ASSESSMENT OF GROUNDWATER CONTAMINATION POTENTIAL OF MUNICIPAL SOLID WASTE DUMPS IN HIMACHAL PRADESH

A

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

Mr. Anirban Dhulia

(Assistant Professor)

by

RIZUL SHARMA (151620)

DIPANSHU THAKUR (151634)

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

MAY 2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the project report entitled **"Assessment of Groundwater Contamination Potential of Municipal Solid Waste dumps in Himachal Pradesh"** submitted for partial fulfillment of the requirements for the degree of bachelor of technology in civil engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Anirban Dhulia**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student

Name -Rizul Sharma, Dipanshu Thakur

Roll no-151620, 151634

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, India

Date:

`

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Assessment of Groundwater Contamination Potential of Municipal Solid Waste dumps in Himachal Pradesh"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, ,**Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Rizul Sharma(151620), Dipanshu Thakur (151634)** during a period from August, 2018 to November, 2018 under the supervision of **Mr. Anirban Dhulia** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement is correct to the best of our knowledge.

Date:

Signature of supervisor	Signature of HOD	Signature of External
Mr. Anirban Dhulia	Dr. Ashok Kumar Gupta	External Examiner
Assistant Professor	Professor & Head	
Department of Civil Engineering	Department of Civil Engineering	
JUIT Waknaghat	JUIT Waknaghat	

`

ACKNOWLEDGMENTS

I would like to thank so many people who have helped in every possible way in successful completion of this project. Firstly I would like to express my gratitude to my project guide

Mr. Anirban Dhulia, who have provided me an opportunity to do this project under his guidance. He has provided valuable ideas and support during the course of this work. This work would not have been possible without his support. I would like to thank our project coordinator and all other faculty members and technical staff of Department of civil engineering of Jaypee University of Information Technology for providing valuable input throughout the course of this work.

`

ABSTRACT

The disposal of solid waste in unrestrained MSW dumpsites can cause critical impacts on the surrounding habitat and human well-being. The health hazard and ecological deterioration from the unrestrained and unlined dumpsites is awell-knownreality. The most frequently reported threat to human health from these dumpsites is the utilizationof contaminated groundwater, which has been polluted by leachate formed from these dumpsites. A method is made to measure the dumpsite leachate pollution via an index. This index is termed as called as Leachate Pollution Index. Leachate Pollution Index is a perceptible means by which the leachate pollutioninformation of the dumpsites could be expressed systematically. The LPI is a rising scale indicator and is developed using Delphi technique. For remedial actions of the dumpsites, hazard ranking is done. Hazard ranking is done by using the DRASTIC method, GW-HARAS, mGW-HARAS and SIMRAS method. The purpose of this research was to estimate the degree of groundwater pollutionin the region of the dumpsites as a result of leachate permeated from five MSW dumpsites. Several physical and chemical parameters were tested which include: pH, BOD_5, COD, Chloride, Iron, Ammonical Nitrogen, Copper, TKN, Chromium, area of the dumpsite, waste height, waste composition, slope of the top surface, soil permeability, depth to the groundwater. Based on the results obtained, it is summarized that a solitary number index which reflects the combined impact of considerablecontaminant variables on leachate pollution is achievable and it can offer a significant, homogeneoussystem of assessing the leachate infectivity potential of dumpsite at a specific time. The study is done for 5 different dumpsites of Himachal Pradesh. The results reflected that the majority of wells were polluted. Here concentrations of nearly all physical and chemical parameters weregreater thanadequatetypical levels for groundwater. It is clear that dumpsites cause potential harm to the neighboringatmosphere.

Keywords: Leachate; Leachate Pollution Index; Rating systems; Groundwater pollution; MSW dumps

CONTENTS

`

`

`

LIST OF TABLES

`

LIST OF FIGURES

`

`

LIST OF ABBREVATIONS

BOD	Bio Chemical Oxygen Demand
COD	Chemical Oxygen Demand
LPI	Leachate Pollution Index
TKN	Total Kjehldal Nitrogen
MSW	Municipal Solid Waste

`

CHAPTER 1

INTRODUCTION

1.1 Project Description

Waste dump sites are hazardous to human beings in several beings in several ways, e.g. groundwater pollution, surface water pollution, odorous emissions & greenhouse gas generation due to off-site migration of landfill gas and aircraft damage due to bird menace at bird menace at waste sites. Prioritization is the first step in planning for closure. The comparativelevel of danger posed by a dumpsite is a suitable criterion for prioritization. Also, dataregarding size of these dumpsites and closeness to the surroundings is of great importance. Ecologicaldeprivation due to the unrestrained dumpsites and landfills is a familiarpiece of evidence. Leachate originated from MSW dumpsites is usually heavily contaminated and contains complex wastewater which is difficult to deal with. The leachate can contaminate the subsurface environment and ultimately the groundwater when dumpsites are not equipped with covers and liners. A major risk caused by the leachate produced is the subsurface pollution. Increasing worryregarding humanwellbeing and deprivation of soil, vadose zone and groundwater demand taking appropriate remedial actions at these sites. The remedial actions and defensive actions have to be taken on the basis of priority. Along these lines, a framework is needed to aid the setting of demands, to set up which dumpsites require quick consideration for remedial purpose. This prioritization is done using three rating frameworks for the assessment – DRASTIC, m GW-HARAS and SIMRAS.For calculating the pollution potential of leachate, LPI (Leachate Pollution Index) is calculated.Leachate Pollution Index is an expanding scale record, where a higher value indicates a poor ecological condition. In this way, to calculate Leachate pollution index of a dumpsite, groupings of the 18 parameters are to be identified. In any case, it is additionally conceivable to information for all the 18 parameters incorporated into the LPI are not accessible. Subsequently the LPI determined dependent on the accessible information is probably going to include some error.

1.2 Objectives

1. To estimate the groundwater pollution potential of MSW dumps in Himachal Pradesh.

2. To investigate the suitable method for the prioritization of MSW dumps for remedial actions in Himachal Pradesh.

3. To calculate the Leachate Pollution Index of leachate samples collected from various MSW dumpsites.

4. To propose the remedial techniques for the MSW sites based on the assessment.

1.3 Treating Leachate

There is a scope of innovations accessible to treat the leachate produced from dumpsites in differenttraditions. These include:

1. Organic Treatment – This is generally the startingstage to treat the leachate. It involves using various channels to evacuate nitrogen and some other natural mixes from the wastewater.The most normal organic treatment is activated sludge, which is a suspended-development process that utilizes high-impact microorganisms to biodegrade natural contaminants in the leachate.

2. Synthetic Physical Processes – Wet oxidation forms, for example, ozonisation, are utilized on the off chance that it is possible to oxidize natural contaminants either totally or to change over bio-refractory contaminants into biodegradable contaminants. Activated carbon adsorption is utilized for cases in which natural pollutions in the leachate can't be corrupted either organically or utilizing wet oxidation forms. The contaminants are first bound to the carbon through adsorption and after that decimated by cremation. Precipitation/flocculation and particle trade forms are less across the board in the field of landfill leachate treatment.

CHAPTER 2

LITERATURE REVIEW

Waste dump sites are hazardous to human beings in several beings in several ways, e.g. groundwater pollution, surface water pollution, odorous emissions & greenhouse gas generation due to off-site migration of landfill gas and aircraft damage due to bird menace at bird menace at waste sites. Prioritization is the first step in planning for closure. The comparativelevel of danger posed bydumpsite is a suitable criterion for prioritization. Also, dataregardingdimensions of these dumpsites and closeness to the surroundings is of great importance. Baseline conditions of the waste dumps in India and world were studied.

2.1 Scenario in India

To obtain the data regarding waste dumps in India 53 cities (having population over 1 million) were selected. But out of these 53 cities, data for dump sites in 23 municipal corporations were obtained. Cities with lower population and other rural areas were out of the scope of the study. Further information was also collected from published literature, existing city reports and websites of municipal corporations.Therefore, information was collected from 26 urban communities. About 44% dumpsites have silt or sand in the vadose zone and 85% sites have groundwater table at a distance less than 25m below the base, posing a significant hazard to the groundwater supplies. For pollution potential of surface water, 40% sites are within a range of 200m of a surface water bodies overall. Regarding the proximity of waste dumps to human receptors, more than 60% of the sites are in close vicinity (within a range of 0-500m) of the communities.

2.1.1 Quantity of Waste generated

India generates more than 1 Million metric tonnes of solid waste every day. Some large cities for instance Bombay and Delhi generate 9000 metric ton and 8300 metric ton of solid waste per day respectively.

2.2 Environmental Impacts created due to MSW dumpsites

(a) Groundwater pollution: In the duration of rainfall,water get in touch with the sullied waste. Then after the organic and inorganic components get dissoluted with it, which lead to the forming of verypoisonous leachate. The leachate produced is very toxic and gets collected at the bottom of the dumpsite. It consists of ammonia, metals, some other pathogenspoisonous compounds.Seepage of leachate may result in defilement of ground water sources. The leachate produced has a high BOD. Therefore when it mixes with groundwater or surface water, it can be a danger to the aquatic life.

(b) Air Pollution:MSW dumpsites mainly consist of organic stuff from household waste and industrial waste. When this waste matter decomposes in the dumpsites, many poisonous gases like methane are liberated. Methane is a greenhouse gas which is very much harmful than carbon dioxide trapped in atmosphere. To minimise this cause, methane liberated is used to generate electricity, it releases carbon dioxide as a by-product which has a very less effect than methane. This leads to unpleasant aromain the surrounding area of the dumpsite.

(c) Subsurface pollution: Degraded matter and mixture of toxic stuff affects the condition of soil in the nearby area the dumpsites. It affects the flora as the vegetation may cease to grow.

2.3 Aim of Hazard Ranking

Municipal Solid Waste dumpsites cause many hazards to the adjoiningatmosphere by means of air, surface water and ground water courses. Among these air contaminants and surface water pollutants are eliminated at regular intervals by high air and water flows in different seasons. On the contrary subsurface pollution and groundwater pollution are long standing phenomena where the pollutants are not eliminated regularly from the ecological system. Therefore, this research is mainly focussed on estimating only the groundwater pollution potential of Municipal Solid Waste dumpsites.

2.3.1 Various hazards from MSW Dumps:

i) Recurring hazards caused by continuous generation of leachate and landfill gas. Leachate from dumpsites, without any liners and spreads, contributes in pollution of

`

the subsurface environment, eventually bringing about groundwater pollution. Groundwater pollution from leachate has been reported numerous times.

ii) Besides groundwater pollution, uncontrolled discharge of leachate likewise pollutes surface water bodies in the region.

iii) Hazards from landfill gas are in terms of air pollution due to odorous, hazardous and GHG emissions.

Waste dumps in Indian cities have to be closed so as to minimize their impact on the environment and human beings. For planning of closure/remediation of the dumpsites, it is imperative to prioritize them according to the hazards posed. The hazards posed by a given MSW dumpsite rely upon the quantity of the waste, its characteristics, proximity and importance of the receptor as well as the characteristics of the pathway through which the pollutants migrate. Source indicates a waste dump and is characterized by a number of parameters which deal with generation of landfill gas/leachate. Pathway indicates to the path taken by emissions when migrating from source to receptor. Receptors include all the living beings and the adjacentsurroundings which are affected by the impact of danger. Closure is a process of cleaning up of soil and groundwater at a contaminated site.

2.4 Formation of leachate

Leachate is formed when the waste in the dumpsite deteriorates and rain water flushes the resultant yield out. The dark fluid consists of organic and inorganic chemicals, heavy metals and pathogens; it could contaminate the groundwater and hence could be a health risk. When the water permeates through waste, it advances and supports the process of disintegration by fungiand bacteria. These processes release the secondary products of decomposition and immediatelymake use of any existing oxygen, leading to anoxic atmosphere. In effectively deteriorating waste, the temperature increases and the pH goes down rapidly and in result many metal ions which are comparatively not soluble at neutral pH get dissoluted in the leachate formed. The disintegration activities liberate more water, which increases the quantity of leachate. Leachate as well reacts with substances which are not susceptible to degradation by

`

themselves. Dumpsites with huge fraction of constructionwaste, particularly which have gypsum plaster, the reaction of leachate and gypsum can producehuge volume of hydrogen sulfide, which mayfree in the leachate and may produce a largeconstituent of the landfill gas.

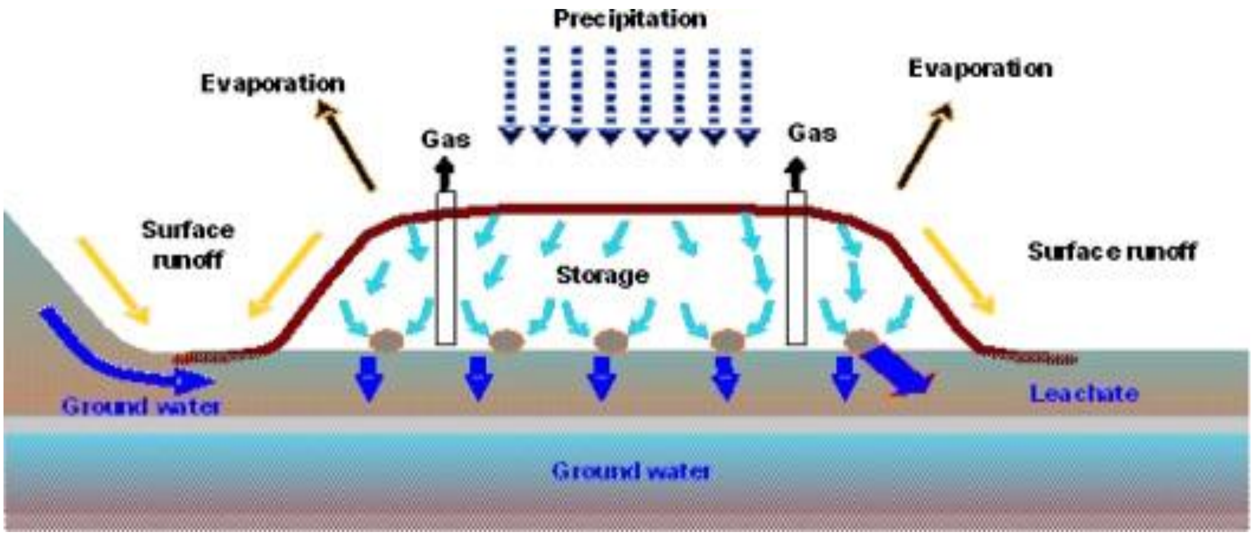

Figure 2.1 Leachate formation process

2.5Human Health Problems Related with Leachate.

When water goes in the course ofthe disposed waste and permeates to the ground, many times it convey the harmful substances from the waste it passes. It can be water in the waste or rainwater. There are many substances involved in the polluting the groundwater and making it unusable for consumption. Health effects could be acute short exposure, or long term chronic exposure to leachate from landfills.

(a)Chemical/metal Health effects from acute exposure

Lead: Abdominal pain, vomiting, drowsiness, diarrhoea

Nickel: Diarrhoea, gum diseases, skin diseases

Mercury: Reanal failure, Bloody diarrhoea, dehydration

Toluene: Tremors, convulsions, coma

(b)Chemical/metal Health effects from long term exposure

Lead: Constipation, hypertension, abdominal pain, anorexia

Mercury: Memory loss, seizures, coma, irritability, acute kidney failure, decrease in platelets

Benzene: disorders related to blood

2.6Development and Formulation of Leachate Pollution Index (LPI)

To develop a system to compare the leachate pollution potential of various landfill sites in a given geographicalarea, 80 panelists, which included academicians in environmentalengineering, environmental regulatory authority scientists, consultingengineers, and members of the International Solid WasteAssociation (ISWA) from around the world, were surveyed. The survey was conducted using multiplequestionnaires to develop a LPI. The index is a mathematicalmethod of calculating a single value from multiple chemical and biological test outcomes of the dumpsite leachate. The solitary value Index is similar to a scale that discloses the overall leachate pollution potential of a dumpsite.It is based upon several leachate pollution parameters at a given time. It is agrowing index, in which a greater value point toward a worseecologicalsituation. The 18 leachate pollutionfactorsincluded in the Leachate Pollution Index, depend upon the investigation done by the analysts, were chromium, lead, chemical oxygen demand (COD), mercury, 5-day biochemical oxygen demand (BOD), arsenic, cyanide, phenolic compounds, zinc, pH, total Kjeldahl nitrogen, nickel, total Coliform bacteria, ammonical nitrogen, total dissolved solids (TDS), copper, chlorides, and total iron. The weights for the givenfactors were considered based upon symbolic levels proposed by the analysts for these factors on a scale of 1 to 5 and are given in Table 2.3. A chosen set of specialists were approached to make graphs for contaminant factors incorporated in the Leachate Pollution Index corresponding to leachate pollution potential ranging from 5 (best) to 100 (terrible). Intensities of leachate pollution from 0 to 100 were demonstrated on the x co-ordinate of every graph, while different levels of concentration of the specific variable, up to the ultimate limits disclosed in literature, were indicated on the abscissa. The graphs made by the specialists wereaveraged in order to find “average sub-index” graphs for every factor.

`

Table 2.1 Weights of Contaminant Variables considered in Leachate Pollution Index

Serial Number	Contaminant	Contaminant weight
1	Chromium	0.064
2	Lead	0.063
3	COD	0.062
4	Mercury	0.062
5	BOD	0.061
6	Arsenic	0.061
7	Cyanide	0.058
8	Phenolic compound	0.057
9	Zinc	0.056
10	pH	0.055
11	TKN	0.053
12	Nickel	0.052
13	Total Coliform bacteria	0.052
14	Ammonia nitrogen	0.051
15	TDS	0.050
16	Copper	0.050
17	Chlorides	0.049
18	Total Iron	0.045
	TOTAL	1.000

`

2.7 Aggregation Function

Aggregation methods are pivotal in the field of environmental indices, as they significantly influence the quality of result from several perspectives. Aggregation has been illustrated as the procedure of tallying factors or units with comparative properties to come up with a particular number which expresses the general estimated value of its specificpart.

Aggregation functions generally comprise of any of the following three arrangements:

1. Additive form (summation function), where individual variables are added together.
2. Multiplicative form (multiplication function), where a product is made of some or all of the factors.
3. Maximum or minimum operator form, where the maximum or the smallest sub index value of the factor is directlyacknowledged.

2.8 Procedure for Selecting Suitable Aggregation Function

The giventraits are to be investigatedfor selection of the suitable aggregation technique.

2.8.1 Functional Form of Index

The index could be an ascending scale index or a descending scaleindex. In the case of an ascending scale index, generally known as“environmental pollution index,” larger values show a poorercondition than smaller values. In the descending scale indices, largervalues are related with a better condition than lower values. These aregenerally known as “environmental quality indices.”

2.8.2 Strength and Shortcomings of Aggregation Function

The two major issues related with aggregation functionsare:

1. An overestimation (ambiguity) issue, where the aggregateindex *I* surpass the critical level without any of the sub-indicessurpassing the critical levels.

`

2. An underestimation (eclipsing) issue, where the aggregateindex *I* does not surpass the critical level even with one or moreof the sub-indices surpassing the critical levels.The best suitable aggregation function will limiteither one orboth the problems.

2.8.3 Parsimony Principle

When contending aggregation functions yieldalikeoutcomesconcerning overestimation and underestimation, mathematically simple aggregation function will be the most suitable.

2.8.4 Transparency of Aggregation Function

To conclude, an aggregation method is fruitful if all presumptions and origins of information are determined, the procedure is clear and openlystated, and the index could be easily disintegrated into the different constituents without any data loss. In addition to the mentioned procedure, the aggregation function chosen for any environmental index should also meet the given conditions.

(a) It should be subtle to the variations in asingular variable all over its range.

(b) It should be unbiased towards decent or deprivedecologicalworth.

(c) It should reflect weighting aspects, as all variables involved in the index are not equal donors to environment pollution.

(d) It should be easy to use.

2.9 Variable Curves

The averaged sub index graphs for everyfactor were made to buildan affinity between the Leachate pollution and strength or concentration of the factor. The averaged sub index graphs are the graphs that represent the affinity between leachate pollution and the strength or concentration of the factor. The averaged sub-index graphs are displayed in Fig. 2.2, 2.3 and 2.4.

The averaged sub index graphs are given for the following leachate contaminant variables

(a) pH

(b) Total dissolved solids

(c) Biological oxygen demand (5 day)

(d) Chemical oxygen demand

(e) totalKjeldahl nitrogen

(f) ammonia nitrogen

(g) total iron

(h) copper

(i) nickel

(j) zinc

(k) lead

(l) chromium

(m) mercury

(n) arsenic

(o) phenolic compounds

(p) chlorides

(q) cyanide

(r) total coliform bacteria.

`

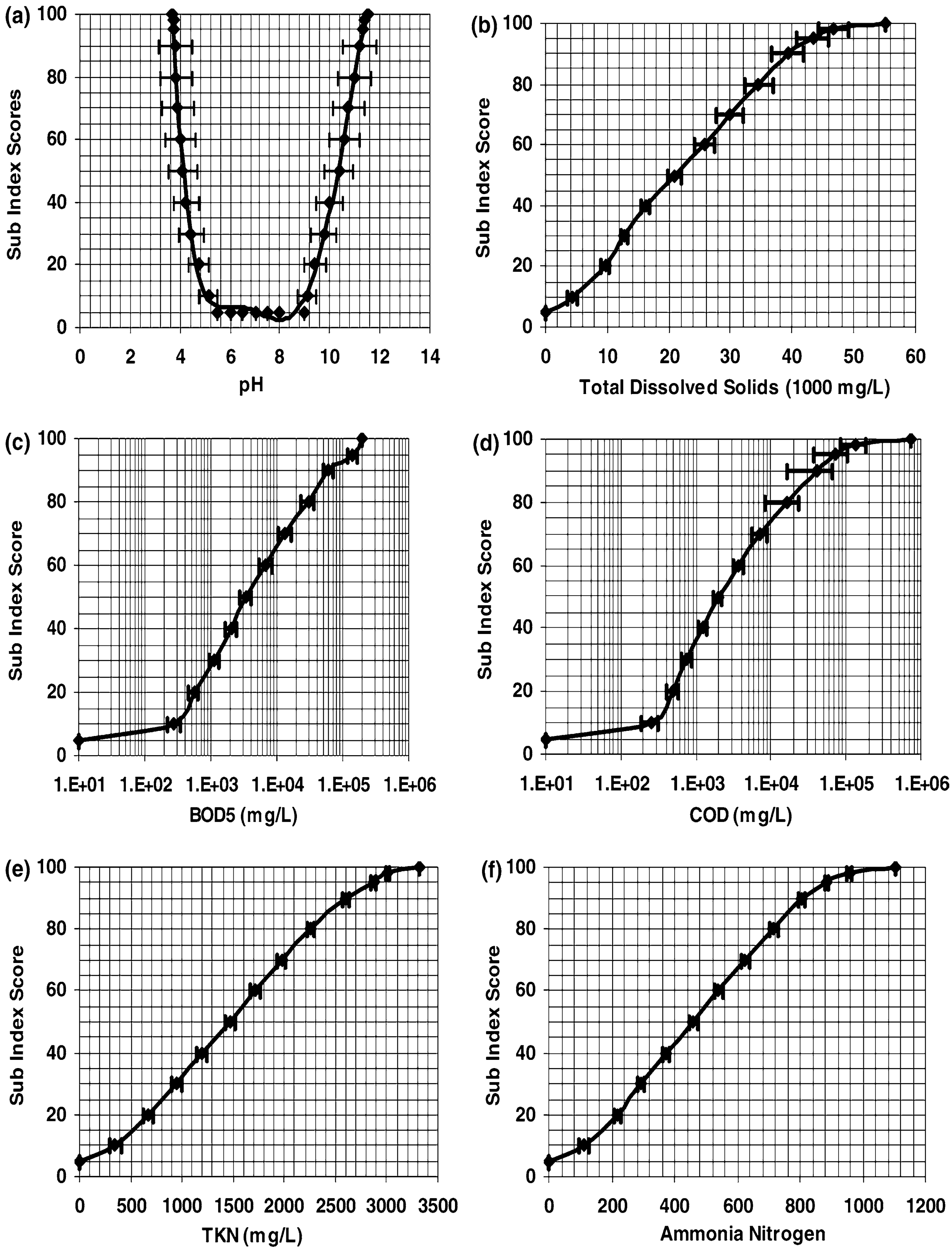

Figure 2.2 Variable curves for pH, TDS, BOD_5, COD, TKN and Ammonical Nitrogen

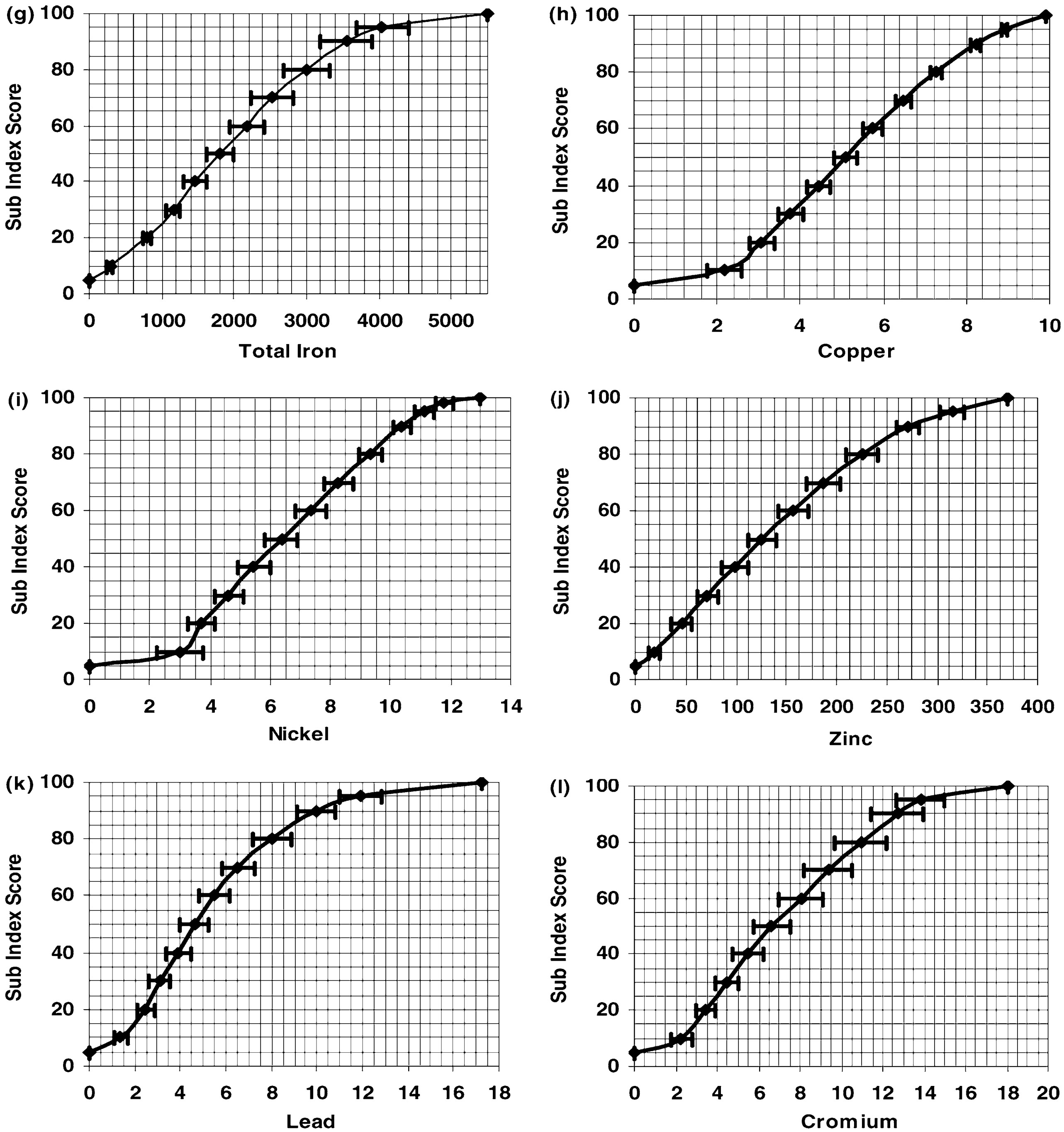

Figure 2.3 Variable curves for Total Iron, Copper, Nickel, Zinc, Lead and Chromium.

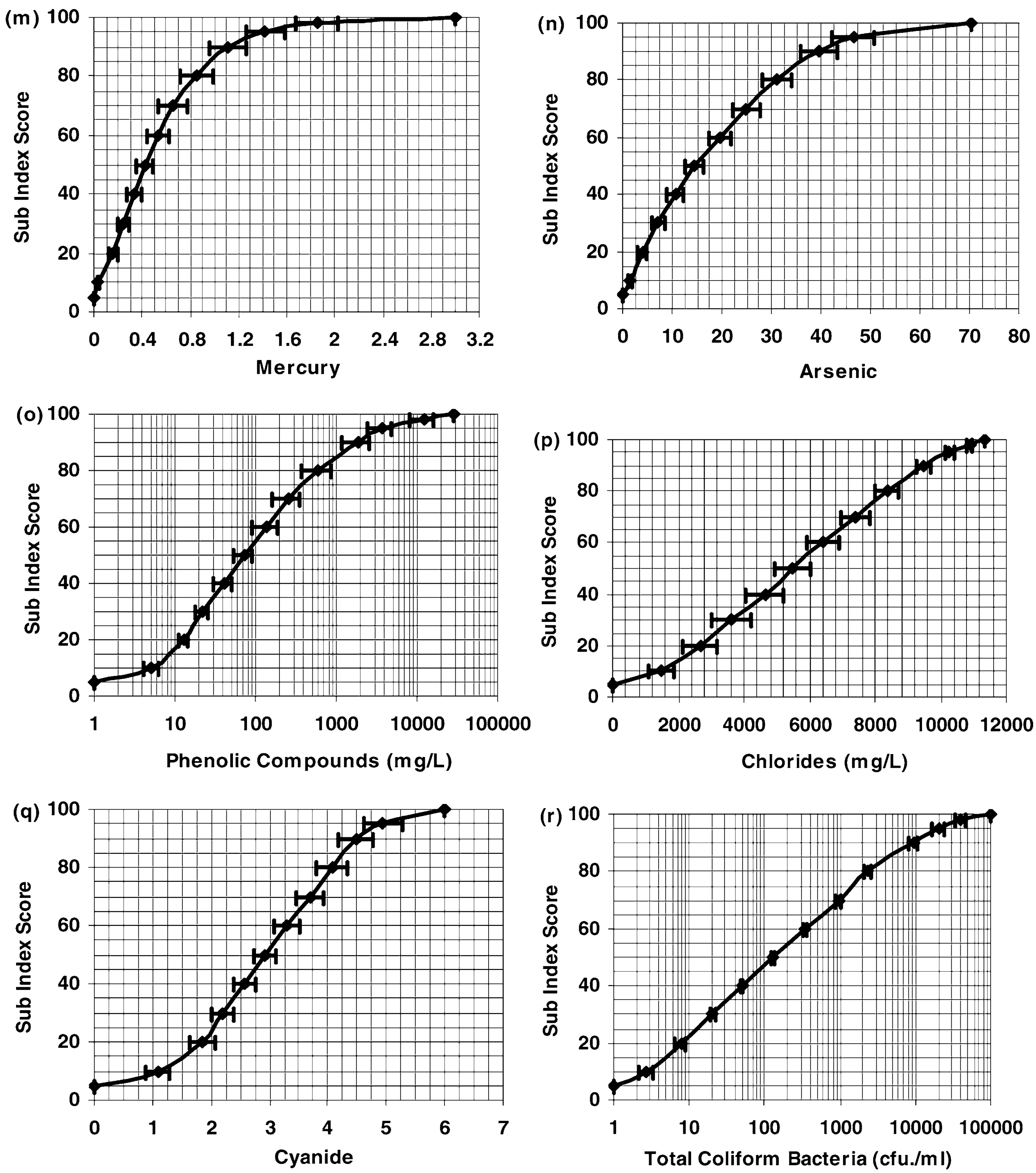

Figure 2.4 Variable curves for Mercury, Arsenic, Phenolic Compounds, Chlorides, Cyanide and Total Coliform Bacteria.

2.11 Variable Aggregation

The weighted sum linear aggregation function was utilizedadding up the behavior of all the leachate contaminant variables. The differentprobable aggregation functions were evaluated to choose the most ideal aggregation function. The LPI can be determined using the equation:

$$LPI = \sum_{i=1}^{n} w_i p_i \qquad \text{..... eq (1)}$$

where LPI = the weighted additive leachate pollution index,

w_i= the weight for the ith contaminant variable,

p_i= the sub index value of the ith leachate contaminant variable,

n = number of leachate contaminant variables used in computing LPI

$\sum_{i=1}^{n} w_i$=1

In case, when information for all the leachate contaminant variables involved in LPI is inaccessible, the LPI can be determined utilizing the information of the accessible leachate contaminants. For that situation, the LPI can be computed by the following equation:

$$LPI = \frac{\sum_{i=1}^{m} w_i p_i}{\sum w_i} \quad \text{..... eq (2)}$$

where m is the number of leachate contaminantfactors for which information is available, but for that situation, m < 18 and w_i< 1.

`

2.12 Summary of important research papers

Table 2.2 Summary of important research papers

Sr. No.	Title of the paper	Year of publication	Author Names	Methodology	Conclusion
01	Groundwater Pollution Hazard Potential Rating of Municipal Solid Waste Dumps and Landfills	September 2007	Raj Kumar Singh, Manoj Datta and Arvind Kumar Nema	It includes rating of all factorscomprising the ones acknowledged from collected works on a measure of 0-10. A score of '0' showed that factor is not significant all, therefore it should not be incorporated, while score of 10 was to be allocated to the most significantparameter .The relative importance weights of several input factors were chosenvia Delphi technique (Dalkey, 1968). The finest value of a factorresemblesto a dumpsite with least	This paper presents a hazard rating system based on different parameters which is used for assessment of groundwater adulteration potential of MSW dumpsites. It uses three types of parameters i.e. source, pathway and receptor. The current model assesses the threat due to a dumpsite more precisely and gives an enhancement over the current hazard rating systems.

`

				threat and the poorest value resembles the site with maximum threat.	
02	Numerical modelling of the environmental impact of landfill leachate leakage on groundwater quality – a field application,	4 July 2006	M.P. Papadopoulou G.P.Karatzas G.G. Bougioukou	In this paper numerical replicasare used to define hydraulic phenomenafor instance flow of groundwaterand pollutant mass movement.The key goal ofmodels like these is to anticipate the longstandingeffect of water extraction and contaminant movement and to study groundwater management substitutes. The Princeton Transport Code is a groundwater flow and contaminant transport simulant which solves	Ecologicalinfluence on groundwater condition of polluted by leachate from the Municipal Solid Waste dumpsite in Patras, Greece, was presented.The outcomes attainedshow that (1) the pollution spreads quicker in the downstream course if the dumpsite is built on large hydraulic conductivity permeable media (2) the water percolated during the monsoons

`

				numerically aarrangement of partial differential equations in order to accurately symbolise the groundwater movement, the rates and the pollutant mass movement of the simulated physical system. PTC uses anexclusive splitting algorithm for solving the fully three dimensional equations, which considerablydecreases the calculation burden.	contribute for a greater dilution of the pollutantthrough that duration and greater values of the pollutant concentration detected in the end of the dry period 3) A hazardinvestigation miniature showed that a decrement inmass of the pollutant at the source in initial stages influences the progress of the pollutant plume and decreases the negative ecologicaleffect on traits of groundwater.
03	Evaluation of local	December 12, 2014	Akhtar Malik Muhammad,	Here DRASTIC way is used for	GIS was utilized to residentialplot

`

	groundwater vulnerability based on DRASTIC index method in Lahore, Pakistan.		Tang Zhonghua, Ammar Salman Dawood and Bailey Earl	estimate of GW measurement. In this method six parameter are studied. Each limit is assign a weighting, from one to ten, according to its capability to concern groundwater. DRASTIC Index is designed. Well-built the worth if this index, higher the susceptibility of groundwater to fall.	which showgreathazardzone of 28.3 % and reasonablydefencelesszones of 46.1% whereaszones of nohazardwere 10 %. The resultinggroundwater susceptibility map provide us a foundation for this meant at protective the aquifer from contaminants.It is also established that industrial & cultivation zones are verysusceptible as evaluate to resolutionzones.

`

04	Ranking criteria for assessment of municipal solid waste dumping sites.	2017	Khalid Mahmood, SyedaAdilaBatool, Muhammad Nawaz Chaudhary, Zia Ul-Haq	This investigation is completed forexpanding a relativeprocedure that is able togradeactive municipal solid wasteremovalservices.Thesecertainparameters are divided into 3 categories:RESIDENT's CONCERN:The site of discarding site is very significant to make sure sustainability of surroundings& to decrease its impact on human beings in its neighbourhood. So, a discarding site whether it is engineered or non-engineered has to be located far from a housing area. GROUNDWATER VULNERABILITY:	This Paper tells us about theInput factors havealienated in three categoriesviz. Resident's concern, Groundwater Vulnerability and Surface services. Isolated Sensing information and GIS study was utilized to arrangemaximum of the input information.To detail the idea, 4 dumping sites selected for investigation purpose, namely Old-FSD, New-FSD, Saggian and Mahmood Booti.Resilience of suggested model to accommodate as

`

				Leachateformed in MSW dump sites percolateall the way through vadose zone and finallycontaminate the groundwater. GW risks are considered as: (GW1) Depth of water table underneath dumping service (GW2) coefficient of permeability of primary sediments(GW3) Time occupied by leachate to attain the water table (GW4) Amount of Leachate manufacture (must be low)(GW5) angle b/wguidelines of the settledarea and flow of groundwater from removal site(highest and utmostappropriate value is 180^0 and	many types and factors in one type will prove advantageous for evolvingdomain where accessibility of information is amajordifficulty in study based ecological sustainability preparation.The miniature can be used even devoid ofbuying satellite information and GIS software, with slightimprecision, using descriptions and dimension tools delivered by Google Earth.The pecking order of goodness found for the nominated sites is :

`

				minimumsuited value is 0^0 . SURFACE FACILITIES: Itinclude social amenities and surface water forms in the form of river, stream or ponds. next are the parameters used in this study: SF1: region of surface water forminside 200m of a dumpsite.SF2: accessibility of concrete road admission to dump site.SF3: Length of highway and recurrently used road inside 100meter of a dumping resourceSF4 : reserve to nearrespectposition SF5: detachment to	New-FSD > Old-FSD > Mahmood Booti>Saggian with relative scores of goodness to surroundings as 36.67, 28.43, 21.26 and 13.63 respectively.

`

				adjacent school	
05	Groundwater vulnerability and risk mapping for the Basaltic aquifer of the Azraq basin of Jordan using GIS, Remote sensing and DRASTIC	6 August 2003	R.A.N. Al-Adamat, I.D.L. Foster , S.M.J. Baban	This study is approved out using DRASTIC processinside the GIS environment to create a groundwater vulnerability map.The author barred hydraulic conductivity from the final DRASTIC computationowing tobe the short of data.The author replace the renew parameter (net recharge) as defined by the US EPA by	This paper attempt to create groundwater vulnerability and danger maps.These maps are intended to illustrate areas of maximumpossibl e for groundwater defect on the foundation of hydro-geological circumstances and human impact.The wholemain geological and hydro-geological

`

				the possible of anregion to have a renewbase on the rainfall quantity, undulation and soil permeability. Three DRASTIC parameters was not used in this research; net refresh, bang of the vadose zone and the aquifer medium. Instead, the authorsadditional new parameters to the DRASTIC index; the land use and septic tank scheme density.Hydraulic conductivity were not used in the expansion of the DRASTIC index because there were lack of data from which to estimation this parameter.The DRASTIC index	factor that affect and manage groundwater group into, during, and out of the study area were included into the DRASTIC copy.deepness to groundwater, renew, aquifer medium, soil media, topography, and crash of the vadose zone are the parameters built-in in the study.The hydraulic conductivity of the aquifer were not built-in in scheming the final DRASTIC index for possiblestain due to a lack of sufficient

`

				was compile in two part stages:Stage one concerned an assessment of groundwater vulnerability, which is dependent relative on the physical circumstances found in a specific environment and is fundamentallyself-governing of the use to which the land is place. phase two concerned the addition of risk factors focus on land use in the learnregion.These factor were extra to the DRASTIC vulnerability index in instruct to make a risk directory.	quantitative information. A Geographical Information scheme (GIS) was used to create a groundwater vulnerability map by overlay the obtainable hydro-geological data.The final DRASTIC model was experiencedby hydro chemical informationas of the aquifer. Around 83% of the study region was classified as life form at reasonable risk while the rest was classified as low risk.It be able to be finished that the move towards adopted to create the DRASTIC

`

					index was incomplete by the ease of use of data.
06	Hazard Rating of MSW dumps and geo-environmental measures for closure.	December 2015	Manoj Datta, Amit Kumar	Baseline circumstances of the waste dump were studied.To get the data concerning waste dumps, all the cities (53 in total) have population over 1-million waschosen.Out of the fifty-three city, information for dump sites in 23 municipal corporation were obtain.Further in order was also obtain from published literature and existing cityinformation. Consequently, data were obtainable from total 26 cities.Cities with	These paper demonstrateshow thedanger rating techniques can be used in assess the relationpotential of MSW dumps for infectivity of groundwater, surface water and air.base on the score scores, one can recognize the appropriateness of geo-environmental events for closure of MSW dumps which containdissimilar collision on the environment due to unreliable site circumstances.Index purposecome close tobase on

`

				inferior population & other countrysidearea were out of the range of the study.For data study, the waste dumps were categorize into three categories: **a)** sites from city having population more than 5000000 **b)** Sites from cities having population between 2000000-5000000. **c)**Sites from cities having population b/w 1000000-2000000 The appropriateness of the next rating system has been assess for MSW dump sites and the nextsystem have beestablishhelpful: NPC and JENV	source-pathway-receptor method is used here.Seven methods of end are assessed for appropriateness of application to 12 MSW dumps with dissimilar hazard ratings. The hazard rating used toassess waste removal sites according to the family member hazards pose by them to human health and environment.

`

				scheme for air contagion; WARM, HRS and RSS for exterior water contagion; GW-HARAS for groundwater contagion.	
07	Groundwater vulnerability Assessment by DRASTIC method using GIS	April 2017	A.V.Ramaraju ,K. Krishna Veni	**Overlay and Index Methods:** These methods join maps of parameters careful to be influential in pollutanttransportati on. Each parameter has a variety of possible principles, representative the amount to which that parameter protect or foliagesusceptible the groundwater in aarea. More complicated systems	The aquifer weakness of East Godavari district of Andhra Pradesh employ the empirical index DRASTIC model of the U.S. Environmental Protection Agency (EPA). Seven environmental parameters were second-hand to stand for the natural hydro-geological setting of the aquifer, Depth to groundwater, Net

`

				allocatearithmeticalscore based on some parameters. The most well-liked of this method, DRASTIC uses a score system baseon 7 hydro geologic kind of a region. **Mathematical Model:** Such models letintimidation to the security of land water supplies to be documented and can play asignificant role in preparation remediation labours.Different other land waterclassforecast methods, numerical models forecast variations of water excellence both in room and in instance.These methods	renew, Aquifer media, Soil media, Topography, collision of vadose zone & Hydraulic conductivity. The results show that vulnerability index range from 78 to 170 and are classified into three classes 79-100, 100 to 140 and 140 to 170 matching to low, medium and high vulnerability zones in that order. The land water vulnerability possible map show that the mainstream of eastern fraction and a number of

`

				aren'twornextensively for susceptibilityexamination. **DRASTIC Method:** This method is based upon the 7 parameters which we discuss below: The Depth of landwater, renew rate, soil media, and slope of the apex surface, effect of vadose zone, hydraulic conductivity of the aquifer. The possible contaminationfor a dumpsite is resolute by multiplyingeveryfactorheaviness with its assignmark or point	areas the length of coast fall under far above the groundsusceptibility followed by medium susceptibility in the central and western areas of the study area.

`

				score plus the whole. It is an effortlesstechnique which uses preservativeprocedure. The series of Index assessed using this scheme has a theoreticvariability of 23-226.	
08	Groundwater Pollution Hazard Potential Rating of Municipal Solid Waste Dumps and Landfills	September 2007	Raj Kumar Singh, Manoj Datta, Arvind Kumar Nema	Numerousschemefactorslabelling the source, pathway and receptor were classifiedbasedupon literature and the expert ideas. The panellists were asked to add any other factor(s) of significance to the groundwater pollution potential of municipalsolid waste dumpsites, and then give ratings to all factors comprising the ones recognised from literature on a scale	In this study a multi-factor hazard assessment system is introduced for assessing groundwater pollution caused due to MSW dumpsites. It is applied for four landfills; two in Delhi and two in Chennai. Then theoutcomes are paralleled with those of the existing models.

`

				of 0-10.A score of '0' showedthat factoris insignificant and hence should not be built-in, whilescoreof 10 was to be allocated to the utmostsignificantfactor. The relative importance weights of severalfactors were establishedby the Delphi technique (Dalkey, 1968). The finest value of a factorcorrespond tosquander site with least probablethreat and the most horrible scorecorrespond to the dumpsite with maximumprobablethreat. If all input factors for a dumpsite are at their poorest scores, the hazard rating will be	The system is based on source-pathway-receptor copy and assesses the site threat potential on a comparative scale of 0 to 1000, taking into deliberation the full leaching life of the waste disposal site.Each classfactors are aggregatedistinctly by a mixture of additive and multiplicative systems. The contrastdisplays that the current model yieldsconsiderablycontradictorymarks for the unlikewaste disposal sites as paralleled to the breathing systems, and thus

`

				highest for that site.	is more approachable to diverse site situations.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Study Area

1. Hamirpuris a town situated in the Himalayan region of Himachal Pradesh (HP). It is additionally the headquarters of the Hamirpur district. It is located in a comparatively colder region in western (HP) with a high altitude. Its average elevation is 738m and exact geographical co-ordinates are 31.68^{o} N 76.52^{o} E. According to 2011 census, the population of Hamirpur town was 17604.It does not have typical very cold type of climate found in most parts of Himachal Pradesh as it is close to the plains. During winters, the climate is cold but pleasant and woolens are required and in summers the temperature goes up to 35^{o}C. In 2012, some parts of Hamirpur district received a moderate snowfall. Most parts of Hamirpur district are covered with pine forests.

`

Figure 3.1 Hamirpur dumpsite

2. Mandiis a major town of Mandi district and also a headquarters of the Mandi district. It is located 145 kilometers north of state capital, Shimla. It lies in the north-west Himalayas at an average altitude of 754m. According to 2011 census, the population of Mandiwas 26422.The climate of Mandi includes sweltering summers and cold winters. This region generallyexperiences rainfall during end of summers. This town lies the lower climatic zone of Himalayas. Temperature in summers is between 18.9^{o}C and 39.6^{o}C and in winters, it is between 6.7^{o}C and 26.2^{o}C.

`

3. Unais a major town of Una district and also a headquarters of the Una district. Its terrain is semi-hilly with low hills. Its altitude is 408m. Its exact co-ordinates are 31°28’34”N 76°16’13”E. It is the main industrial hub of Himachal Pradesh. It is located in the foothills of Himalayas. Its climate is mostly sub-tropical. Temperature goes down to -3.5°C in winters and goes as high as 48°C in summers. The average annual rainfall is 1253mm.

4. Santokhgarhis a t district of Himac elevation is 322m. census, its populati coordinates are 31.3 average rainfall recei 1253 mm. The clim tropical.

Figure 3.2 Santok

5. NIT Hamirpur engineering institu Hamirpur town of Himachal Pradesh.

`

Figure 3.3NIT Hamirpur Dumpsite

3.2 Methods used for site ranking

In the totalobtainable raring system for hazardous dumpsites. Amongst these, twelve rating systems are futurefirst and foremost for hazardous waste dumpsites. These systemsget into explanation the poisonousness of the majoritydangerousmix on the place to approximation the hazard for receptor, and hence are not in a straight line applicable to MSW sites.Absent of these three rating systems, only one i.e. DRASTIC, directly assess the groundwater infection potential instead ofdanger to the receptors i.e. person beings. In adding, twoscore systems i.e. GW-HARAS ,anenhanced and improved variant, mGW-HARAS are 2latelyestablished groundwater threatrankingsystem which can be used for rating of pollution potential by eliminating the partconnecting to receptors.

`

Table 3.1 Existing rating systems and their applicability to MSW dumpsites for groundwater pollution

Application of rating systems	No. of rating systems	Rating systems
Predominantly for hazardous waste	12	Hazard Assessment Rating Methodology, Hazard Ranking System, Defense Priority Model, Hazard Ranking System-1990, Washington Ranking Method, National Corrective Action Prioritization System, Relative Risk Site Evaluation Method, Environmental Repair Program Hazard Ranking System, Indiana Scoring Model, Risk Screening System, Risk Assessment of Small Closed Landfills, National Classification System.
For hazardous waste and/or MSW waste but yield a combined score of groundwater, surface water and air	03	Hazard Ranking Using Fuzzy Composite Programming, JENV, National Productivity Council System
For MSW waste to evaluate groundwater pollution	03	DRASTIC, GW-HARAS, mGW-HARAS

3.2.1 Methods of Ranking

For assessment of pollution from MSW dumps, generally four methods are used which are given as:

1. DRASTIC

2. GW-HARAS

3. mGW-HARAS

`

4. SIMRAS

Table 3.2 Parameters employed by DRASTIC, GW-HARAS and mGW- HARAS:

Parameter	DRASTIC	GW-HARAS	mGW-HARAS
Area in (ha)		√	√
Waste height in(m)		√	√
Waste composition		√	√
Rainfall	√	√	√
Depth to groundwater	√	√	√
Soil Permeability	√	√	√
Groundwater gradient	√	√	√
Slope of the top surface	√	√	√
Aquifer permeability	√	√	
Aquifer thickness		√	

1. DRASTIC

It dependsupon six factors: depth to groundwater, rainfall, soil media, and slope of the top surface, impact of vadose zone and hydraulic conductivity of the aquifer. The pollution potential of a place is calculated by multiplying each factor weight by its allocated score or point rating and adding the total. It is a simple technique which mainly uses additive set of rules. DRASTIC Index indicating the pollution is given by:

DRASTIC Index = $\sum w_i R_i$

The range of the Index assessed by this system has a theoretical range of 23-226 (greater score shows more prominent hazard to groundwater).

2. GW-HARAS

It depends on source-pathway-receptor connections and assesses the groundwater pollutionthreatranking of dumpsites on a comparative scale of 0-1000. It uses ten factors: area of the dumpsite, height of the waste, waste composition, rainfall, depth to groundwater, soil permeability, groundwater gradient, gradient, aquifer permeability and aquifer thickness.

`

It primarily uses multiplicative algorithm. The groundwater pollution hazard rating is given by:

$HR = H_S * H_P * H_R$

Where

H_s= source hazard rating;

$H_{R=}$ receptor hazard rating;

H_P=pathway hazard rating.

3. mGW-HARAS

It is a modification over GW-HARAS. It uses the following parameters: Area, waste height, waste composition,rainfall, depth of groundwater, soil permeability, groundwater gradient, soil permeability, groundwater gradient and slope of the top surface.

The groundwater pollution hazard rating is given by:

$HR = H_S * H_P * H_R$

Where,H_s= source hazard rating, $H_{R=}$ receptor hazard rating, H_P=pathway hazard rating

Table 3.3 Comparison of GW-HARAS and mGW-HARAS:

Component	GW-HARAS (HR = $H_s*H_{p*}H_R$)			mGW-HARAS (HR = $H_s*H_{p*}H_R$)		
	Formulae	Mnv[a]	Mxv[a]		Mnv[a]	Mxv[a]
Source	$H_s = W_{qi} * W_{ci} * I_{pi}$ $W_{qi} = \sqrt{(W_q/3)}$ $W_{ci} = (25H + 5B + C)/5$ $I_{pi} = P_s * i_s$	37 258 0.45 0.32	1000 1000 1.0 1.0	$H_s = W_{qi} * W_{ci} * I_{pi}$ $W_{qi} = 225*(W_q)^{0.1}$ $W_{ci}=0.6+0.4*[(25H+5B+C)/500]$ $I_{pi}=0.6+0.4*(P_s * i_s)/10$	427 763 0.8 0.7	1000 1000 1.0 1.0
Pathway	$H_p = V_i * A_{qi}$	0.56	1.0	$H_p = V_i * A_{qi}$	0.16	1.0

`

	$V_i = 0.7+0.3[(\log(z)_{v,b}-\log(z)_v)/\log(z)_{v,b}-\log(z)_{v,w}]$ $Z_v=0.5*k_v/L$	0.7	1.0	$V_i = X_1+X_2[\log(k_v)_b-\log(k_v)/\log(k_v)_b-\log(k_v)_w] * [L_b-L_f/t_b-t_w]$ Where $X_2=1-X_1$ and, X_1={0.2 for $K\leq10^{-8}$ m/s 0.4 for $10^{-8}< k(m/s)\leq 10^{-6}$ 0.7 for $k(m/s) > 10^{-6}$}	0.2	1.0
Receptor	$Aqi = 0.8+0.2 [w_{at}(z_{ai,b}-z_{at}/z_{ai,b}-z_{at,w})+w_{ap}(LogZ_{gg}-Z_{gg,b}/Z_{gg,w}-Z_{gg,b})] * (Z_{dw,b}-Z_{dw}/Z_{dw,b}-Z_{dw,w})$ $H_R = SG_i+\sum_{j=1}^{j=m} Gu_{ij}$	0.8 0.8	1.0 1.0	$A_{qi}= 0.8+0.2 * [Z^{0.5}_{gg}-Z^{0.5}_{gg,b}/Z^{0.5}_{gg.w}-Z^{0.5}_{gg.b}]$ $H_R= \max(Gu_{ij})$	0.8 0.6	1.0 1.0

Where,

HR-Hazard rating

H_s-Source hazard rating

H_p- pathway hazard rating

H_R- Receptor hazard rating

W_{qi}– Waste quantity indicator

W_{ci}– Waste composition indicator

I_{pi}– Infiltrating precipitation indicator

W_q– waste quantity (tons)

`

H – Hazardous fraction

B- Biodegradable fraction

C- Construction and demolition factor

P_s- precipitation score

i_s – infiltration score

V_i– vadose zone indicator

K_v – vadose zone permeability in metres per second

L- vadose zone thickness in meters

A_{qi}- aquifer zone indicator

W_{at}, w_{ap}, w_{gg}, relative important weights and Z_{at}, Z_{ap}, Z_{gg} and $Z_{dw}$are the parameter values of aquifer thickness, aquifer permeability, groundwater gradient and distance to nearest groundwater well respectively.

The subscripts b and w represent best and worst values

SG_i indicator for subsoil or groundwater

Gu_{ij}-indicator for jth groundwater user category

m – number of groundwater user categories

M_{nv} – minimum value computed for the best site

M_{xv} – maximum value computed for the worst site

3. SIMRAS

For a hazard rating system, waste hazard rating is given by:

$HR \propto H_s * H_P * H_R$

`

A hazard rating system can be converted into a pollution potential rating by eliminating the influence of receptor component. The influence of receptor component can be eliminated by assigning H_R a value of 1. Hence pollution potential rating (CPR) is given by:

$CPR = P_S * P_P * P_R$

Where,

P_S = Source potential rating

P_P = pathway potential rating

P_R = Receptor potential rating (taken as unity)

Source potential rating, P_S is given as:

$P_S = I_{wq} * I_{wc} * I_p$

Where,

I_{wq}= waste quantity indicator

I_{wc}= waste composition indicator

I_p= infiltrating precipitation indicator

Pathway potential indicator is given as:

$P_P = I_v * I_{aq}$

Where,

I_v= Vadose zone indicator (based on depth to groundwater and permeability of vadose zone

I_{aq}= Aquifer indicator

The receptor indicator P_R is taken as unity.

For assessment, a set of waste sites with varying conditions was adopted. After obtaining the rating scores, these were normalized to 0-1000 scale.

`

3.3 Procedure to calculate LPI

The stepwise strategy to calculate LPI is given below.

Step 1-Testing of Leachate Pollutants

We have to find out leachate contaminants concentration from the samples of leachate collected from the dumpsites of MSW, recognition of concentration by performing tests in the laboratory (analytical).

Step 2-Calculating Sub-Index Values

To compute the Leachate Pollution Index, one initially calculates the sub-index value of the factorsfrom the sub-index graphs established on the concentration of the leachate contaminantsachievedon performing various tests. The sub-index values are found by tracing the concentration of the leachate contaminant on the horizontal axis of the sub index graph for that contaminant and observing theleachate pollution sub-index value where it transects the graph.

Step 3-Aggregation of Sub-Index Values

The sub index values attained were multiplied with the corresponding weights allocated to everyfactor. The equation (1) is used to compute LPI if the concentrations of all the 18 variables involved in LPI are identified. Else, equation (2) is used when information for some of the contaminants is not accessible. It isdetected that LPI values can be computed with minimalinaccuracyby means of equation (2), when the information for some of the contaminants is notaccessible. In current investigation, out of 18, 9major parameters were recovered, so equation (2) is used.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Data Collection

Table 4.1 - Site parameters for various MSW dumpsites for post monsoons

Dumpsite → Parameters ↓	NIT HAMIRPUR	HAMIRPUR	MANDI	UNA	SANTOKHGARH
Area (hectares)	0.13	0.24	0.55	0.77	0.2
Waste height (meters)	1.5	0.90-1.2	10-12	1.5	10
Rainfall(mm)	47.3	47.3	82.3	23.8	23.8
Depth to GW (meters)	45	63	19.5	15.5	18.24
Soil Permeability(m/sec)	10^{-1}	10^{-8}	10^{-7}	10^{-4}	10^{-4}
Groundwater Gradient					
Slope of top surface (%)	0	33.33	0	0	0

Table 4.2 Site parameters for various MSW dumpsites for winters

Dumpsite → Parameters ↓	NIT HAMIRPUR	HAMIRPUR	MANDI	UNA	SANTOKHGARH
Area (hectares)	0.13	0.24	0.55	0.77	0.2
Waste height (meters)	1.5	0.90-1.2	10-12	1.5	10
Rainfall(mm)	323.9	323.9	339	323.1	323.1
Depth to GW (meters)	45	63	19.5	15.5	18.24

`

Soil Permeability(m/sec)	10^{-1}	10^{-8}	10^{-7}	10^{-4}	10^{-4}
Groundwater Gradient					
Slope of top surface (%)	0	33.33	0	0	0

Table 4.3 Site parameters for various MSW dumpsites for summers

Dumpsite → Parameters ↓	NIT HAMIRPUR	HAMIRPUR	MANDI	UNA	SANTOKHGARH
Area (hectares)	0.13	0.24	0.55	0.77	0.2
Waste height (meters)	1.5	0.90-1.2	10-12	1.5	10
Rainfall(mm)	26.8	26.8	38.7	27.6	27.6
Depth to GW (meters)	50	68	24.5	20.5	23.88
Soil Permeability(m/sec)	10^{-1}	10^{-8}	10^{-7}	10^{-4}	10^{-4}
Groundwater Gradient					

`

Slope of top surface (%)	0	33.33	0	0	0
Aquifer Permeability					

Table 4.4 Waste composition for various MSW dumpsites

Dumpsite → / Waste composition	NIT HAMIRPUR	HAMIRPUR	MANDI	UNA	SANTOSHGARH
Wood	7%	10%	8%	6.3%	9.3%

Paper	28%	18.2%	23.2%	27.4%	17.5%
Metals	6%	6%	7.4%	7.9%	3.5%
Glass	5%	2%	3%	4.6%	8%
Food Waste	30%	27.2%	29.3%	14.5%	28.5%
Plastic	12%	15.7%	13.2%	12.7%	8.3%
Leather	2%		3.1%	4.7%	2%
Textile	8%	7.1%	9%	4%	4.3%
Construction materials	-	8.8%	-	12.7%	10.6%
Hazardous waste	-	4%	1.8%	3.2%	6%
Others	1.2%	1%	2%	2%	2%

4.2 Results

4.2.1Groundwater pollution potential scores from DRASTIC, GW-HARAS, mGW-HARAS and SIMRAS for POST MONSOON season.

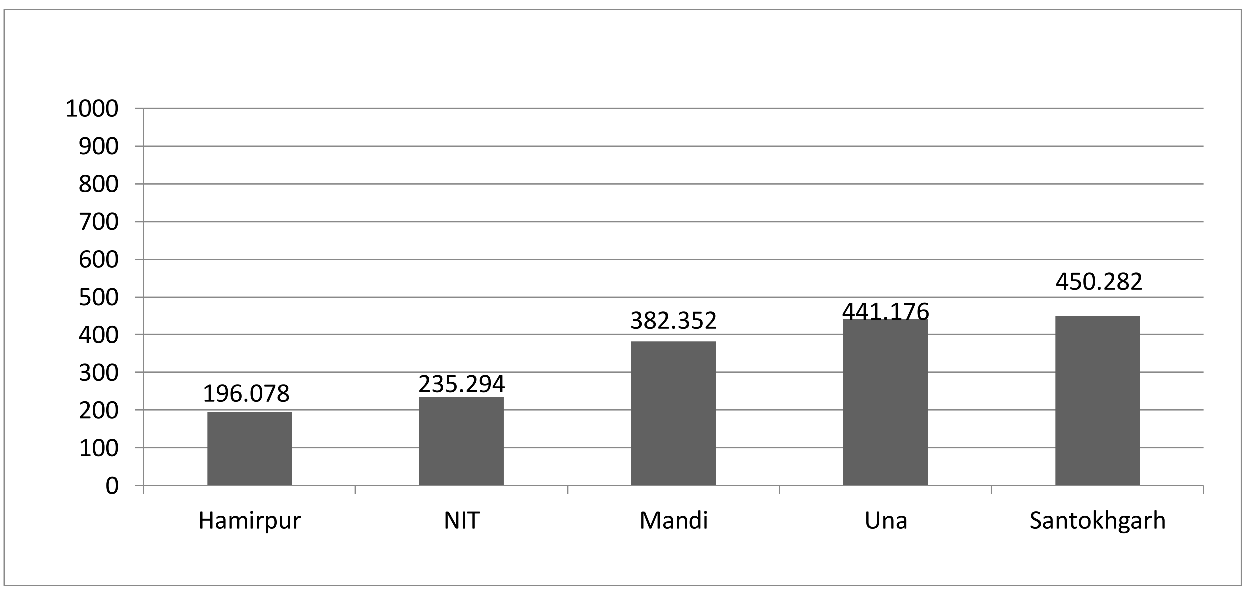

Figure 4.1 Groundwater pollution potential scores for MSW dumpsites from Himachal Pradesh from DRASTIC for post monsoons.

`

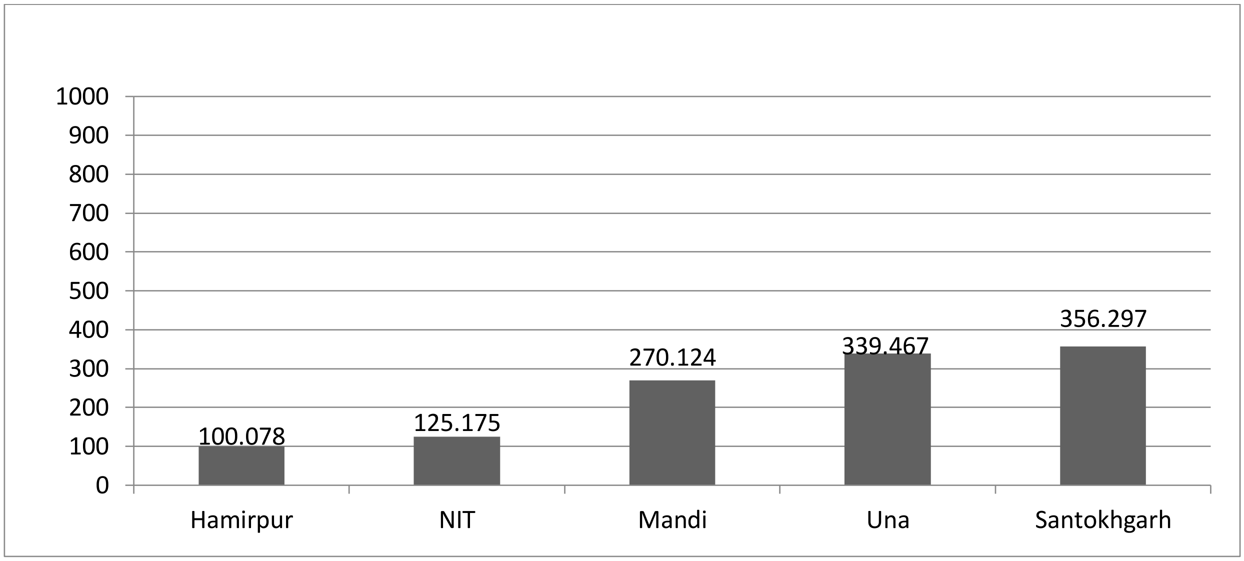

Figure 4.2 Groundwater pollution potential scores for MSW dumpsites from Himachal Pradesh from GW-HARAS for post monsoons.

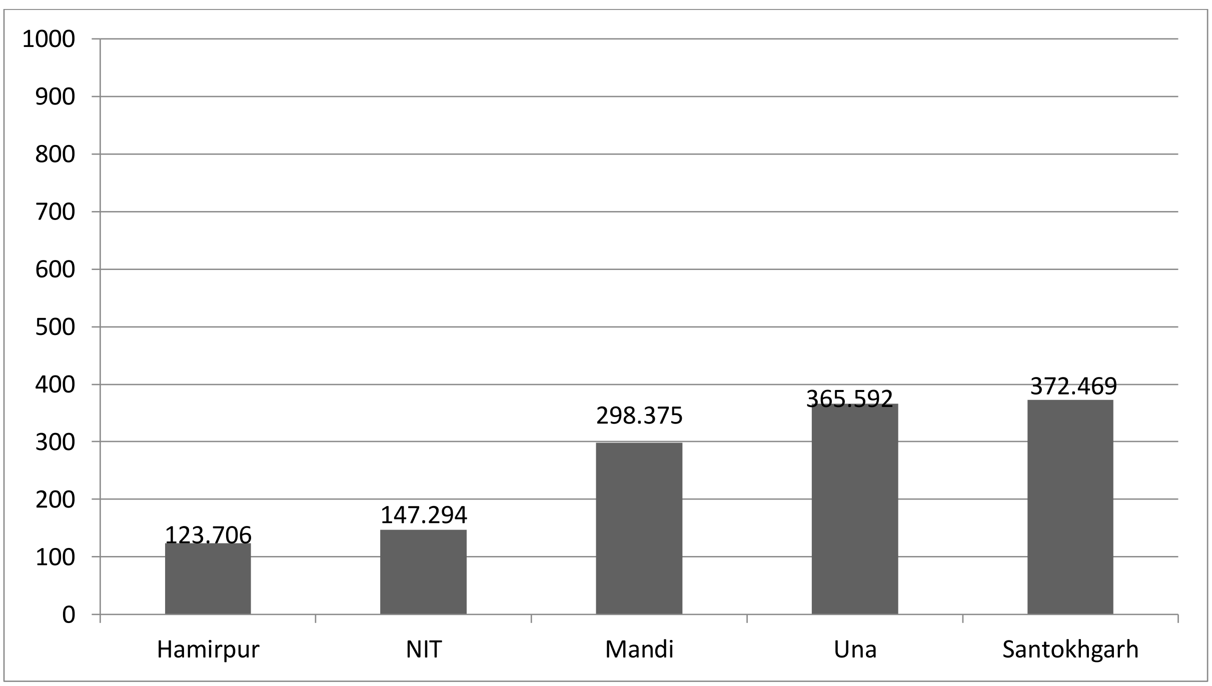

Figure 4.3 Groundwater pollution potential scores for MSW dumpsites in Himachal Pradesh from mGW-HARAS for post monsoons.

`

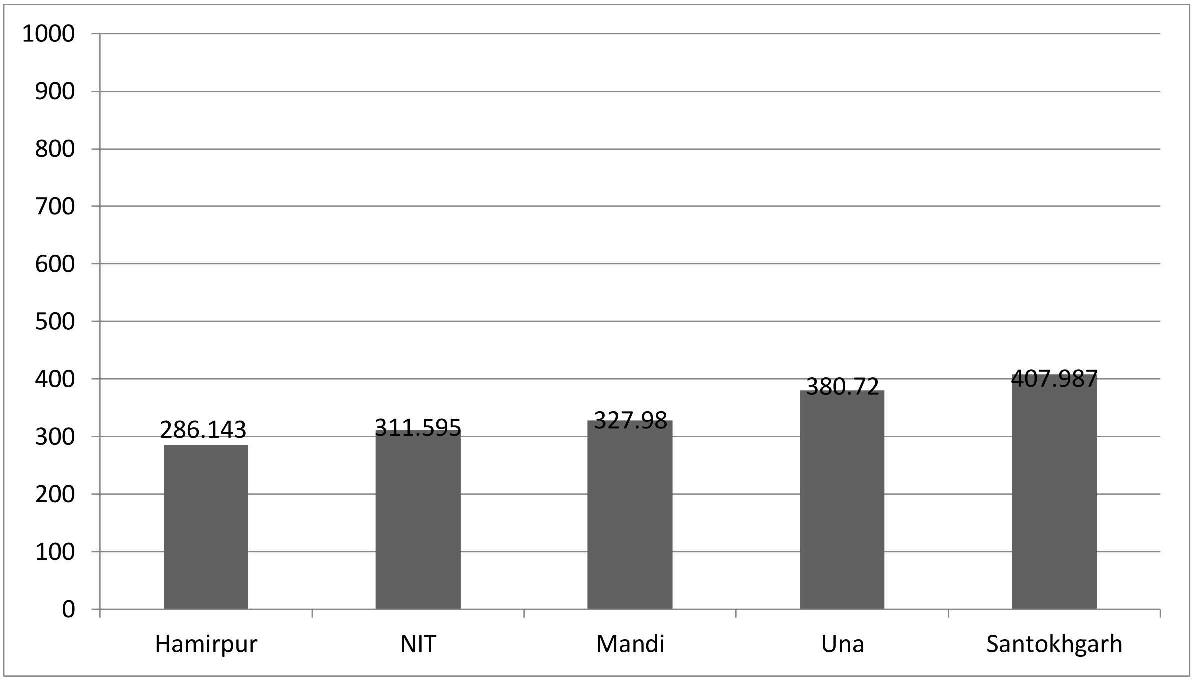

Figure 4.4 Groundwater pollution potential scores for MSW dumpsites in Himachal Pradesh from SIMRAS for post monsoons.

4.2.2 Groundwater pollution potential scores from DRASTIC, GW-HARAS, mGW-HARAS and SIMRAS for winter season.

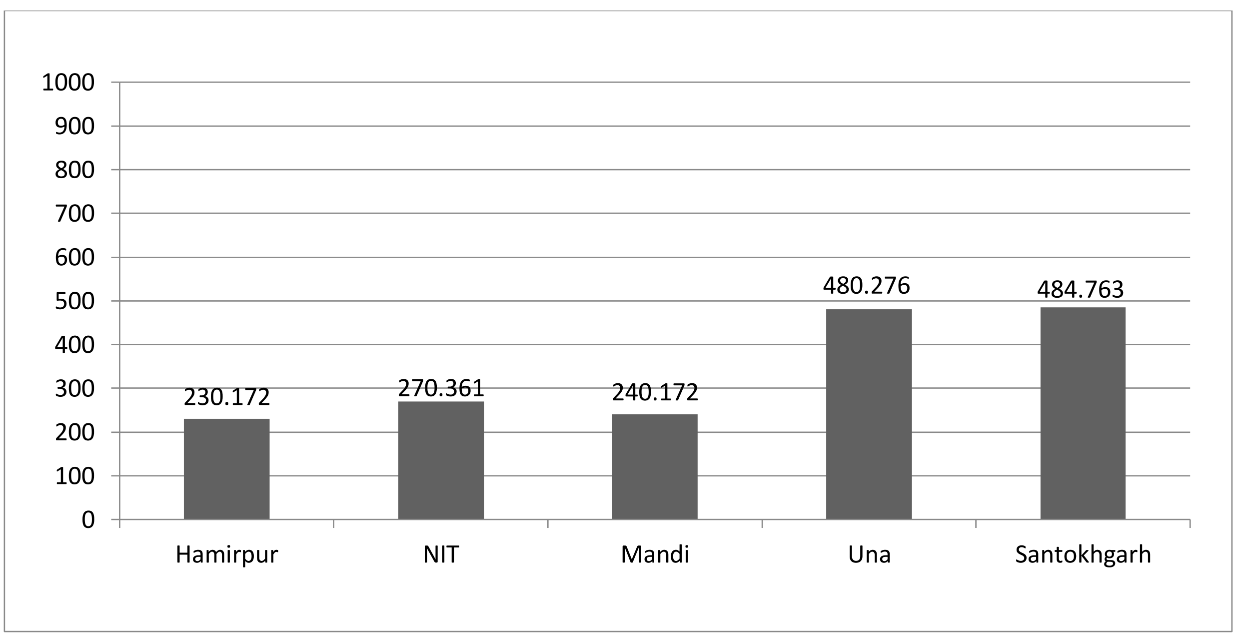

Figure 4.5 Groundwater pollution potential scores for MSW dumpsites in Himachal Pradesh from DRASTIC for winter season.

`

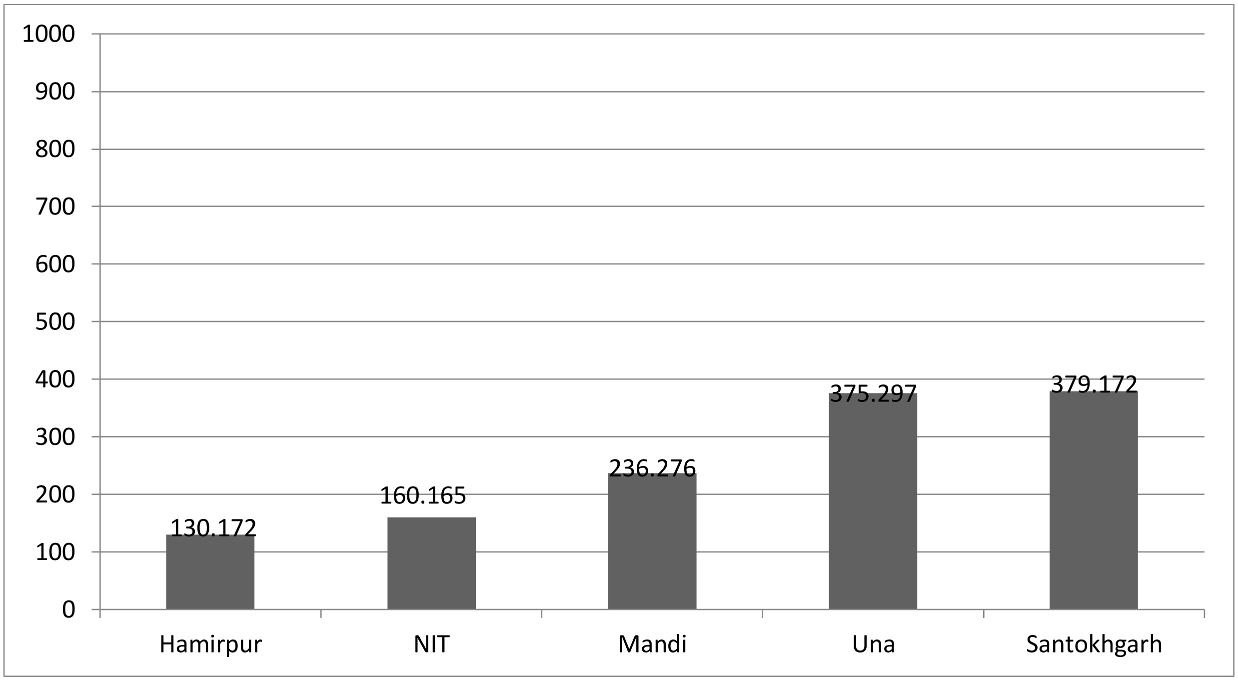

Figure 4.6 Groundwater pollution potential scores for MSW dumpsites in Himachal Pradesh from GW-HARAS for winter season.

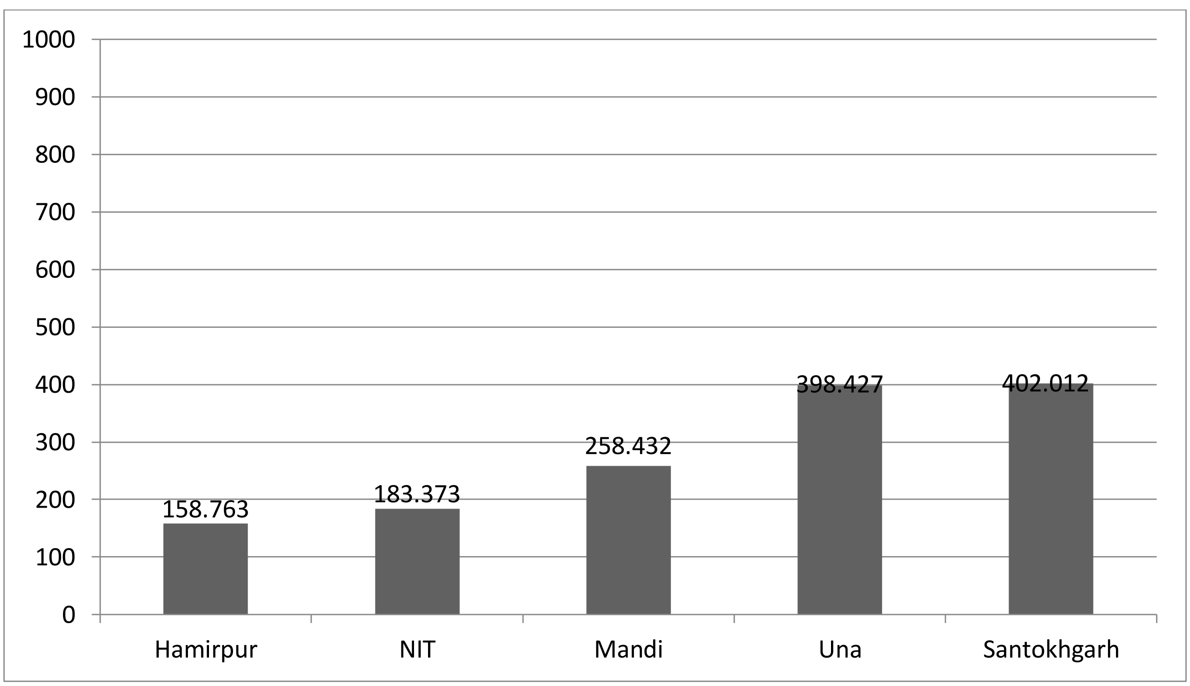

Figure 4.7 Groundwater pollution potential scores for MSW dumpsites in Himachal Pradesh from mGW-HARAS for winter season.

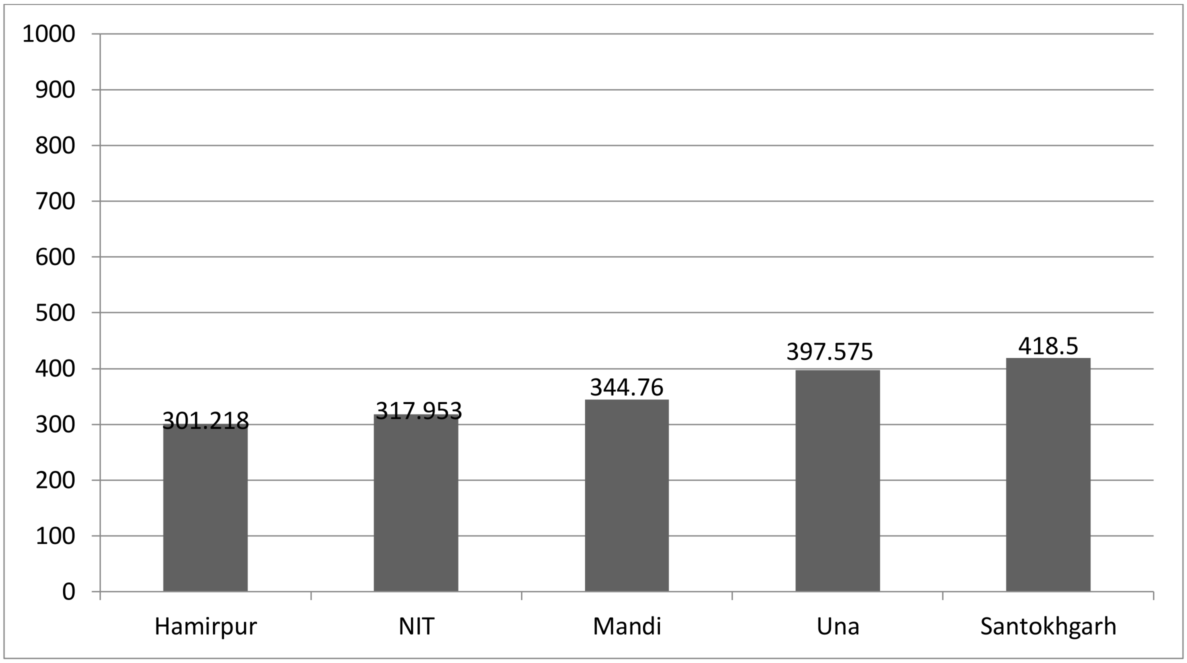

Figure 4.8 Groundwater pollution potential scores for MSW dumpsites in Himachal Pradesh from SIMRAS for winter season.

4.2.3Groundwater pollution potential scores from DRASTIC, GW-HARAS, Mgw-HARAS and SIMRAS for summer season.

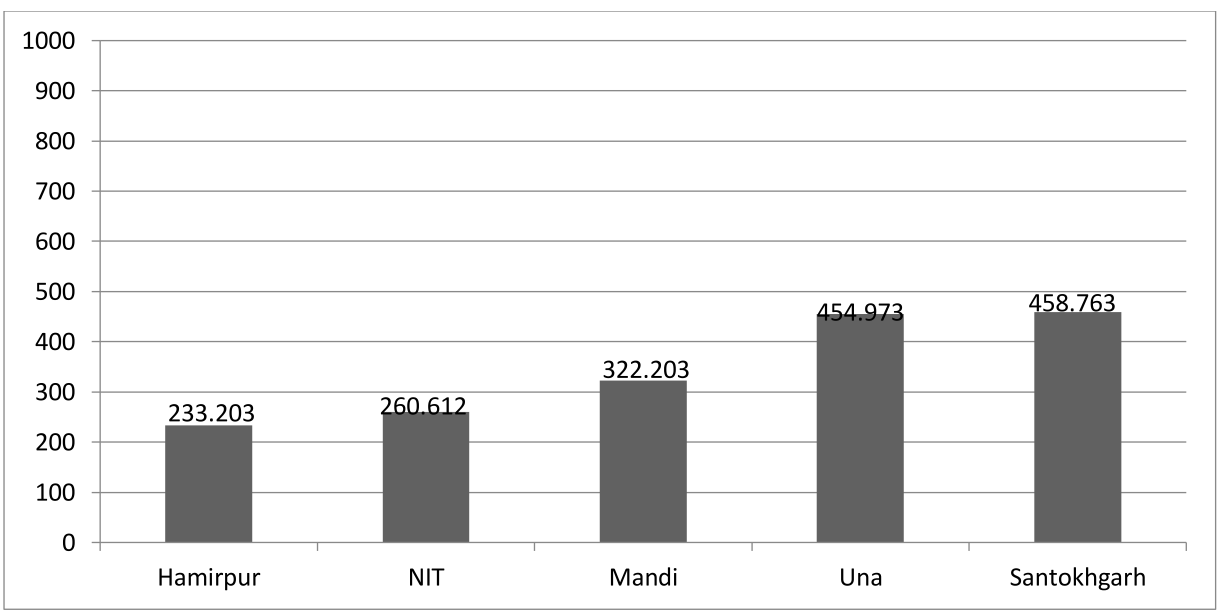

Figure 4.9 Groundwater pollution potential scores for MSW dumpsites in Himachal Pradesh from DRASTIC for summer season.

`

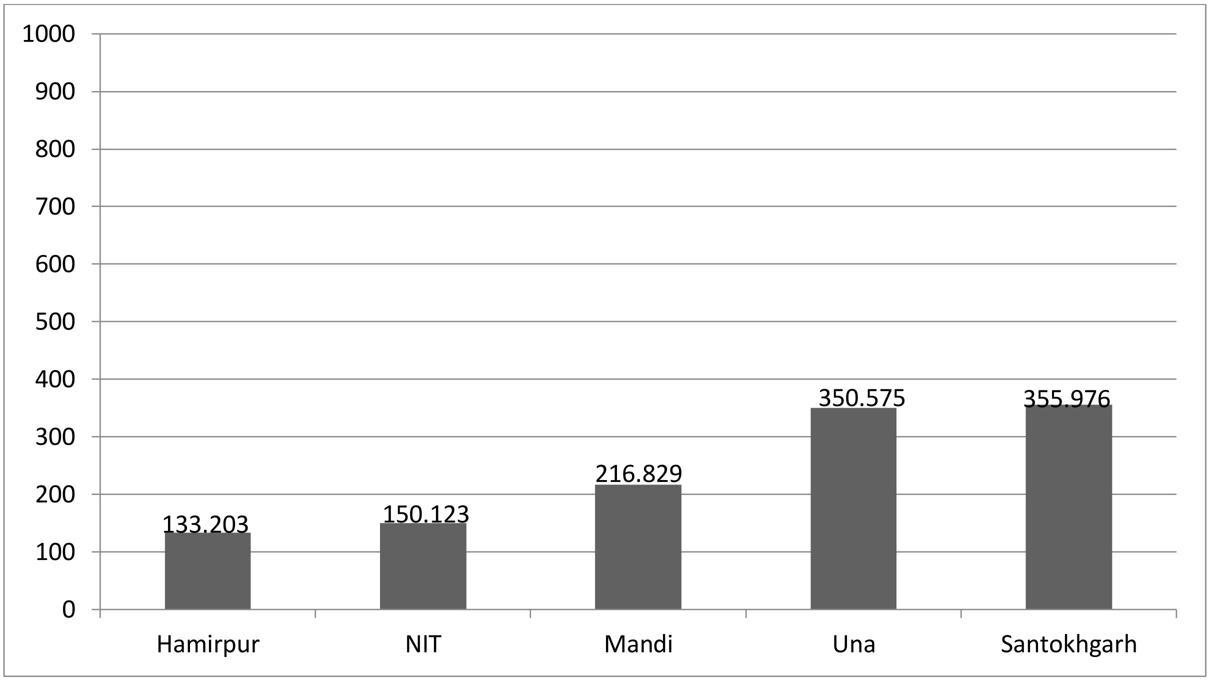

Figure 4.10 Groundwater pollution potential scores for MSW dumps in Himachal Pradesh from GW-HARAS for summer season.

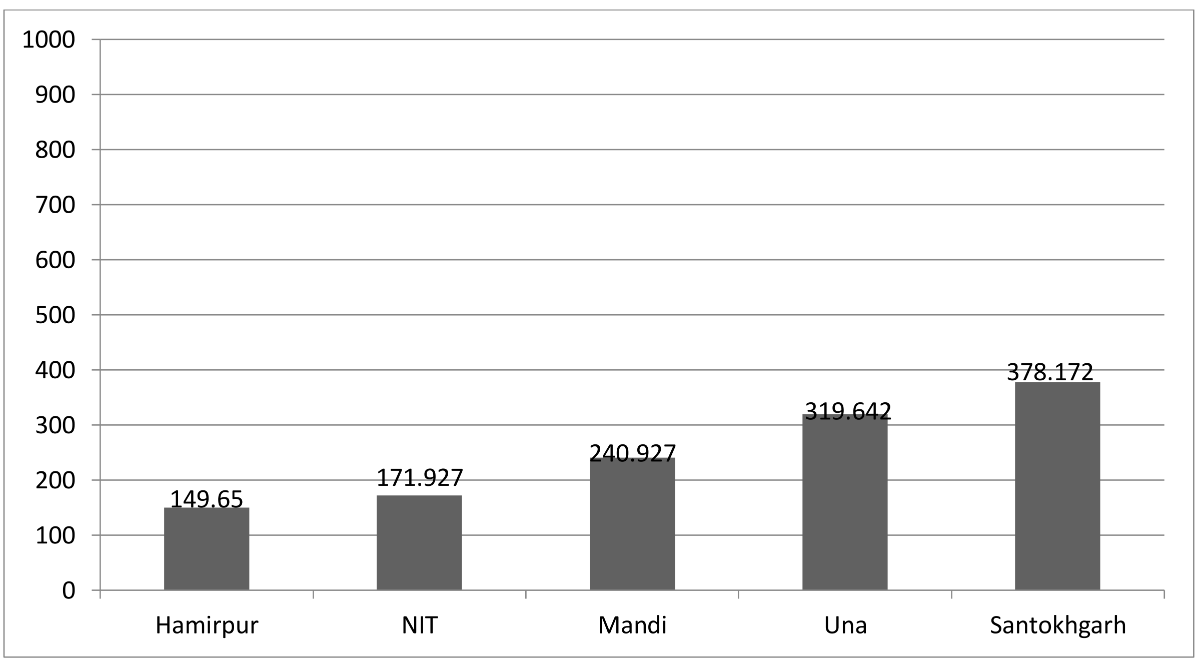

Figure 4.11 Groundwater pollution potential scores for MSW dumps in Himachal Pradesh from mGW-HARAS for summer season.

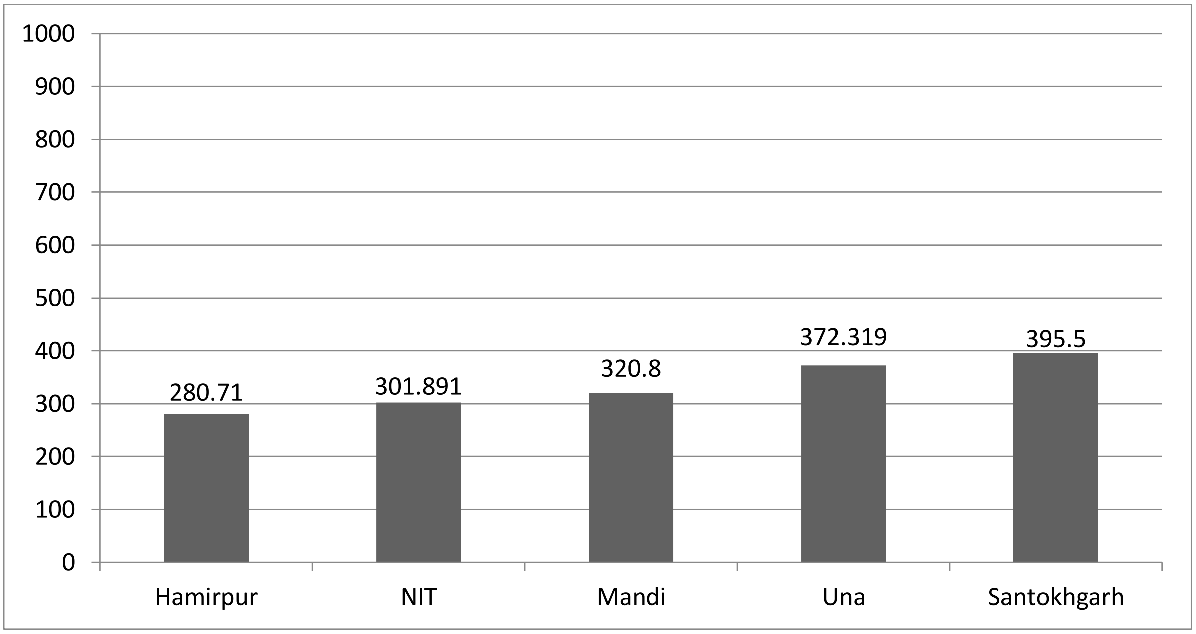

Figure 4.12 Groundwater pollution potential scores for MSW dumps in Himachal Pradesh from SIMRAS for summer season.

4.4.4 Results for LPI

Table 4.5 LPI for the NIT Hamirpur dumpsite for post monsoon

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	7.2	0.055	5	0.275
COD	1400	0.062	36	2.232
BOD_5	320	0.061	8	0.488
Chloride	78	0.048	5	0.22
Iron	1.2	0.044	5	0.25
Copper	0.01	0.050	5	0.30
TKN	47	0.053	5	0.265
Ammonical Nitrogen	32.8	0.051	5	0.255
Chromium	0.38	0.064	6	0.384
Final LPI value = **9.42**		Sum = 0.488		Sum = 4.5797

`

Table 4.6 LPI for the Hamirpur dumpsite for post monsoon

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	7.6	0.055	5	0.275
COD	1567	0.062	37	2.294
BOD_5	326	0.061	8	0.488
Chloride	92	0.048	5	0.22
Iron	3.7	0.044	5	0.25
Copper	0.01	0.050	6	0.318
TKN	52.4	0.053	6	0.306
Ammonical Nitrogen	25.4	0.051	5	0.24
Chromium	0.4	0.064	6	0.384
Final LPI value = **6.65**		Sum = 0.488		Sum = 3.2452

Table 4.7 LPI for the Mandi dumpsite for post monsoon

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	8.2	0.055	4	0.22
COD	1600	0.062	37	2.294
BOD_5	334	0.061	8	0.488
Chloride	49.1	0.048	5	0.24
Iron	6.3	0.044	5	0.22
Copper	0.6	0.050	6	0.3
TKN	55.3	0.053	6	0.318
Ammonical Nitrogen	29.4	0.051	6	0.306
Chromium	0.4	0.064	6	0.384
Final LPI value	=**9.77**	Sum = 0.488		Sum = 4.77

Table 4.8 LPI for the Santokhgarh dumpsite for post monsoon

Parameters	Concentration of	Variable weight,	Pollutant sub-	Aggregation, W_iP_i

`

	pollutants	W_i	index value, P_i	
pH	8.9	0.055	0.055	0.4125
COD	2100	0.062	40	2.48
BOD_5	335	0.061	9	0.549
Chloride	53.9	0.048	5	0.24
Iron	5.7	0.044	5	0.22
Copper	0.5	0.050	6	0.30
TKN	78.6	0.053	7	0.37
Ammonical Nitrogen	68.1	0.051	7	0.357
Chromium	1.12	0.064	8	0.512
Final LPI value	= **10.05**	Sum = 0.488		Sum = 4.9075

Table 4.9 LPI for the Una dumpsite for post monsoon

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	9	0.055	7.5	0.4125
COD	2000	0.062	39	2.294
BOD_5	335	0.061	8	0.488
Chloride	54.3	0.048	5	0.24
Iron	6	0.044	5	0.22
Copper	0.83	0.050	7	0.35
TKN	87.5	0.053	7	0.371
Ammonical Nitrogen	80	0.051	9	0.459
Chromium	0.63	0.064	5	0.32
Final LPI value	=**10.05**	Sum = 0.488		Sum = 4.9075

Table 4.10 LPI for the NIT Hamirpur dumpsite in winter season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	7.5	0.055	5	0.275

`

COD	1300	0.062	36	2.232
BOD_5	350	0.061	9	0.549
Chloride	80	0.048	5	0.24
Iron	2.5	0.044	5	0.22
Copper	0.01	0.050	5	0.25
TKN	46.1	0.053	5	0.265
Ammonical Nitrogen	34.2	0.051	6	0.305
Chromium	0.12	0.064	7	0.448
Final LPI value = **9.80**		Sum = 0.488		Sum = 4.7824

Table 4.11 LPI for the Hamirpur dumpsite in winter season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	8.0	0.055	5	0.165
COD	1500	0.062	37	2.294
BOD_5	340	0.061	8	0.488
Chloride	46.8	0.048	5	0.24
Iron	5.2	0.044	5	0.22
Copper	0.5	0.050	6	0.30
TKN	55	0.053	6	0.318
Ammonical Nitrogen	28.1	0.051	6	0.306
Chromium	0.3	0.064	6	0.384
Final LPI value = **9.66**		Sum = 0.488		Sum = 4.715

Table 4.12LPI for the Mandi dumpsite in winter season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	7.6	0.055	5	0.275
COD	1700	0.062	40	2.48

`

BOD_5	325	0.061	7	0.427
Chloride	47.4	0.048	5	0.24
Iron	6.6	0.044	5	0.22
Copper	0.4	0.050	5	0.20
TKN	46.8	0.053	5	0.265
Ammonical Nitrogen	31.2	0.051	6	0.306
Chromium	0.5	0.064	6	0.384
Final LPI value = **9.827**		Sum = 0.488		Sum = 4.796

Table 4.13LPI for the Una dumpsite in winter season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	9.4	0.055	9	0.495
COD	2200	0.062	41	2.542
BOD_5	337	0.061	9	0.549
Chloride	60.2	0.048	5	0.24
Iron	7.1	0.044	5	0.22
Copper	0.81	0.050	5	0.25
TKN	88.4	0.053	6	0.318
Ammonical Nitrogen	81.5	0.051	7	0.357
Chromium	0.71	0.064	6	0.384
Final LPI value = **10.97**		Sum = 0.488		Sum = 5.355

Table 4.14LPI for the Santokhgarh dumpsite in winter season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	9.0	0.055	9	0.495
COD	2150	0.062	40	2.48

`

BOD_5	340	0.061	9	0.549
Chloride	62.8	0.048	5	0.24
Iron	6.1	0.044	5	0.22
Copper	0.6	0.050	6	0.30
TKN	80.1	0.053	6	0.318
Ammonical Nitrogen	69.2	0.051	8	0.408
Chromium	1.05	0.064	7	0.448
Final LPI value = **11**		Sum = 0.488		Sum = 5.368

Table 4.15 LPI for the NIT Hamirpur dumpsite in summer season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	7.5	0.055	5	0.275
COD	1652.4	0.062	37	2.294
BOD_5	325	0.061	8	0.488
Chloride	93.4	0.048	5	0.24
Iron	3.2	0.044	5	0.22
Copper	0.02	0.050	5	0.25
TKN	95.3	0.053	6	0.318
Ammonical Nitrogen	84.6	0.051	6	0.306
Chromium	0.40	0.064	7	0.448
Final LPI value = **9.91**		Sum = 0.488		Sum = 4.839

Table 4.16LPI for the Hamirpur dumpsite in summer season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	7.8	0.055	3	0.165
COD	1600	0.062	38	2.356
BOD_5	332	0.061	8	0.488
Chloride	94.7	0.048	5	0.24

`

Iron	4.1	0.044	5	0.22
Copper	0.01	0.050	5	0.25
TKN	58	0.053	6	0.318
Ammonical Nitrogen	30.2	0.051	6	0.306
Chromium	0.35	0.064	6	0.384
Final LPI value = **9.68**		Sum = 0.488		Sum = 4.727

Table 4.17LPI for the Mandi dumpsite in summer season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	7.5	0.055	5	0.165
COD	1580	0.062	40	2.294
BOD_5	315	0.061	8	0.488
Chloride	50.2	0.048	5	0.24
Iron	2.3	0.044	5	0.22
Copper	0.01	0.050	5	0.25
TKN	46.1	0.053	5	0.318
Ammonical Nitrogen	30.2	0.051	6	0.306
Chromium	0.1	0.064	7	0.384
Final LPI value = **10.185**		Sum = 0.488		Sum = 5.3118

Table 4.18 LPI for the Una dumpsite in summer season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	9.4	0.055	9	0.495
COD	2160	0.062	40	2.48
BOD_5	340	0.061	9	0.549
Chloride	56.8	0.048	5	0.24
Iron	7.5	0.044	5	0.22
Copper	0.90	0.050	7	0.35
TKN	90.5	0.053	7	0.317

Ammonical Nitrogen	80.8	0.051	9	0.459
Chromium	0.75	0.064	6	0.384
Final LPI value = **11.36**		Sum = 0.488		Sum = 5.548

Table 4.19 LPI for the Santokhgarh dumpsite in summer season

Parameters	Concentration of pollutants	Variable weight, W_i	Pollutant sub-index value, P_i	Aggregation, W_iP_i
pH	9.1	0.055	9	0.495
COD	2109	0.062	40	2.48
BOD_5	345	0.061	9	0.549
Chloride	90.4	0.048	5	0.24
Iron	6.3	0.044	5	0.22
Copper	0.6	0.050	6	0.3
TKN	82.4	0.053	7	0.371
Ammonical Nitrogen	70.2	0.051	8	0.408
Chromium	1.84	0.064	9	0.576
Final LPI value = **11.55**		Sum = 0.488		Sum = 5.639

Table 4.20 LPI for Leachate disposal standards

Parameters	Leachate Pollution Standards	Variable weight, W_i	Pollutant sub-index value, P_s	Aggregation, W_iP_i
pH	5.5-9	0.055	5	0.275
COD	250	0.062	10	0.62
BOD_5	30	0.061	6	0.366
Chloride	100	0.048	8	0.384
Iron	NS	0.044	-	-
Copper	3	0.050	18	0.9
TKN	100	0.053	6	0.318
Ammonical	50	0.051	7	0.357

`

Nitrogen				
Chromium	2	0.064	9	0.876
Final LPI value	**= 7.762**	Sum = 0.488		Sum =3.796

4.3 Discussion

4.3.1 Results of LPI values of all the MSW dumpsites compared with LPI of leachate disposal standards

Leachate samples from five different MSW dumpsites were collected and analyzed for 9 significant leachate pollutant variables viz pH, BOD_5, COD, Chloride, Iron, Copper, Total Kjeldal Nitrogen, Ammonical Nitrogen and Chromium to estimate their pollution potential. LPI of all the sites was calculated as shown in table 4.5 to 4.9 for post monsoons, table 4.10 to 4.14 for winter season and table 4.15 to 4.19 for summer season. LPI of the leachate disposal standards was calculated as shown in table 4.20.

The LPI values of the standards for the disposal of leachate to inland surface water shall not exceed 7.378 (when calculated for all the 18 parameters) which is the permissible limit for the disposal of leachate to inland surface waters as per the standards given under Municipal Solid Waste (Management and Handling) Rules, 2000 notified by Government of India. But in our case, we have examined 9 parameters instead of 18 due to lack of resources. Thus, LPI value of standard for disposal of leachate to inland surface water shall not exceed 7.762 when calculated for 9 parameters.

4.3.2 Hazard Ranking of dumpsites from DRASTIC, GW-HARAS, mGW-HARAS and SIMRAS methods

Groundwater pollution potential scores for Municipal Solid Waste dumpsites from Himachal Pradesh from DRASTIC, GW-HARAS, mGW-HARAS and SIMRAS methodsare given in, figure 4.1 to 4.4, for post monsoon, figure 4.5 to 4.8 for winter season and figure 4.9 to 4.12 for summer season.

From rating scores, it could be seen that, DRASTIC produced scores which are in a clustered array. On the other hand SIMRAS produces almost similar scores for all the sites. GW-HARAS and mGW-HARAS produces best results with more variation in rankings.

CHAPTER 5

CONCLUSION

For groundwater pollution potential ratings of all the five dumpsites, minimum rating comes out to be of Hamirpur dumpsite and maximum rating comes out of Satokhgarh dumpsite from all the four rating systems i.e. DRASTIC, GW-HARAS, mGW-HARAS and SIMRAS. Seasonal variation in ratings depends basically on rainfall received and depth to groundwater. In summer season the rainfall is less, water table goes down and depth to groundwater increases. So, the rating is less in summer season. During post monsoons, the amount of rainfall received is more as compared to summers so depth to groundwater increases. So, the rating score increases for post monsoon season as compared to summer season. During winters the amount of rainfall is maximum, water table comes up. So the rating scores are maximum in winter season. From results it could be clearly concluded that Hamirpur dumpsite comes on first rank with minimum rating scores. NIT Hamirpur dumpsite comes on second place. Mandi dumpsite comes on third place, Una dumpsite on fourth place and Santokhgarh on fifth rank with maximum rating score. Therefore, Santokhgarh and Una dumpsite needs immediate remedial actions.

Various remedial techniques could be applied such as using liners and covers because all these dumpsites are not having any liners and covers. These liners and covers can be made using geopolymers, PVC, High density Polyethylene (HDPE).

In all the four systems, DRASTIC method and SIMRAS method produce almost similar results for all the five MSW dumpsites. In contrast GW-HARAS and mGW-HARAS produce improved results and among these two methods GW-HARAS has more standard deviation in results. So, best results are produced by GW-HARAS. Therefore, GW-HARAS comes out to be the most appropriate method for site ranking.

`

LPI value could be used to calculate the pollution potential of leachate from various MSW dumpsites. In the present study, the LPI estimations are 9.42, 6.65, 9.77, 10.05, and 10.05 for Hamirpur, NIT Hamirpur, Mandi, Una and Santokhgarh dumpsites respectively for the post monsoons. In winter season the LPI estimations are 9.66, 9.80, 9.827, 10.97 and 11 for Hamirpur, NIT Hamirpur, Mandi, Una and Santokhgarh dumpsites respectively. In summer season the LPI estimations are 9.68, 9.91, 10.158, 11.36 and 11.55 for Hamirpur, NIT Hamirpur, Mandi, Una and Santokhgarh dumpsites respectively. It is clearly seen that the smallest values of LPI are of post monsoons and the largest values of LPI are for summer season. This is because the concentration of pollutants was maximum during the summer season and gets diluted during monsoon. After monsoons a gradual increase in LPI is evident. In summers the leachate gets concentrated due to evaporation loss.

The LPI value of standards for the disposal of leachate to inland surface water should not not be more than 7.738 which is the permitted limit for the removal of leachate to inland surface water as per the standards given under Municipal Solid Waste (Management and Handling) Rules, 2000 notified by Government of India. But in our case we were able to examine only nine parameters. Thus, LPI value of standards for disposal of leachate to inland surface water shall not exceed 7.378. The comparison of the LPI values of landfill sites for all the three seasons comes out to be more than 7.378 except the Hamirpur dumpsite for post monsoon. This clearly shows that the leachate produced from the MSW dumpsites is significantly polluted and needs action before the disposal.

`

REFERNCES

- Datta, M., & Kumar, A. (2017). Assessment of Subsurface Pollution Potential of Municipal Solid Waste (MSW) Dumps. *Indian Geotechnical Journal*, *47*(4), 410-420.
- Fatta, D., Papadopoulos, A., &Loizidou, M. (1999). A study on the landfill leachate and its impact on the groundwater quality of the greater area. *Environmental Geochemistry and Health*, *21*(2), 175-190.
- Datta, M., & Kumar, A. (2016). Waste dumps and contaminated sites in India—status and framework for remediation and control. *Geo-Chicago 2016 GSP*, *273*.
- Datta, M., & Kumar, A. (2015). Hazard rating of MSW dumps and geoenvironmental measures for closure. In *50th Indian Geotechnical Conference. Pune, India*.
- Singh, R.K., Singh, R. K., Datta, M., &Nema, A. K. (2007). Groundwater pollution hazard potential rating of municipal solid waste dumps and landfills. In *Proceedings of the International Conference on Sustainable Solid Waste Management, Chennai, India* (pp. 296-303).
- Singh, R. K., Datta, M., &Nema, A. K. (2009). A new system for groundwater pollution hazard rating of landfills. *Journal of Environmental Management*, *91*(2), 344-357.
- Singh, R. K., Datta, M., &Nema, A. K. (2007). Groundwater pollution hazard potential rating of municipal solid waste dumps and landfills. In *Proceedings of the International Conference on Sustainable Solid Waste Management, Chennai, India* (pp. 296-303).
- Mahmood, K., Batool, S. A., Chaudhary, M. N., &Ul-Haq, Z. (2017). Ranking criteria for assessment of municipal solid waste dumping sites. *Archives of Environmental Protection*, *43*(1), 95-105.
- Kumar, D., &Alappat, B. J. (2004). Selection of the appropriate aggregation function for calculating leachate pollution index. *Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, *8*(4), 253-264.
- Kumar, D., &Alappat, B. J. (2003, October). A technique to quantify landfill leachate pollution. In *ninth International Landfill symposium* (pp. 243-244)

`