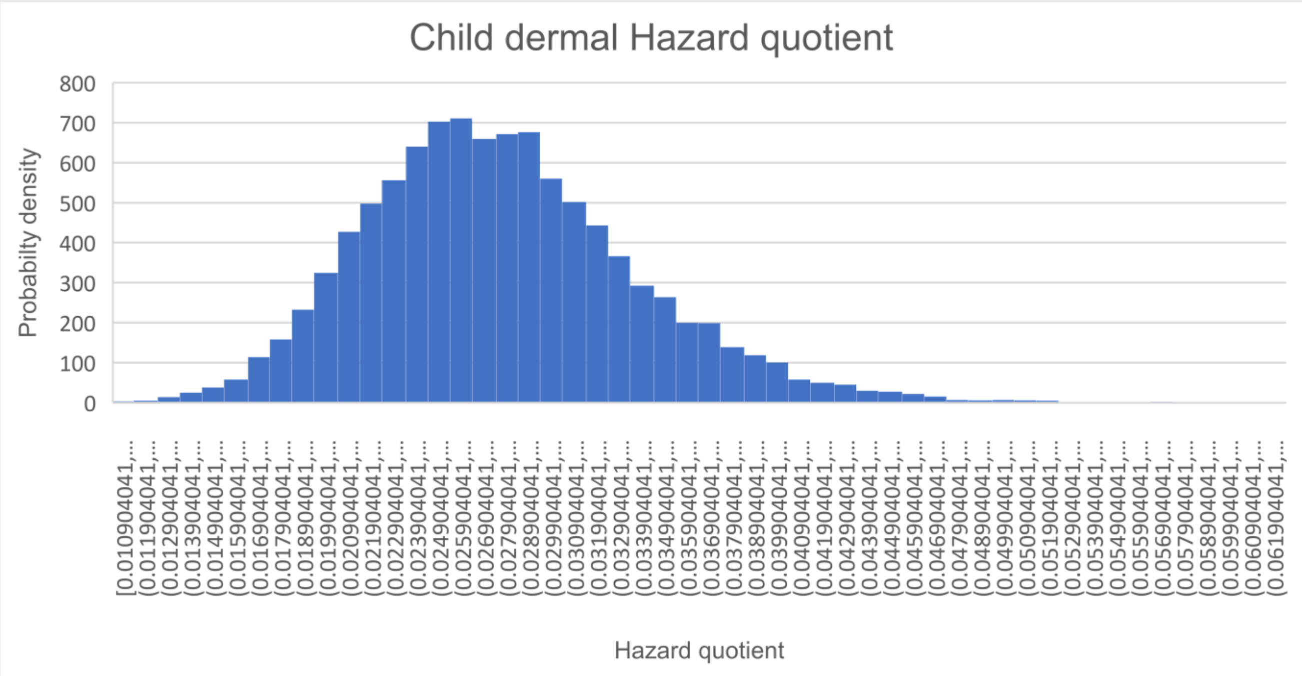

Figure 19 Probability distribution Vs. Hazard quotient for child dermal in groundwater of dumpsite surroundings

Properties	Value
Mean	0.028168
Max	0.062265
Min	0.010904
5th percentile	0.01932
50th percentile	0.02765
95th percentile	0.03898
99th percentile	0.0450

Table 29 Non-cancer risk values from monte Carlo simulation for child dermal for groundwater in dumpsite surrounding areas

We can see that the 95th percentile value is 0.03898, which is well within the acceptable value

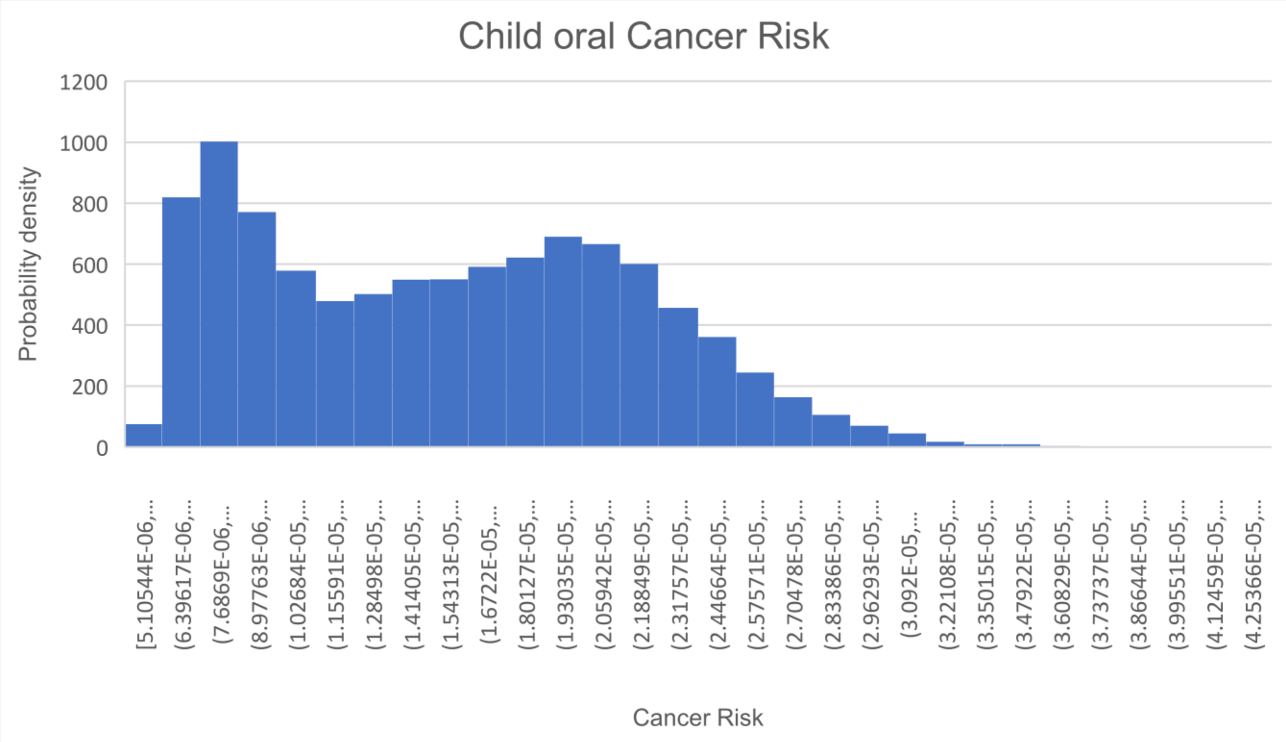

Figure 20 Probability distribution Vs. Cancer risk for child oral in groundwater of dumpsite surroundings

Properties	Value
Mean	1.6E-05
Max	4.38E-05
Min	5.1E-06
5th percentile	7.2E-06
50th percentile	1.598E-05
95th percentile	2.66E-05
99th percentile	3.079E-05

Table 30 Cancer risk values from monte Carlo simulation for child oral for groundwater in dumpsite surrounding areas

We can see that the 95th percentile value is 26.6E-06 which is more than the acceptable value.

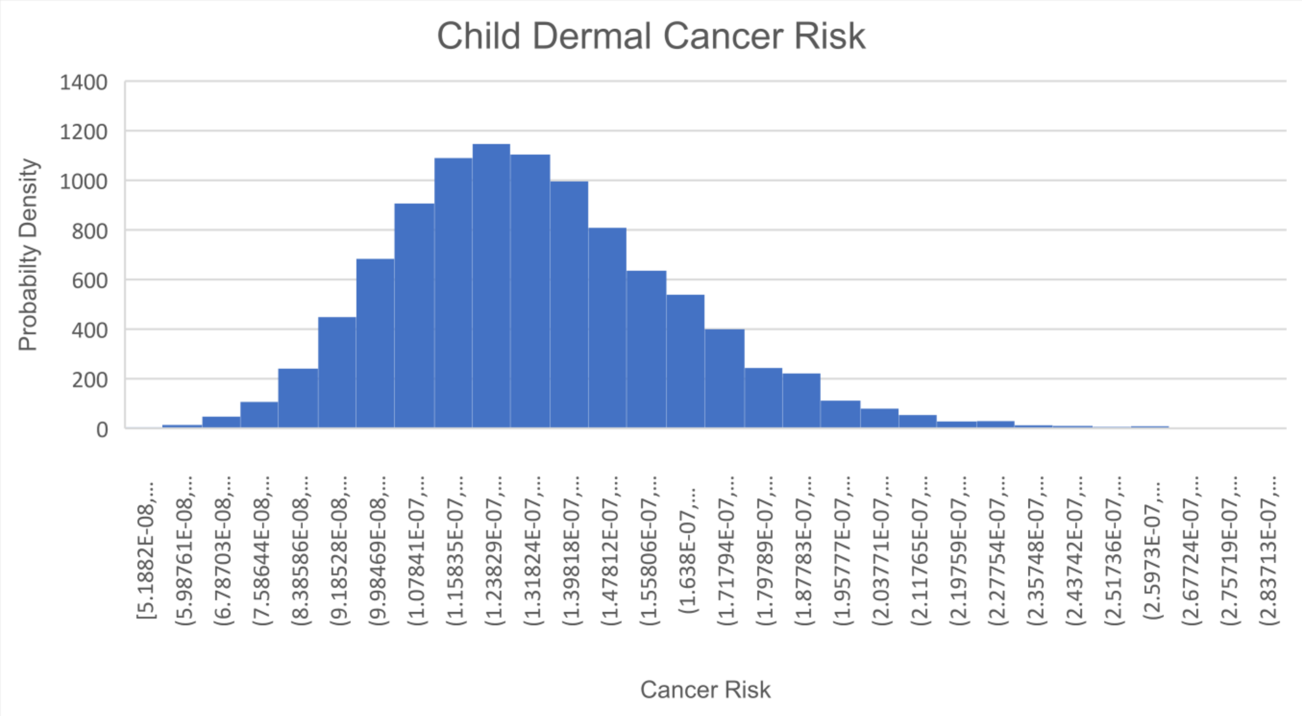

Figure 21 Probability distribution Vs. Cancer risk for child dermal in groundwater of dumpsite surroundings

Properties	Value
Mean	1.36E-07
Max	2.197E-07
Min	5.1E-08
5^{th} percentile	9.38E-08
50^{th} percentile	1.34E-07
95^{th} percentile	1.899E-07
99^{th} percentile	2.2E-07

Table 31 Cancer risk values from monte Carlo simulation for child dermal for groundwater in dumpsite surrounding areas

We can see that the 95^{th} percentile value is 0.1899E-06 which is well within the limit.

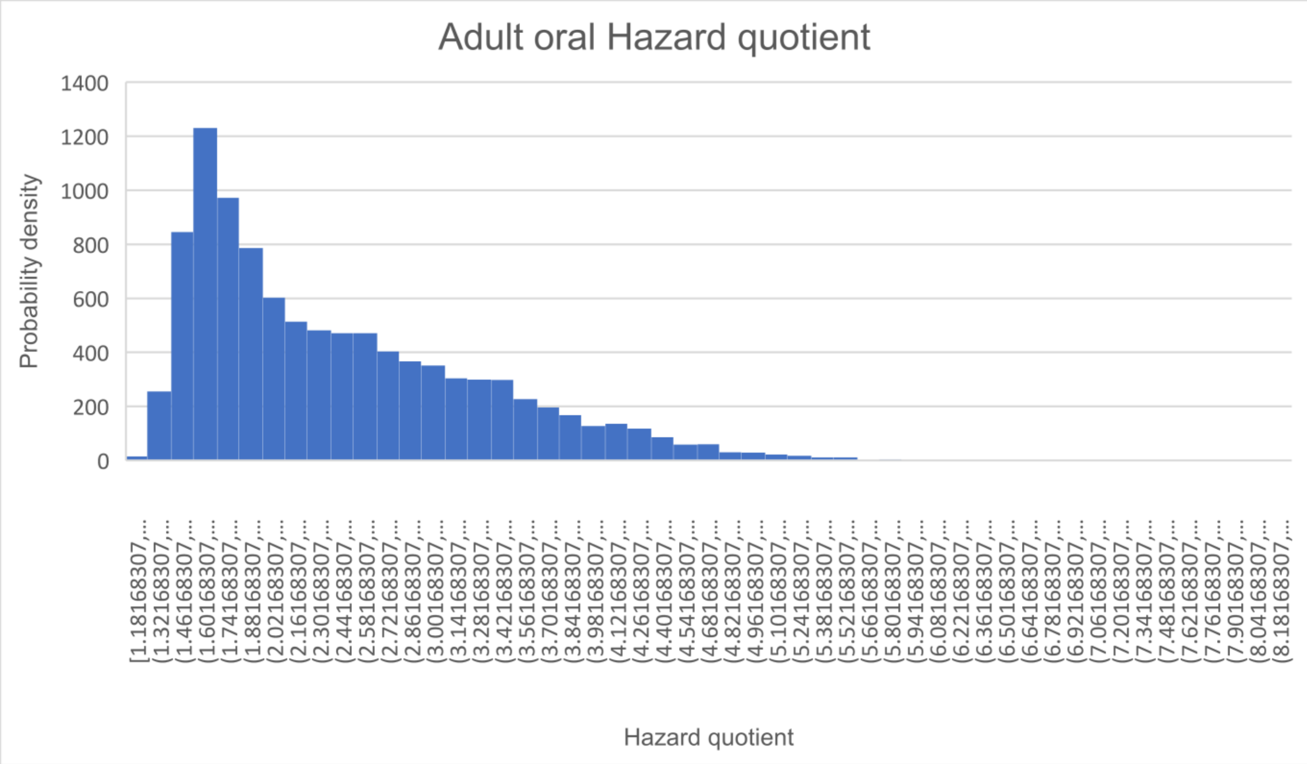

Figure 22 Probability distribution Vs. Hazard quotient for adult oral in groundwater of dumpsite surroundings

Properties	Value
Mean	2.48
Max	8.25
Min	1.181
5th percentile	1.511
50th percentile	2.23
95th percentile	4.23
99th percentile	5.014

Table 32 Non-cancer risk values from monte Carlo simulation for adult oral for groundwater in dumpsite surrounding areas

We can see that the 95th percentile value is 4.23, which Is more than the acceptable value.

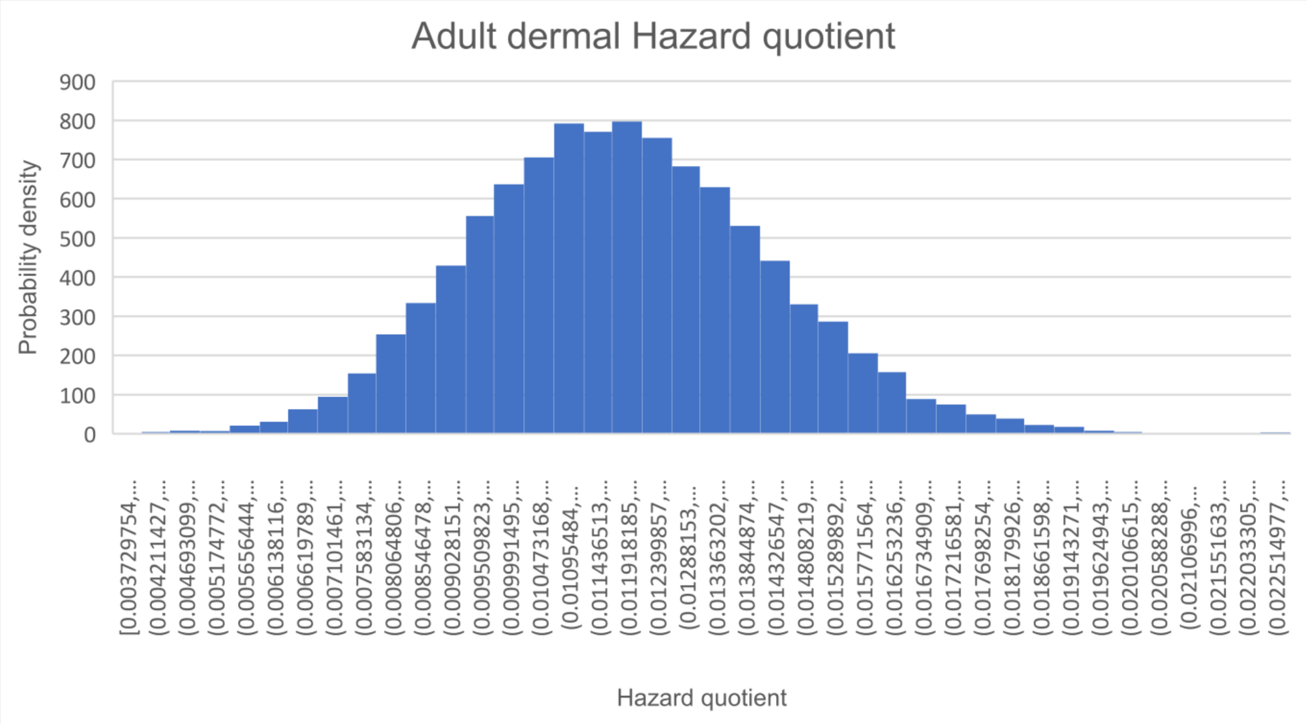

Figure 23 Probability distribution Vs. Hazard quotient for adult dermal in groundwater of dumpsite surroundings

Properties	Value
Mean	0.012083
Max	0.022997
Min	0.00373
5th percentile	0.00829
50th percentile	0.011997
95th percentile	0.016176
99th percentile	0.018176

Table 33 Non-cancer risk values from monte Carlo simulation for adult dermal for groundwater in dumpsite surrounding areas

We can see that the 95th percentile value is 0.0161, which is well within the limit.

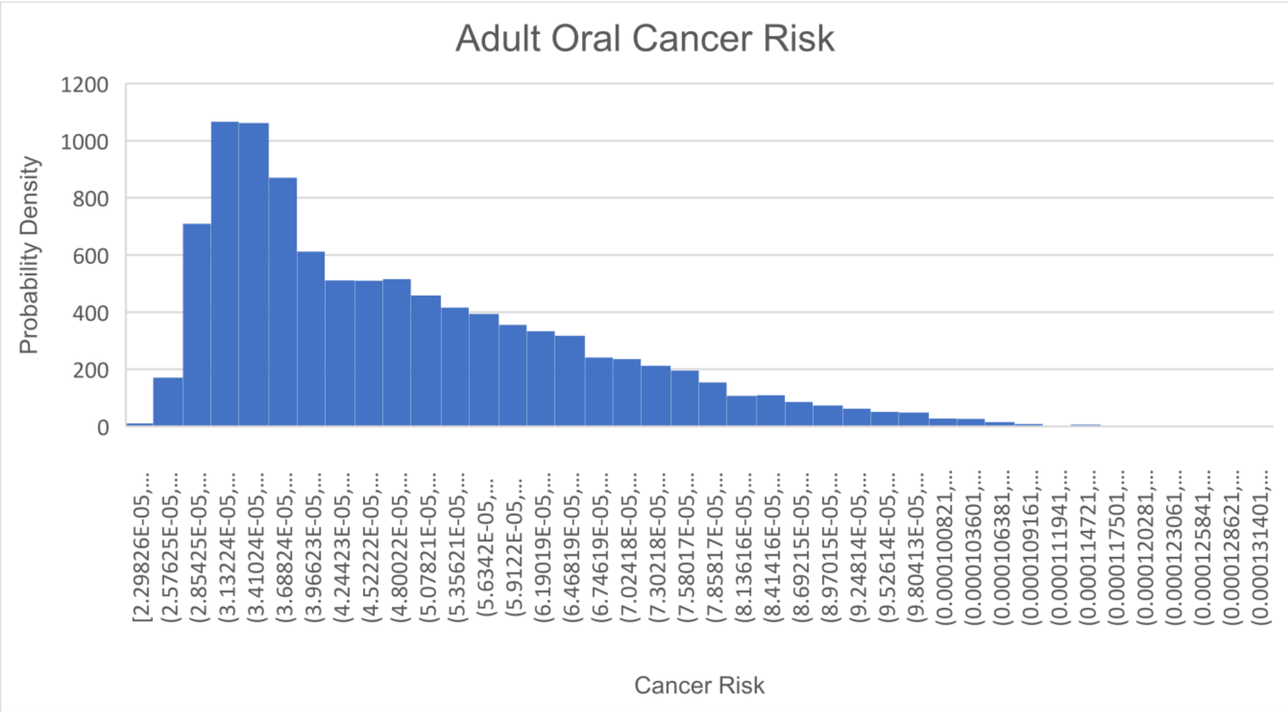

Figure 24 Probability distribution Vs. Cancer risk for adult oral in groundwater of dumpsite surroundings

Properties	Value
Mean	4.9E-05
Max	13.4E-05
Min	2.2E-05
5th percentile	3E-05
50th percentile	4.5E-05
95th percentile	8.499E-05
99th percentile	10E-05

Table 34 Cancer risk values from monte Carlo simulation for adult oral for groundwater in dumpsite surrounding areas

We can see that the 95th percentile value is 84.99E-06 which is more than the acceptable risk value.

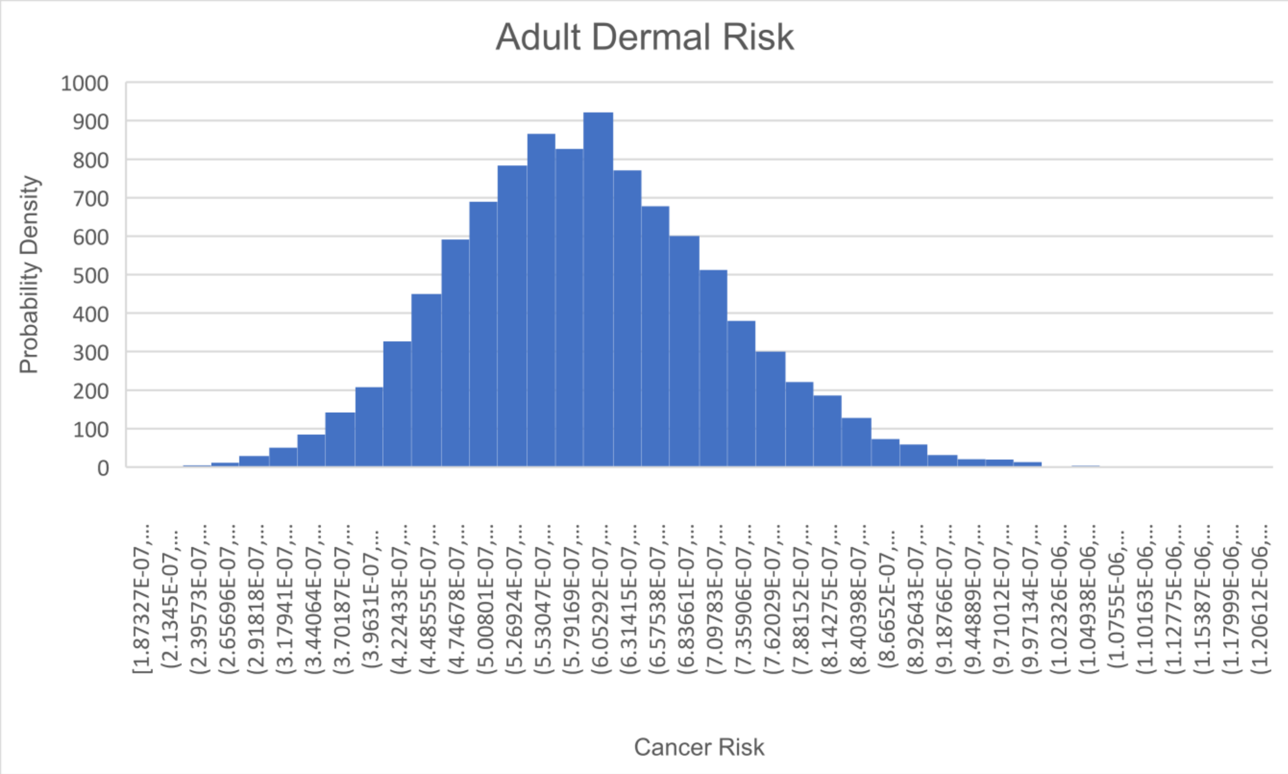

Figure 25 Probability distribution Vs. Cancer risk for adult dermal in groundwater of dumpsite surroundings

Properties	Value
Mean	6.08E-07
Max	1.23E-06
Min	1.87E-07
5th percentile	4.1E-07
50th percentile	6.02E-07
95th percentile	8.2090E-07
99th percentile	9.16E-07

Table 35 Cancer risk values from monte Carlo simulation for adult dermal for groundwater in dumpsite surrounding areas

We can see that the 95th percentile value is 0.82E-06 which is well within the limit.

For leachate of Perungudi Dumpsite

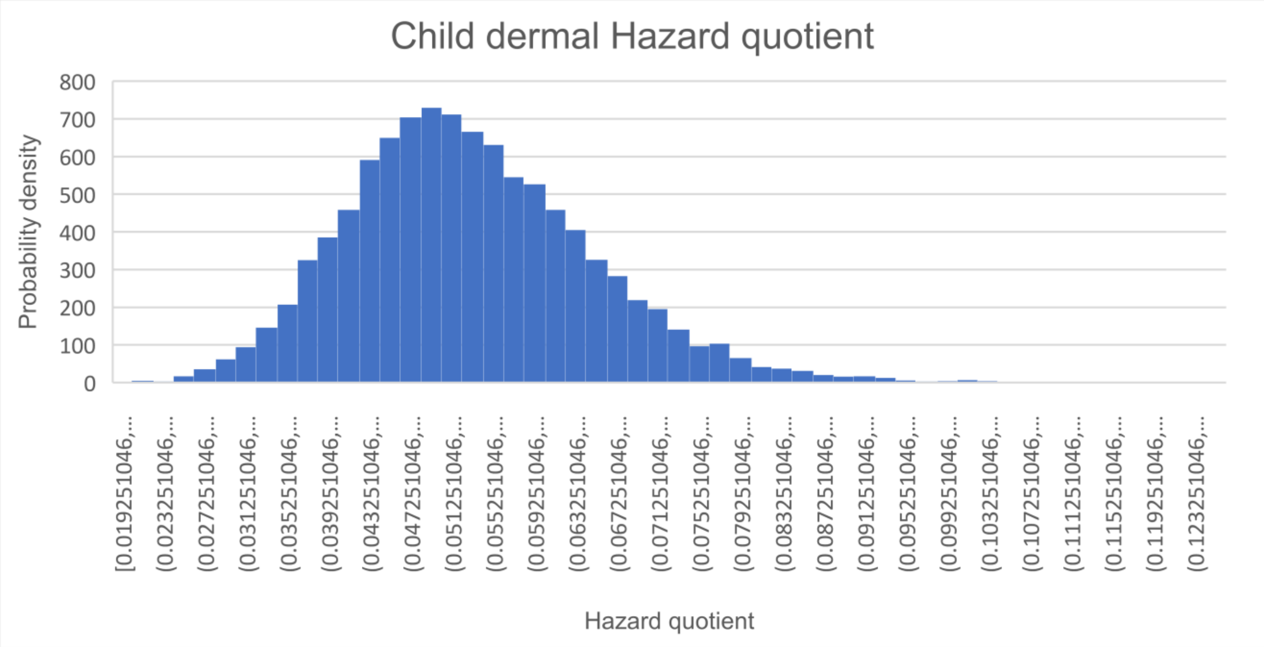

Figure 26 Probability distribution Vs. Hazard quotient for child dermal in the leachate of a dumpsite

Properties	Value
Mean	0.054043
Max	0.125409
Min	0.019251
5th percentile	0.03662
50th percentile	0.052898
95th percentile	0.07486
99th percentile	0.08707

Table 36 Non-cancer risk values from monte Carlo simulation for child dermal for leachate of a dumpsite

We can see that the 95th percentile value is 0.07486, which well within the limit value.

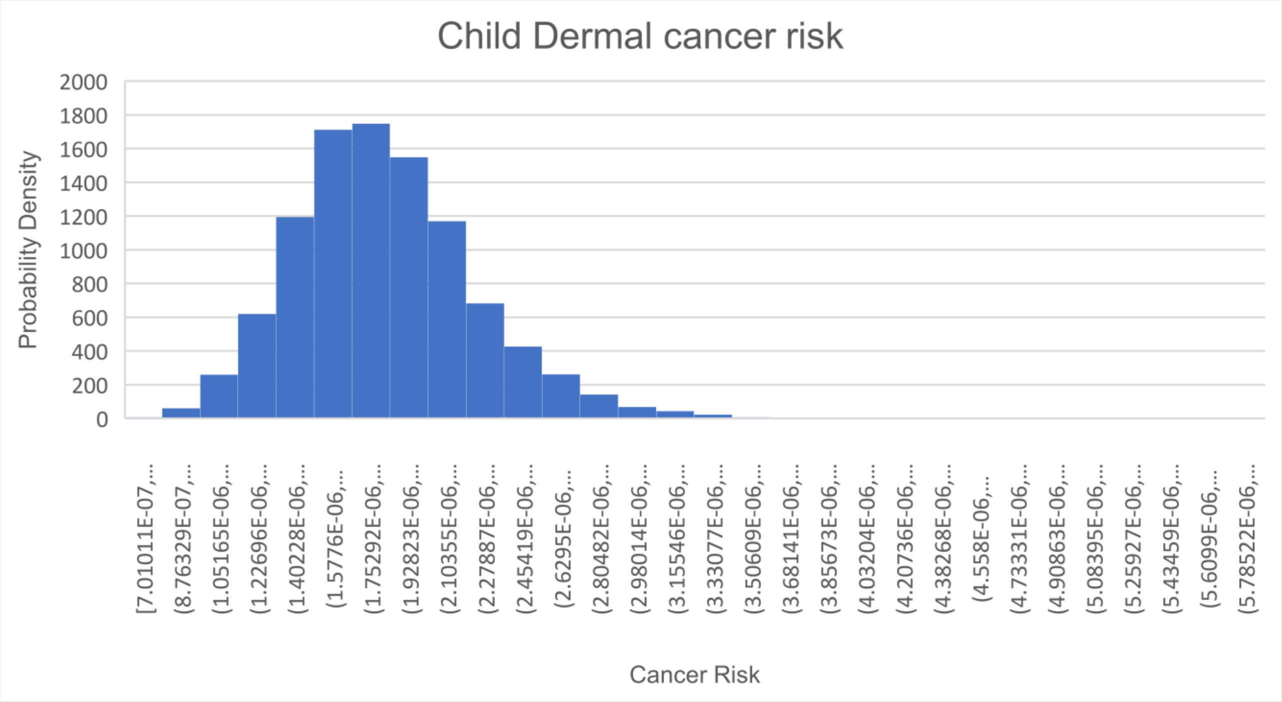

Figure 27 Probability distribution Vs. Cancer risk for child dermal in the leachate of a dumpsite

Properties	Value
Mean	1.90E-06
Max	5.96E-06
Min	7E-07
5th percentile	1.29E-06
50th percentile	1.86E-06
95th percentile	2.66E-06
99th percentile	3.12E-06

Table 37 Cancer risk values from monte Carlo simulation for child dermal for leachate of a dumpsite

We can see that the 95th percentile value is 2.66E-06 which is more than the acceptable risk value.

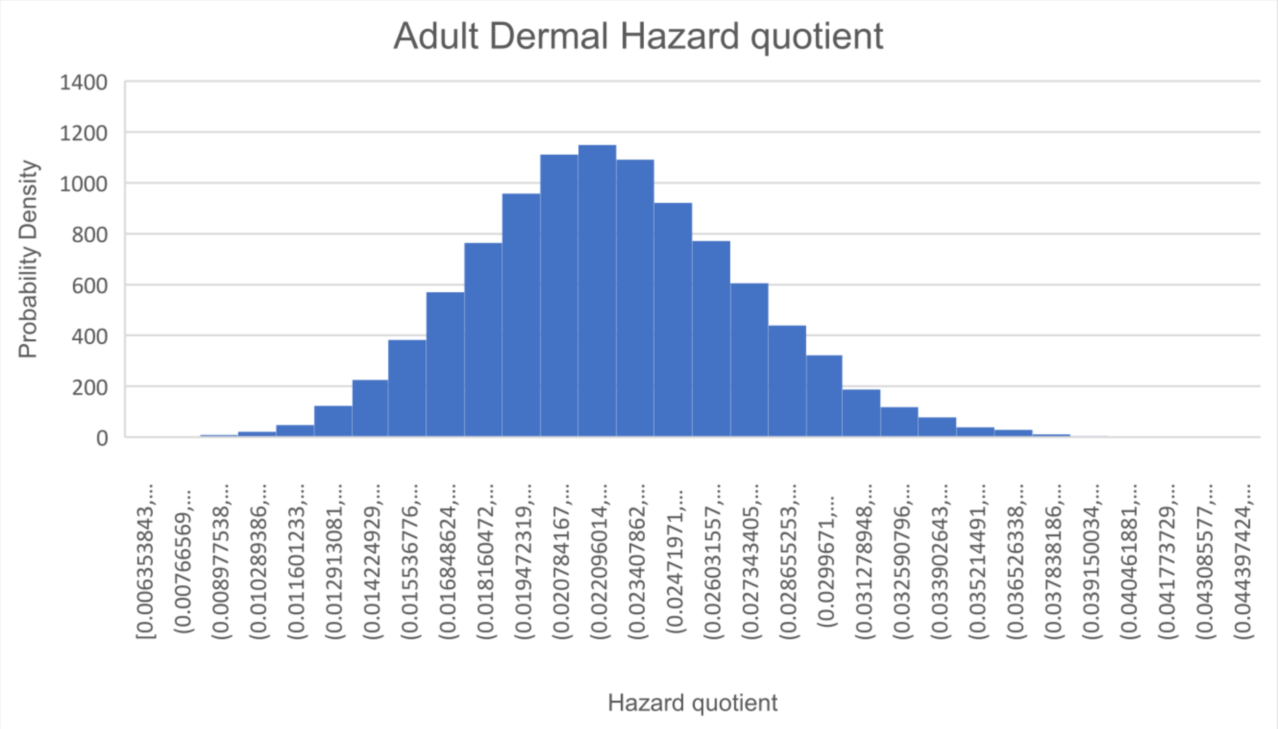

Figure 28 Probability distribution Vs Hazard quotient for adult dermal in leachate of dumpsite

Properties	Value
Mean	0.023192
Max	0.045709
Min	0.006354
5th percentile	0.015842
50th percentile	0.02298
95th percentile	0.03114
99th percentile	0.03503

Table 38 Non-cancer risk values from monte Carlo simulation for adult dermal for leachate of a dumpsite

We can see that the 95th percentile value is 0.03114, which is well within the limit.

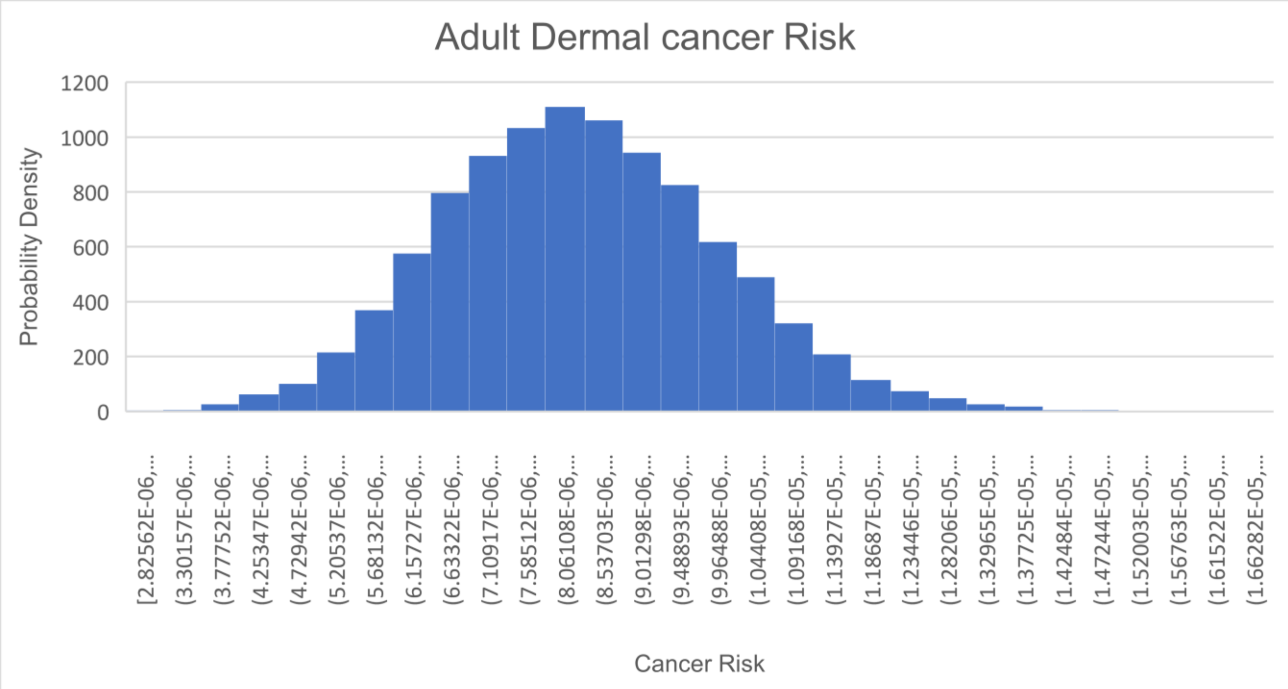

Figure 29 Probability distribution Vs. Cancer Risk for adult dermal in the leachate of a dumpsite

Properties	Value
Mean	8.5E-06
Max	1.71E-05
Min	2.8E-06
5th percentile	5.83E-06
50th percentile	8.43E-06
95th percentile	1.139E-05
99th percentile	1.28E-05

Table 39 Cancer risk values from monte Carlo simulation for adult dermal for leachate of a dumpsite

We can see that the 95th percentile value Is 11.39E-06 which is more than the acceptable risk value.

For the soil in dumpsite through the dermal pathway

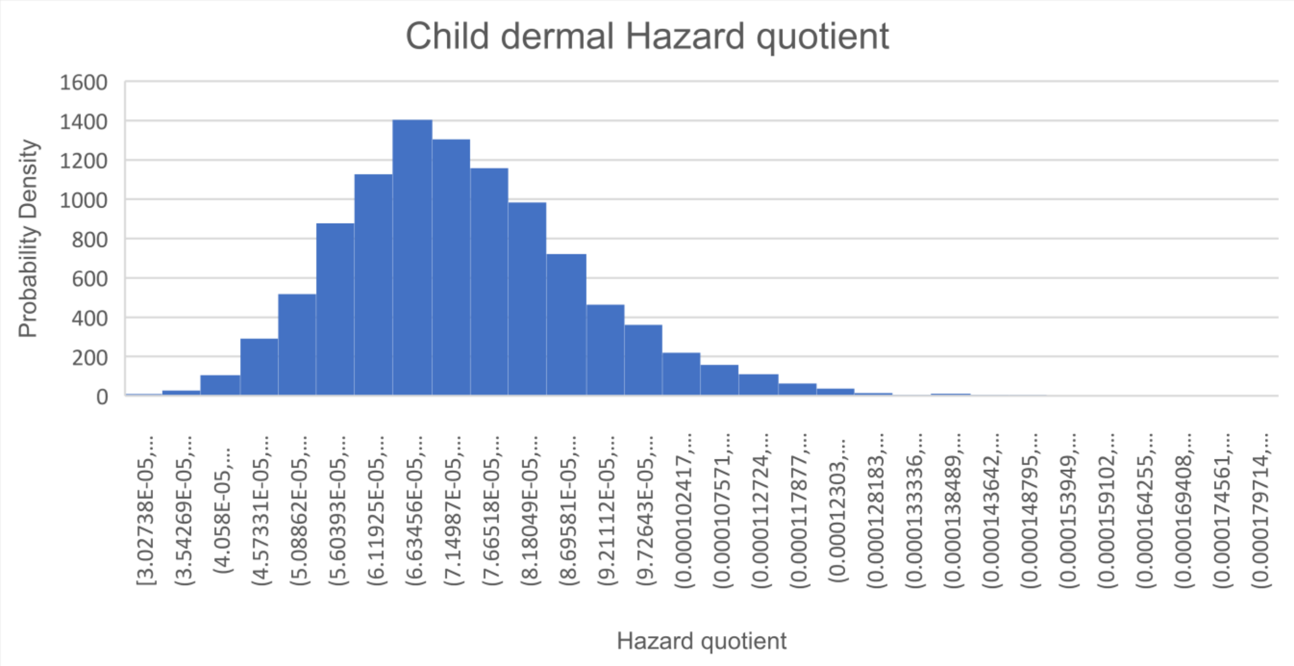

Figure 30 Probability distribution Vs. Hazard quotient for child dermal in the soil of dumpsite

Properties	Value
Mean	7.57E-05
Max	18.4E-05
Min	3.027E-05
5th percentile	5.176E-05
50th percentile	7.40E-05
95th percentile	10.53E-05
99th percentile	12.2E-05

Table 40 Non-cancer risk values from monte Carlo simulation for child dermal for the soil of dumpsite

We can see that the 95th percentile value is 100.53E-06 which is well within the acceptable value.

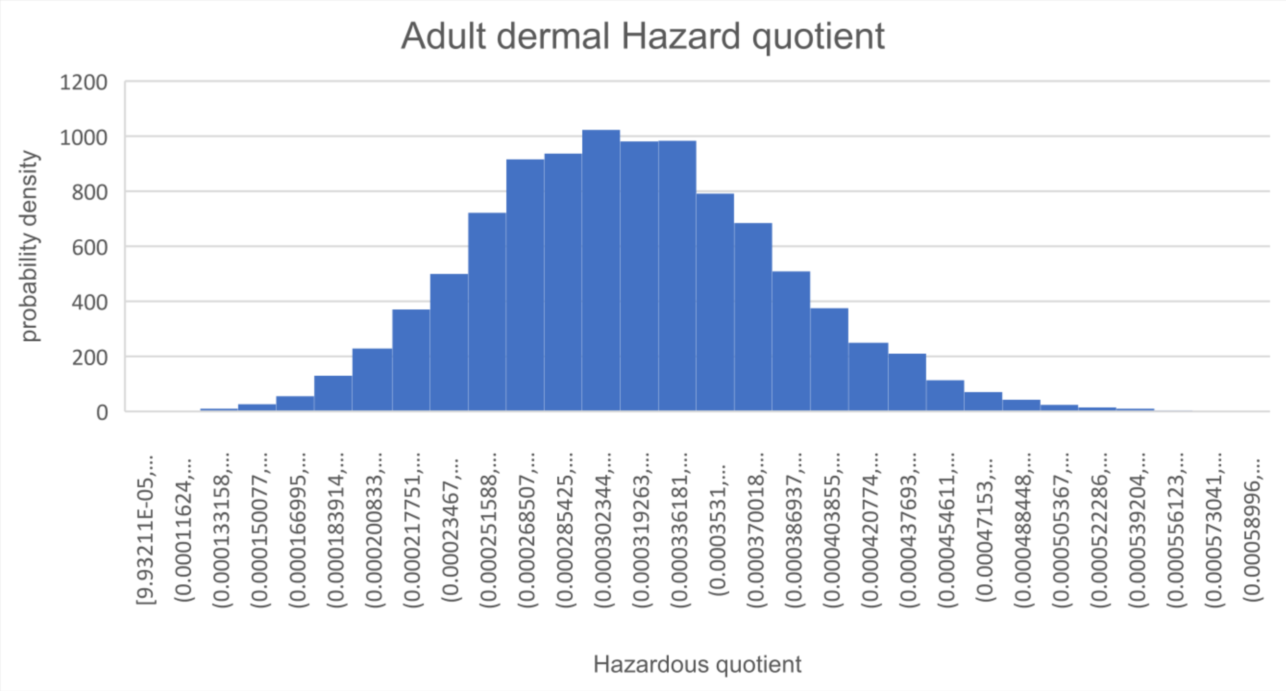

Figure 31Probability distribution Vs. Hazard quotient for adult dermal in the soil of dumpsite

Properties	Value
Mean	0.000323
Max	0.000607
Min	9.9321E-05
5th percentile	0.000220
50th percentile	0.000320
95th percentile	0.000437
99th percentile	0.000489153

Table 41 Non-cancer risk values from monte Carlo simulation for adult dermal for the soil of dumpsite

We can see that the 95th percentile value is 43.7E-05 which well within the acceptable value.

Deterministic method Vs. Probabilistic Method

			Non-Cancer Risk		Cancer Risk(1E-06)	
			Deterministic	Probabilistic	Deterministic	Probabilistic
Dump site Ground Water	Child	Oral	50.43	85.87	1180	1983.4
		Dermal	0.24863	0.35265	9.91	14.095
	Adult	Oral	22.199	26.299	5423	6284
		Dermal	0.001746	0.1455	72.4	60.4
Surrounding Ground Water	Child	Oral	8.2629	13.869	15.8	26.6
		Dermal	0.02761	0.03898	0.135	0.1899
	Adult	Oral	3.6374	4.23	72.5	84.99
		Dermal	0.019394	0.0161	0.98	0.82
Leachate in Dump site	Child	Dermal	0.053	0.07486	1.87	2.66
	Adult	Dermal	0.03722	0.03114	13.6	11.39
The soil in a dumpsite	Child	Dermal	7.42E-05	1.01E-04	NA.	NA
	Adult	Dermal	2.60E-04	4.37E-04	NA	NA

Table 42 Comparison of results between deterministic and probabilistic method

Compared to deterministic to probabilistic, we can see that the risk is increased most of the time, decreasing for some.

Creating a User-friendly TOOL

One of our scope for this study is to develop a user-friendly spreadsheet that can be shared with people living surrounding the Perungudi dumpsite so that they can check their risk calculated by entering the more detailed input data like how many liters of water they drink every day, how long they have been living there, how many times they bath daily if they groundwater for drinking, domestic purpose.

We created a website http://perungudiriskassesment.wordpress.com/, and we kept our excel file where we let users download and check their risk using that excel file.

Here I am attaching that excel tool model here.

Risk over the Years

For this study, we will calculate the risk for two different years and see how they increase or decrease; over the years, we will referring (Vasanthi et al., 2008), which is a 2008 paper, and (Sijelmass, 2014) which is 2014 paper. To get a detailed study, we will be using the same heavy metals from both studies.

From (Vasanthi et al., 2008)

component	Concentration data found(mg/l)
Arsenic (Ar)	Below detection limit
Iron (Fe)	5.497
Manganese (Mn)	0.416
Lead (Pb)	0.038
Cadmium (Cd)	0.021
Copper (Cu)	0.219
Chromium (Cr)	0.2
Zinc (Zn)	7.448

Table 43 Heavy metal concentrations from vasanthi 2008 study for groundwater of dumpsite surroundings

From (Sijelmass, 2014)

Mn(mg/l)	0.169-1.97
co(mg/l)	0.001-0.006
pb(mg/l)	0.0005-0.095
cd(mg/l)	0.00006-0.001
cr(mg/l)	0.004-0.014

Table 44 Heavy metal concentrations from sijelmass2014 study for groundwater of dumpsite surroundings

The common Heavy from both studies was Chromium, Lead, Cadmium, manganese.

Using the above studies is 3.084 for non-cancer adult risk in 2014, 3.657 for non-cancer adult risk in 2008. 73.5E-06 for cancer adult risk in 2014, 1075.541E-06 cancer risk in 2008.

We can observe that risk is decreased from 2008 to 2014, but the risk has to increase, but we see otherwise because there might be many chances for this type of result. After all, both studies are not from the same place. Also, 2014 data is taken post-monsoon, which might be diluted due to rainwater. Also, we do not know the accuracy of data in the 12 years old 2008 paper. Therefore, to get accurate information for this study, we should take measurements simultaneously over the years.

Limitations of this study

This study has many limitations, like the input data we have taken for the risk calculation like body weight, ingestion rate, surface area, etc., are taken from American standard and applying it to the Indian study, which led to a decrease in the accuracy of our study.

Also, for the Heavy metal concentration data, we used to calculate the risk value are from mostly 2014-2016, which are 4-6 years old. For the most reliable risk, the most recent concentration data is needed.

Summary of results

From the Different environmental media with different pathways, we found that in our study that the residential area surrounding the dumpsite reported an oral risk of 13.869 when compared to adults of 4.23 for the non-cancer risk. In contrast, the oral cancer risk is 15.8E-06 for a child compared to 72.5E-06 for the adult, for the dermal non-cancer risk is 0.03898 for the child with the 0.0161, whereas the for the dermal cancer risk it is reported 0.1899E-06 for the children and 0.82E-06 for the adult.

For the people working in the dumpsite in our study, we found that 15min is the maximum time they can expose to leachate in that dumpsite without the safety equipment, which stresses the importance of safety equipment when working in that type of landfill. Also, another problem many people are complaining about is the foul smell from landfills, especially in the monsoon season. From the soil environment media, we found that risk is negligible.

Conclusion

Our study found that there was both non-cancer oral risk and dermal risk involved for both child and children in the groundwater of the dumpsite. Whereas for the groundwater from the surrounding dumpsite, the oral risk is present and dermal risk is well within the limit, which indicates there will risk from the dermal pathway in the future.

For the cancer risk, it is found that there was both oral and dermal cancer risk involved for both child and adult for the groundwater under the dumpsite. Moreover, only oral cancer risk is involved for the surrounding residential areas, and dermal cancer is well within the limit.

From the(Sijelmass, 2014), we found that there was excellent awareness among most people about the harmful effects of the groundwater surrounding the dumpsite, making them purchase the packaged water from water plants nearby for the drinking purpose. Since most people living nearby, the dumpsite is from the economically weaker section, can not buy the water for domestic purposes. Which makes most of the people rely on the Borewell water for domestic purposes.

In our study, we found that there was no dermal risk involved, but the values are at very much border. Also, the concentration data is from 2014, which is already seven years old. There may be a chance that the dermal risk may cross the acceptable risk value now. We need to make sure by conducting the new study over there.

Generally, we think that child is more prone to risk when compared to adults because of their less body weight, well it is valid for the non-cancer risk. However, we found that adults are more prone to risk for cancer risk when compared to a child. It is crucial to note because most of the cleanup or remedy actions give importance to a child compared to the adults.

Our study shows that contamination is spreading from the landfill because only oral is present for surrounding residential areas groundwater. In contrast, it is reported that both oral and dermal risks are present for groundwater of dumpsite.

In our study, we can see which elements are contributing how much risk to the total risk, which enables the policymakers to select the remedy plan based on how much it is economical to do specific remedy plans.

Also, we created a website that enables the user to check theirs based on their living conditions. It also shows how much oral risk and dermal risk are involved, which help the user plan their groundwater usage and how to mitigate it.

We did a risk assessment for only Heavy metals, which we did not consider due to organic compounds. When compounded with heavy metals, the risk may increase by many folds, making dermal risk possible.

Finally, it is essential to conduct a new study with the latest concentration data of organic and heavy metals, specifically on groundwater's dermal pathway. Because the people who live nearby dumpsite are from the economically weaker section who may not have primary health care facilities, they cannot afford to buy the water for domestic purposes. Hopefully, the local government will take the necessary actions to mitigate this risk.

Supplementary data

Excel files where we did the deterministic method and Monte Carlo simulation can found here

References

Ali, I.H., Siddeeg, S.M., Idris, A.M., Brima, E.I., Ibrahim, K.A., Ebraheem, S.A.M., Arshad, M., 2021. Contamination and human health risk assessment of heavy metals in soil of a municipal solid waste dumpsite in Khamees-Mushait, Saudi Arabia. Toxin Rev. 40, 102–115.

Aram, I.A., 2016. Physico-Chemical Chemical Analysis of f Groundwater Quality in Pallikaranai Marshland 3, 107–110.

Arthika, B., Maheswari, K., 2019. Assessment of groundwater quality by water quality index for Perungudi, Chennai, International Journal of Recent Technology and Engineering.

Jayaprakash, M., Urban, B., Velmurugan, P.M., Srinivasalu, S., 2010. Accumulation of total trace metals due to rapid urbanization in microtidal zone of Pallikaranai marsh, South of Chennai, India, Environmental Monitoring and Assessment.

Mageswari, S., Iyappan, L., Aravind, S., Sameer, N.M., Vignesh, R., Kumar, P.V., 2017. Contamination of Groundwater Quality Due to Municipal Solid Waste Disposal – A GIS Based Study in Perungudi Dump Yard, International Research Journal of Engineering and Technology(IRJET).

Mor, S., Ravindra, K., Dahiya, R.P., Chandra, A., 2006. Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site. Environ. Monit. Assess. 118, 435–456.

Parameswari, K., Mudgal, B. V., 2014. Geochemical investigation of groundwater contamination in Perungudi dumpsite, South India, Arabian Journal of Geosciences.

Parameswari, K., Mudgal, B. V., 2015. Assessment of contaminant migration in an unconfined aquifer around an open dumping yard: Perungudi a case study, Environmental Earth Sciences. Springer Berlin Heidelberg.

Parameswari, K., Mudgal, B. V., Padmini, T.K., 2016. Awareness on usage of contaminated groundwater around Perungudi dumpsite, Tamil Nadu, India, Environment, Development and Sustainability. Springer Netherlands.

Parameswari, K., Padmini, T.K., Mudgal, B. V., 2015. Assessment of soil contamination around municipal solid waste dumpsite, Indian Journal of Science and Technology.

Peter, A.E., Shiva Nagendra, S.M., Nambi, I.M., 2018. Comprehensive analysis of inhalable toxic particulate emissions from an old municipal solid waste dumpsite and neighborhood health risks. Atmos. Pollut. Res. 9, 1021–1031.

Peter, A.E., Shiva Nagendra, S.M., Nambi, I.M., 2019. Environmental burden by an open dumpsite in urban India, Waste Management. Elsevier Ltd.

Raghab, S.M., Abd El Meguid, A.M., Hegazi, H.A., 2013. Treatment of leachate from municipal solid waste landfill. HBRC J. 9, 187–192.

Rajasekhar, B., Nambi, I.M., Govindarajan, S.K., 2018. Human health risk assessment of ground water contaminated with petroleum PAHs using Monte Carlo simulations: A case study of an Indian metropolitan city. J. Environ. Manage. 205, 183–191.

Sijelmass, R., 2014. The effect of waste dumping on water quality in Pallikaranai: Wasting the Indian marshlands 1–57.

Sree Sharmila, T., Swathika, R., 2016. Prediction of environmental changes in dumpyard sites: A case study of pallikaranai dumpyard, Chennai, Tamilnadu, Communications in Computer and Information Science.

Swati, M., Rema, T., Joseph, K., 2008. Hazardous organic compounds in urban municipal solid waste from a developing country, Journal of Hazardous Materials.

Tripathy, B.K., Ramesh, G., Debnath, A., Kumar, M., 2019. Mature landfill leachate treatment using sonolytic-persulfate/hydrogen peroxide oxidation: Optimization of process parameters, Ultrasonics Sonochemistry. Elsevier.

Vasanthi, P., Kaliappan, S., Srinivasaraghavan, R., 2008. Impact of poor solid waste management on ground water, Environmental Monitoring and Assessment.