DESIGN AND DEVELOPMENT OF AN EXPERT SYSTEM WITH EMPHASIS ON FUTURISTIC PLANNING AND IMPACT ANALYSIS OF MUNICIPAL SOLID WASTE FOR DEHRADUN CITY OF UTTARAKHAND

A thesis submitted to the
University of Petroleum and Energy Studies

For the Award of
Doctor of Philosophy
in
Health Safety and Environment Engineering

By
Ritesh Saini

June 2020

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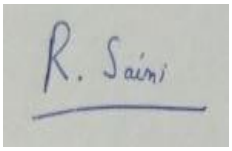
DECLARATION

I declare that the thesis entitled “Design and development of an expert system with emphasis on futuristic planning and impact analysis of municipal solid waste for Dehradun city of Uttarakhand” has been prepared by me under the guidance of Dr. Neelu J. Ahuja (Supervisor), Professor, Department of Computer Science, University of Petroleum and Energy Studies and Dr. Kanchan Deoli Bahukhandi (Co-Supervisor), Assistant Professor (SG), Department of HSE and Civil Engineering, University of Petroleum and Energy Studies. No part of this thesis has formed the basis for the award of any degree or fellowship previously.



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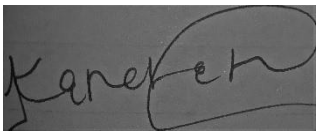
DATE : 29th June 2020

THESIS COMPLETION CERTIFICATE

This is to certify that the thesis entitled **"Design and development of an expert system with emphasis on futuristic planning and impact analysis of municipal solid waste for Dehradun city of Uttarakhand"** by **Ritesh Saini, (SAP ID: 500031478)** in partial completion of the requirements for the award of the Degree of Doctor of Philosophy in Health Safety and Environment Engineering is an original work carried out by him under our joint supervision and guidance. It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other University.



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ABSTRACT

Now a days, the management of the waste has taken a critical situation in every city. Municipal Solid Waste characteristics and quantities change significantly with time. The ground water contamination is being observed at the various waste disposal sites emitting leachates as is also evidenced from the concentration of contaminants at the monitoring points.

The present case study also provides information related to waste generation in future. A prediction model has been developed that uses the present waste generation data, along with different environmental and economic factors. These factors have been implicitly incorporated using quantity of solid waste as a time-series dataset to simulate a supervised Artificial Neural Network (ANN) in MATLAB - Nonlinear Autoregressive Neural Network (NARnet).With the present current solid waste quantity as input parameters for the assessment of solid waste production, the pre-planning of solid waste management can be carried out.

The physico-chemical analysis carried out for the surface and ground water especially surrounding the waste disposal sites in Dehradun revealed the fact that most of the parameters for which the analysis were carried out using the various analytical techniques were not found to be fit for drinking water as per the BIS norms. The investigation for the water samples was drifting out to analyse the specific criterion like pH, temperature, TDS, TSS, electrical conductivity, hardness, alkalinity, calcium, magnesium, sulphate, nitrate, phosphate, chloride and heavy metals like cadmium, copper, lead and iron etc. were studied using various scientific techniques.

The scientific management of the landfill site involves various steps to be taken up physically. Any error or negligence handling may lead to catastrophic events. In order to prevent/minimize such catastrophic events at landfill sites, a fuzzy expert system has been developed which proposes a bioreactor landfill for city of Dehradun of Uttarakhand. The fuzzy expert system "Advisory for Handling Landfill Operational Problems" also indicates early admonition and helps advancement of emergency response plans.

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Ritesh Saini

29th June 2020

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
APHA	American Public Health Association
BIS	Bureau of Indian Standard
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DNN	Dehradun Nagar Nigam
DO	Dissolved Oxygen
DSS	Decision Support System
DVWM	Doon Valley Waste Management
EDSS	Environment Decision Support System
EDTA	Ethylene Diamine Tetra Acetic Acid
EPA	Environmental Protection Agency
ES	Expert System
FRI	Forest Research Institute
GIS	Geographical Information System
GMP	Groundwater Management Plan
IGNFA	Indira Gandhi National Forest Academy
IIP	Indian Institute of Petroleum
IIRS	Indian Institute of Remote Sensing
IMA	Indian Military Academy
ISWM	Integrated Solid Waste Management
LFG	Landfill Gas

LOMA	Landfill Operation Management advisory
MIS	Management Information System
MSWM	Municipal Solid Waste Management
NABL	National Accreditation Board for Testing and Calibration Laboratories
NARNet	Nonlinear Autoregressive Neural Network
NEPA	National Environmental Policy Act
NTU	Nepthlometer Turbidity Unit
ONGC	Oil and Natural Gas Corporation
PI	Permeability Index
RDF	Refuse Derived Fuel
RIMC	Rashtriya Indian Military College
SAR	Sodium Adsorption Ratio
STP	Sewerage Treatment Plant
SWES	Solid Waste Expert System
SWM	Solid Waste Management
SWMES	Solid Waste Management and Existing System
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
ULB	Urban Local Body
VOC	Volatile Organic Compound
WHO	World Health Organization
WQI	Water Quality Index
WTP	Water Treatment Plant

CHAPTER 1

INTRODUCTION

1.1 Overview

Dehradun city has seen huge development in the course of the most recent 20 years. Because of the reason of its precedence in educational region and excessive international remittances, it relishes a huge per capita profit. The city has seen a phenomenal transition into broad urban centre. Many National Institutes and Organizations such as Indian Institute of Remote Sensing (IIRS), Oil and Natural Gas Corporation (ONGC), Indian Institute of Petroleum (IIP), Survey of India, Forest Research Institute (FRI) are stationed in the city. Some of the prime educational and Training Institutes like Indira Gandhi National Foreign Academy (IGNFA), Rashtriya Indian Military College (RIMC) and Indian Military Academy (IMA) etc. have opened centre here. It is a preferred landing place for tourists, pilgrims, traveller and admirer from different areas because of its peaceful vicinity. Dehradun city becomes state capital in 2000 and has been expanding speedily but the framework advancement has not stayed up with this development. It has seen considerable growth in population because of fast urbanization, industrialization and influx of foreign workforce, leading to increased generation of solid waste. Administration of Solid Waste is amid the key infrastructure that is extensively deficient. Administration of Municipal Solid Waste in Dehradun striving to adhere with Solid Waste Management Rules 2016, and is insufficient in entire components i.e. primary collection, source segregation, transportation and most importantly scientific disposal of waste. City has no scheme of treatment and dumping of waste, the total waste yield daily is disposed of haphazardly at numerous corners in the city. DNN (Dehradun Nagar

Nigam) has processed an action plan for SWM for Dehradun city to comply with an order of the Honorable Supreme Court and Solid Waste Management Rules 2016, but implementation of the action plan is still awaited. Swachh Bharat Mission project regarding cleanliness which is a Govt. of India scheme being implemented throughout the country since 2nd October 2014 is also being implemented in Dehradun city. The Ministry of Housing and Urban Affairs, GOI, every year carryout third party evaluation on the fixed parameter for the scheme. In the recent results in Swachh Survekshans, it has been observed that the cleanliness has not improved much in Dehradun. There is requirement for a balanced deliberately arranged approach, integrated with domain knowledge, targeted towards guided and monitored implementation.

1.2 Motivation/Need of Research

(a) The main reason for chaotic and haphazard approach in SWM is lack of domain expertise and a need for channelizing it with proper guidance (Nassereldeen, 2011). Hence, an integrated solid waste management (ISWM) expert system is proposed to be developed with integrated modules to provide access to comprehensive background of the SWM domain, analyze and impact of solid waste on water quality, identify land-fill operational problems, provide control measures, generate advice facilitating development of emergency response plans by land-fill managers, projection of solid waste generated in the years to come, accordingly predict potential impact and effect on water quality, and to provide estimation of landfill size needed.

(b) The growing complexity of arguments tangled in integrated SWM appeals knowledge-based tools and a very high degree of monitored implementation. It is a tool that provides information which can be used by city authorities at various levels. It acts as a counseling appliance that can be utilized by the work power at the vital equable of the management, and an educational appliance for current new staff individuals of the SWM team. It is an operational tool for the naive landfill managers. It assists in planning through its prediction modules by

providing details such as the quantity of SW likely to be generated in the future, and the potential deterioration of water quality thereof.

1.3 Objectives

- To study the current status of solid waste management and water quality of Dehradun city, with focus on SWM plan.
- Quantification and characterization of municipal solid waste to elucidate effects of its improper disposal on water quality.
- To develop an integrated expert system for knowledge dissemination, impact analysis, planning and emergency response support for SWM.

1.4 Research Methodology

Any discarded or disposed material of humans or from animal is treated as a solid waste. One of the real problems being appeared by using urban communities and township is in the area of municipal solid waste (MSW). Waste aggregates are rising and municipal authorities are now not capable to enhance or scale up the amenities needed for desirable administration of such wastes. In the vast majority of the cities and towns, garbage is scattered on streets and roads. Citizens are additionally now not habituated to use storage amenities (dust bins) set up by means of the authorities. At large, lack of equipped structure of door to door garbage collection and collection series has created the littering nature. This measure is typically initiated to decrease their consequences on fitness and environment. All waste materials such as solids, liquids or gases require suitable waste management. It is categorized into residential, municipal, commercial, agricultural, industrial, hazardous and construction & demolition wastes. Management of waste is the accountability of Urban Local Bodies. The absolute quantum of solid waste generated in vicinity depends upon its population and urbanization. SWM is amid the key infrastructure that’s considerably deficient. Municipal Solid Waste Management in Dehradun is coping to suits with Solid

Waste Management Rules 2016, and is poor in all factors i.e. door-to-door garbage collection, segregation, transportation, treatment and scientific disposal of waste. City has no device of remedy and disposal of waste, the gross waste generated every day is disposed of haphazardly at numerous locations within the city. Therefore a Solid Waste Management Expert System having integrated models is proposed to be developed to analyze the deterioration water quality due to solid waste, discover land-fill operational problems, provide manipulate measures , generate advice facilitating development of emergency response plans via landfill managers, projection of solid waste generated in the years to come, thus predict viable affect and results on water quality and to provide estimation of land-fill measurement needed and operational problems of landfill.

:

1.5 Study Area

Dehradun, having mountainous topography is perhaps the oldest cities of India and is presently capital of Uttarakhand State. The ward wise map is given in Fig.1.1 in which rivers flows through Dehradun city were Rispana River & Bindal River (Highlighted in blue in map).

The study area comprises of dumping sites Nunarkheda, Shastradhara road and in different wards of Dehradun town. It falls in Dehradun district, the capital city of the territory of Uttarakhand in the northern part of India and positioned in the Garhwal region. A total geographical area is 67.0 sq.km. and the population is about 578,420 (census,2011). The altitude of Dehradun is 2200 feet above mean sea level. All alongside the summer season months, the temperature degrees between 36ºC and 16.7ºC and winters are chillier with the most and minimal temperatures 23.4ºC to5.2ºC respectively (Singh,2013).The annual rainfall is about 2000mm which occurs between June and September.

The Doon valley falls in Dehradun district of Uttarakhand and is embarked between 29˚ 50 '- 30 ˚ 30’ N Latitude and 77 ˚ 35’ - 78 ˚ 20’ E Longitude. The

river Ganga flows in the eastern part which is fed by the Song river whereas the Yamuna flows in western part of the Doon valley and is fed by Asan river. The Asan and Song rivers are fed by number of perennial and non-perennial streams which are commenced in Lesser Himalaya in the north and Sub Himalaya in the south (Dudeja 2011, Jayangondaperumal, 2018). The lesser Himalaya, central valley and Siwaliks forms three hydrological zones in the doon valley which are based on different lithology, physiography setting and hydrological properties (Bartarya 1995; Jayangondaperumal 2018).

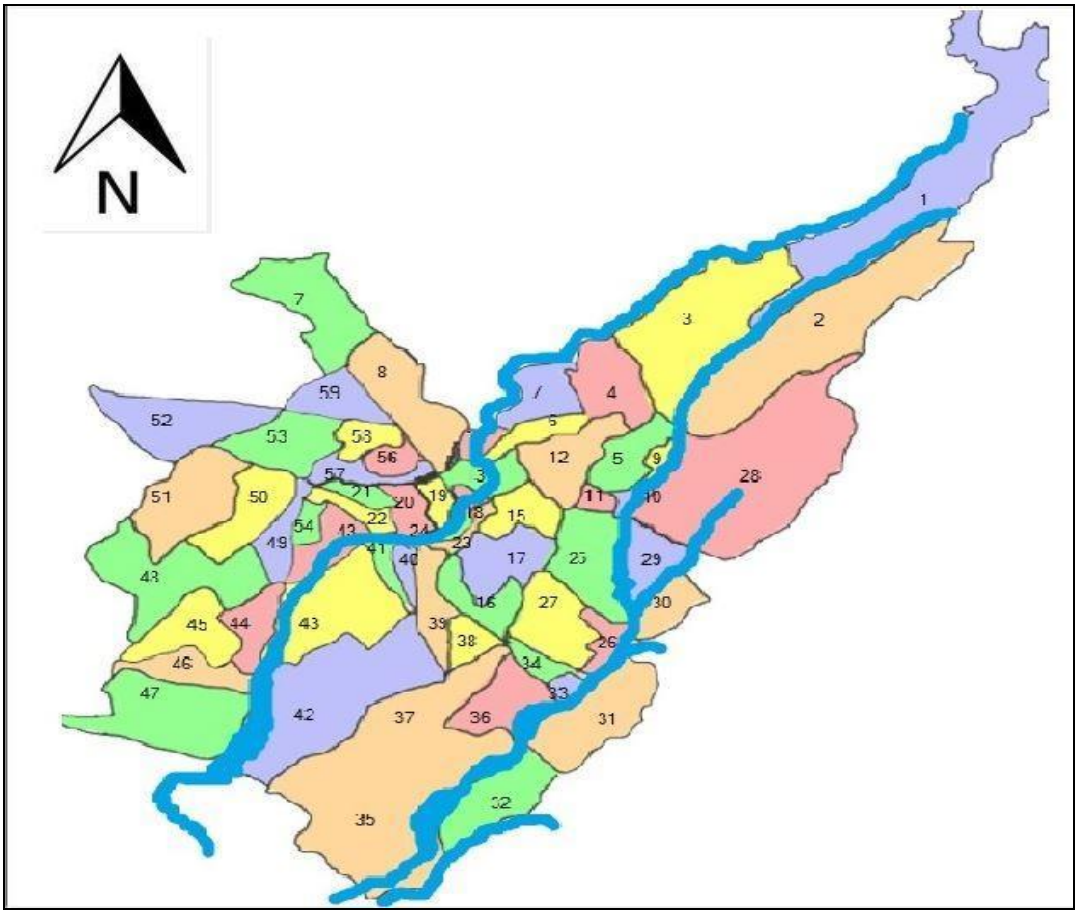


Fig. 1.1: Map of Dehradun City

1.6 District Boundaries and other Details

The district is in the north-western part of the state. The Dehradun district touches the boundaries of Uttarkashi in north-west, Tehri Garhwal and Pauri-Garhwal in east, Saharanpur (Uttar Pradesh)/Haridwar in south. Similarly district Sirmour and river Tons and Yamuna touches the western boundary.

CHAPTER 2
LITERATURE SURVEY

State of the art literature review revealed that, so far no effort has been made to design an expert system for SWM in India. However, lots of work has been done in SWM area through studies on its impact, effects and its monitoring etc. There are number of works has been done previously and suggested for improvements which have been included as below:

S.N.	Authors	Journal & Year	Study Area	Key findings
1.	Thomas B., Tamblyn D., Baetz B.W.	Journal of Urban Planning and Development (1990)	Expert systems in MSWM planning.	1. In this paper the pertinence of master mechanism to squander the waste management planning were investigated and further the characteristics used in waste management planning are highlighted. 2. The controversy related to solid waste planning are

				reviewed which prompts to critical evaluation of the job role of expert framework in tending to these issues.
2.	Richard T.L.	Biomass and Bioenergy (1992)	Municipal solid waste and composting	1. Paper explains about the technologies regarding composting facilities which includes segregation, material preparation, size reduction and biological processes control. 2. The advancement in technology has transformed waste into value added product. 3. This paper deals with the various composting technologies to enhance the production of compost.
3.	Canet, R.	Bioresource	Solid Waste	1. In this paper, the

	and Pomares F.	Technology (1995)	Management and Composting	composting mechanisms in two municipal solid waste recycling plants located in Valencia were studied. The different methodologies were used for piles aerated by mechanical turning. 2. The study revealed that the physico-chemical parameter indicates about processes that were occurring in the composting piles alongwith other components of the composts.
4.	Mohan, S. and Arumugam, N.	Computers and Electronics in Agriculture (1997)	Expert system for irrigation management.	1. In this paper, a professional system is developed for complex of irrigation and management problems for which experience and professionals are

				required for efficient judgement making in this domain. 2. The research on expert system for said domain helps in irrigation scheduling, evapo-transpiration interest and incorporated operation of irrigation system a framework segment which is required for ideal water use.
5.	Kuniyal, J.C., Jain A.P., Shannigrahi A.S.	Waste Management, (2003)	Solid waste management	1. Paper clarifies solid waste generation in tourist circle of the Indian Himalayan locale. 2. The study shows the waste generation per capita and compared the same with the imperial average of 350 gram per capita. The study reflects that the generation of non-biodegradable waste

				is ideally high whereas the generation of biodegradable waste is found to be very less. 3. The study also suggests that non-biodegradable waste can easily be managed by reusing or recycling whereas halting natural waste could be utilized as feedstock for fertilizing the soil. Waste generation in Indian Himalayan region with tourist influx has been studied.
6.	Jayawardha-nna L.C., Manipurra A., Alwisb A.D., Ranasinghe-a M., Pilapitiyac	Expert Systems with Applications (2003)	ES for solid waste composting.	1. In this paper, the expert system BESTCOMP was discussed which helps local authorities for better solid waste management composting.

	S., Abeygunaw-ardena I.			2. The developed expert system helps user to conquer all facets of ISWM planning problems for example, technology selection, land choice, rules and guidelines which ought to be considered before planning. 3. The BESTCOMP incorporates with the decision support model so that user can investigate issues quicker, examine different alternatives and settle on decisions.
7.	Manaf, L.A., Basri H., Basri N.E.A.	Journal of Sustainable Development (2008)	Integrated solid waste management.	1. Paper explains about an ES UrusSisa for designing and selecting solid waste management technology. 2. The expert system dwells of preference ranking using

				Analytical Hierarchy Process (AHP) and exploratory design of recommending solid waste technology which includes composting, recycling, sanitary landfill and incineration.
8.	Abu-Naser S., Kashkash K.A., Fayyad M.	Journal of Artificial Intelligence (2008)	Expert system for diagnosis of plant diseases.	1. Paper explains regarding the detection of plant diseases and treatment through expert system. 2. The necessity is that the user ought to be capable in utilizing the master framework. 3. The expert system acts as agriculture expert and provides different treatment and diagnostic option to the user.
9.	Kumar, S., Bhattacharya	Waste Management	Waste Management	1. The assessment of waste generation in

	J.K., Vaidya A.N., Chakrabarti T., Devotta S., Akolkar A.B.	(2009)		class I, class II and metro cities as well as state capitals in India were studied and it was found that the composition of MSW varies at different places and also depends on the standards of living. 2. As mentioned above the physico-chemical composition for MSW in above mentioned cities are studied. 3. The study shows that there are many drawbacks in the existing practices which are primarily pertain to inadequate manpower, machinery and financial resources.
10.	Gupta, N., Sharma, R.C., Tripathi	Journal of Environmental Biology. (2008)	Bio-physico-chemical characteristics	1. In this paper, the study of bio-physico-chemical characteristics of

	A.K.			Mothronwala swamp has been undertaken. 2. The various physico-chemical parameters were analysed at three sampling sites selected in Mothronwala swamp. 3. It was studied that fresh water swamp of Mothronwala is under threat due to human interference and other anthropogenic activities. The ameliorative measures for the protection of aquatic environment and the conservation measures for the swamp have been suggested.
11.	Dokas I.M., Karras D.A., Panagiotak	Environmental Modelling & Software. (2009)	Landfill operations	1. This paper discusses the development of early warning systems for engineering

	-opoulos D.C.			equipment by combining and integrating ideas and technologies that already exist. 2. An early warning and emergency response program Landfill Operational Management Advisor (LOMA) has been developed to help waste management and avoid operational problems and incidents. 3. The other focal point is to spread information and knowledge about and adverse consequences of landfills to the general public. 4. The user input the working conditions at the landfill in the LOMA and output is the capable operational problems

				and afterwards it provides the advice for prevention and how to respond if any operational problem occurs.
12.	Bani M.S., Rashid Z.A., Hamid K.H.K., Harbawi M.E., Alias A.B., and Aris M.J.	International Journal of Chemical, Molecular, Nuclear, Materials and Metallurgical Engineering (2009)	DSS for Waste Management.	1. Paper explains that the numbers of Decision Support System (DSS) for waste management developed are lacking practical applications and not widely marketed; this is because of complexity in mathematical model and number of variables which comprise the assumptions and constraints mandatory in decision making. 2. The examination or study to recognize the entirety of the potential outcomes all together for the

				DSS to be an amazing dynamic instrument regardless of issues of waste generation, vulnerabilities, expectation and ideal portion of waste stream for waste to energy, landfill, reusing and fertilizing the soil.
13.	Ohri, A. and Singh P.K.	International Journal of Environmental Sciences (2010)	Decision support system for municipal solid waste management.	1. Paper explains that a number of decision support systems were refined and utilized for municipal solid waste administration but maximum of them address one of few section of the procedure. 2. The conceptual frame work of user friendly EDSS-MSWI expert system is presented which have ability of DSS regarding solid waste

				management.
14.	Al-Khatib, I.A., Maria M.B., Abdul S.F., Abu Z.C., Hafez Q.S.D.	Journal of Environmental Management (2010)	Solid waste characterization and quantification	1. The huge Solid waste generation poses serious pollution problems in developing countries. 2. The case study of SWM in Nablus district - Palestine was presented in the paper in which per capita waste generation diverse between different localities. The large quantity of organic waste can be utilized for compost or animal feed. 3. The study suggests there is a need to boost sustainable SWM, funding, public alertness, equipment, expertise to tackle the arising solid waste management issues.
15.	Aderemi,	African Journal	Groundwater	1. In this paper, the

	A.O., Oriaku A.V., Adewumi G.A., Otitoloju A.A.	of Environmental Science and Technology (2011)	contamination by leachate	physico-chemical and microbiological criterion were studied in leachate and tests taken from ground, distant locations near the municipal solid waste lowland so as to examine the impingement of leachate on groundwater quality. 2. The study examined that the leachate developed from the landfill site contains a contamination on the groundwater quality within the locality. 3. The results accessed from this assessment laid out that groundwater of the near landfill site is not appropriate for drinking water Supply and hence emphasize the need

				for waste management practices and constructing adequately designed sanitary waste sites to minimize groundwater pollution.
16.	Abhishek, G., Gopal, P., Anirudh S.	Current World Environment (2011)	Assessment of Ground Water Quality	1. The paper outlines the effects of discarding of municipal solid waste at dumping site which slowly damaging the environment. 2. The dumping causes environmental pollution by depreciating the ground water quality. 3. The toxic substances have contaminated the ground water in the study area.
17.	Dudeja D., Bartarya	Environmental Monitoring and	Hydrochemical and water quality	1. The Paper explain the quality of ground

	S.K., Biyani A.K.	Assessment (2011)	assessment	water *vis-a-vis* ionic sources for its use in irrigation and drinking purpose in doon valley having more hardness with moderate dissolved solid contents.
18.	Nassereldeen A., Kabbashi N.A., Saedi M., Jazzar M.A., Azman N.A.	African Journal of Biotechnology (2011)	Waste management using expert system.	1. In this paper, an expert mechanism was maintained for ISWM in Kuala Lumpur. 2. The whole information was received from books, magazines, journals, internet web sites and annual reports. 3. The improvement of an expert system was carried out in great phases which consist of hassle identification, literature review, trouble statement, prototype development, identification of

				domain experts, know-how acquisition and know how representation. 4. The improvement of Scheduled waste expert gadget based totally on five kinds of scheduled waste administration which are bundling prerequisites, label requirements, have an effect on of scheduled wastes, recycling of scheduled wastes and recommendations. Further, additionally consists of more than a few sub-modules by using which the user reap a complete history of the domain. 5. The final output is to help amazing inherit scheduled waste management.

19.	Bartarya, S.K., Bahukhandi, K. D.	Global Journal of Engineering, Design and Technology (2012)	Impact Assessment on surface and groundwater	1. Paper explains about the effect of urbanization and industrialization contiguous surface and ground water quality. 2. The Water quality also changes with seasonal variation. The periodic variation in surface and ground water represent huge ionic concentration in summer season when contrasted with winter and post monsoon season. Impact of urbanization and industrialization on surface and ground water quality has been clarified.
20.	Madan, S., Dutta, S.,Chanchal.	Journal of Applied and Natural Science. (2013)	Water Quality Assessment	1. In this paper, the water quality of Tons river near Tapkeshwar temple in Dehradun was

				assessed in terms of their physico-chemical parameters. 2. The total nine number of samples were analysed and correlation matrices among parameters was determined. 3. The study revealed that the Tons river water is unpolluted near the Tapkeshwar temple because physico-chemical parameters analysed during the assessment were found to be under the acceptable limits of BIS.
21.	Han D., Tong X., Currell M.J., Cao G.	Journal of Geochemical Exploration (2014)	Effect of leachate from landfill on encompassing groundwater quality.	1. Paper illustrates that leachate from landfill contaminates the surrounding groundwater. 2. The analytical results conclude that

				the shallow groundwater of examined area around the landfill is contaminated and not fit for drinking, requiring to control the pollution.
22.	Bahukhandi, K D., Bartarya, S.K.	Octa Journal of Environmental Research (2014)	Impact Assessment of Anthropogenic Sources	1. The paper outlines the study of leading ion chemistry of river catchment to acquisition out the brunt of anthropogenic action on water aspect. 2. The surface water alongside groundwater tests were accumulated and inspected for contemplating major ion chemistry of surface and ground water of Asan waterway catchment. 3. The bodily parameter such as pH, temperature,

				DO and conductivity had been deliberate in the terrain whilst for the investigation of other criterion the samples were analyzed in the laboratory with the assist of fashionable techniques of APHA for water and waste water analysis. 4. All anions and cations were connected with WHO and BIS standard of drinking water quality to discover its suitability for drinking purpose. The water quality in the examination region has been impacted by the anthropogenic sources in the catchment area.

23.	Oluseyi, T., Adetunde O., Amadi E.	International Journal of Science, Environment and Technology (2014)	Impact assessment of dumpsites on soil and water.	1. Paper explains about the impact assessment of groundwater quality at Lagos Nigeria of abandoned and functional waste dump site. 2. The soil and water samples were picked from dumpsites and wells at distinct location nearby the dumpsite and analyzed for physico- chemical, microbial and heavy metals. 3. The soil and water analyzed at dumping site shows no significant difference in concentration.
24.	Abhineet, N., Sumit, S.	International Journal of Engineering, Research & Technology (2017)	Water Quality Assessment	1. This paper outlines the various physical, chemical & bacterial criterion required to study the Water Quality

				Index. 2. The result of analysis was correlated with the World Health Organization and Bureau of Indian Standards. 3. The contamination level in water was studied after analysis of water samples and comparison with BIS and WHO standards.
25.	Sharma, R.C., Kumar, R.	Applied Water Science. (2017)	Water Quality Assessment.	1. The paper explains about the water quality of Satopanth glacial lake located at an altitude of 4600 m above sea level in Garhwal Himalayas. 2. The sixteen physico-chemical were analyzed in ice free period. 3. The pysico-chemical values of

				all the samples were within the prescribed WHO/BIS limit for drinking water.
26.	Kumar, R., Chauhan, A., Rawat, L.	Journal of Environmental & Analytical Toxicology. (2017)	Analysis of Surface and Ground Water.	1. In this paper, the quality of surface and ground water were assessed to determine its suitability for drinking, agriculture and industrial purpose. 2. The values of all physiochemical and alkali metals were found within the permissible limits of the WHO guidelines and Indian standard limits and few of sites even have higher values as compared with standard limits which are may be due to excess use of chemicals and unplanned flow of

				effluent.
27.	Kumar, R., Sharma, R.C.	International Journal of Fisheries and Aquatic Studies. (2018)	Assessment of surface water quality.	1. This paper outlines the study which was carried out for investigation of water quality of Badhani Lake. 2. The water quality index was developed by assessing the 16 physico-chemical parameters. 3. The water quality of the lake is found to be excellent as reported in the resultant values of physico-chemical parameters.
28.	Bisht, S., Sharma, R.C., Rawat, S., Kumar, R.	MOJ Ecology & Environmental Sciences. (2018)	River Water Analysis.	1. This paper shows the results of river water samples. 2. The physico-chemical analysis were carried out from the samples collected from three different sites i.e. Mandakini,

				Alaknanda and confluence. 3. The seven bacterial species were also identified from the water sample collected from the study area.
29.	Rawat, S., Daverey, A.	Environmental Engineering Research. (2018)	Municipal Solid Waste Management.	1. In this paper, the municipal solid waste management system in one of the Class II Indian city i.e. Rishikesh was studies. 2. The Characte-rization of household solid waste was done by collecting 329 solid waste samples from 47 households. 3. The key issues identified were non segregation of waste, poor collection efficiency and unscientific disposal of waste.
30.	Sharma,	Applied Water	Physico-chemical	4. In this paper, the

	R.C., Tiwari, V.	Science. (2018)	characterization of water.	physico-chemical parameters of water quality of sacred lake Nachiketa Tal of Garhwal Himalayas was studied. 5. The seasonal variations of various parameters at four sampling stations was analyzed and recorded. 6. The study revealed that the water quality of the Nachiketa Tal was degraded during monsoon season and was better during the winter season.

CHAPTER 3

RESEARCH METHODOLOGY

Section below presents the detailed methodology undertaken in the research

3.1 Sample Collection and Analysis: Water and Solid Waste

3.1.1 Sample Collection:

Ward-wise map of Dehradun city was collected from DNN (Dehradun Nagar Nigam) and different sampling sites for sample collection were selected and marked covering the different wards of Dehradun city including solid waste dumping site (Nunarkheda, Sahastradhara near Hill View Apartment) and illegal dumping sites i.e. Bindal river and Rispana river. The Water tests were gathered during monsoon season (July – August 2013), winter season (November 2013-January 2014), summer season (March-June 2014) and Municipal Solid Waste samples were gathered from distinct legal and illegal dumping sites of Dehradun city.

3.1.2 Sample Analysis:

3.1.2.1 Water:

- Water samples gathered from the open dumping site were evaluated for physical and chemical parameters ie. pH, temperature, TDS, DO and conductivity are analyzed in field, while for the measurement of anions (Chloride, Fluoride, Suphate, Nitrate, Phosphate) and cations (Ca, Mg, Na, K,), heavy metals (Cu, Fe, Pb,) and their investigation, samples were taken into laboratory and analyzed by Standard method of APHA 1992. The bicarbonate, Total Hardness had been measured with the help of acid- base titration method, EDTA titration method, and Chloride is measured with

silver nitrate method. The parameter i.e. SO_4, NO_3, PO_4, F were measured with spectrophotometer, turbidity measured with the aid of turbidity meter, pH measured with pH meter, conductivity measured with conductivity meter, and TDS and TSS were measured with gravimetric method. Heavy metals i.e. iron, lead, copper were analyzed with AAS.

Table 3.1: Analytical methods: Analysis of water samples was carried out in NABL Accredited, Health Safety and Environmental Engineering Lab, UPES according to the standard methodology described by APHA (1992) and instructions were followed as per the prescribed manual of the apparatus.

S.No.	Parameter	Instrument / procedure
Physical Parameter		
1	pH	pH Meter
2	Temperature	Thermometer
3	Conductivity	Conductivity meter
4	TDS	TDS meter
5	Dissolved Oxygen	DO Sampler
6	Turbidity	Turbidity Meter
Chemical Parameter		
7	Anions – Cl, NO_3, SO_4,PO4,F etc.	Titration method, U.V. Spectrophotometer
8	Cations – Na, K, Ca, Mg.	EDTA Titration method, Flame Photometer
9	Bicarbonate	Titration Method.
10	Heavy Metals i.e. Fe, Cu, Pb.	AAS.

3.1.2.2 Solid Waste Quantification and Characterization

- ➢ MSW (Municipal Solid Waste) samples were gathered in the sampling bags and segregated into various categories i.e. plastic, glass, metals and kitchen waste, grass, paper, litter and inert material by weighing method.
- ➢ Quantification and Segregation of Waste Sample: Samples were weighed and segregated into organic (food, plant etc.) and inorganic waste (plastic, paper, textile, metals, glass etc.)
- ➢ Analyses of Waste Sample Moisture content, total solids, volatile & non-volatile contents, ash content, were carried out in laboratory.

3.1.2.3 Weather Parameters

- ➢ Effects of Rainfall on Solid Waste.
- ➢ Effects of Temperature on Solid Waste.
- ➢ Effects of Humidity on Solid Waste**.**

3.1.2.4 Terrain Parameters

- ➢ Soil Type
- ➢ Water Table

3.1.3 Comparative Analysis of Data

For Comparative analysis weather parameters, physical and chemical criterions of water, solid waste generation rate have been used. Comparison of Dehradun with other cities such as Nainital, Ooty, Jammu and Delhi has been done**.**

3.2 Expert system Development

It was undertaken in following stages:

3.2.1 Knowledge Acquisition

Foremost process of methodology executed was to acquire knowledge through various sources

- Visits and meetings with SWM officials Dehradun Nagar Nigam, Doon Valley Waste Management.
- Knowledge sources literature review, research publications, articles and reports.
- SWM sites were visited to record details of current status of SWM in Dehradun city.

3.2.2 Knowledge Representation

- Expert System Shell 'Flex' [LPA Inc, UK] was used to code water analysis module.
- Knowledge were represented as *if....then* rules, concerning standards of measurable parameters to adjudge SW impact on water quality & effectively disposal of MSW.
- Expected output was final conclusion on impact on water quality, based on comparison with BIS standards.

3.2.3 Incorporation of Forecasting and Prediction Module

- Using MATLAB (Math works Ltd.) Futuristic Neural Network time series tool box, prediction model were developed using NAR Net (Nonlinear autoregressive neural network).

- Inputs to the system were current solid waste generation statistics (week-wise), and output was forecasting of solid waste generated half yearly/ short term.
- For estimation of landfill capacity, the solid waste prediction slanted as input and the necessary capacity for landfill as a result will be achieved.
- Advisory for handling landfill operational problems developed to assist landfill managers and provide advice in handling landfill problems.

3.2.4 User Interface/Front-end of Expert System

- User-Interface developed were in .NET (C# Programming language), for interaction with expert system. Once the inputs in form of lab test data and current SW statistics are entered, the impact analysis, harmful effects of derailed parameters, forecast of solid waste generated was displayed as output through this interface.
- The model for Novel Capacity Estimation for Dehradun city was designed and integrated.
- Advisory for handling landfill operational problems was developed and integrated.
- Additionally, available knowledge on SWM was disseminated through this interface.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Analytical Output:-

4.1.1 Water Analysis:

The water samples were collected from all the wards of Dehradun city. The water samples were evaluated for physical and chemical parameters i.e. pH, temperature, TDS, DO and conductivity are analyzed in field, while for the measurement of anions (Chloride, Fluoride, Sulphate, Nitrate, phosphate) and cations (Ca, Mg,Na,K), heavy metals (Cu,Fe,Pb) and their investigation, samples were taken into laboratory and analyzed by Standard method of APHA 1992. The bicarbonate, Total Hardness had been measured with the help of EDTA titration method and chloride is measured with silver nitrate method. The parameter i.e. SO_4, NO_3, PO_4, F were measured with spectrophotometer, pH measured with pH meter, conductivity measured with gravimetric method. Heavy metals i.e. iron, lead, copper were analyzed with Atomic Absorption Spectrophotometer. The results for monsoon, winter and summer seasons are given in Table 4.1, 4.2 and 4.3 whereas the average result of all seasons for water samples are given in Table 4.4.

Table 4.1: Results for Monsoon Season water samples

Parameters	Unit	Average	MAX.	MIN.	IS (Indian Standards)
Temp.	°C	29.17	32.4	26.4	-
pH	-	7.32	7.97	6.53	6.5-8.5
Turbidity	NTU	0.02	0.04	0.01	5
EC	µS/cm	326.15	665	125	-
DO	mg/l	13.70	15.74	10.23	-
TDS	mg/l	319.33	630	60	500

Total Hardness	mg/l	362.33	540	220	300
Ca	mg/l	101.53	151.38	63.07	75
Mg	mg/l	26.62	73.2645	1.57	30
Na	mg/l	7.99	24.5	1.5	-
K	mg/l	1.53	11.7	0.5	-
HCO3	mg/l	324.52	561.2	42.7	200
Cl	mg/l	72.43	124.07	43.44	250
F	mg/l	0.31	0.92	0.02	1
SO4	mg/l	264.65	426.76	154.82	200
NO3	mg/l	5.39	10.90	0.80	45
PO4	mg/l	13.06	67.56	0.02	-
Fe	mg/l	0.10	0.3	0.01	0.3
Cu	mg/l	0.01	0.09	0.01	0.05
Pb	mg/l	0.009	0.02	0	0.05

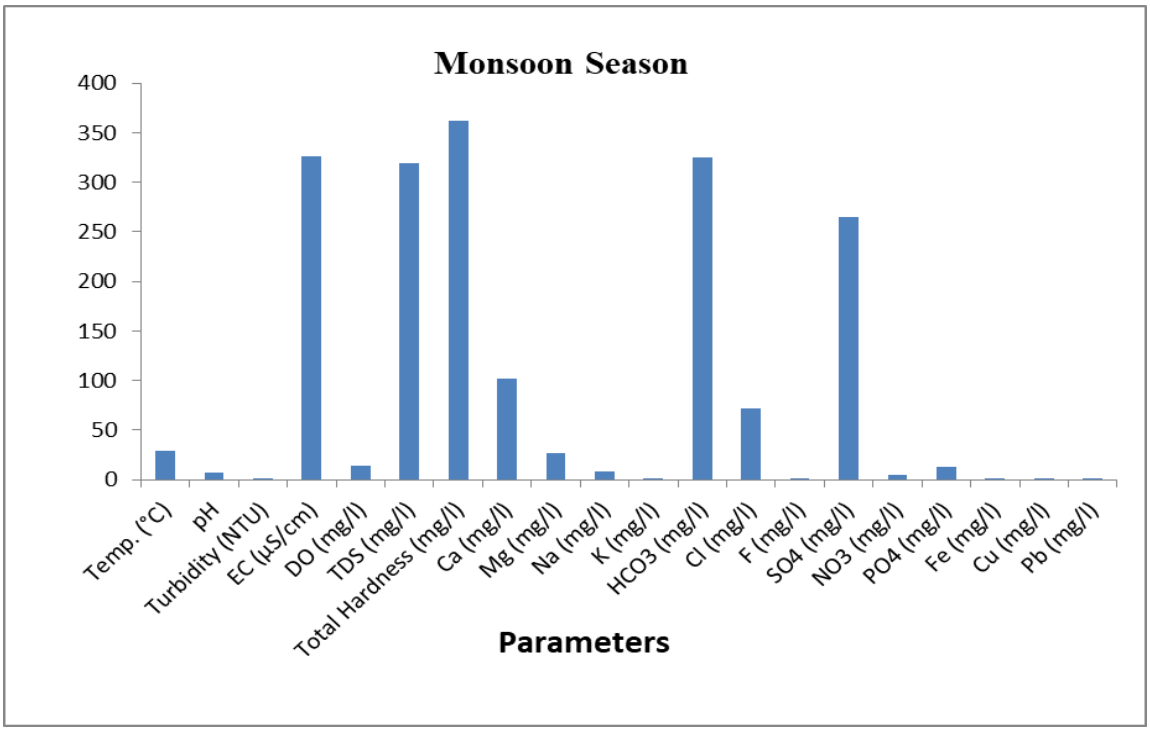


Fig. 4.1: Parameters for monsoon Season water samples

Table 4.2: Results for Winter Season water samples

Parameters	Unit	Average	MAX.	MIN.	IS (Indian Standards)
Temp.	°C	22.78	26.5	19.2	-
pH	-	7.13	7.63	6.56	6.5-8.5
Turbidity	NTU	0.01	0.03	0.01	5
EC	µS/cm	342.53	667	140	-
DO	mg/l	11.60	13.85	6.45	-
TDS	mg/l	324.41	640	70	500
Total Hardness	mg/l	363.83	550	220	300
Ca	mg/l	102.80	152.56	64.65	75
Mg	mg/l	27.41	74.12	2.32	30
Na	mg/l	8.39	25.3	1.6	-
K	mg/l	1.64	10.2	0.8	-
HCO_3	mg/l	325.59	562.3	43.2	200
Cl	mg/l	73.39	125.32	44.56	250
F	mg/l	0.32	0.91	0.03	1
SO_4	mg/l	266.01	425.45	155.23	200
NO_3	mg/l	5.44	11.21	0.91	45
PO_4	mg/l	13.27	68.45	0.032	-
Fe	mg/l	0.12	0.8	0.02	0.3
Cu	mg/l	0.02	0.08	0.01	0.05
Pb	mg/l	0.01	0.02	0	0.05

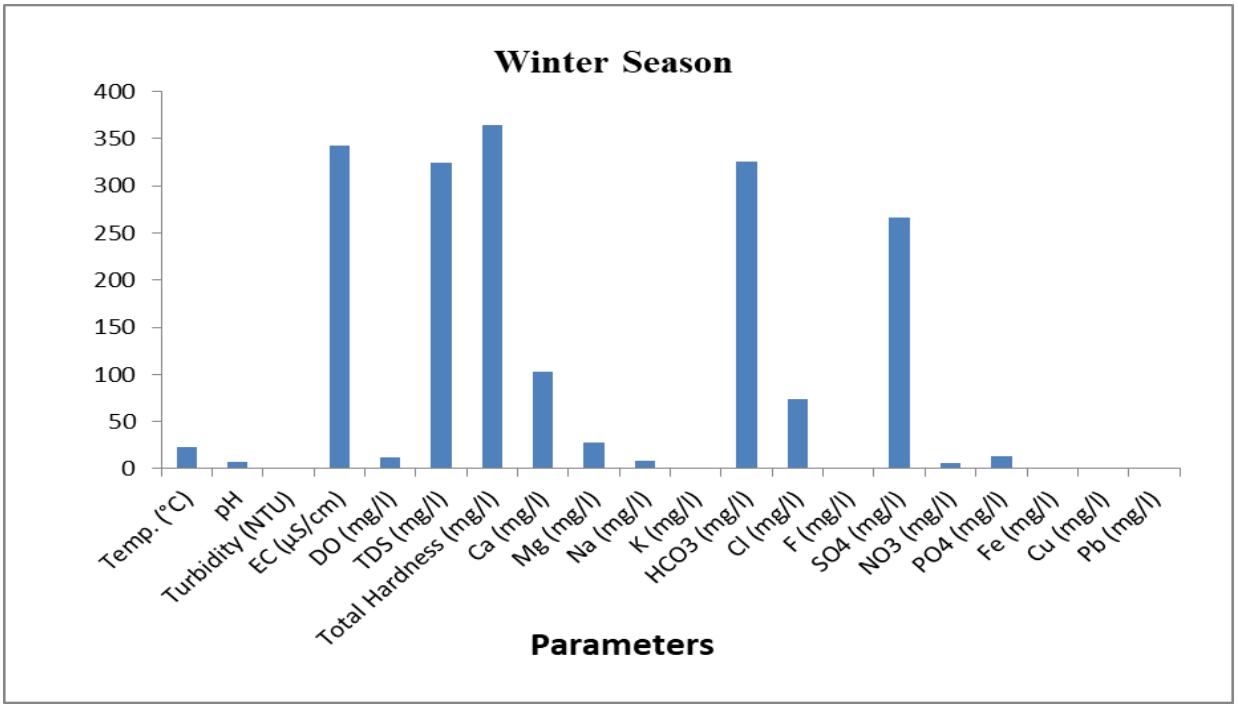


Fig. 4.2: Parameters for winter season water samples

Table 4.3: Results for Summer Season water samples

Parameters	Unit	Average	MAX.	MIN.	IS (Indian Standards)
Temp.	°C	32.37	35.3	29.4	-
pH	-	7.55	8.32	7.02	6.5-8.5
Turbidity	NTU	5.77	345	0.01	5
EC	µS/cm	355.3	680	110	-
DO	mg/l	10.58	14.65	6.75	-
TDS	mg/l	323.16	650	50	500
Total Hardness	mg/l	360.83	570	210	300
Ca	mg/l	103.47	153.95	65.45	75
Mg	mg/l	28.16	75.45	2.57	30
Na	mg/l	8.55	23.5	1.7	-

K	mg/l	1.86	11.4	1.2	-
HCO_3	mg/l	326.29	563.1	44.1	200
Cl	mg/l	74.05	128.43	46.1	250
F	mg/l	0.34	0.87	0.08	1
SO_4	mg/l	266.25	427.32	156.86	200
NO_3	mg/l	5.47	11.34	0.85	45
PO_4	mg/l	13.31	67.78	0.043	-
Fe	mg/l	0.10	0.28	0.02	0.3
Cu	mg/l	0.02	0.07	0.01	0.05
Pb	mg/l	0.01	0.02	0	0.05

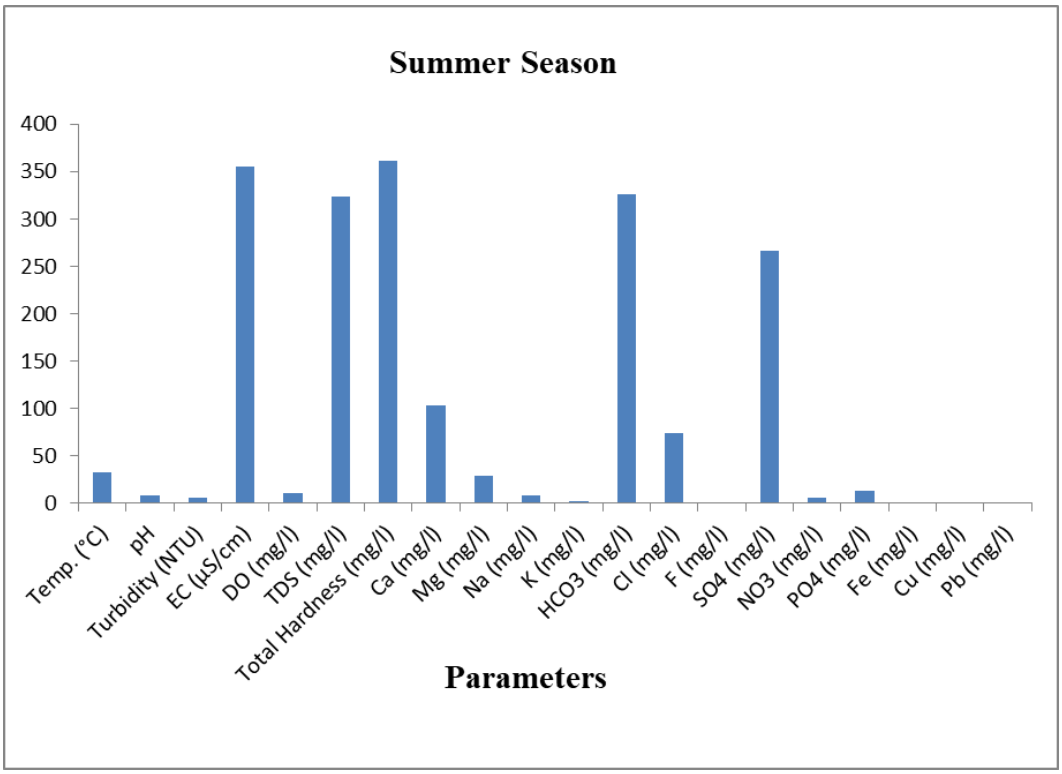


Fig. 4.3: Parameters for summer season water samples

Table 4.4: Average result of all Seasons water samples

Parameters	Unit	Average	Max.	Min.	IS (Indian Standards)
Temp.	℃	28.11	35.3	19.2	-
pH	-	7.33	8.32	6.53	6.5-8.5
Turbidity	NTU	1.93	345	0.01	5
EC	µS/cm	341.32	680	110	-
DO	mg/l	11.96	14.74	7.81	-
TDS	mg/l	322.30	650	50	500
Total Hardness	mg/l	362.33	570	210	300
Ca	mg/l	102.60	153.95	63.07	75
Mg	mg/l	27.40	75.45	1.57	30
Na	mg/l	8.31	25.3	1.5	-
K	mg/l	1.68	11.7	0.5	-
HCO_3	mg/l	325.47	563.1	42.7	200
Cl	mg/l	73.29	128.43	43.44	250
F	mg/l	0.32	0.92	0.02	1
SO_4	mg/l	265.64	427.32	154.82	200
NO_3	mg/l	5.43	11.34	0.85	45
PO_4	mg/l	13.22	68.45	0.021	-
Fe	mg/l	0.11	0.8	0.01	0.3
Cu	mg/l	0.02	0.09	0.01	0.05
Pb	mg/l	0.01	0.02	0	0.05

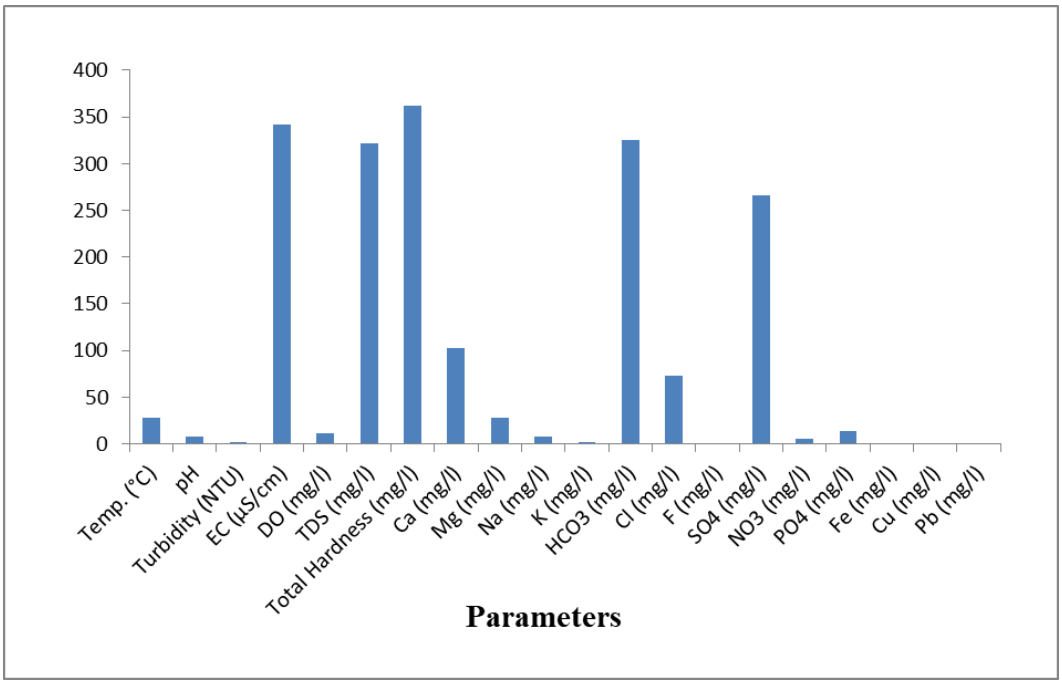


Fig. 4.4: Average Parameters of all water samples

The concentration of physico-chemical indicators in water specimens are obtained from different wards of Dehradun town are outlined in the Table 4.4. The pH value is a crucial benchmark for acidic and alkaline nature of drinking water. The range of drinking water is from 6.5 to 8.5. A variety of organic substance reacts with each other to provide enough resulting pH rate of the specimen. The pH scale ranges in analyzed specimens is between 6.53-8.32. This is between the BIS and WHO guidelines of drinking water and is suitable for drinking purposes.

Temperature has a significant impact on biological growth and development. It creates impact on chemical and physical phenomenon of water. Water holds less oxygen at raised temperatures. The range of temperature lies between 19.2^{o}C-35.3^{o}C. Water's turbidity is accountable for the dispersion of sunlight. As a result, turbidity in natural fresh water prevents light infiltration and thus limits photosynthesis or chemical transition, which thereupon undergoes reduction of amount of oxygen. Turbidity ranges from 0.01 to 0.04. An immense amount of EC customarily suggests huge degree of salinity. For this reason, EC is regarded

as a key factor for measuring water quality in the evaluation of drinking water in combination with groundwater. The level of EC ranges from 110 micro Siemens to 680 micro Siemens. The water with slender solvents is less favorable and the ensembles for drinking desire are less palatable. The value of dissolved oxygen ranges between 7.81 to 14.74. DO is the most important factor in aquatic systems, since all plants and animals need oxygen for respiration. Oxygen levels are often used to indicate the quality of freshwater, health of streams and rivers and the intensity of aquatic pollution. It also limits tastes, odours, discolouration and corrosion in drinking water. Under several circumstances, the influential degree of TDS may be aesthetically inadequate for washing and bathing. The concentration of TDS recorded as is between 50 mg/l to 650 mg/l. The more advanced concentration of TDS in overhead sampling location may be accredited to leaching of chemicals / ions because of improper disposal of solid waste, contaminating surface and ground water aspect of Dehradun city. Ammonical nitrogen is a symbol of organic contamination. Throughout the course of consolidation with excessive chloride, the presence of landfill leachate may be detected. The level of chloride dissolved in the groundwater specimen may vary from 43.44 to 128.0 mg/l. As per BIS, the legal allowable level of chloride in fresh drinking water is 250 mg /l. The study presented in this research work has demonstrated the values are inside the normal limits. The bulk of sulphate ion is predicted to be in the range of 154.82 mg/l - 427.32 mg/l. The permissible limit of sulphate is in the range of 200-400 mg/l. The surplus quantity of sulphate induces diarrhea. Few specimens pass over the range. The higher concentration is presumably due to weathering of gypsum bearing carbonate rock of Krol formation exist in northern part of Doon Valley. Sulphate produces an unpleasant taste in the range of 300-400 mg /l and produces a slightly vicious taste at the level of 500 mg /l. [Gitanjali G., 2006]

The total hardness is a crucial parameter in water for residential and other commercial purposes. The observed hardness is ranging between 210 to 570 mg/l. The WHO and Indian guidelines permits value of total hardness in water upto 500

mg /l. For some specimens, total hardness was found to be marginally small. The alkaline nature of water is the indicator used to neutralize a high acid nature liquid and symbolizes the existence of any hydroxyl ion that is effective to interact with the hydrogen ion. Discreet ionic contaminants that devote themselves to alkalinity comprises of bicarbonate, hydroxide, phosphate, borate and organic acids [Sharma, M.R. 2004]. The bicarbonate alkaline nature is represented as a cumulative alkalinity in between range of 42.7 -561.2 mg /l.

The alkalinity values of entire specimens are chiefly greater than the admissible range of 200 mg/l in drinkable fresh water as per standards given by BIS. Nonetheless, an irregular amount of alkaline nature of fresh water is not injurious to the health of human beings. [Singh, T.B., 1999]. The values of analyzed samples are in the range of 0.85 to 11.34 mg/l. The values of analyzed samples are in accordance with the range of recommended value of BIS. In drinking water, the World Health Organization set a limit of 10 mg/l nitrate to avoid methemoglobinemia. Large amount of nitrate levels in fresh ground water are probably due to chemical and waste contamination. [Nair G.A., 2006]. Sodium concentration were found in between 1.5 to 25.3 mg/l. The recommended range of Sodium by USEPA is 20 mg/l. The greater amount of sodium in drinking water can cause high blood pressure and other cardiovascular ailments. Excessive sodium concentrations may provide unsuitable water used for irrigation purposes. Enormous percentage of sodium gives a sour taste when united with chloride. The depletion of rocks increases the level of potassium in ground water, while the amount of contaminated water increased due to the dumping of wastewater. Potassium level in water specimens ranged from 0.5 to 11.7 mg /l. The maximum acceptable calcium level in potable water is 75 mg/l as indicated by BIS. The calcium values are ranging between 63.08 to 153.95 mg/l. Many of the values went outside the normal guidelines. The excess calcium in drinking water can cause kidney stones in human being. Magnesium resistance by human beings is decreased as in comparison to Calcium and excessive amounts act as a laxative and offensive type to water and contributes to hardness. The calculated values of

magnesium were between 1.58 to 75.45 mg /l, while overall permissible range for magnesium in drinkable water is 30 mg /l. The excess amount of magnesium in drinking water can cause diarrhea and other laxative effects.

4.1.1.1 Ion Chemistry

The HCO_3 were most dominance ion among anions followed by SO_4, Cl, PO_4, NO_3, and F. Among cations Ca was most dominant cations pursue by Mg, Na and K. The order of abundance of major anions and cation are HCO_3(39.71%)>SO_4(32.36%)>Cl(8.89%)>Mg(3.25%)>PO_4(1.59%)>Na(0.97%) >NO_3(0.66%)>K(0.18%)>F(0.03%)

Table 4.5: Result for Water calculated as meq/l to determine equivalent ratios

Parameters	Average (meq/l)	Max. (meq/l)	Min.(meq/l)
Ca	5.0	7.56	0.64
Mg	2.21	6.10	0.13
Na	0.34	1.06	0.06
K	0.03	0.3	0
HCO_3	5.31	9.2	0.7
Cl	2.04	3.49	1.25
F	0.01	0.03	0.00
SO_4	5.50	8.89	3.22
NO_3	0.08	0.17	0.01
PO_4	0.13	0.69	0.00

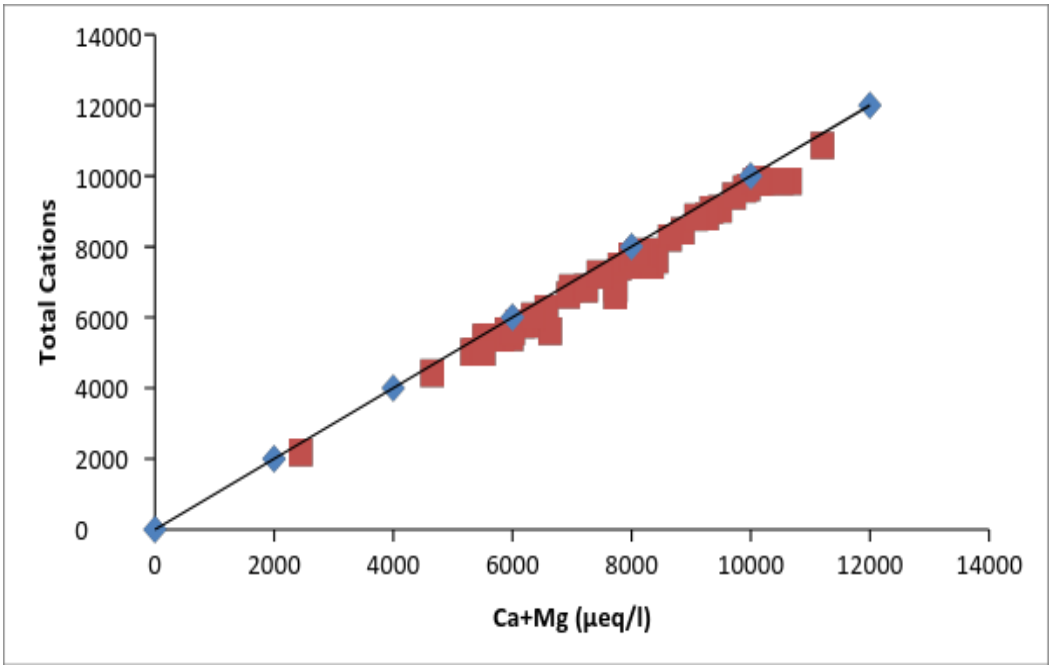


Fig. 4.5: Equivalent ratio of Ca+Mg and Total cations

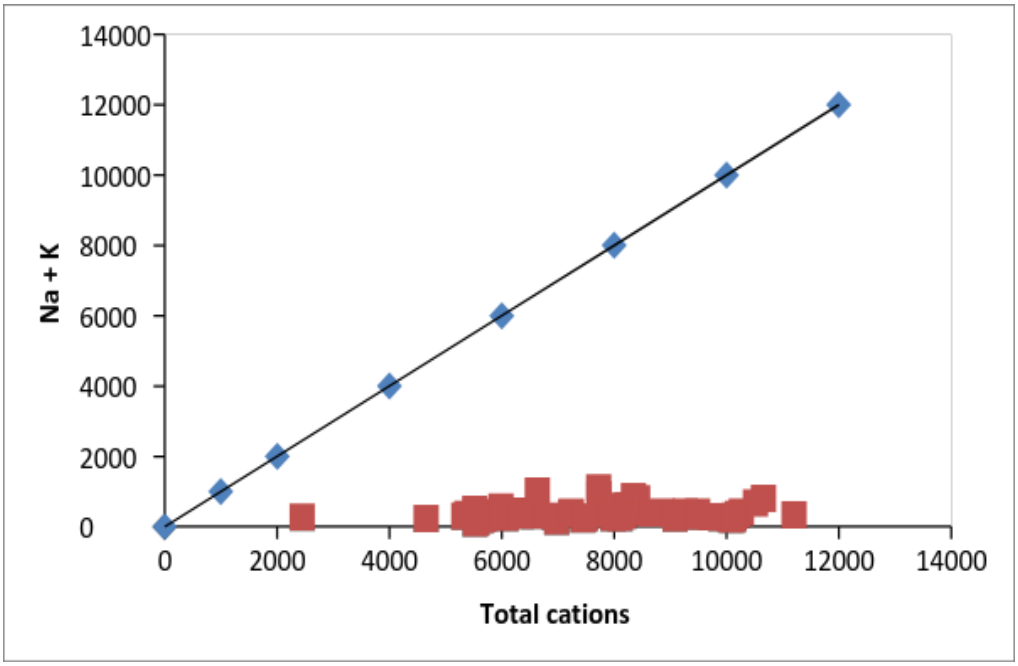


Fig. 4.6: Equivalent ratio of Na + K and Total cations

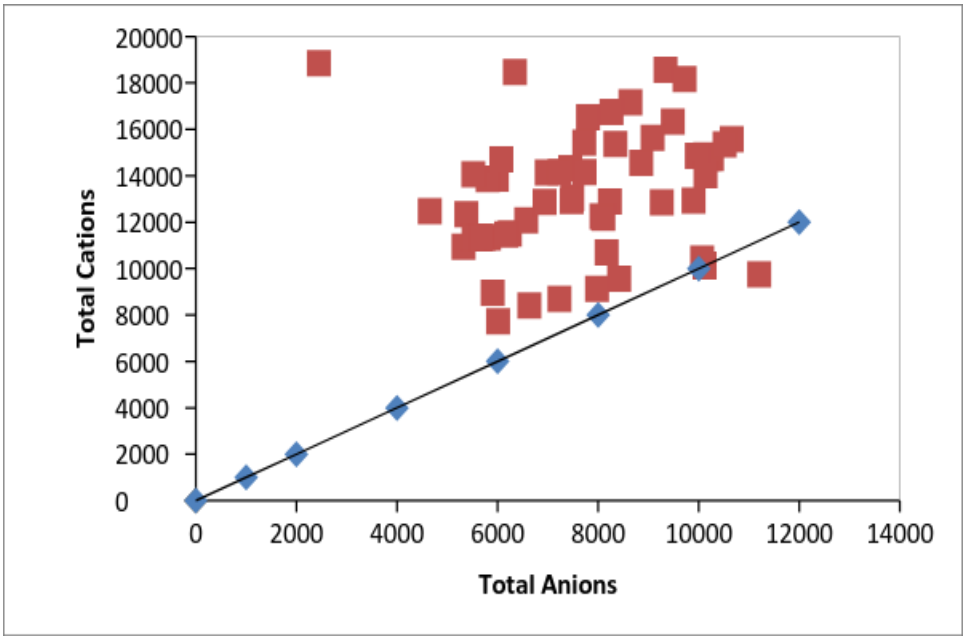


Fig. 4.7: Equivalent ratio of total anions and total cations

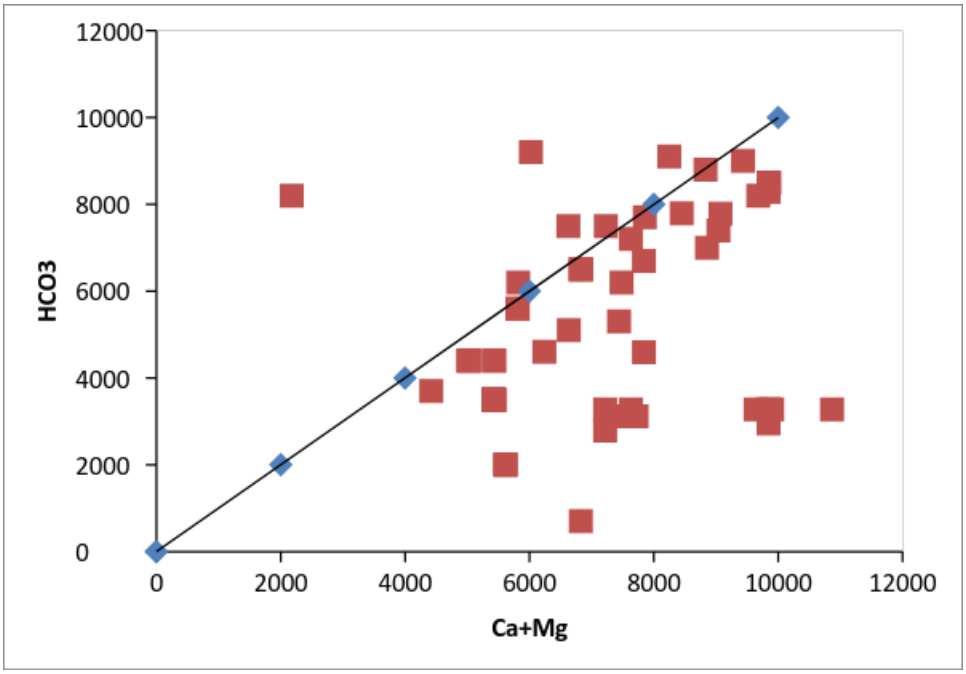


Fig. 4.8: Equivalent ratio of Ca+Mg and HCO_3

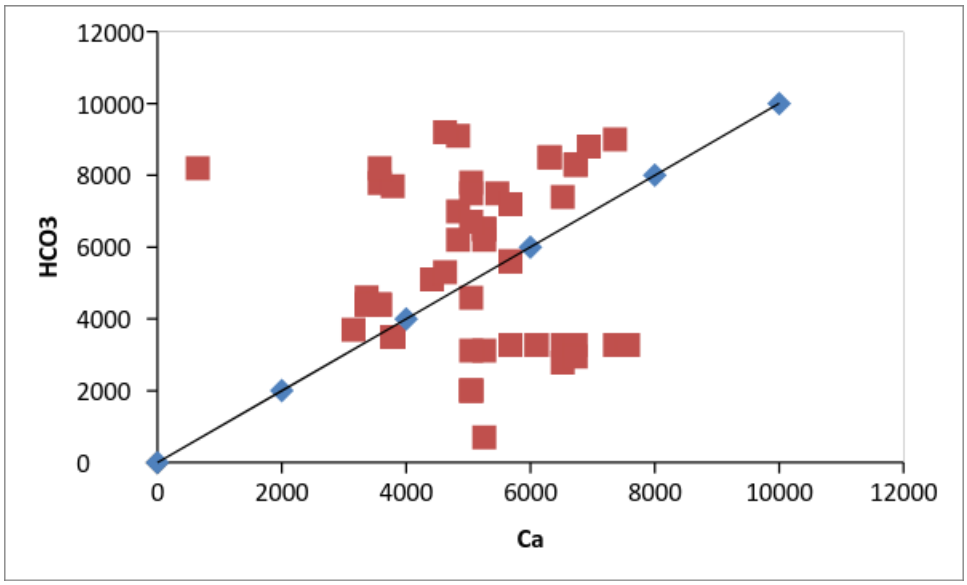


Fig. 4.9: Equivalent ratio of Ca and total HCO_3

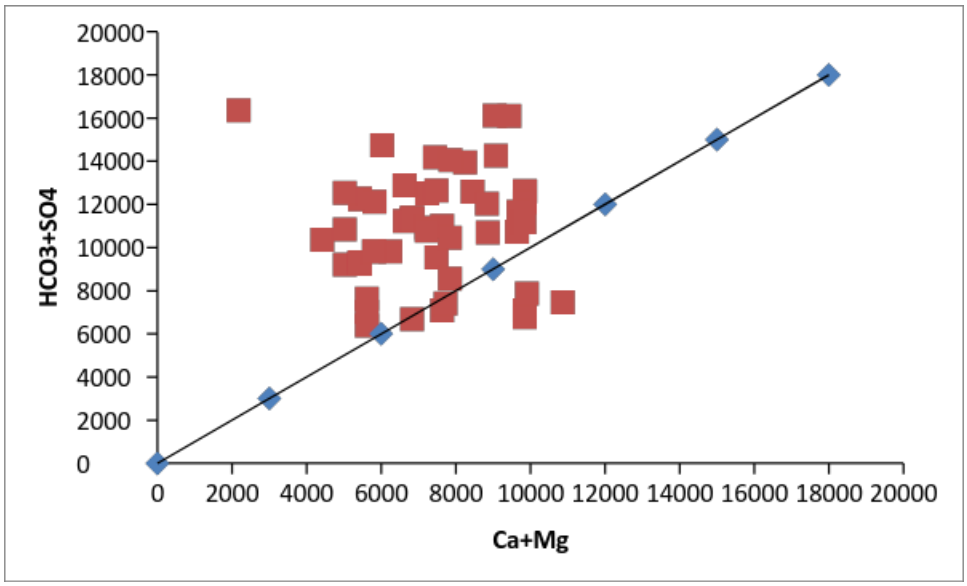


Fig. 4.10: Equivalent ratio of Ca+Mg and HCO_3+SO_4

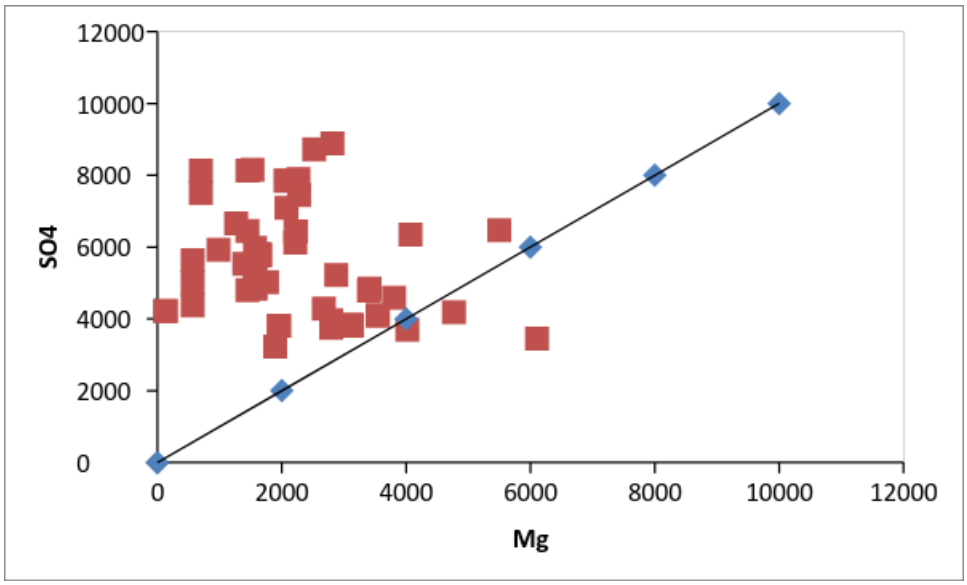


Fig. 4.11: Equivalent ratio of Mg and SO_4

4.1.1.2 Correlation Matrix

The statistical analysis was based on Pearson's correlation coefficient amidst with numerous water quality indicators and to design and develop the compelling correlation amid the physico-chemical parameters (Bhandari, 2008). The value of correlation coefficient is adjacent to positive +1 (positive correlation) implies that as one variable surges and other decreases linearly (Seth, 2014). The value which is near to 0 (zero) indicate that slight linear correlation in between variables and therefore it is concluded that correlation doesn't exist (Mugdyal, 2009). The TDS showed strong positive correlation with HCO_3 (r = 0.89) followed by Cl (r= 0.56), NO_3 (r = 0.52), Mg (r = 0.38), Ca (r = 0.21) and SO_4 (r =0.14) (Table 4.6). The calcium showed negative correlation with SO_4 (r = -0.26), and HCO_3 (r = 0.52). The PO_4 indicated positive correlation with Ca (r = 0.36), Mg (r = 0.13) , Na (r = 0.34) and K (r = 0.2).

Table 4.6: Correlation water Sample Details

Para-meters	TDS	EC	HCO_3	Cl	F	SO_4	NO_3	PO_4	Ca	Mg	Na	K
TDS	1	0.17	0.89	0.56	0.04	0.14	0.52	0.05	0.21	0.38	0.13	0.06
EC	0.17	1	0.22	0.13	0.07	-0.09	0.04	-0.03	-0.07	0.21	-0.01	0.16
HCO_3	0.88	0.22	1	0.52	0.13	-0.20	0.45	-0.09	0.09	0.38	0.11	0.11
Cl	0.56	0.12	0.52	1	0.24	-0.19	0.41	0.08	0.17	0.33	-0.01	-0.14
F	0.06	0.07	0.13	0.24	1	-0.16	0.25	-0.21	0.06	0.10	-0.20	0.19
SO_4	0.14	-0.09	-0.21	-0.2	-0.16	1	-0.2	-0.17	-0.26	-0.26	-0.10	-0.06
NO_3	0.52	0.04	0.45	0.41	0.25	-0.20	1	0.18	0.59	0.38	-0.02	-0.04
PO_4	0.05	-0.03	-0.1	0.08	-0.21	-0.17	0.18	1	0.36	0.13	0.34	0.02
Ca	0.21	0.21	0.09	0.17	0.06	-0.26	0.59	0.36	1	0.07	0.10	-0.04
Mg	0.38	0.21	0.38	0.33	0.10	-0.26	0.38	0.13	0.07	1	-0.07	0.117
Na	0.13	-0.01	0.11	-0.01	-0.20	-0.10	-0.02	0.34	0.10	-0.07	1	-0.04
K	0.06	0.16	0.11	-0.14	0.19	-0.06	-0.04	0.02	-0.03	0.11	-0.04	1

4.1.1.3 Chadha (1999) Diagram

Chadha (1999) proposed a hydro chemical diagram and practiced to classify distinct hydrochemical process. The overall information was transformed into percentage reaction values (milliequivalent percentage). The contrast values between alkaline earth (Ca + Mg) and alkali metallic (Na + K) for cation and discrepancy between weak acidic anions (HCO3 + CO3) and robust acidic anions (Cl + SO4) has been calculated. As per Chadha (1999) diagram, the reverse ion alternate water is of Ca - Mg - Cl type, recharge water is of Ca - Mg - HCO3 type, and sea water is Na- HCO3 type. Recharge water formed when the surface water moved to the ground water and whilst shifting to aquifers, the surface water dissolve carbonate in the form of HCO3 and geochemically mobile Ca. When the (Ca+Mg) – (Na+K) values were plotted against HCO_3 – (Cl+SO_4) the recharge characteristics of water was observed (Fig. 4.12). The ground water and surface water of Dehradun city were erect to be of Ca-Mg-HCO_3 type.

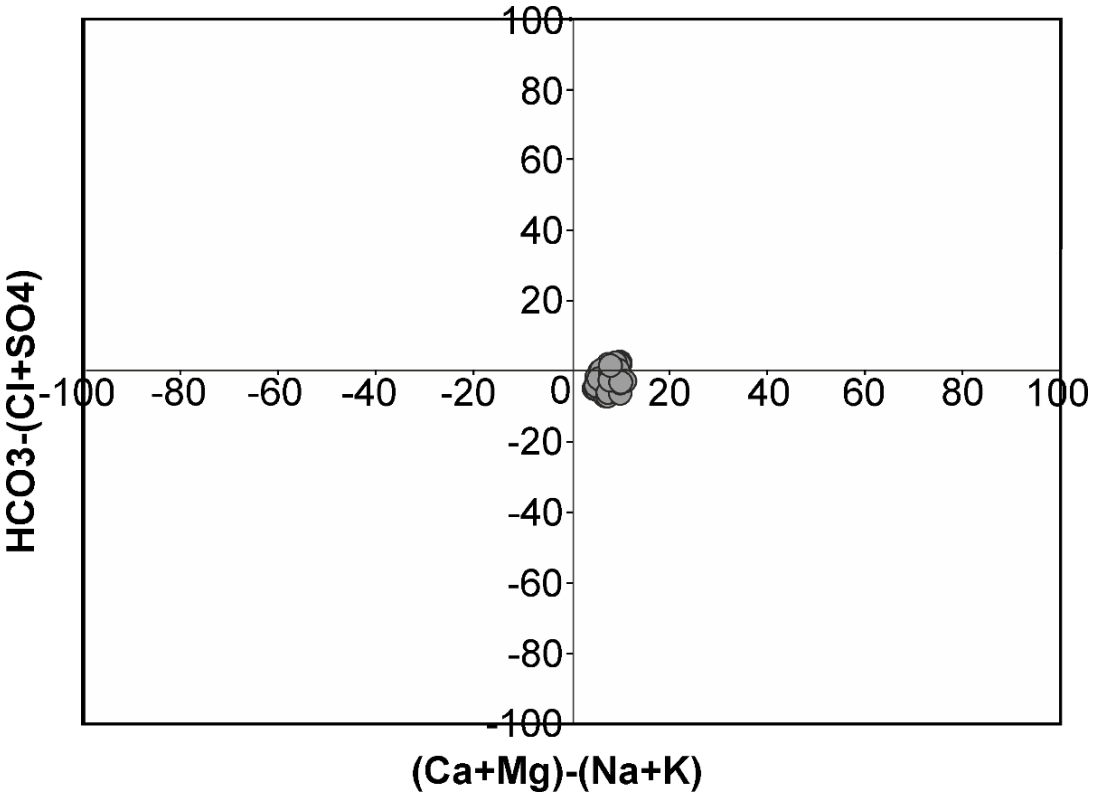


Fig. 4.12: Chaddha Diagram

(Ca+Mg)-(Na+K) values were plotted against HCO_3-(Cl+SO_4) to characterize the water samples. In most of the water samples is Ca-Mg-HCO_3 type.

4.1.1.4 Salinity:

All TDS and EC define the salinity quote in water. The salts displayed in the water, which directly stir the plant life boom, also influence the structure of the soil, permeability and aeration which affect the plant growing discursively. The maximum dissolved solids & electrical conductivity are thus the dominant parameters in the irrigation organization of water.

Based mainly on the full absorption of soluble salts (Todd, 1980), this classification has been established.

200-500- Medium Salinity = 68.33%

Less than 200- Low Salinity Zone= 18.33%

More than 500- High Salinity Zone= 13.33%

4.1.1.5 Permeability Index:

The index is accustomed by Doneen (1964) for classifying water for agricultural perspective is given as follows

$$PI = \frac{Na^{+} + \sqrt{HCO_{s}^{-}} \times 100}{Ca^{2+} + Mg^{2+} + Na^{+}}$$

The water samples lie between the 10.71-75.91 with maximum & minimum Permeability Index. The average is 20.094.

4.1.1.6 Sodium Adsorption Ratio:

The undesirable effects of soil properties and permeability is due to the excess sodium in water (Kelly 1951). High sodium amount in water may also develop alkaline soil. The risk of sodium and alkali in irrigation water is determined by the amount of cations and indicated with term know as SAR. The calculations of SAR are as follows:

$$SAR = \frac{Na^{+}}{\sqrt{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)}}$$

Where Na,Ca& Mg are in meq/l.

The waters have been classified in alliance to irrigation based on the levels of SAR values (Richards 1954). The SAR value levels in Dehradun City from 3.32 to 12.98.

4.1.1.7 Sodium Percentage:

Soils consist of large amount of sodium with carbonate as the predominant anion are termed alkali Soils.

$$\%Na = \frac{(Na+K)}{(Na+K+Ca+Mg)} \times 100$$

Where Na, K, Ca & Mg are in meq/l.

The percent sodium values of samples varied from 1.19 to 47.89.

4.1.1.8 Irrigation Water Quality:

After:

Electrical conductivity is utmost imperative parameter in finding out the suitability of water for irrigation use. Salinity of river water that is used for irrigation is decisive by using EC, which is used as measure of entire dissolved solids. The symptoms such as Electrical Conductivity, Sodium Adsorption Ratio (SAR) and Sodium Percentage (Na %) had been estimated to test the suitability of ground water and surface water for irrigation purpose. The illustration of irrigation waters classification was used to investigate the quality of the water (Wilcox, 1955)

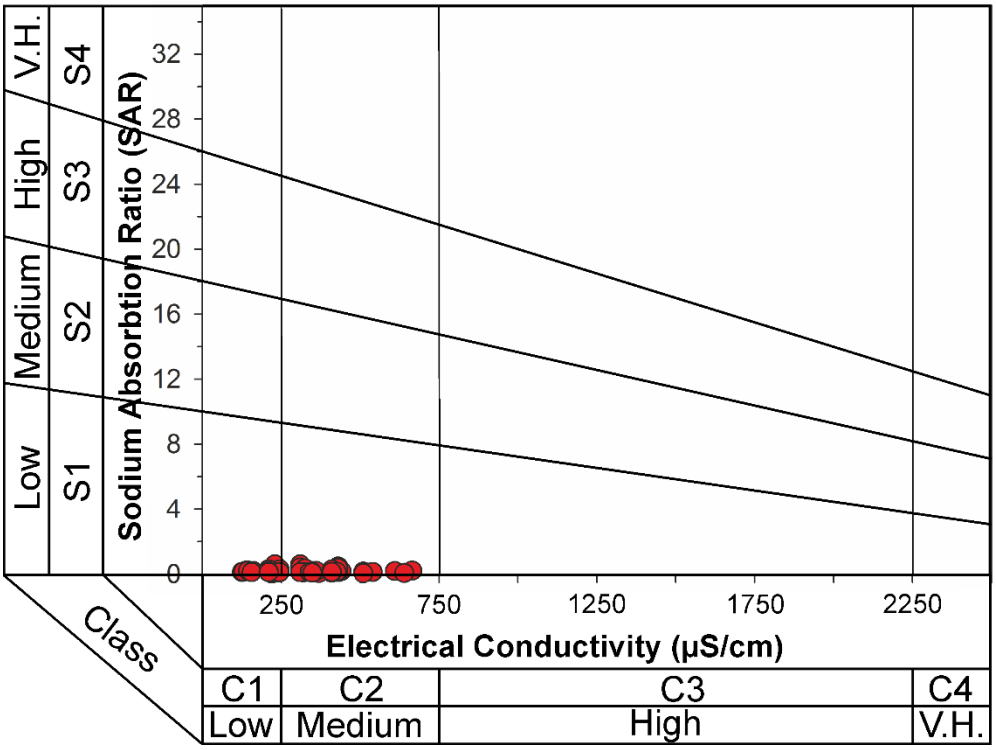


Fig. 4.13: Wilcox diagram

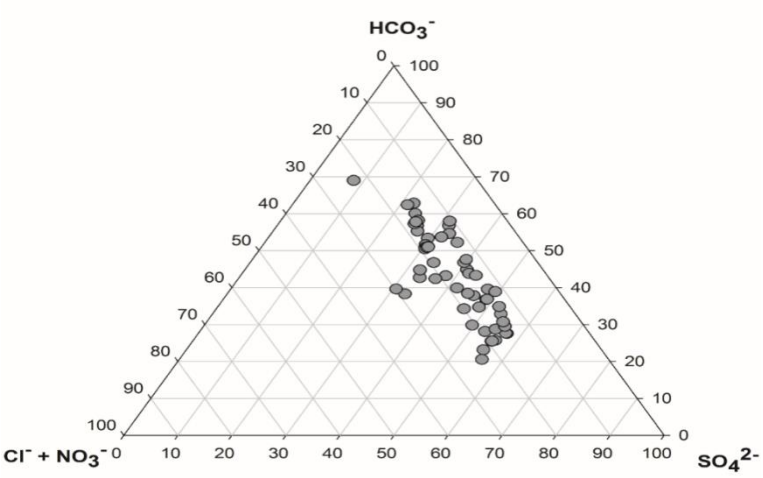
The illustration shown in Fig. 4.13 depicts that most of the samples lies between the C2-S1 class which is medium salanity threat and small Sodium (Alkali) threat.

4.1.1.9 Hydro Chemical facies

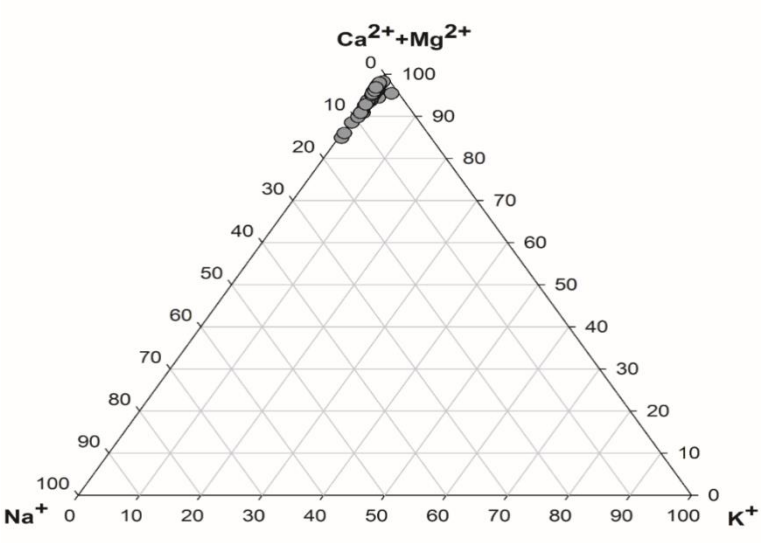
The hydrochemical characterization of water was evaluated by means of major considerable anions HCO_3, SO_4, NO_3, and PO_4 and major considerable cations Ca, Mg, Na, K. The chemical investigation of water samples were plotted on Piper using geochemistry software Rock works 17.

The ternary plot of HCO_3, SO_4 and (Cl + NO_3) revealed that many of the samples fall towards the apex of HCO_3 and SO_4 (Fig. 4.14) while in a trilinear plot of Ca, Mg and (Na+K) most of the samples fall towards the apex of Ca (Fig. 4.15). This specifies that the chemistry of Dehradun city is affected by the weathering of carbonate rocks. A Piper diagram (Piper 1994) shows the supremacy of alkaline ions, i.e., Ca^{2+} and Mg^{2+} over alkalis (Na^+ and K^+) and less acidic nature of HCO_3^-

has exceeded the strong acid (SO_4^{2-}) in majority of the samples. Piper diagram (Piper 1994) (Fig. 4.15) shows major ion chemistry of Dehradun city largely dominated by Ca, HCO_3 and SO_4 ions. The hydro chemistry of the region indicates that there is leading phenomenon for hydrochemical in Dehradun are Ca-HCO_3 and Ca-Mg-HCO_3 (Fig. 4.15).



(a)



(b)

Fig. 4.14: Ternary plot between a) $HCO_3$and (Cl + NO_3 and SO_4) b) (Ca + Mg), Na & K.

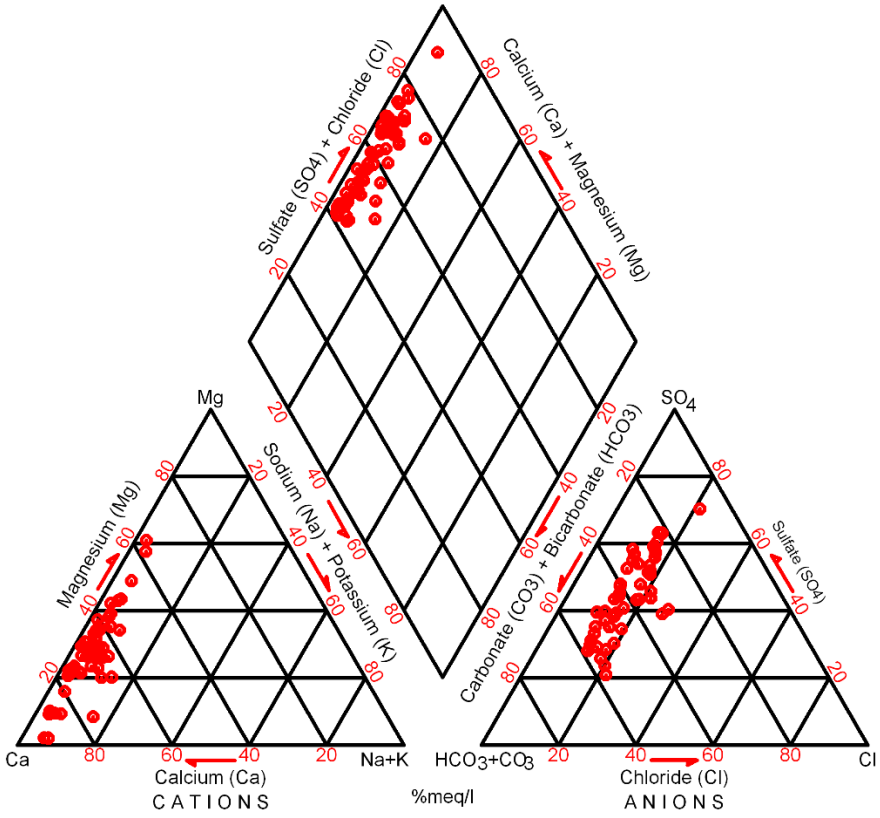


Fig. 4.15: **Piper trilinear diagram showing the dominant hydrochemical facies**.

4.1.1.10 Schoeller Diagram

The Schoeller diagram depicts the concentration discrepancies of chemical ingredients of ground water in Dehradun City. The statistics defined that the chemical inorganic solutes of water samples accumulated in the Dehradun City had been preferably affected by anthropogenic input in contrast to the natural chemical weathering.

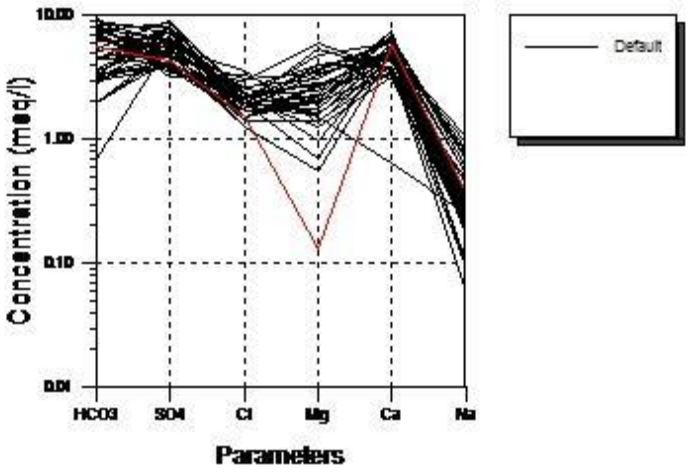


Fig. 4.16: Schoeller diagram

4.1.2 Solid Waste Analysis:

4.1.2.1Solid Waste Quantification & Characterization study of legal and illegal dumping sites:

Solid waste samples were collected in sampling bags.

- Solid waste samples have been collected from legal dumping site Nunarkheda (Sahastradhara road) and illegal dumping sites near Bindal Bridge & Rispana Bridge in Dehradun City. Total 10 number of samples were gathered from the distinct sites.

Table 4.7: Solid waste sample Quantification

Sample No.	Plastic/Paper (g)	Organic Waste(g)	Textile(g)	Glass (g)	Inert Material (g)	Total(g)
Sample No. 1	0.54	0.83	0.23	0.14	0.089	1.829
Sample No. 2	0.64	0.68	0.34	0.35	0.18	2.19
Sample No. 3	0.89	0.84	0.24	0.46	0.21	2.64
Sample No. 4	0.43	0.58	0.35	0.43	0.115	1.905
Sample No. 5	0.64	0.73	0.34	0.11	0.089	1.909
Sample No. 6	0.34	0.43	0.31	0.24	0.13	1.45
Sample No. 7	0.73	0.44	0.31	0.13	0.11	1.72
Sample No. 8	0.84	0.63	0.31	0.11	0.08	1.97
Sample No. 9	0.63	0.876	0.41	0.096	0.24	2.252
Sample No. 10	0.57	0.76	0.38	0.119	0.12	1.949

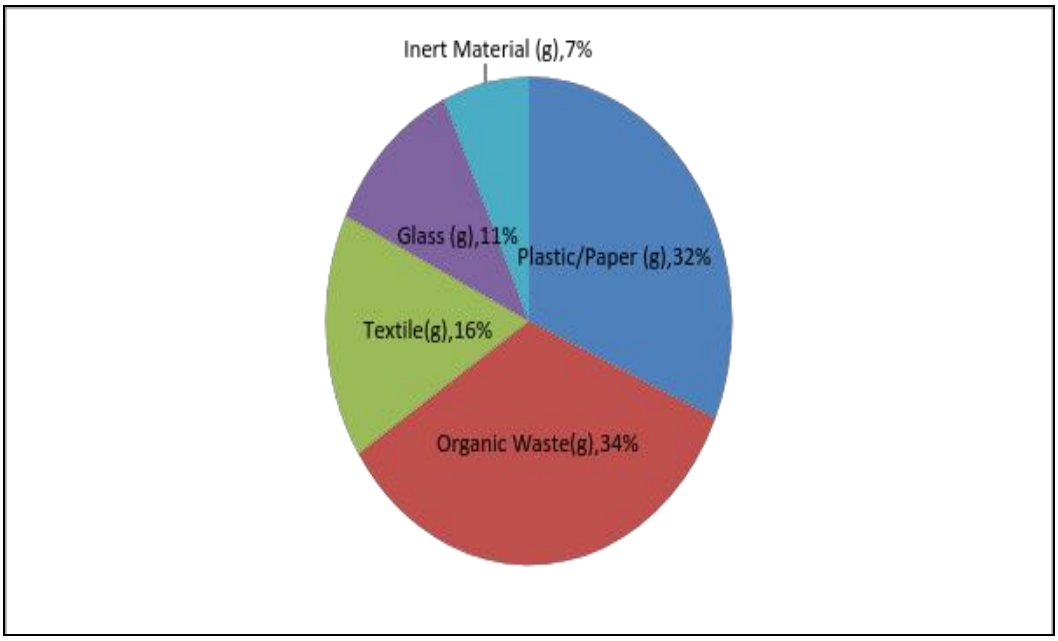


Fig. 4.17: Solid waste composition Quantification

4.1.2.2 Solid Waste Characterization:

Table 4.8: Solid waste Characterization

Sample No.	Moisture Content (%)	Total Solids (%)	Volatile Contents (%)	Non-Volatile Contents (%)	Ash Contents (%)
Sample No.1	17.88	82.11	4.55	95.44	4.64
Sample No.2	11.49	88.5	6.49	93.5	7.26
Sample No.3	12.34	87.65	4.68	95.31	5.13

Sample No. 4	13.9	86	5.2	94.7	5.6
Sample No.5	16.32	83.68	5.43	94.57	5.33
Sample No. 6	14.32	85.68	6.32	93.68	7.32
Sample No. 7	17.13	82.87	5.43	94.57	6.43
Sample No. 8	16.36	83.64	5.41	94.59	5.32
Sample No. 9	14.32	85.68	5.32	94.68	6.42
Sample No. 10	16.31	83.69	5.31	94.69	5.31

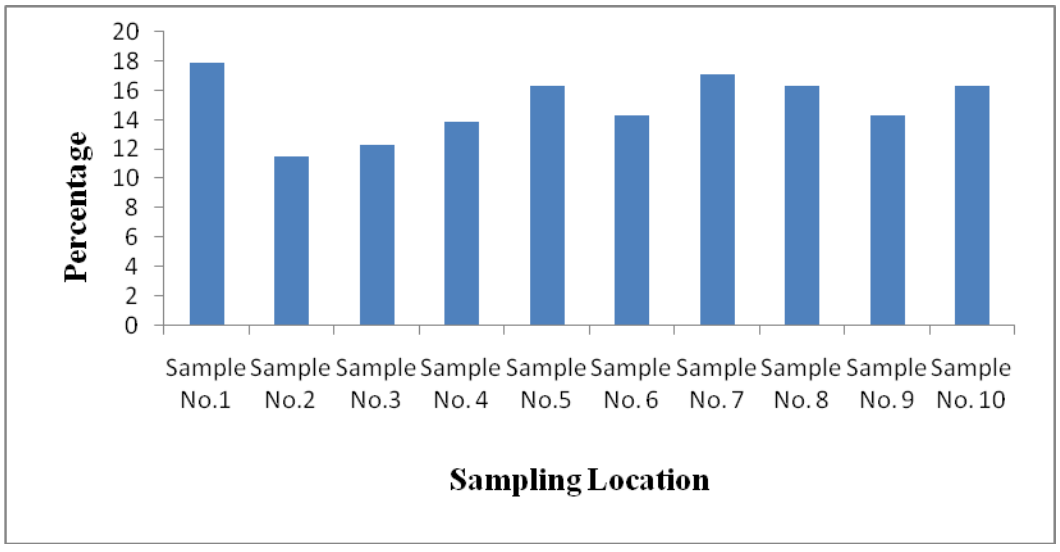


Fig. 4.18: Moisture content in solid waste

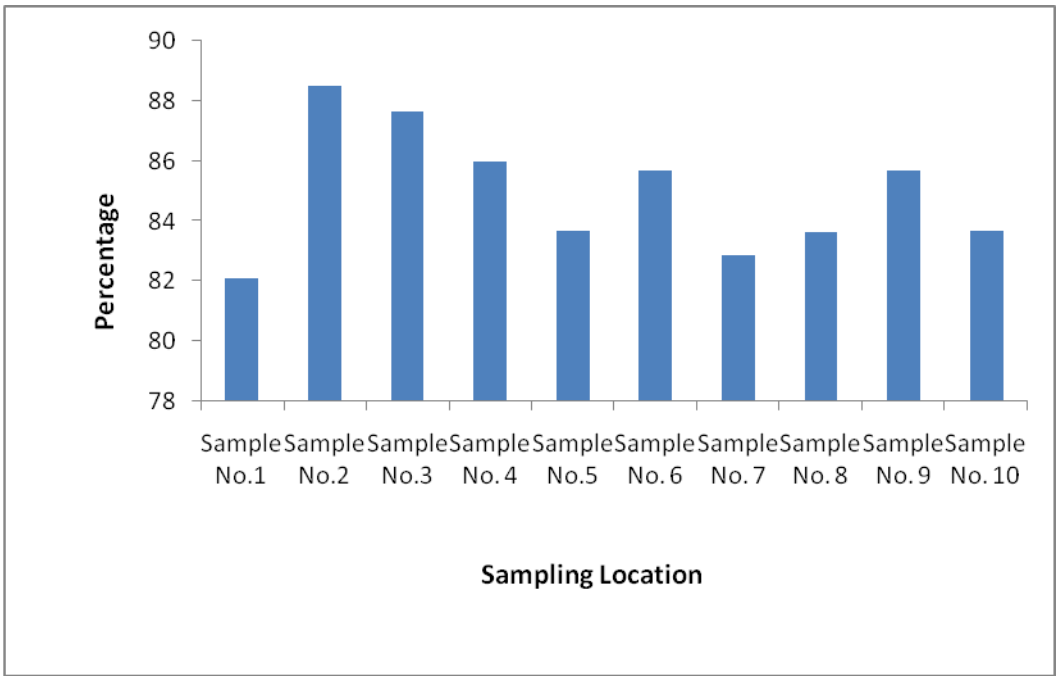


Fig. 4.19: Total solid content in solid waste

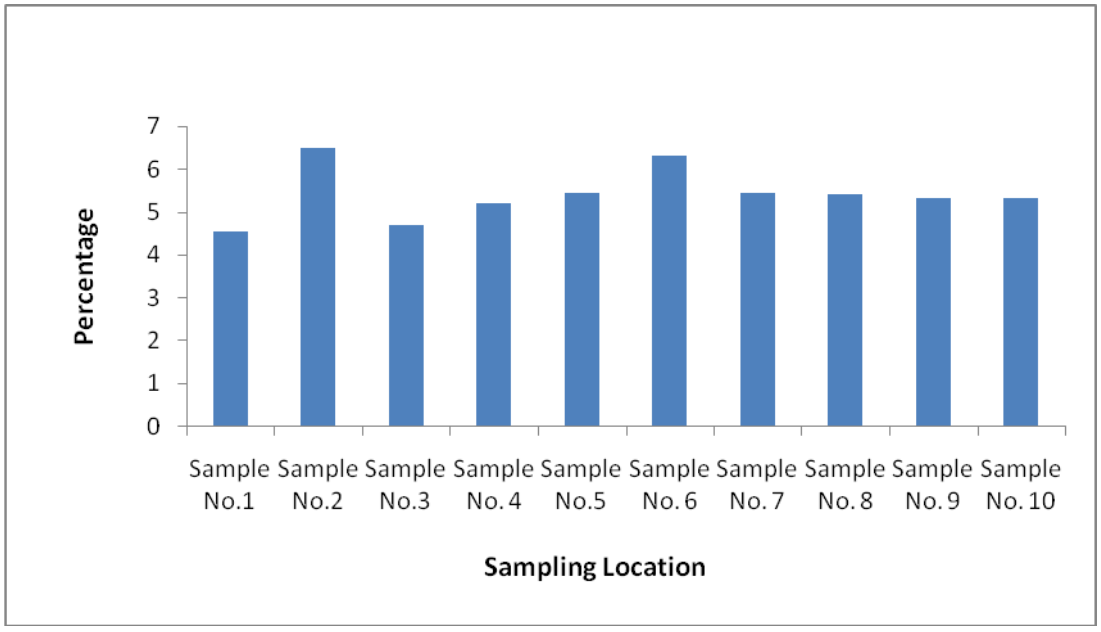


Fig. 4.20: Volatile content in solid waste

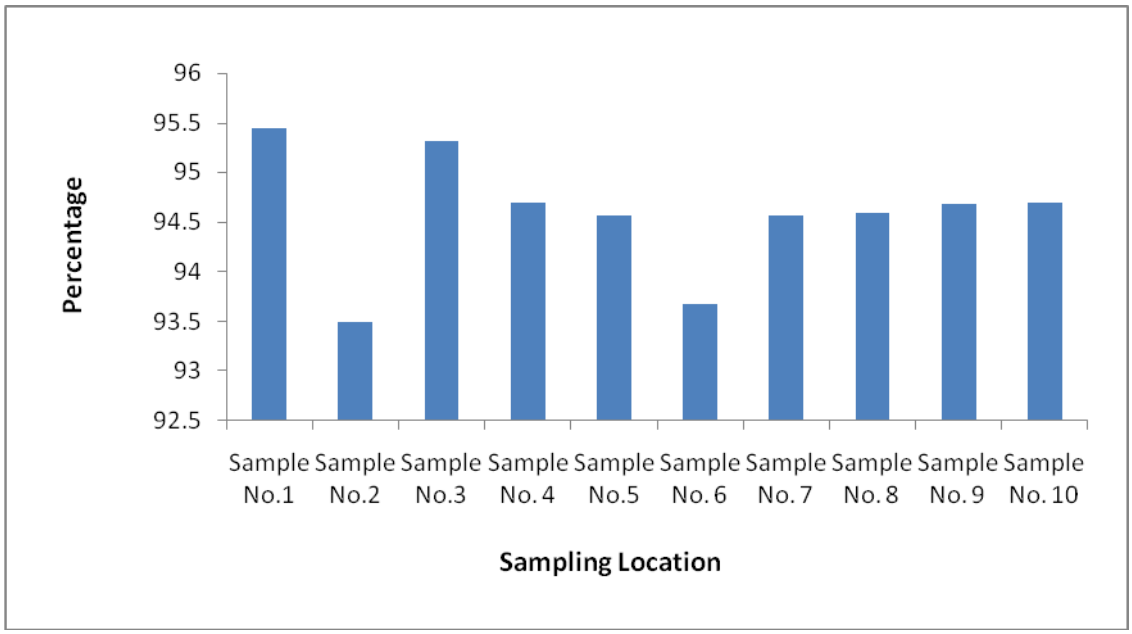


Fig. 4.21: Non-Volatile content in solid waste

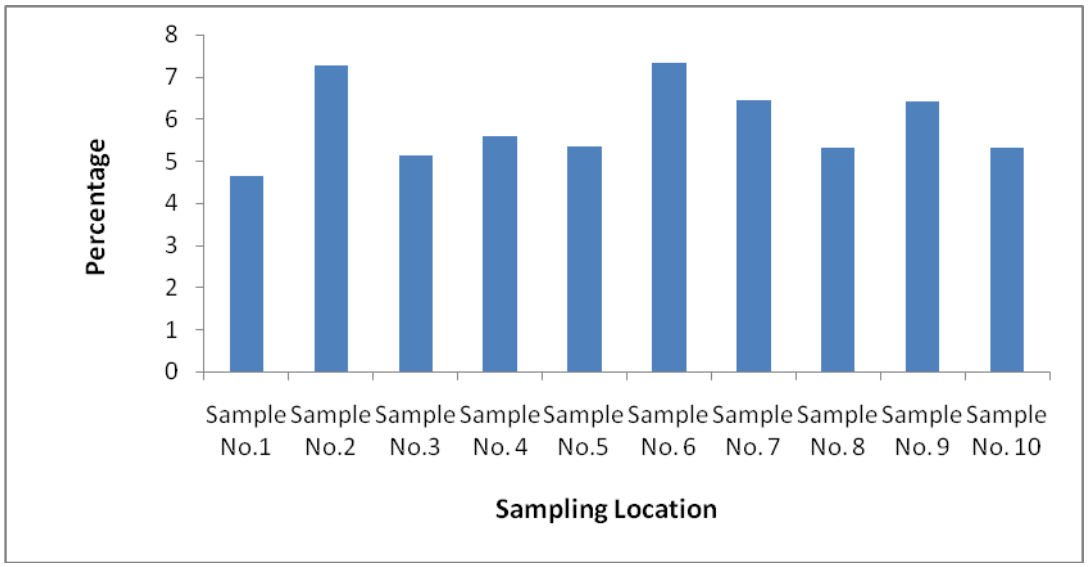


Fig. 4.22: Ash content in solid waste

4.1.2.3 Quantification & Characterization study of Household Municipal Waste

A. Solid Waste Quantification:

The Household MSW is collected from Dehradun city is divided into three zones on the basis of income level i.e. High Income Level (Vasant Vihar), Middle Income Level (ChamanVihar), Low Income Level (Kanwali Road, M.D.D.A Colony). The results of the waste quantification and characterization are given below:

Table 4.9: Quantification of MSW from High, Middle & Low Income Level Zones

Sample No.	Recyclable Waste		Food Waste		Total (kg)
	In kg	In %	In kg	In %	
High Income Level	0.90	12.67	6.405	87.32	7.33
Middle Income Level	1.73	42.57	2.34	57.42	4.07
Low Income Level	0.76	16.61	3.84	83.38	4.60

a. High Income Level:

Quantification of high income level waste generation has been discover out, and it was validated that food waste was 6.405 kg per day it and recyclable waste used to be 0.930 kg per day. Recyclable waste represent 12.67% whereas food waste constitute 87.32 percent per day.

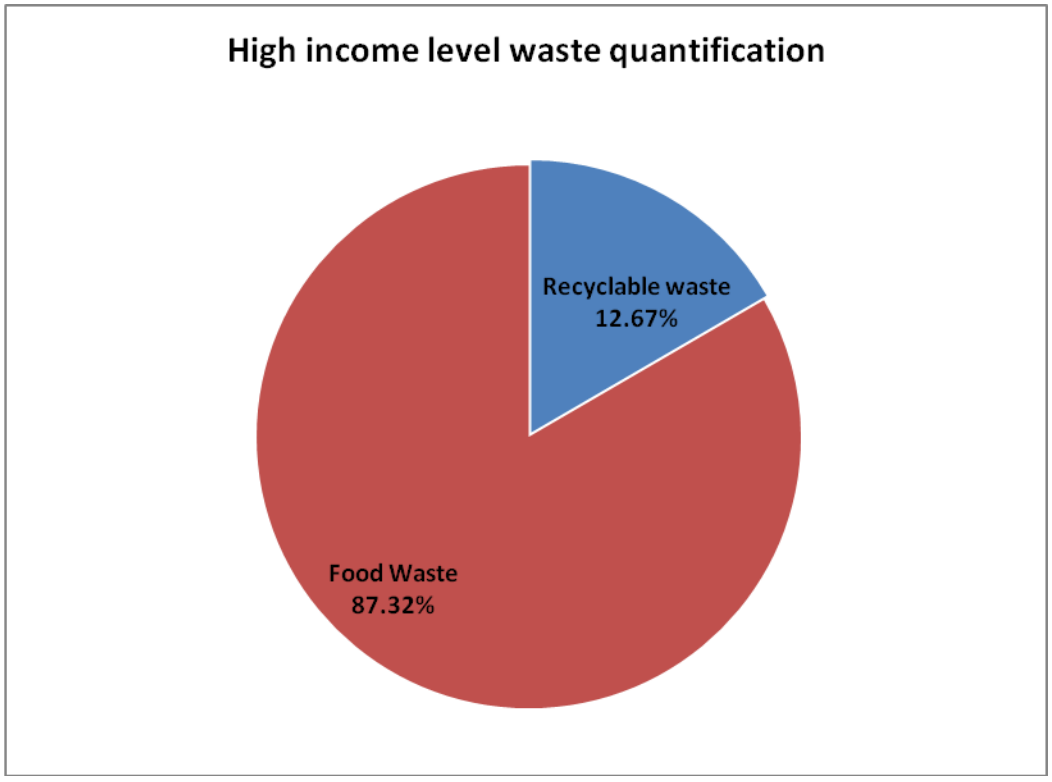


Fig. 4.23: High income level waste quantification

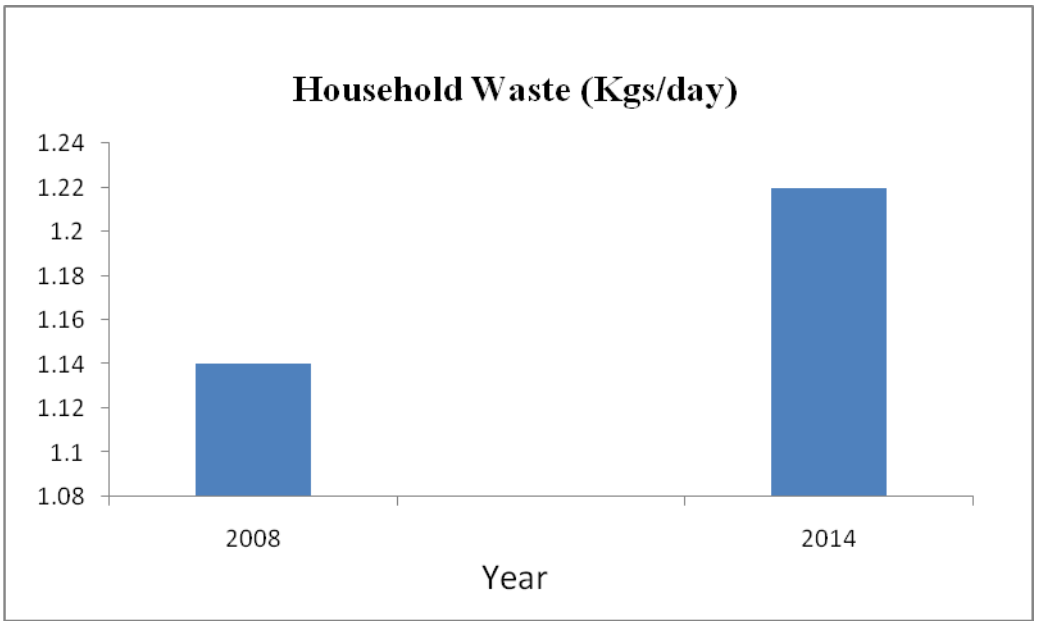


Fig. 4.24: Comparison of year 2008 data with present solid waste data

From the survey, it was concluded that 1.22 kg per household waste is produces.

➢It would yield 8.54 kg wastes during the week from each household.

➢In the year, 445.3 kg waste would be produced from each household.

➢ From the study carried out in the year 2008, it was found that household waste of high income zone per day was 1.14 kg. [DPR, Dehradun, JNNURM]

➢The latest 2014 survey shows a fast increase of 0.8 kg / day.

b. Middle Income Level (ChamanVihar):

Middle-Income Zone shows that the production of non - recyclable waste was 2.34 kg per day and food waste was 1.735 kg per day. The percentage of recyclable waste and food waste observed are 42.57% and 57.42% per day respectively.

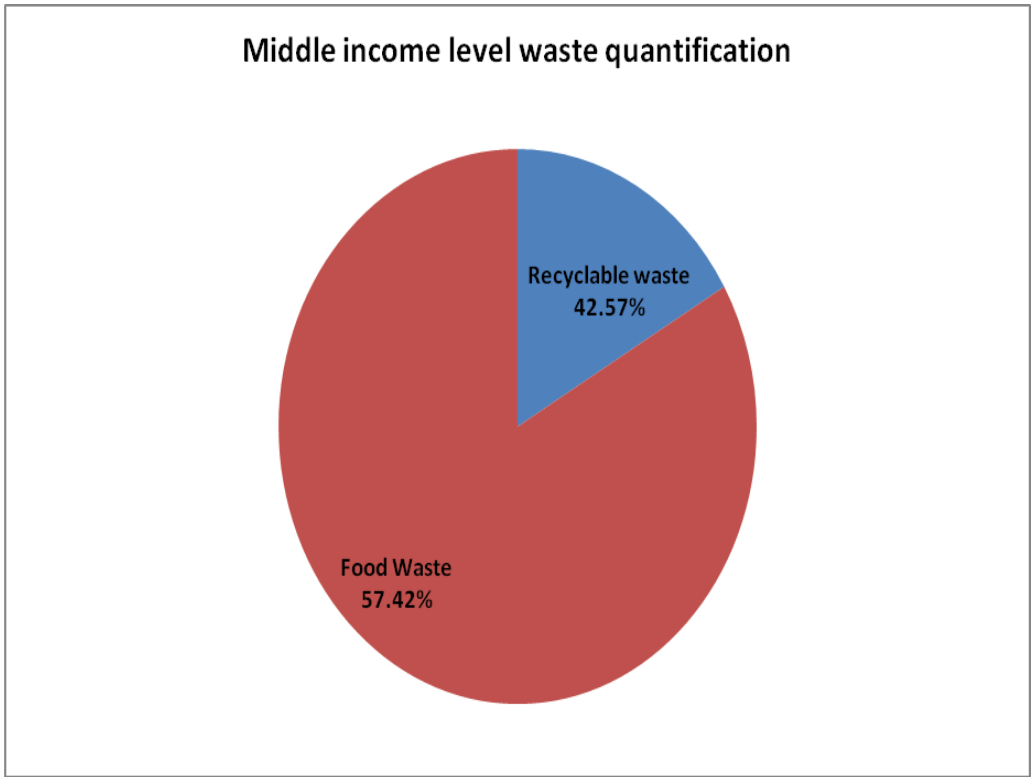


Fig. 4.25: Middle income level waste quantification

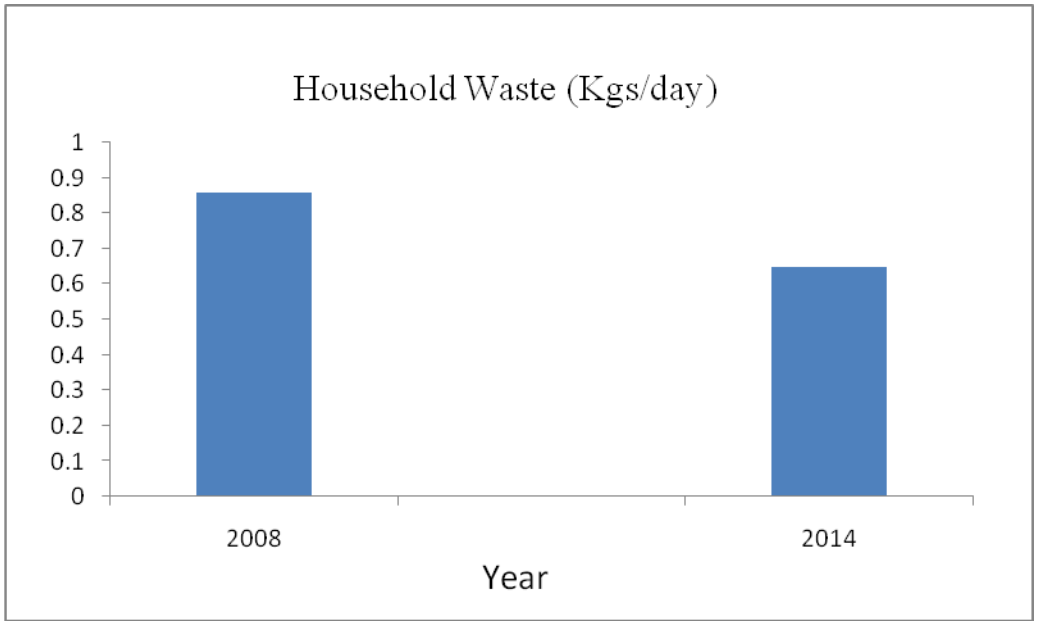


Fig. 4.26: Comparison of Year 2008 data with present Solid Waste data.

- The present study shows that 0.58 kg of waste is generated from each household.
- The waste generation of the week would be 4.06 kg from each household.
- The waste generation for the year would be 211.7 kg from each household.
- From the study carried out in the year 2008, it was found that household waste of middle-income zone per day was 1.02 kg. [DPR, Dehradun, JNNURM]
- The latest 2014 survey shows that there is reduction of 0.44 kg of waste with respect to study carried out in the year 2008.

a. Low Income level (Kanwali Road, M.D.D.A Colony):

Quantification of low income level waste has been depicted out, and it is used to be restrained that food waste was 0.765 kg per day and recyclable waste was 3.84 kg per day. The percentage of recyclable waste constitutes 16.61% and food waste constitutes 83.38% per day.

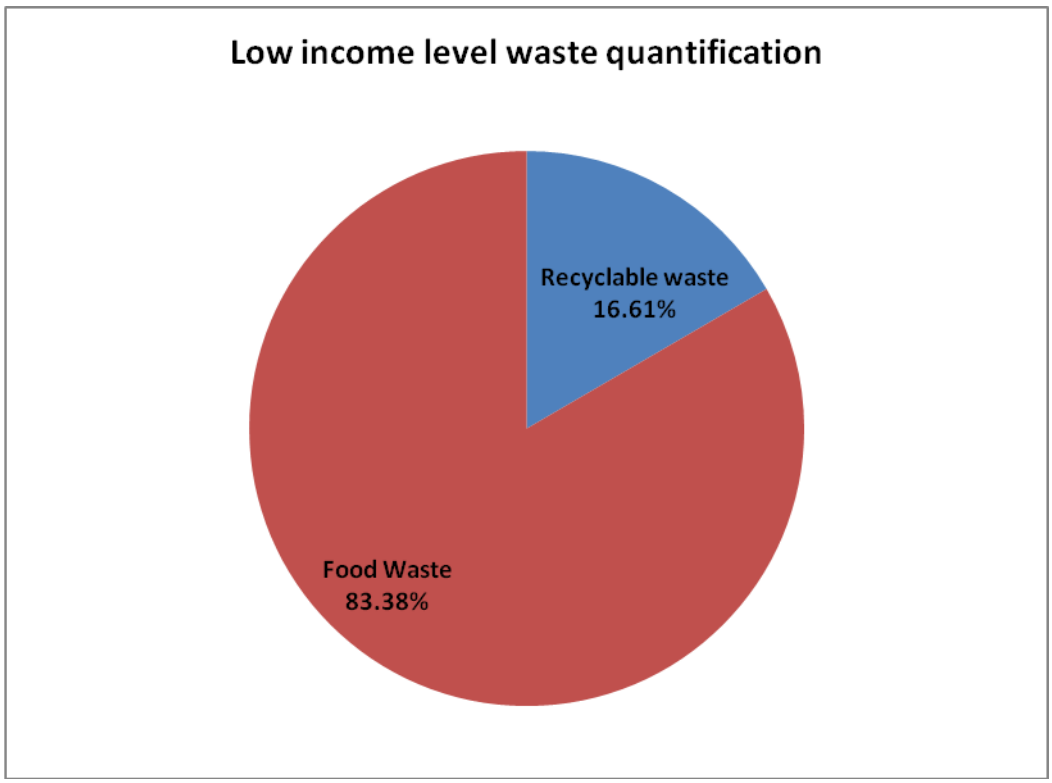


Fig. 4.27: Low income level waste quantification

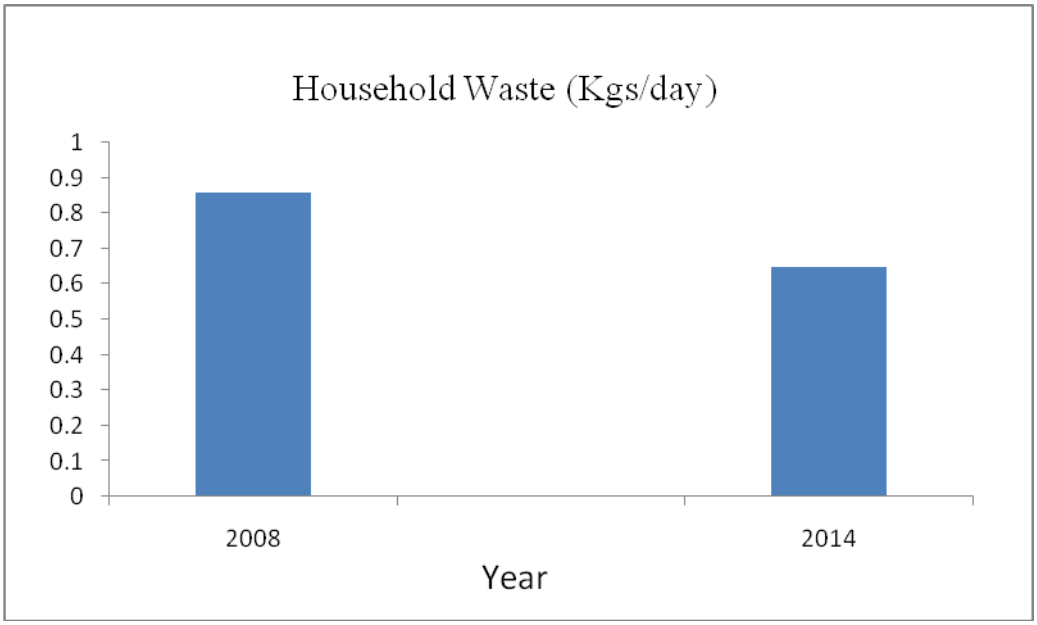


Fig. 4.28: Comparison of year 2008 data with present solid waste data.

● From the present study, it concluded that 0.65 kg per household waste is produced.

● The waste generation of the week would be 4.55 kg from each household.

● The waste generation for the year would be 237.25 kg from each household.

● From the study carried out in the year 2008, it was found that household waste of low-income zone per day was 0.86 kg.[DPR, Dehradun, JNNURM]

● The latest survey shows that there is reduction of 0.21 kg of waste with respect to study carried out in the year 2008.

B. Chemical analysis for household municipal solid waste:

The household samples were analyzed for the moisture content, total solids, volatile and non-volatile contents, Ash Contents and the results were given below:

Table 4.10: Analysis of household municipal solid waste

Sample No.	Moisture Content (%)	Total Solids (%)	Volatile Contents (%)	Non-Volatile Contents (%)	Ash Contents (%)
High Income Level	14.32	85.68	6.32	93.68	7.32
Middle Income Level	16.31	83.69	5.31	94.69	5.31
Low Income Level	17.13	82.87	5.43	94.57	6.43

4.1.2.4 Weather and Terrain Parameters

4.1.2.4.1 Weather Parameter

a. Effects of Rainfall on Solid Waste

The district receives approximate annual rainfall of 2149.9 mm. Most of the rainfall occurs from June to September, while July and August months are the maximum rainfall period. The location nearby Raipur receives the utmost rain, whereas the southern half of it obtains the smallest quantity of rain in the district, related to 87% of the annual rain is got in the route of the quantity from June to September. The details of the Rainfall in Doon Valley are listed in the table below:

Table 4.11: Annual rainfall

Months	Rainfall (mm)
January	57.9
February	66.8
March	37.9
April	19.6
May	35.8
June	184.4
July	655.6
August	713.0
September	304.5

October	41.9
November	7.6
December	24.9

(*Average for last 25 years)

Considering the above rainfall data of Dehradun city which gives an average annual rainfall of 180mm, which can be calculated with rational equation calculation, of area 1 km^2 so with the soil co-efficient and solid waste water accumulation it is found that 90000 m^3 of waste water as leachate is coming out from the solid waste which pollute the ground water table and soil quality of the particular area.

b. Effects of Temperature on Solid Waste

At times, the district has high hills of the External Himalayas as accurate as the Doon Valley, with environmental stipulations much like these within the plains. The value of temperature relies upon the height. The weather of the Doon is usually temperate in nature. In the mountainous regions, the summer season is magnificent on the different hand within the Doon Valley, the warmness if generally intense. The temperature drops underneath freezing factor now no longer entirely at excessive altitudes however additionally even at locations like Dehradun at some stage in the winters, as soon as the top peaks measure beneath snow. The summer season starts in March and lasts until the middle of June when the monsoon units arrive. Generally, in the month of May and early June are with average temperature rise up to 36.2 ° C in Dehradun. At Dehradun, the maximum temperature rises upto 42°C. Winter begins in November and lasts until February. The maximum daily temperature at any point in the winter season is 19.1 ° C at Dehradun. The mean value of temperature in January during the day is 6.1 ° C in Dehradun.

Table 4.12: Annual Average temperature

Months	Max.	Min.	Average
January	19.3	3.6	10.9
February	22.4	5.6	13.3
March	26.2	9.1	17.5
April	32	13.3	22.7
May	35.3	16.8	25.4
June	34.4	29.4	27.1
July	30.5	22.6	25.1
August	29.7	22.3	25.3
September	29.8	19.7	24.2
October	28.5	13.3	20.5
November	24.8	7.6	15.7
December	21.9	4.0	12.0

The temperature range in Dehradun city, the variation can be seen in the table, the value of maximum temperature is reached in the month of May of about 35.3°C and minimum temperature is at January of about 3.6°C. This minimum temperature will stop the growth of bacteria and stop the biodegradation process,

which create problem for filling and again Leachate generation is higher. At the time of higher temperature, the methane generation is higher when compare to other months so care need to be taken to avoid fire accidents.

c. Effects of Humidity on Solid Waste.

Moisture is the combination of water fed on into the material as vapor or liquid. It can be asserted in two different ways, as an end result percentage of the moist weight of the specimen or as a percentage of the dry weight of the specimen. The variation of moisture depends on the change in climatic condition of the Dehradun city; it depends on rainfall, ambient temperature, mountain covers and wind velocity.

Table 4.13: Annual Humidity

Months	Relative Humidity (%)
January	91
February	83
March	69
April	53
May	49
June	65
July	86
August	89
September	83

October	74
November	82
December	89

The RH of the city is quite higher throughout the year except in the month of April and May, it varies from 70- 85 % on average.

Moisture will smash various substances in an tremendously capability that they are not viable to recycle. For instance if wet waste and dry waste area unit sequestered at supply, the waste can be reclaimable if transported straight from first customer to the client, then again the standard will perhaps deteriorate if it is transported first to recycler's yard and from there to client. Within the yard the material lays outside and if there is rain, the material will get wet. Particularly paper and other fiber products are touchy to wetness, as a result of it cuts fibers and makes the fabric dirty. During this case the materials are certified as energy waste. This as a result regarded as downshifting will show up very often for calculable reasons. One in all the most essential reasons is that these substances will lay for long durations of time exterior and also the cloth gets wet, and additionally due to tiny yards where mixing with other substances shall also takes place.

4.1.2.4.2 Terrain Parameters

a. Water Table:

The contamination in groundwater is usually irreversible i.e. it is difficult to revitalize the preliminary creation of water as soon as it is contaminated. Excessive groundwater mineralization degrades water to an inconceivable taste, smell, and hardness. The Nunarkheda dump site on Sahastradhara road, in Dehradun,was selected. The boring wells and hand pumps are available in

residential areas around this dump site. The depth of the hand pumps on the site ranges from 350 - 450 ft. The present research was aimed to investigate underground water parameters for their physical and chemical properties. The parameters of physico-chemical applications were studied and analyzed, including temperatures, total dissolved solids, pH, electric conductivity and alkalinity. This is an effort to check quality of ground water and its adverse effects on people who settled near a dumping site. The total five number of sampling site were identified for determining the current groundwater quality at Nunarkheda dumping site (Bore-well at Hill view apartment). While carrying out the physico-chemical analysis and comparing the same with BIS standards it is observed that the water is not fit for drinking purpose and quality is considered fair. The information on this suggests that sites in densely populated cities needs be monitored on daily basis. It reveals that ground water near to such dump sites are no longer suitable for drinking water purpose until they meet the specific norms of drinking water and spherical of low waste deposits until they meet specific norms, and the processing of waste in areas built without splendid and efficient waste management procedures must be avoided.

Table 4.14: Results of water quality near dumping site

Parameters	Unit	Average	MAX.	MIN.	IS (Indian Standards)
Temp.	°C	29.28	29.4	29.1	-
pH	-	7.5	7.8	7.29	6.5-8.5
Turbidity	NTU	0.03	0.05	0.03	5
EC	µS/cm	354	370	330	-
DO	mg/l	15.98	16.9	15.1	-
TDS	mg/l	358	390	320	500
Total Hardness	mg/l	314	330	290	300

Ca	mg/l	71.4	79	60	75
Mg	mg/l	1.66	1.92	1.32	30
Na	mg/l	7.6	7.9	7.3	-
K	mg/l	1.56	1.8	1.3	-
HCO_3	mg/l	359.84	384.2	335.6	200
Cl	mg/l	56.8	59.2	53.7	250
F	mg/l	0.44	0.56	0.31	1
SO_4	mg/l	189.57	202.76	173.4	200
NO_3	mg/l	3.87	4.92	3.26	45
PO_4	mg/l	4.78	5.76	4.12	-
Fe	mg/l	0.06	0.09	0.04	0.3
Cu	mg/l	0.01	0.03	0.01	0.05
Pb	mg/l	0.01	0.03	0.01	0.05

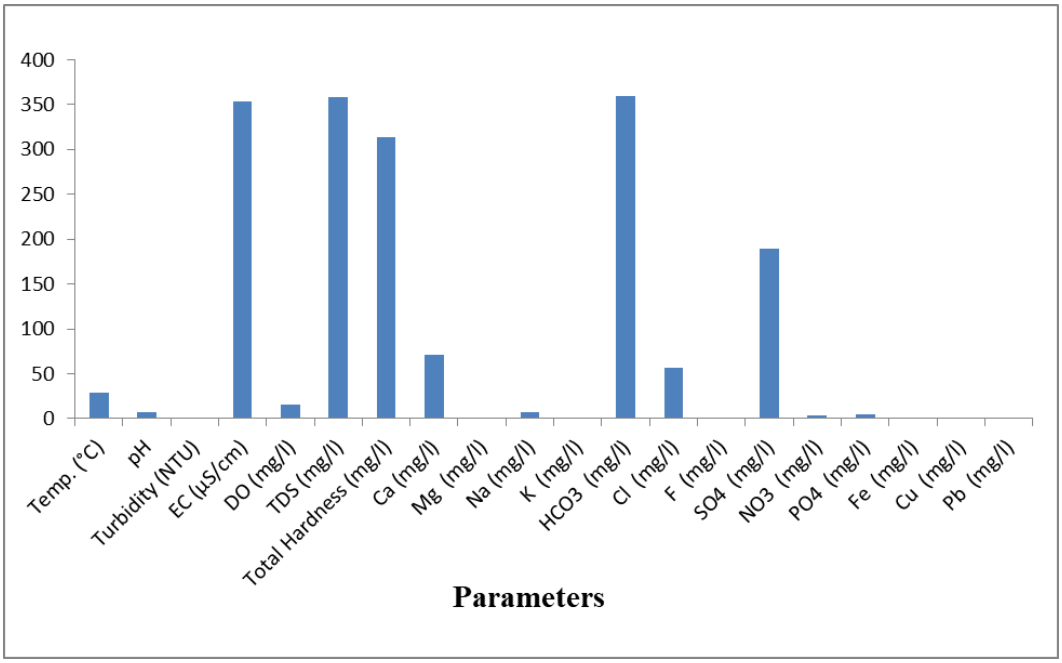


Fig. 4.29: Graph showing water quality near dumping site.

b. Soil Type:

In agriculture, nature and soil type have a very necessary role and are directly related to water charging. The nature and type of soil are based on the physiography, atmosphere, geology and drainage. The type of soil also relies on the soil erosion and slope.

Table 4.15: Physiography and characteristics of soil in Dehradun city.

Physiography	Characteristics
Mountains	Moderately deep, well-drained, heat-cutting loamy soils, solid, stony, linked to low - lying and over-drained loamy skeleton soil.
Soils on Upper piedmont plains	Wide loamy cowl, well-drained, scant land on a gentle, loamy slope and moderate erosion. Like poorly drained soils with a moderate to medium erosion surface. Wide, excellently drained, coarse to rocky, loamy soil, with mild to moderate erosion.
Soiloon Lower piedmont plains	Deep, well drained, gross loamy cowl on almost stage plains with a loam-filled surfacing over fragmentary soils. Deep, well-drained, exceptional loamy soil with a loamy base. Wide, well drained, loose, great soil with loamy soil and moderate degradation on very mild slopes. Deep, properly drained and slight to reasonably erosive loamy ground.

Disposal solid waste onto land could also be a common waste disposal technology and specifically practiced throughout cities around the world. Precipitation that infiltrates the rotten waste components through municipal solid waste leaches leading to contamination of soil by organic or inorganic solutes. Accordingly, an assessment in this regard has been carried in the present study. Before and after

refusal place, soil profile pits were excavated. When the solid waste are inserted there before the solid waste was placed, they were compared to the physico - chemical parameters. The study suggests that solid waste disposal modified the color and texture of the receiving soil along with improving its quality. The nature and interactions between the metals and the organic contents (adsorption and sophisticated forming) was clearly observed as describing the top values of the components analyzed in the soil when the waste has been poured into soil. The major change in the properties of soil is found in the dumping sites. The analysis or study of soil parameters is shown in the following table.

Table 4.16: Results of soil parameters near dumping site

Parameter	Unit	Average	Max.	Min.
pH	-	5.58	6.9	5
E.C.	µS/cm	6.03	20	0.3
Sulfur	mg/l	11.60	27	5.5
Calcium	mg/l	1523.8	2300	1001
Magnesium	mg/l	109.4	190	62
Potassium	mg/l	111.35	190	62
Chloride	mg/l	191.73	390	72
Iron	mg/l	3.71	5.7	2.3
Lead	mg/l	210.45	490	47
Copper	mg/l	1.57	7	0.4
Cadmium	mg/l	4.68	105	0.1
Nitrogen	mg/l	42.8	90	13
Phosphorous	mg/l	53.36	112	12
Zinc	mg/l	1.34	2.3	1

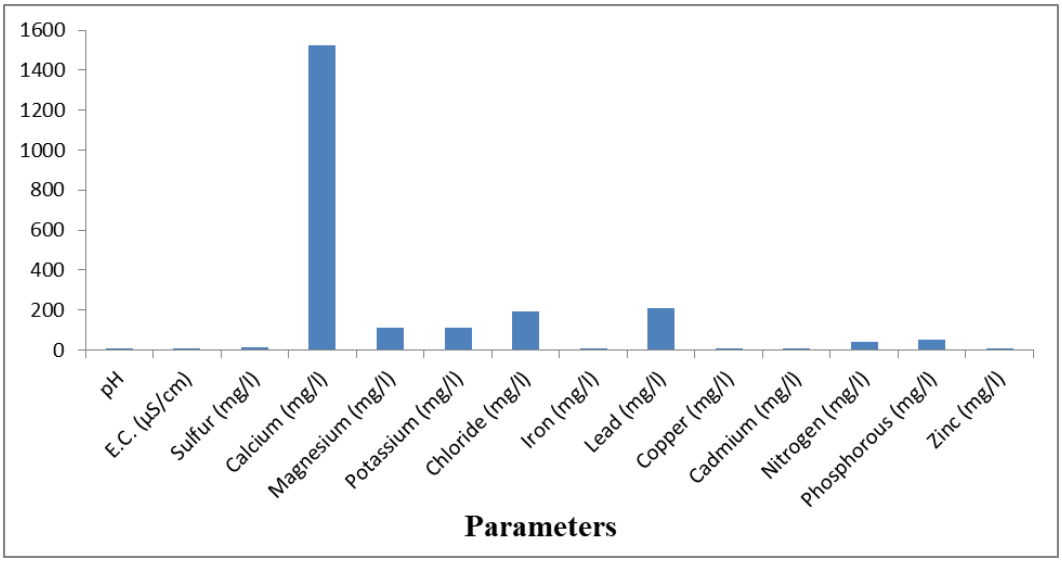


Fig. 4.30: Graph showing result of soil parameters near dumping site

The values of parameters in soil samples collected from dumping site (Nunarkheda) of Dehradun City are categorized in table above. The pH value affects the growth of plants due to nutrient deficiencies, rise in certain nutrients concentration and increasing levels of soil contaminants. The pH level varies from 5.0 to 6.9. The normal recommended value is 5.0 to 6.5.

The EC values lie between 0.3 and 20, with an average of 6.04. EC hampers the growth of the plants particularly. It describes salinity content in soil. Permissible values lies between 0.1 to 16.

Low nitrogen affects plants growth and excessive nitrogen can lead to Excess Foliage Growth, root growing stunting and underwater pollution. Nitrogen levels were found to be in between 13 to 90 mg/l with an average of 42.8 mg/l.

Phosphorous affects plant's reproduction, increased weed growth and affects plants ability to absorb water, zinc etc. from the soil. It's presence was found to be in the range of 12 mg/l to 112 mg/l with an average of 53.37 mg/l.

Potassium levels were found in the range 62 to 190 mg/l, with an average value of 111.35 mg/l. It stimulates early growth, protects plant from disease, microorganisms and increases protein production in plants.

Calcium improves soil structure in heavy clay soil, it helps plants to absorb nutrients better and helps in cell wall formation of plant. It was found in the range of 1001 to 2300 mg/l, as opposed to a prescribed range of 1000 to 2000 mg/l.

Magnesium aids in plant oil and fat formation and aids nitrogen fixation in soil, sugar synthesis in plant and helps in phosphorous transport to the plant from soil. Range of 62 to 90 mg/l was found in the soil specimens.

Sulphur was found in the range of 5.5 to 27 mg/l. Sulphur is a catalyst for chlorophyll production, promotes nodule formation in legumes and important component of compound that gives flavor to onion, mustard etc. It should not exceed 20 mg/l.

Iron should be present in the range 2.5 to 5.0 mg/l for it to help in chlorophyll development in plant, play a vital role in energy transfer within the plant, function in plant respiration and involve in nitrogen fixation. It was found in the range 2.3 to 5.7 mg/l.

Zinc was found in the range 1.0 to 2.3 mg/l. It is contaminant in soil which clings in food chain, has adverse effects in plants and living beings, results in discoloration of leaves and reduces leaf blade size. It should not exceed 1.7 mg/l.

Copper is contaminant in soil which clings in food chain, has adverse effects in plants and living beings and responsible for root growth of plant and helps in maintaining pH of the soil. Ideal range for Cu presence is 0.6 to 2.3 mg/l while it was found to be in the range 0.4 to 7.0 mg/l.

Permitted range for Lead is 43 to 480 mg/l. Lead is contaminant in soil which clings in food chain and has adverse effects in plants and living beings. Presence of lead was found in the range 47 to 490 mg/l with an average of 210.45 mg/l.

4.1.2.4.3 Comparative analysis of Data

a. Comparison of Jammu with Dehradun City

The amount of rainfall in Jammu is more than Dehradun, so the amount of leachate generation will be more in Jammu. The amount of humidity is almost same the biological activity will be similar in both the places. Minimum temperature of Jammu will stop the growth of bacteria and stop the biodegradation process, which create problem for filling and again Leachate generation is higher. At the time of higher temperature as of Dehradun, the methane generation is higher so care need to be taken to avoid fire accidents. The generation of waste in Dehradun is higher than Jammu which will lead to various problems such as waste management, bad odour & beauty of place etc. The pH of water in Jammu & Dehradun are alkaline so the composting will be done with ease and will mature early and used as bio-fertilizer. Low BOD level in water in both the places so the dissolved oxygen is better for aquatic life. The amount of TDS in water is more in Dehradun as compared to Jammu so the ions will be more present leading to increased corrosiveness & hardness of water. The COD value of water is more of Dehradun than Jammu which will lead to oxygen deficiency in water affecting aquatic life. Conductivity of Jammu is higher than Dehradun so the dissolved minerals in water of Jammu will be more.

Table 4.17: Comparison data of Dehradun and Jammu

S.No	Parameters	Dehradun	Jammu
1	Rainfall (mm)	1896	1909.7
2	Humidity (%)	55	57
3	Temperature (°C)	21.8	13.5
4	Solid Waste Generation (MT/day)	131	40.8
5	pH	7.67	8.48
6	BOD (mg/l)	3.7	2.71

7	TDS (mg/l)	628.33	370
8	COD (mg/l)	80	5.82
9	Conductivity (mS/cm)	146	197

(Data Source: State Pollution Control Board, Jammu and Kashmir)

4.2 Results and Discussion- Software Design and Development:

4.2.1 Modules of Expert System:

The section below presents expert system modules and their functionality. The following modules have been designed:-Map, Literature, Legislature, Waste Management, Analysis, Planning, Gallery, Reports, and Help. The expert system presents user interface as shown in Fig. 4.31. It also presents a login screen to accept login credentials of the user.

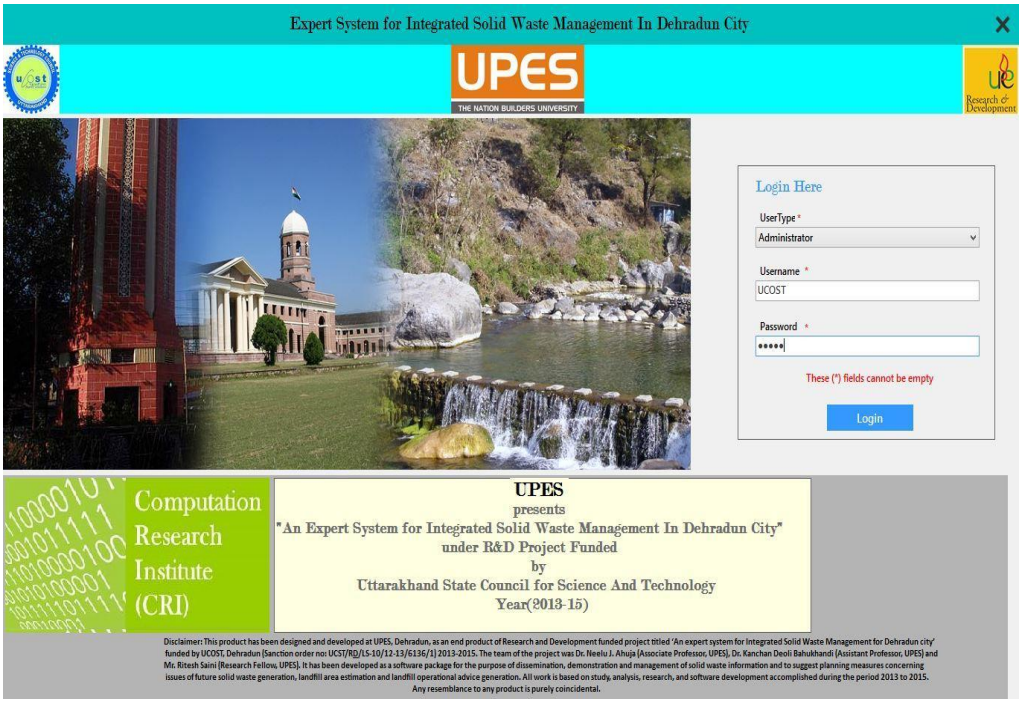


Fig. 4.31: Opening screen of Expert system

The user is expected to enter valid username and password to logon to the system. Here are two user types: - 'Administrator' and 'User'.

For ADMINISTRATOR Level : Username is "upes" and Password is "upes".

For USER Level : Username is "ucost" and Password is "ucost".

The user id & password are case-sensitive.

Next Screen presents a menu with all modules & sub modules. The section below presents each module, its purpose and a procedure to access its functionality.

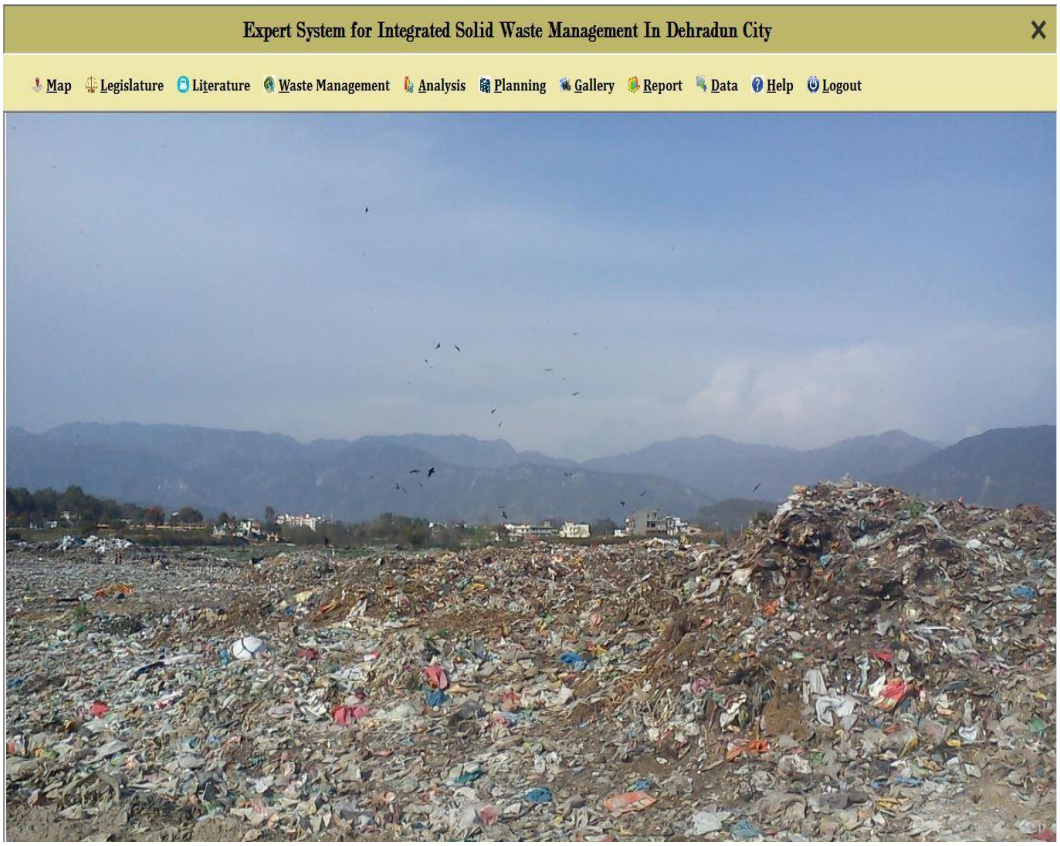


Fig. 4.32: Showing Main Menu

4.2.1.1 Map Module:

It consists of all the information of sampling sites. The ward wise sampling locations are indicated in the Map module.

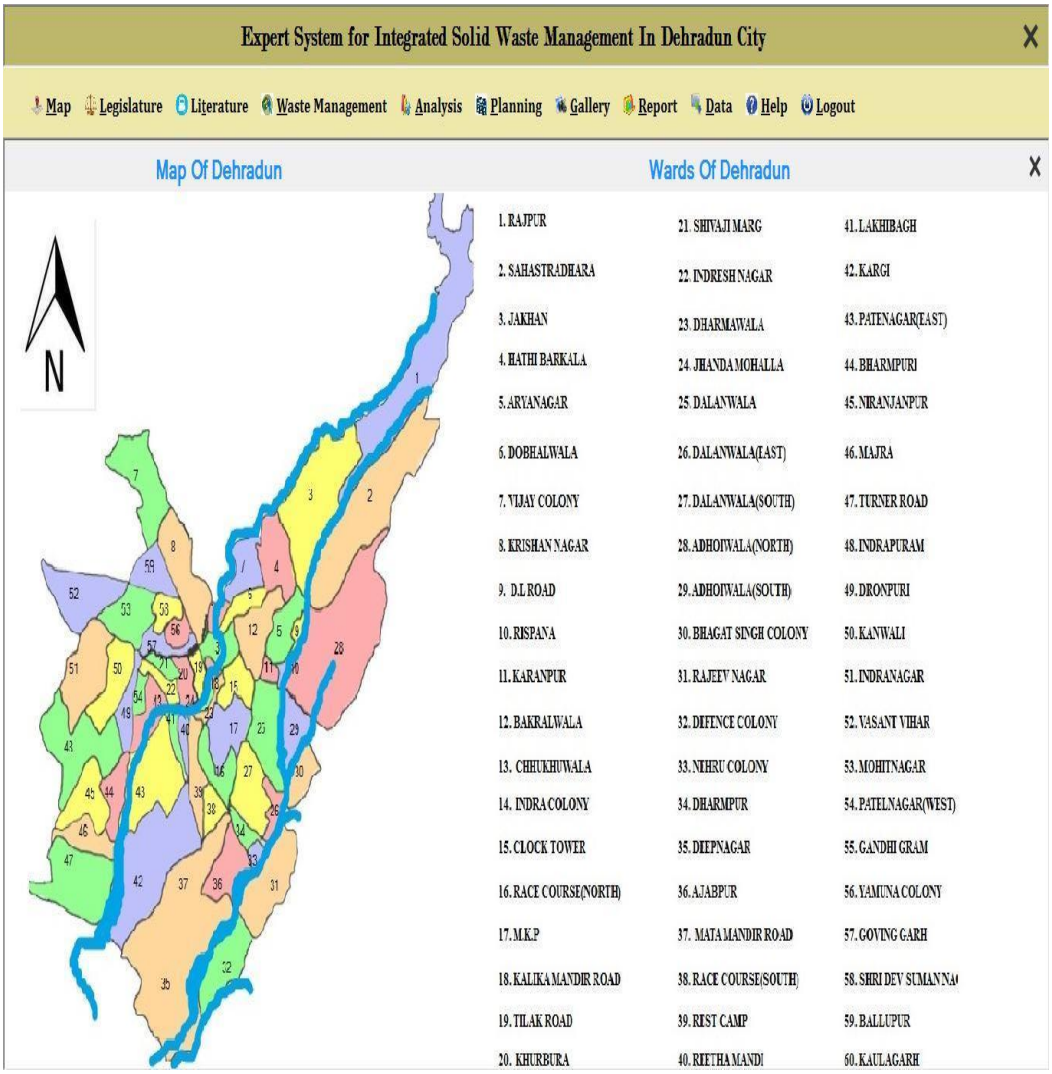


Fig. 4.33: Showing Map Module

4.2.1.2 Legislature Module:

It consists of all the information regarding laws and acts related to Municipal Solid waste and Environment.

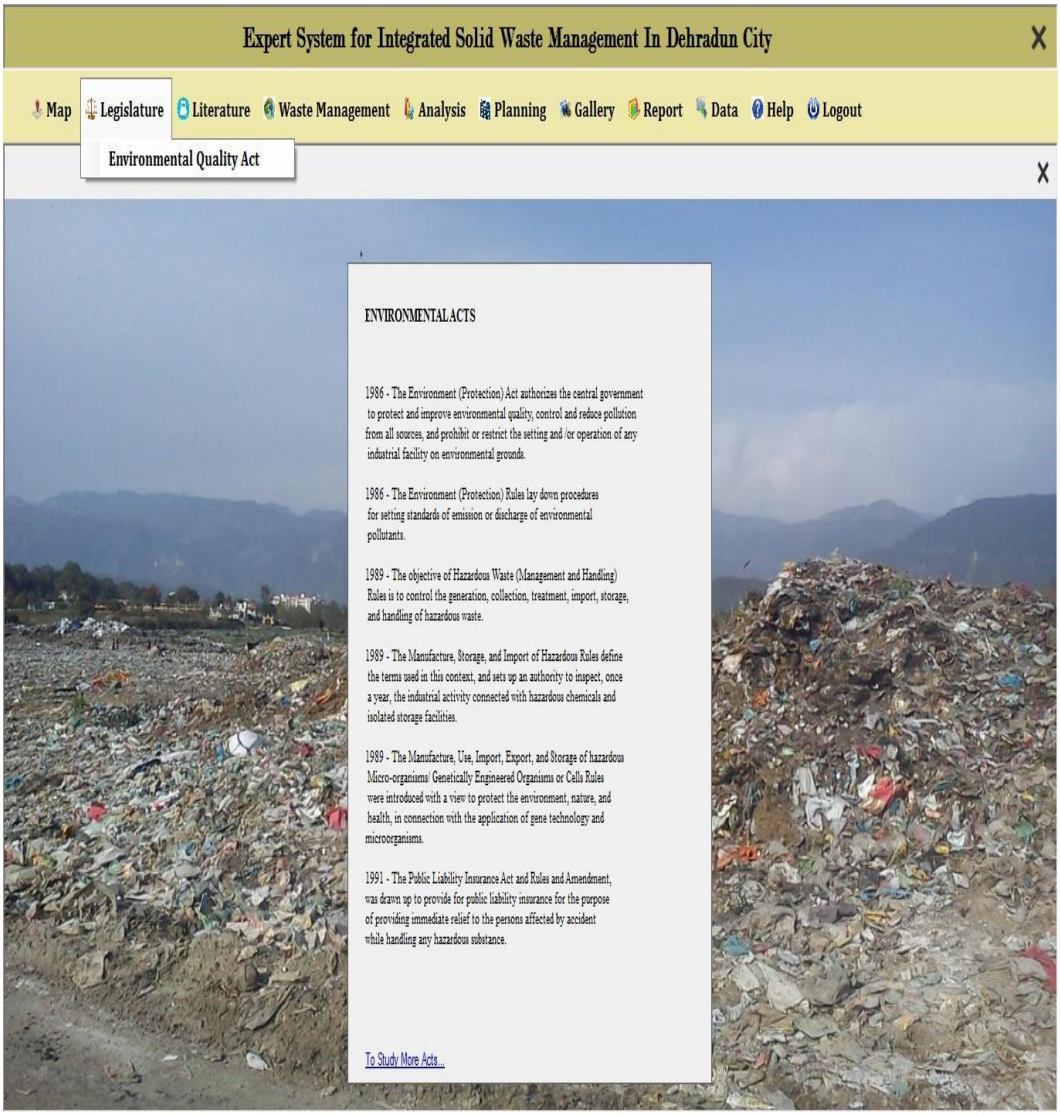


Fig. 4.34: Showing Legislature Module

4.2.1.3 Literature Module:

It presents literature on Expert systems and Solid waste Management. It also presents abstracts of research articles referenced during design & development of the present expert system through the life period of this study.

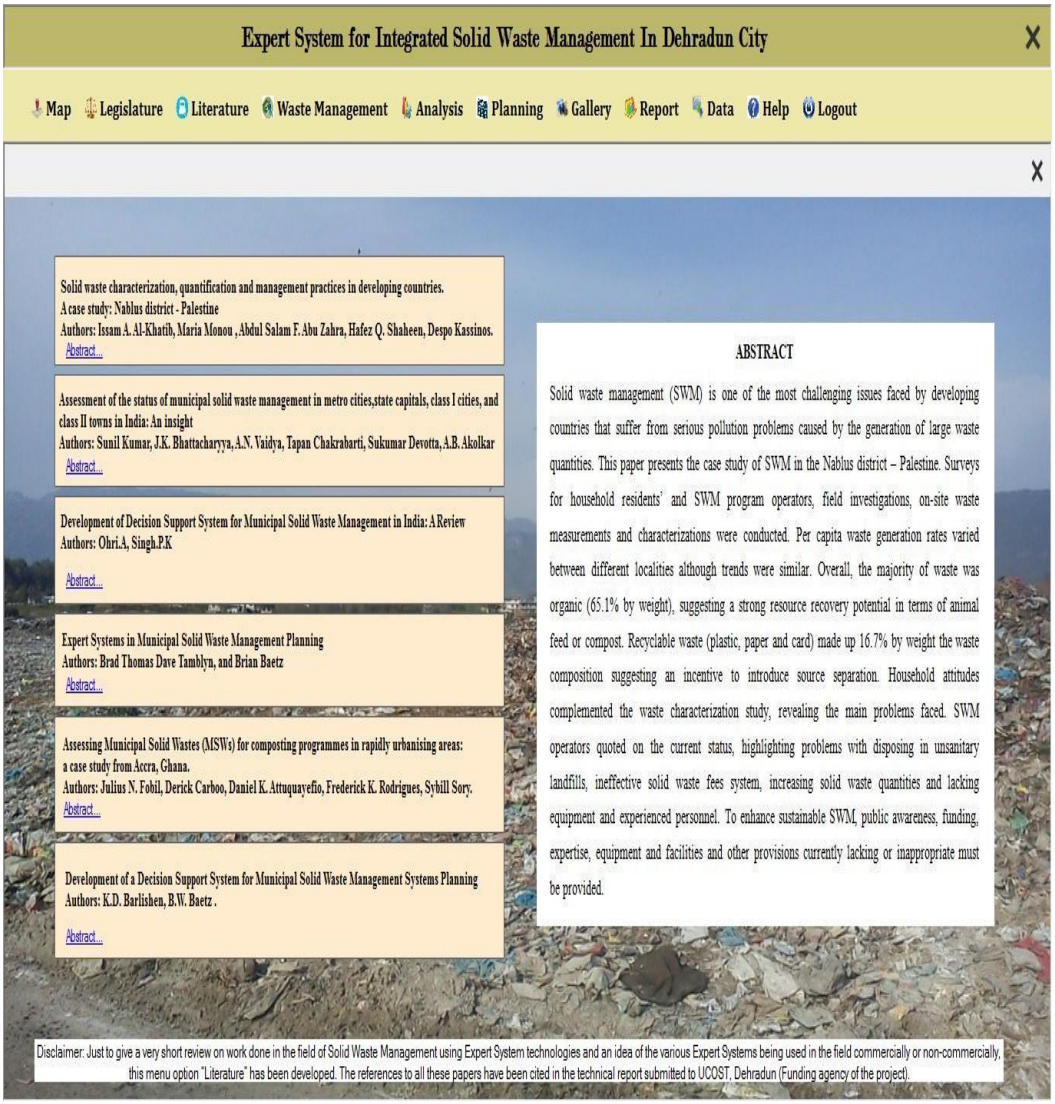


Fig. 4.35: Showing Literature Module

4.2.1.4 Waste Management Module:

It presents write up & reference information concerning handling and waste flow from waste generation site to the waste disposal site under three different sub modules," Program schemes", Waste collection process", & "Waste flow cycle", The relevant information is presented (Refer Fig. 4.36 to 4.42)

Fig. 4.36: Showing Waste Management Module

(a) Program Scheme Sub-Module:

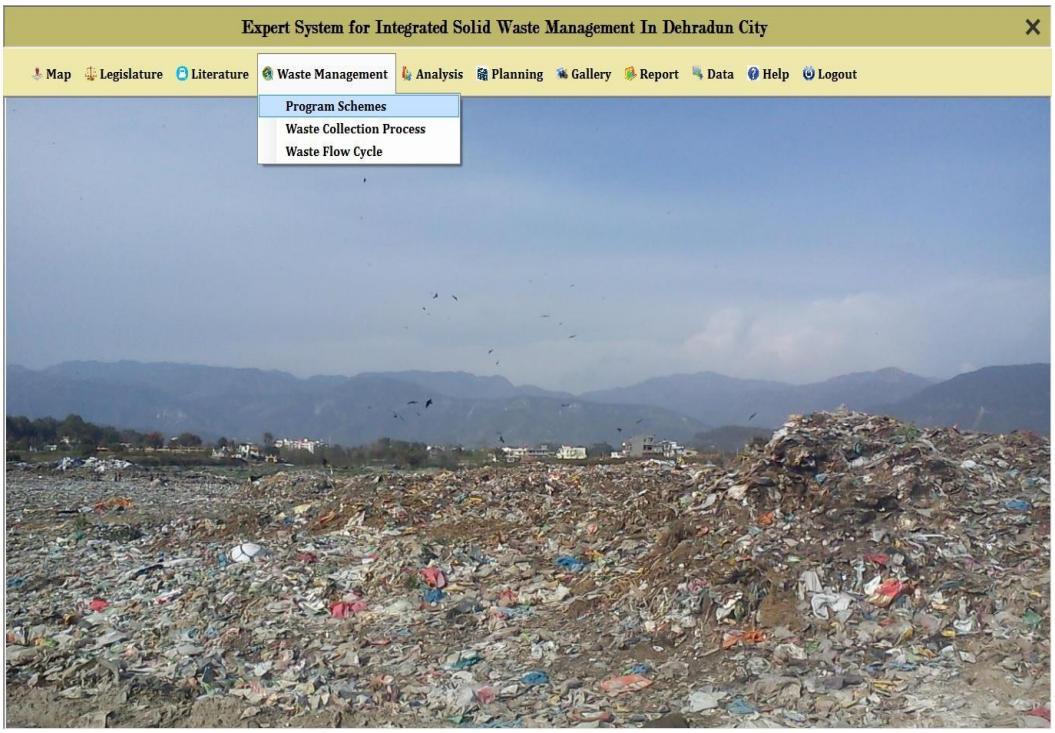


Fig. 4.37: Program Scheme Sub-module

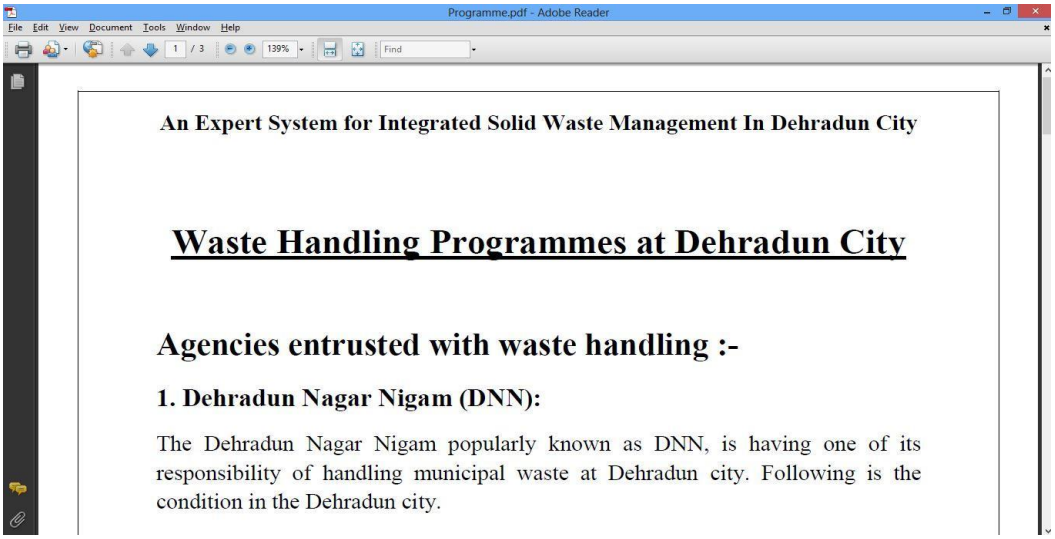


Fig. 4.38: Output Screen of Program Sub-module

(b) Waste Collection Process Sub-Module:

Fig. 4.39: Waste Collection Process Sub-module

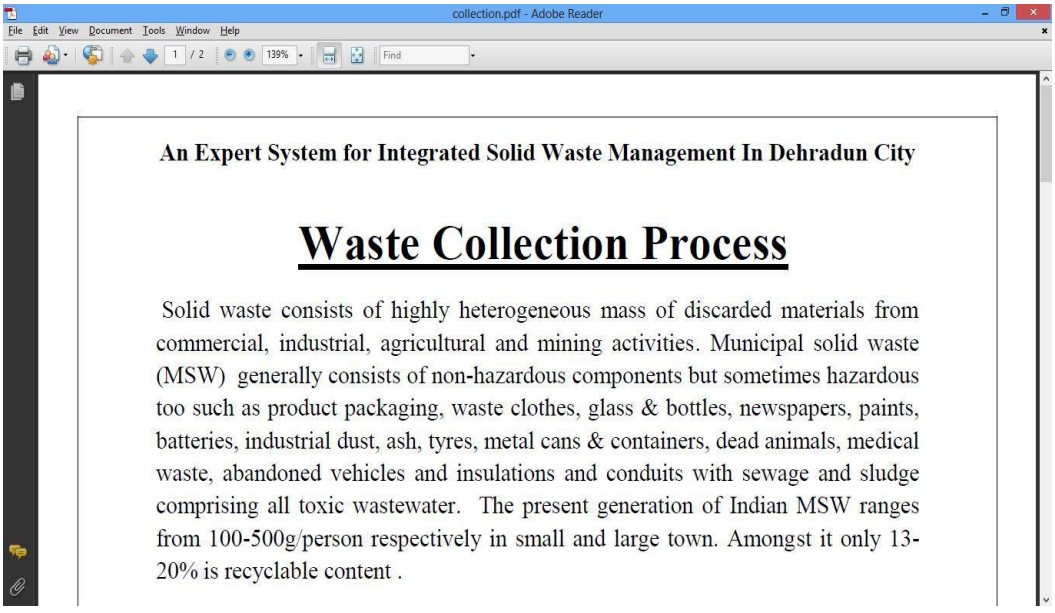


Fig. 4.40: Output Screen of Waste Collection Process Sub-module

(c) Waste Flow Cycle Sub-module:

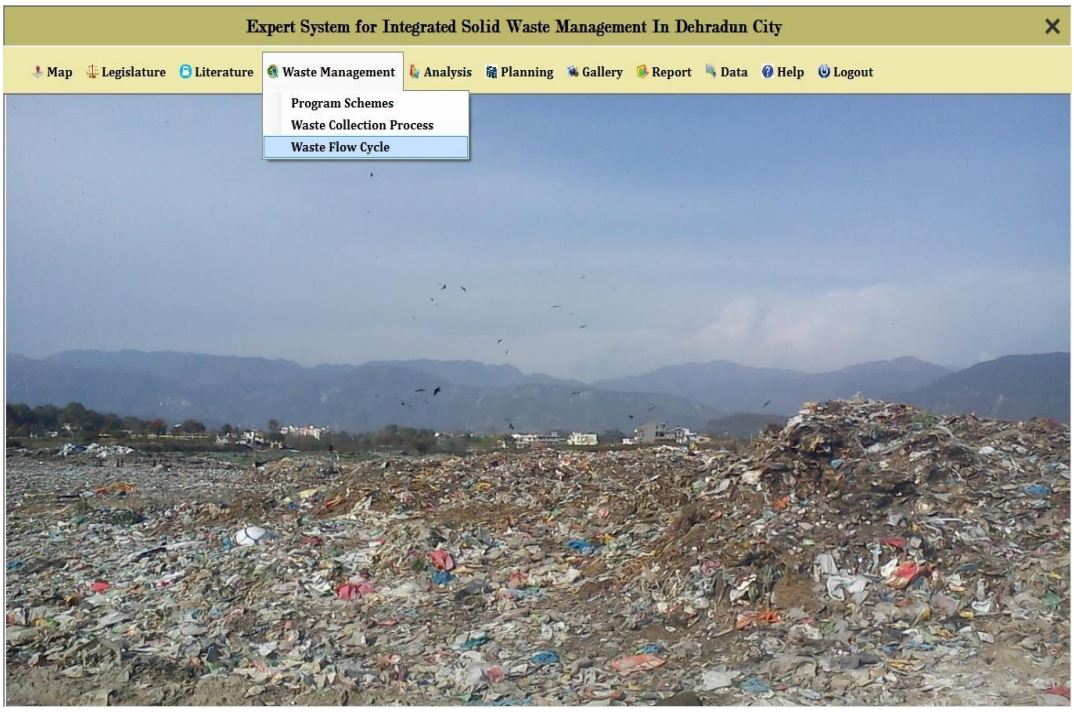


Fig. 4.41: Waste Flow Cycle Sub-module

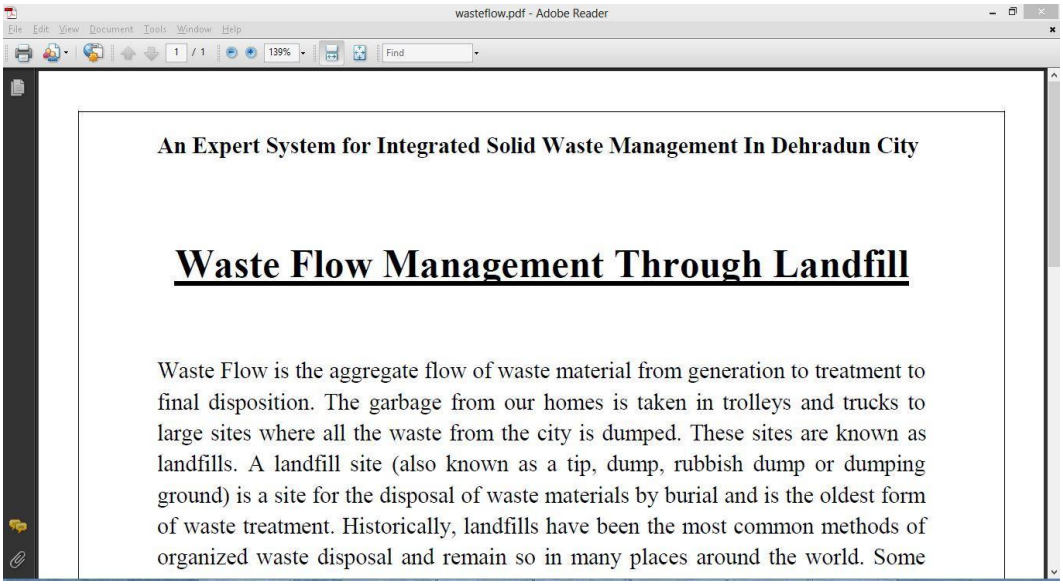


Fig. 4.42: Output Screen of Waste flow Cycle Sub-module

4.2.1.5 Analysis Module:

Reading obtained after lab analysis of collected samples are input in this module. In response it presents detailed water quality deterioration due to solid waste. This module presents sub module “water” to allow for input of analytical data of water analysis respectively.

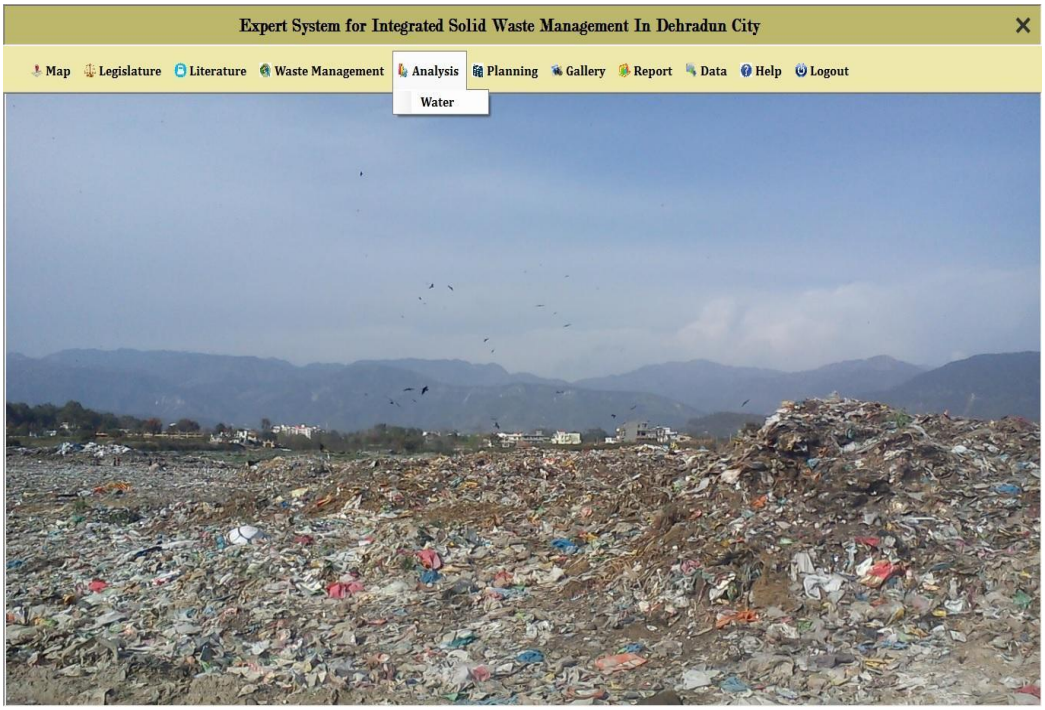


Fig. 4.43: Water Analysis module

(a) Water Analysis Sub-module:

Sub section below presents the data entry screens to accept analytical data & are followed by results display indicating impact of solid waste on water. The user is expected to choose ward names from the available ward list, category of analysis (Physical and/or Chemical), names of parameters from the parameter list, and enter the available lab analytical data. Thereafter the system displays comprehensive influence of solid waste on water quality. The system generates this output after comparing the observed analytical data with the standard values, thus bringing out the derailed parameters and their impact thereof.

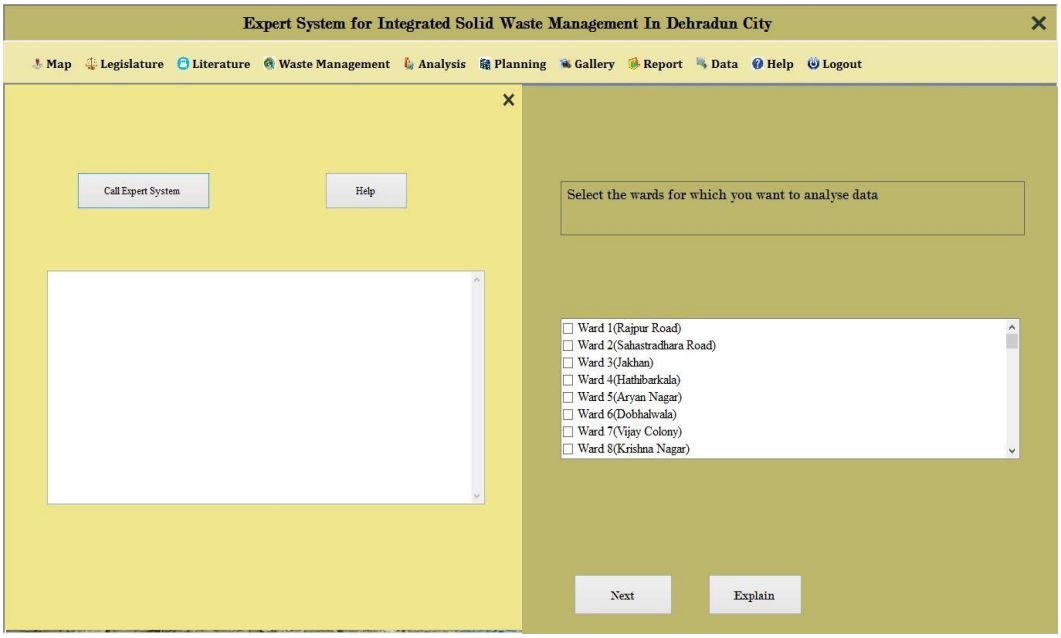


Fig. 4.44: Water Analysis Sub-module

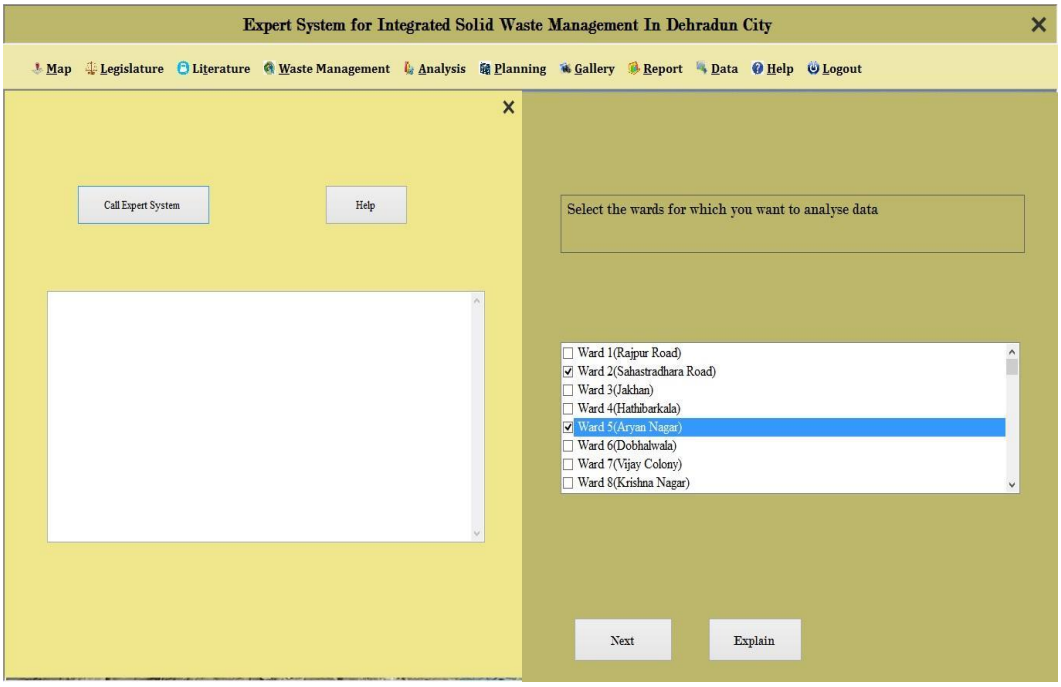


Fig. 4.45: Water Analysis Sub-module

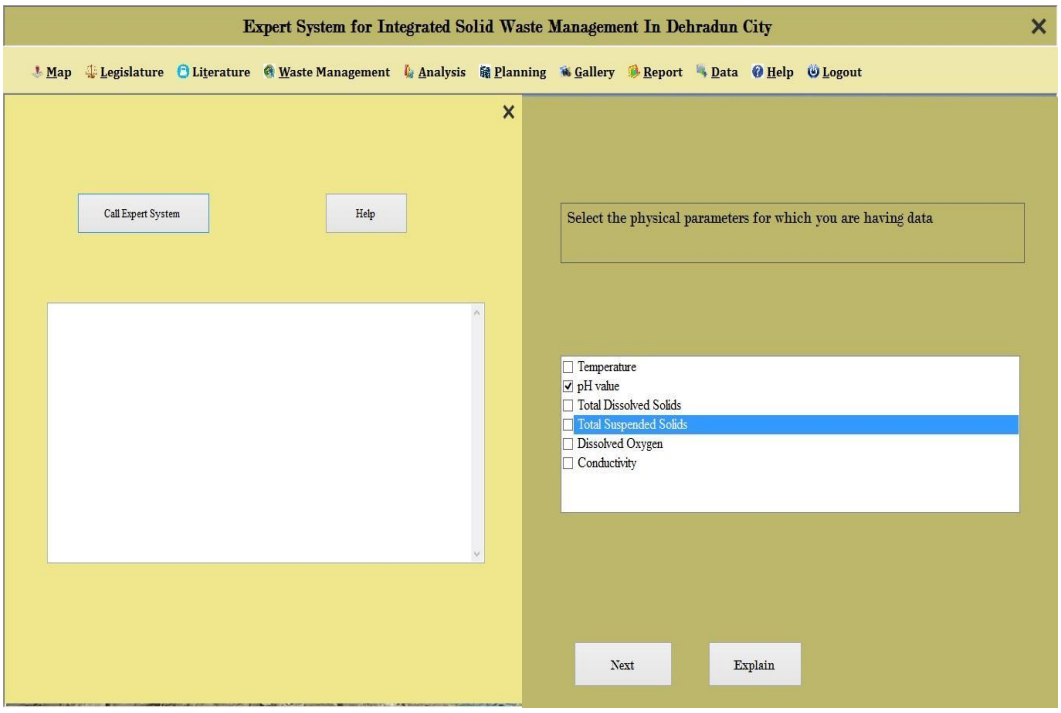


Fig. 4.46: Water Analysis Sub-module

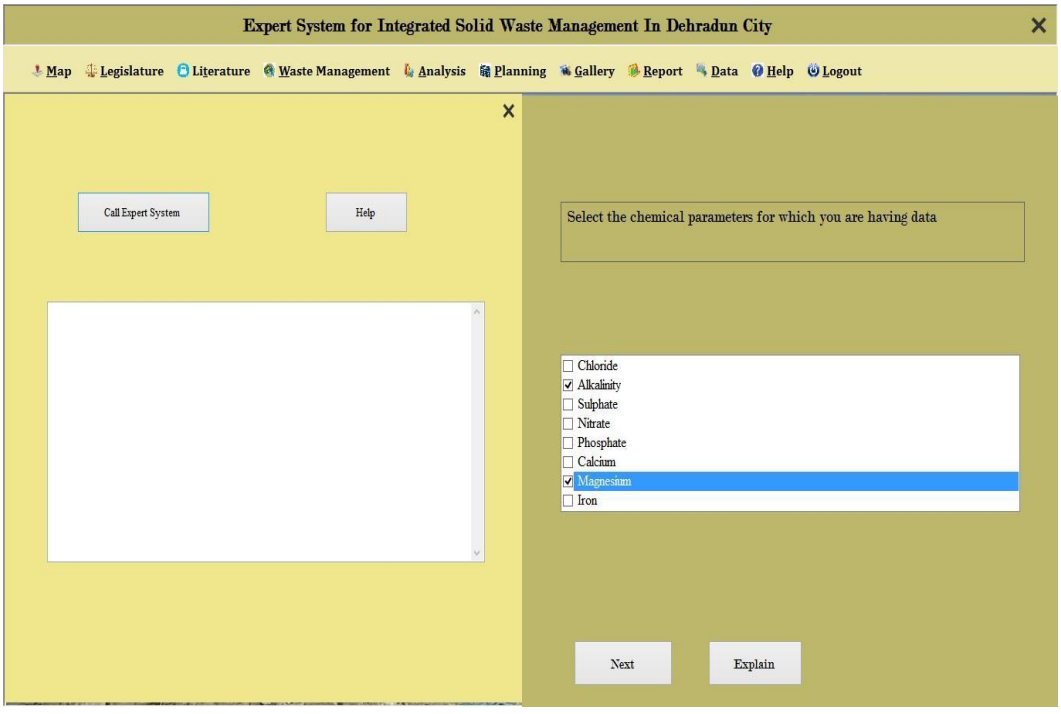


Fig. 4.47: Water Analysis Sub-module

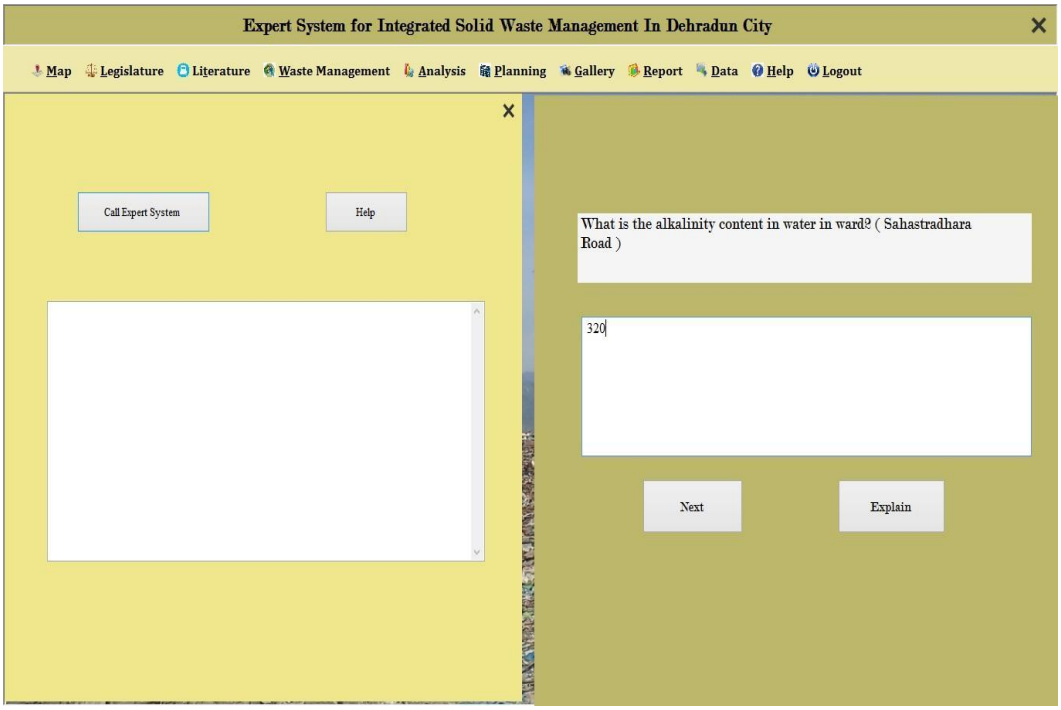


Fig. 4.48: Water Analysis Sub-module

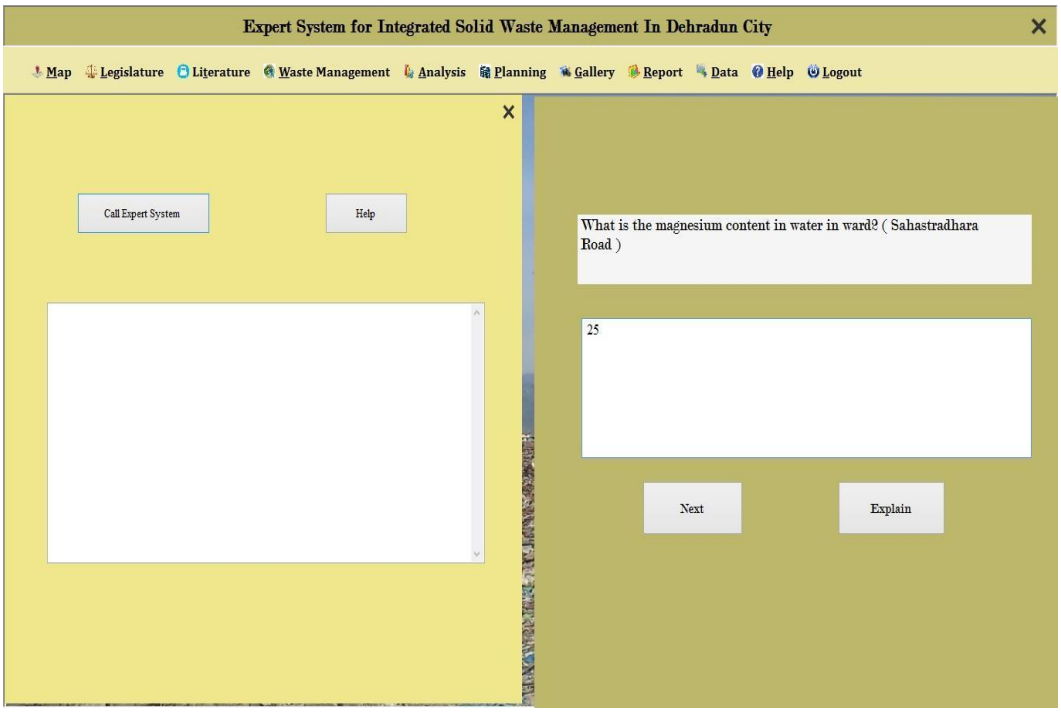


Fig. 4.49: Water Analysis Sub-module

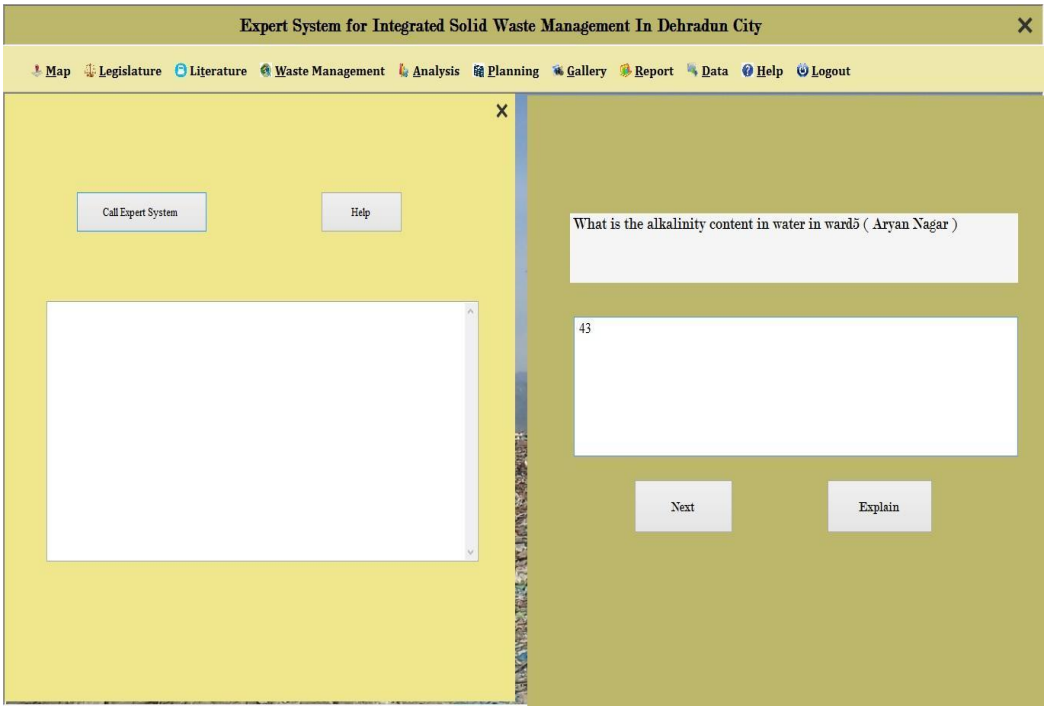


Fig. 4.50: Water Analysis Sub-module

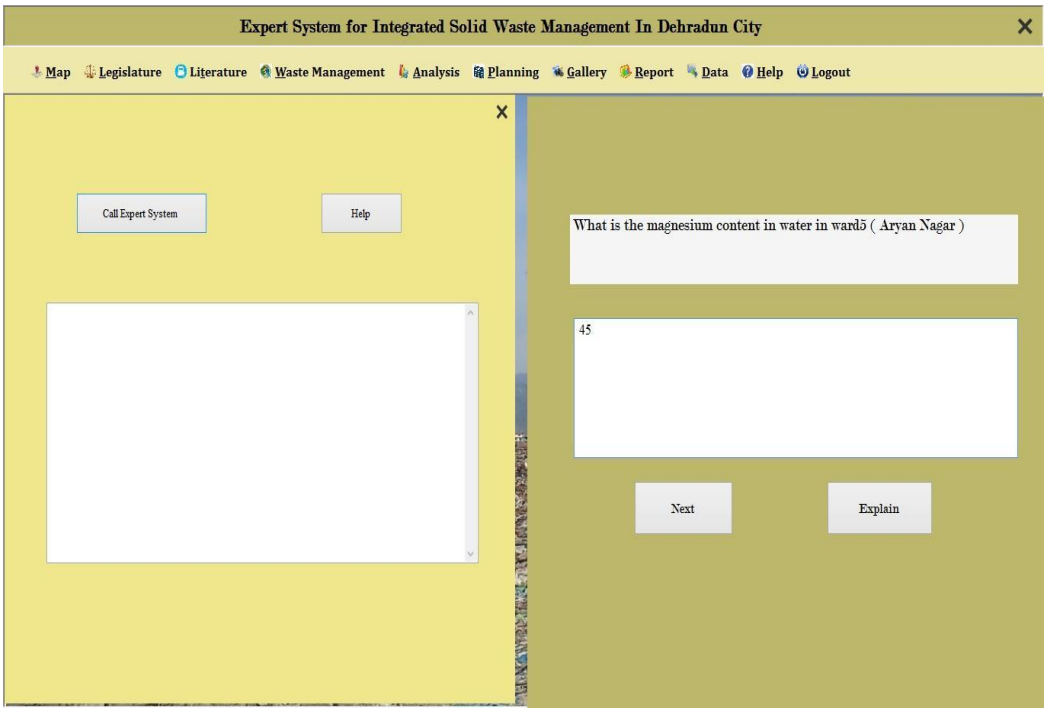


Fig. 4.51: Water Analysis Sub-module

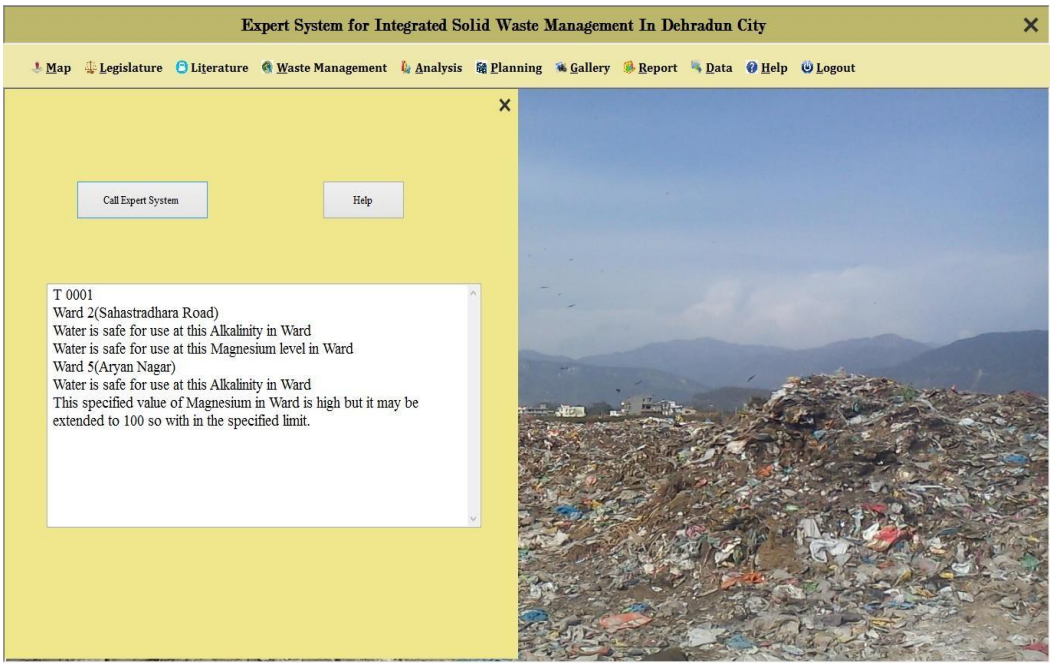


Fig. 4.52: Water Analysis Sub-module

4.2.1.6 Planning Module:

This module consists of three sub modules as follows:

Fig. 4.53: Planning module

(a) Projection of Solid Waste Generation Sub-module:

The statistics of current production of solid waste is collected from DVWM, DNN for a duration of August 2011 to January 2014 were presented to neural network architecture (NarNet) in MATLAB toolkit. The data depicting daily waste generation was converted to weekly waste generation and incorporating time delay presented to time series toolbox.

Present waste generation data is presented to the module and it displays as output, projected quantity of solid waste (approx. next 6 months period). This model can be used for short-term projection facilitating pre planning.

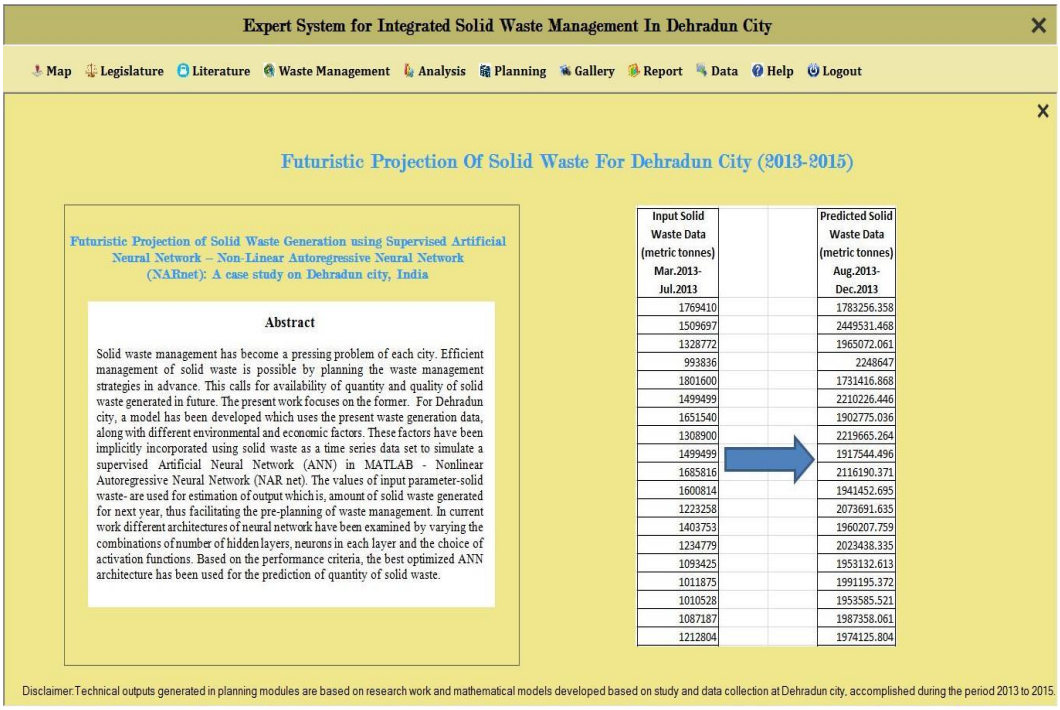


Fig. 4.54: Projection of solid waste generation Sub-module

(b) Novel Landfill Capacity Estimation Model for Dehradun City:

In this module, solid waste prediction accustomed as input, the needed quantity of land for engineering of a landfill, is done as result. The submodule presents facts input display screen to take delivery of contemporary waste generation, rate of increment, proposed life of landfill and generates output waste technology in *n* years, Total quantity of waste in *n* year, Total quantity of everyday cover in *n* year, volume of settlement and finally estimated volume of proposed landfill. Considering waste characterization and evaluation of the waste generated in Dehradun city, a bioreactor landfill is recommended.

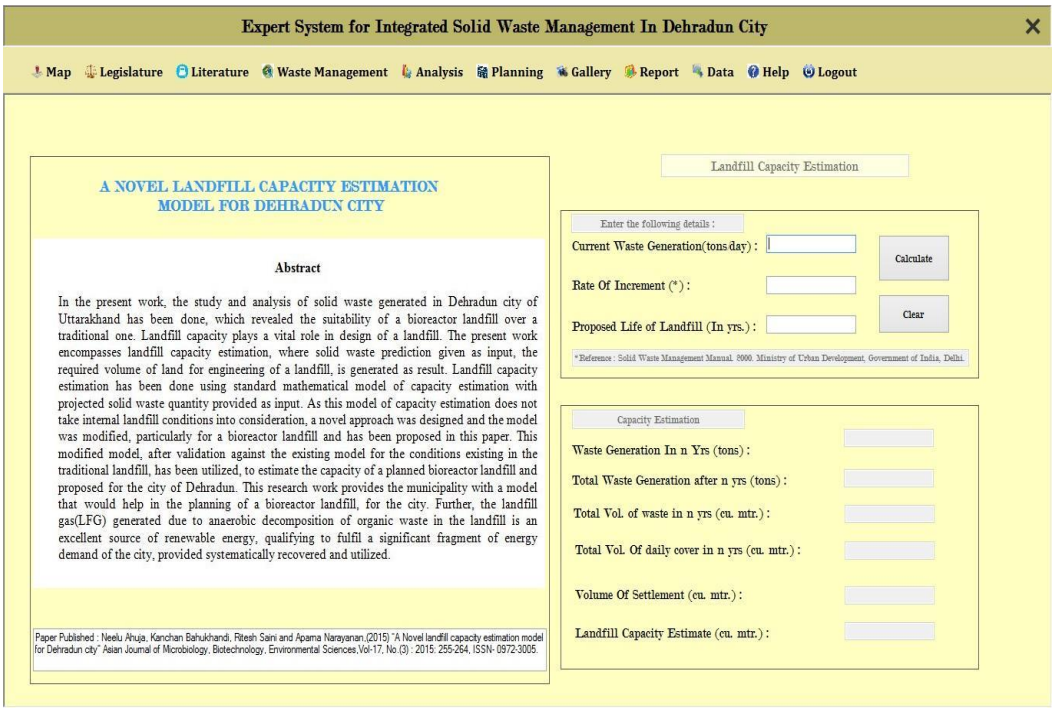


Fig. 4.55: Landfill capacity estimation Sub-module

The study and analysis of the type of waste producing in Dehradun city of Uttarkhand has been carried out and it shows that bioreactor landfill is being

suitable as compared to traditional one. The estimation for the volume plays a major role for designing of any type of landfill. In the module shown in Fig. 4.55, the amount of solid waste predicted to be inserted as input and the required capacity of land for landfill is generated as result. The capacity of landfill required has been calculated using standard mathematical model in which the projected solid waste amount inserted as an input. The various internal landfill site conditions were not considered in this model, therefore new model was designed and modified especially for a bioreactor landfill and has been presented in this study. After validation, the conditions of traditional landfill has been used for estimation of the capacity of planned bioreactor landfill and also suggested the same for the Dehradun City. The model for municipality which would help in forecasting a bioreactor landfill for Dehradun city is studied in the present study. Further, the generation of landfill gas (LFG) due to decomposition of biodegradable waste is a good source of renewable energy to fulfill energy demand of the city, provided systematically recovered and utilized.

(c) Advisory for Handling Landfill Operational Problems:

This sub module has been built to help the landfill manager in the smooth operations of the landfill. It accepts monitored parameters of land fill operation and presents advice (Fig. 4.64) to handle problems that are expected to arise. It also helps to support emergency response planning by landfill managers.

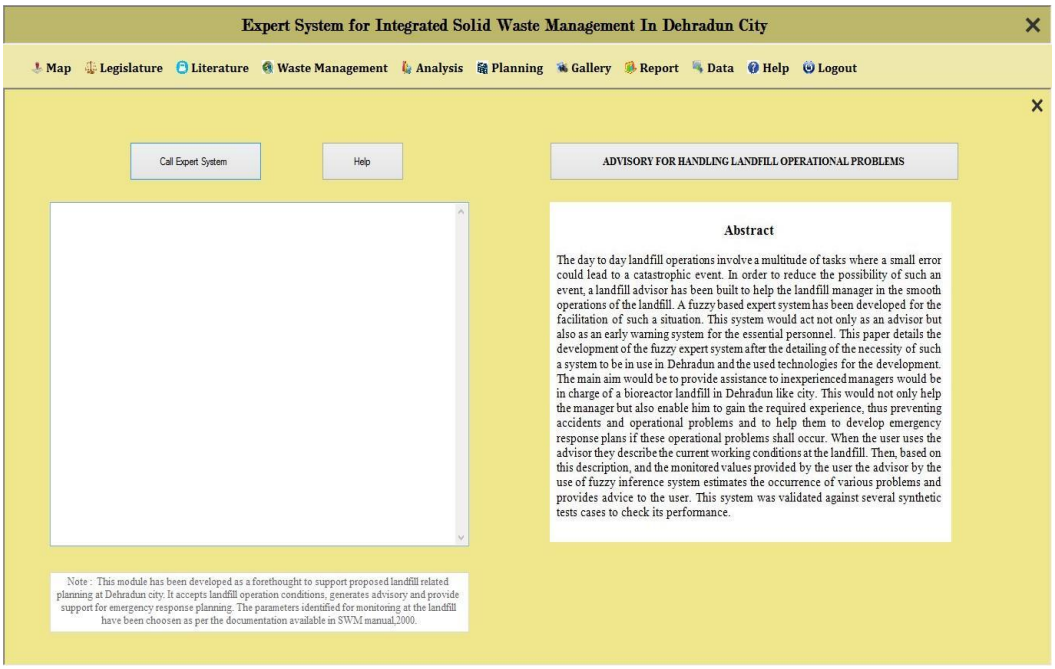


Fig. 4.56: Advisory for handling Landfill operational problems Sub-module

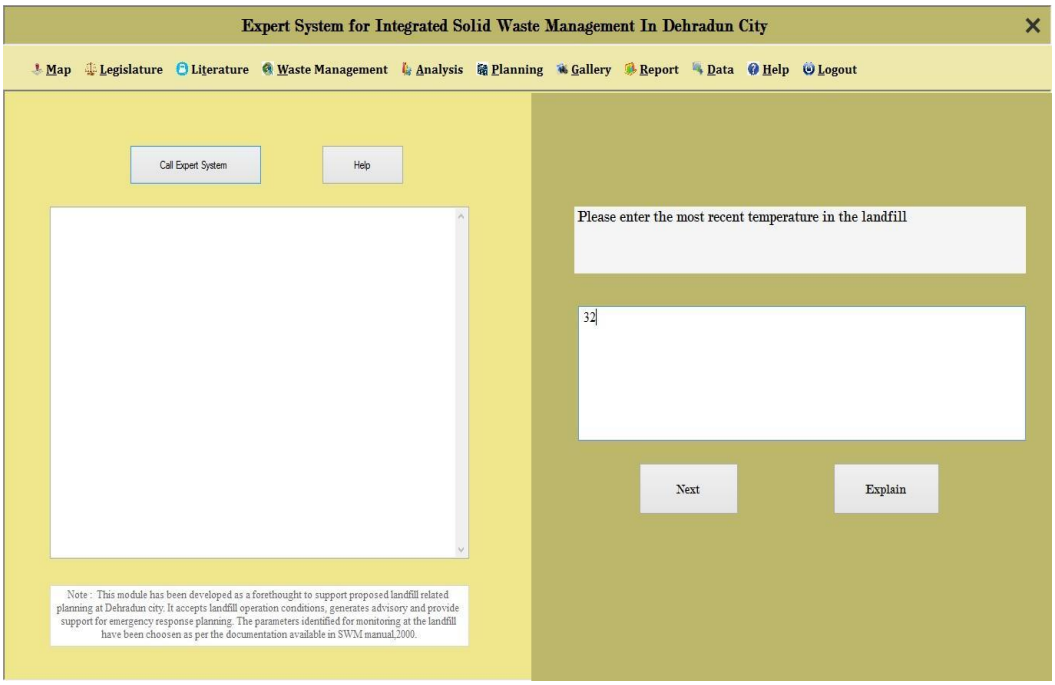


Fig. 4.57:Sub-module

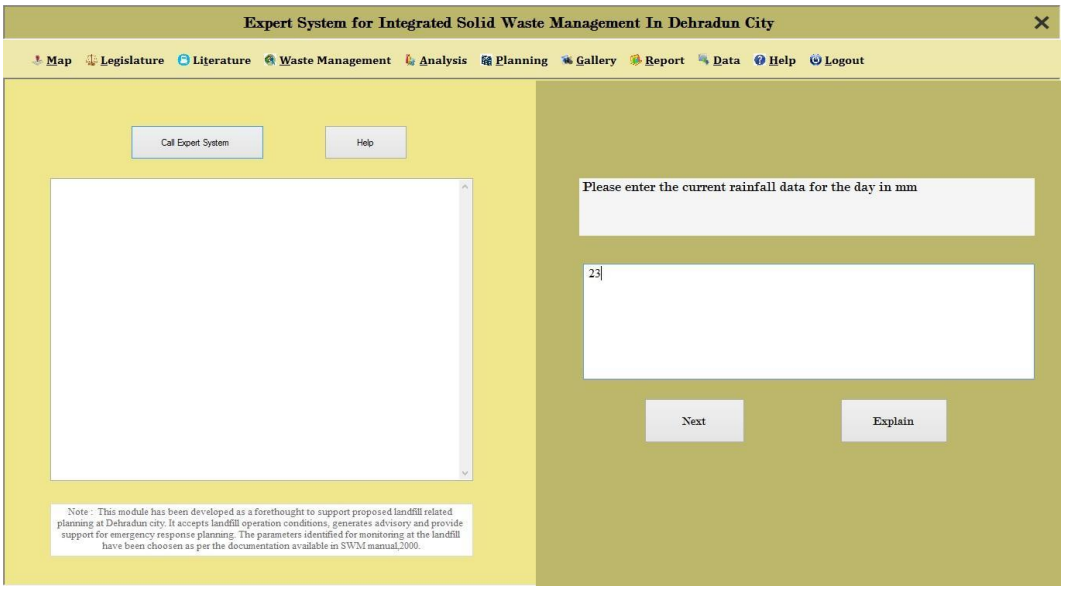


Fig. 4.58: Sub-module

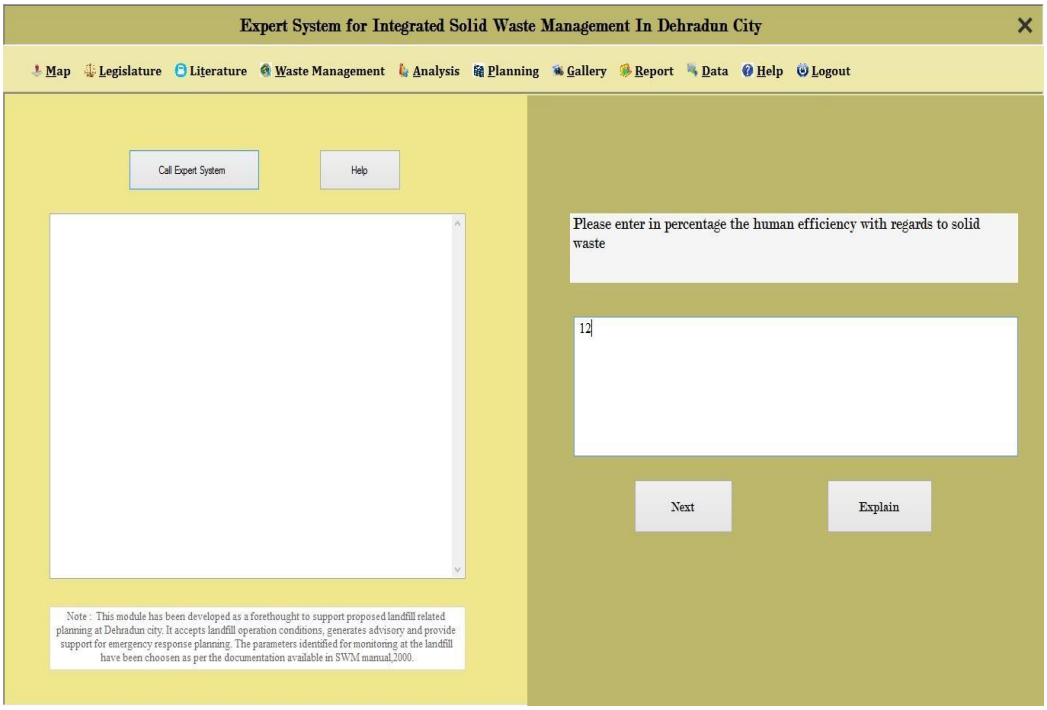


Fig. 4.59:Sub-module

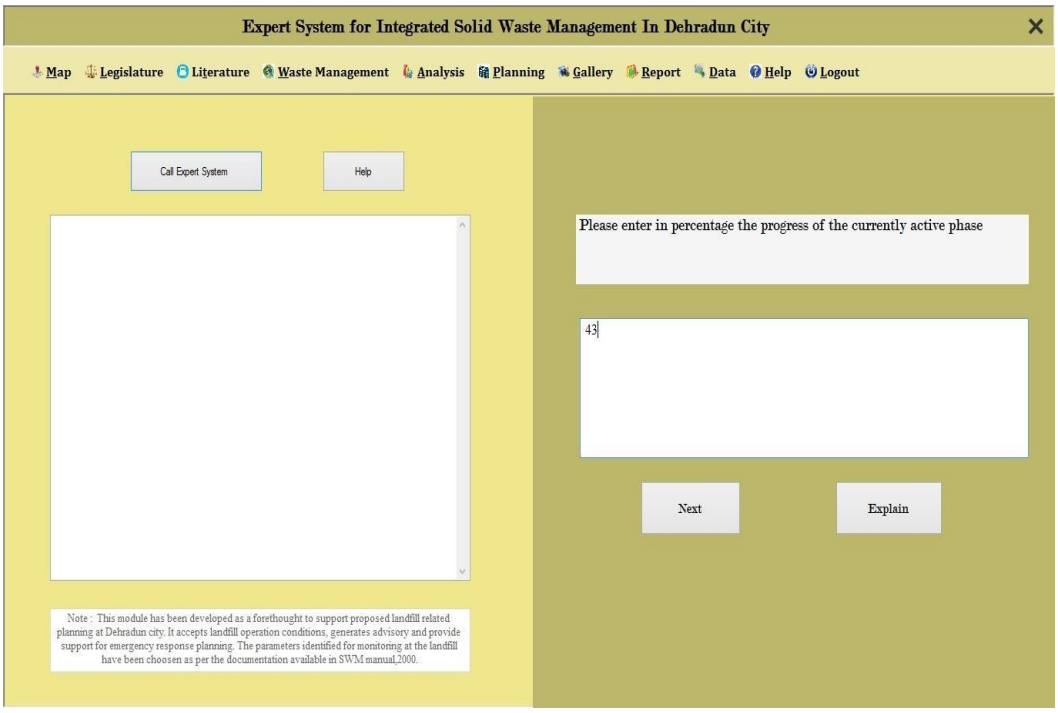


Fig. 4.60: Sub-module

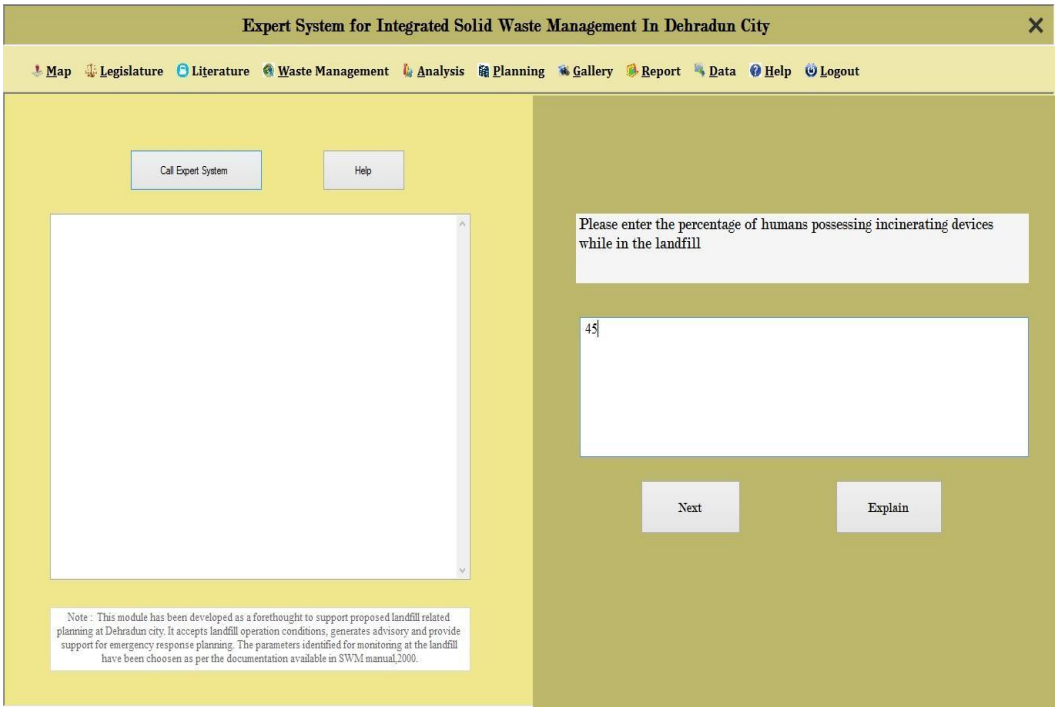


Fig. 4.61: Sub-module

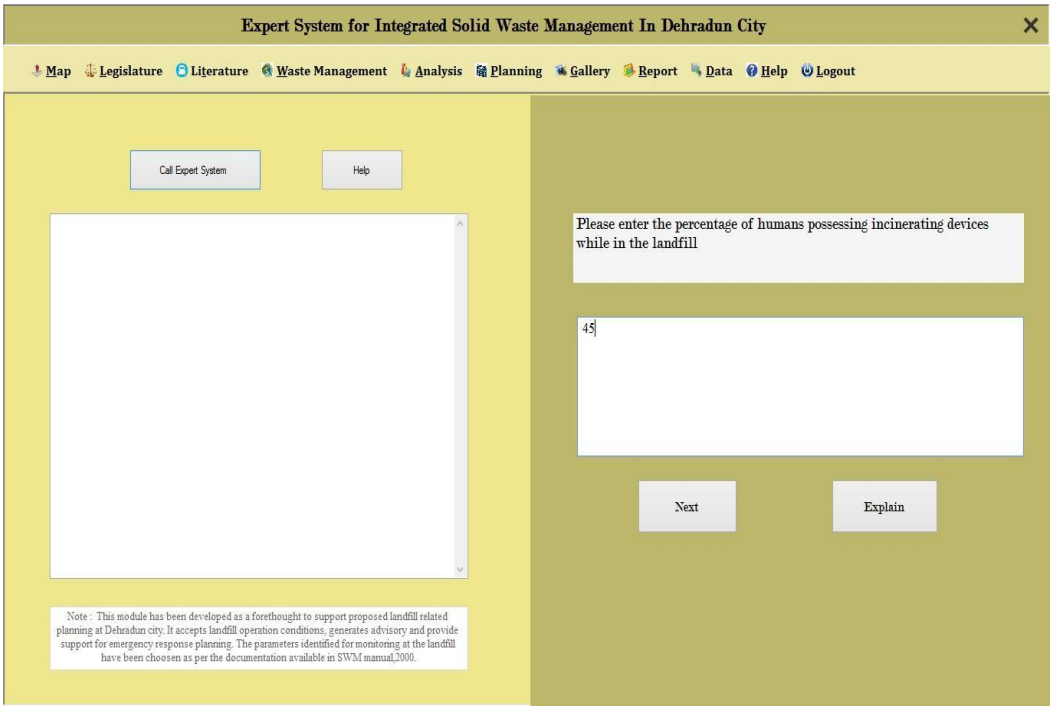


Fig. 4.62: Sub-module

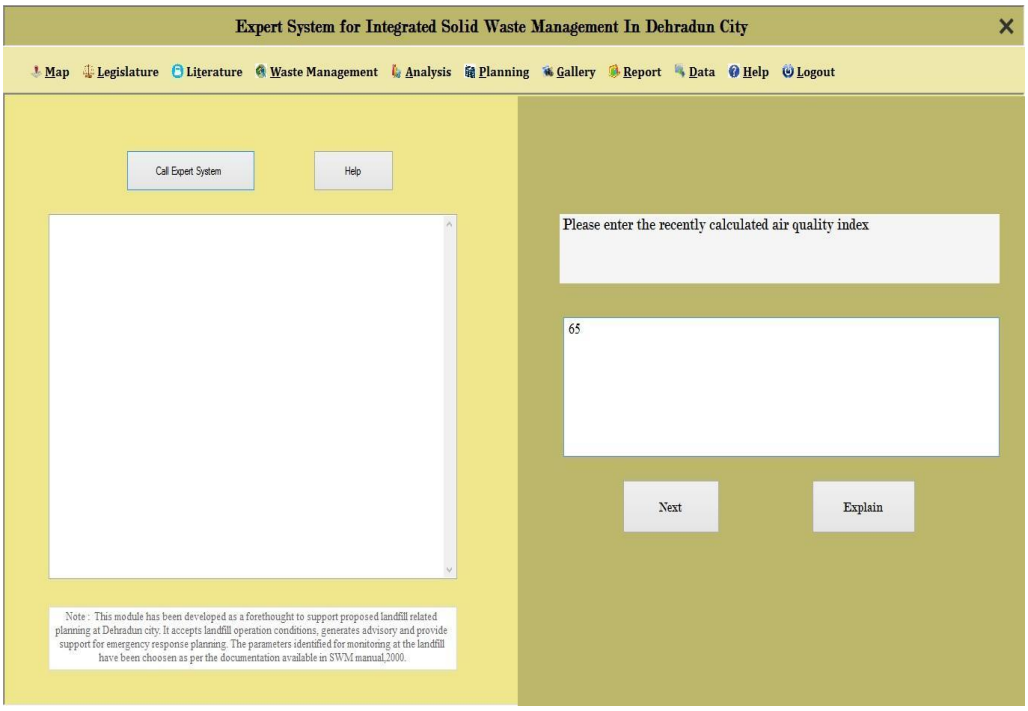


Fig. 4.63: Sub-module

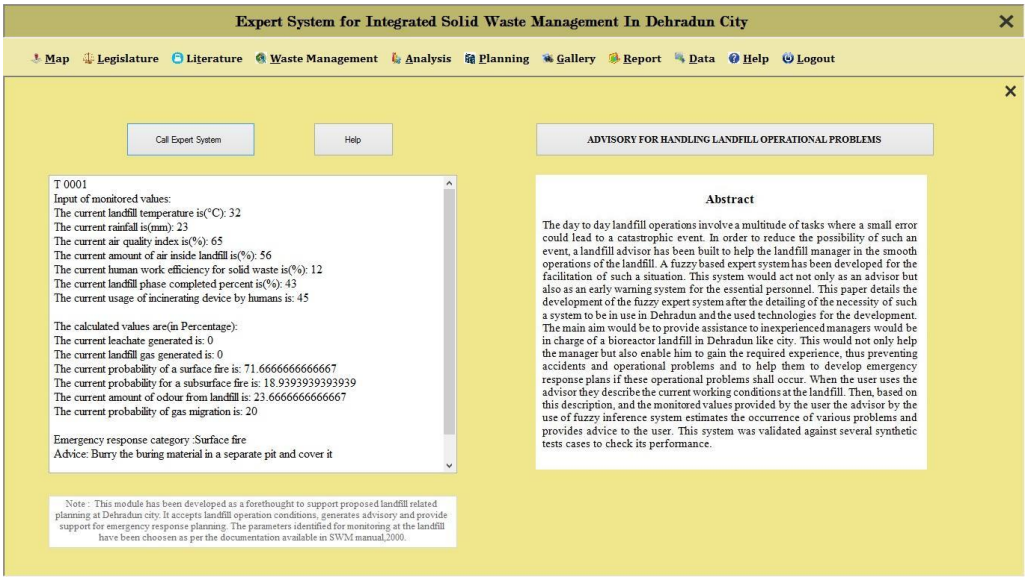


Fig. 4.64: Sub-module

4.2.1.7 Gallery Module:

The module presents photo gallery of sample collection analytical work and other related work undertaken during this project work.

Fig. 4.65: Gallery module

4.2.1.8 Report Module:

The physico-chemical parameters analyzed in the lab are presented under water sub modules respectively**.**

Fig. 4.66: Report module

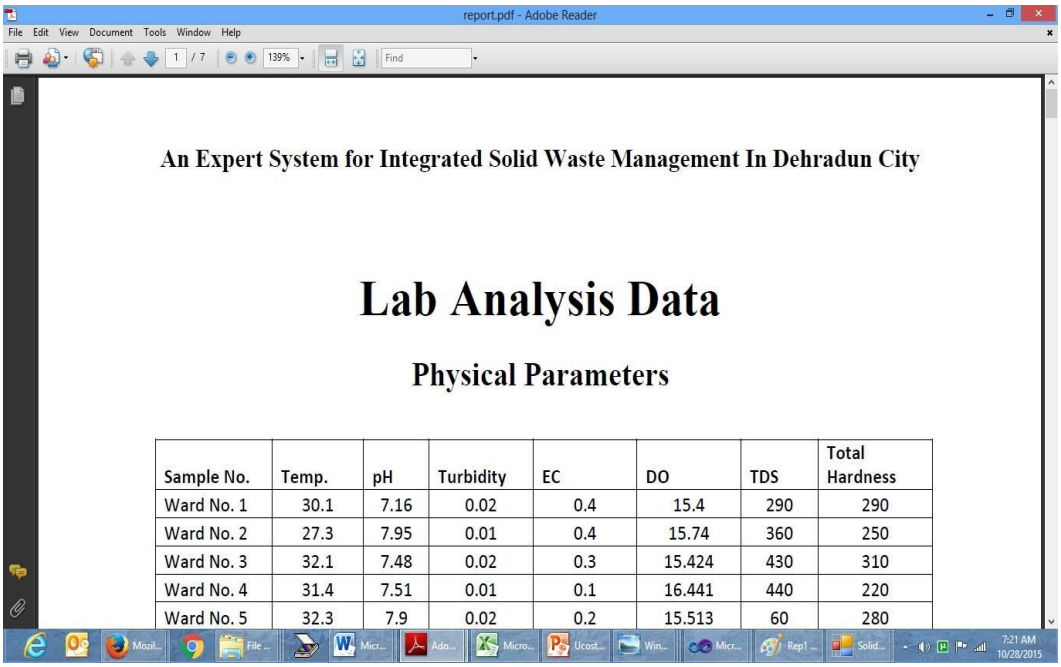


Fig. 4.67: Report Sub-module

4.2.1.9 Comparative Analysis Module:

This module presents the comparative analysis of weather parameters, physical and chemical criterion of water, solid waste generation rate data of Dehradun with other cities such as Nanital, Ooty, Jammu and Delhi.

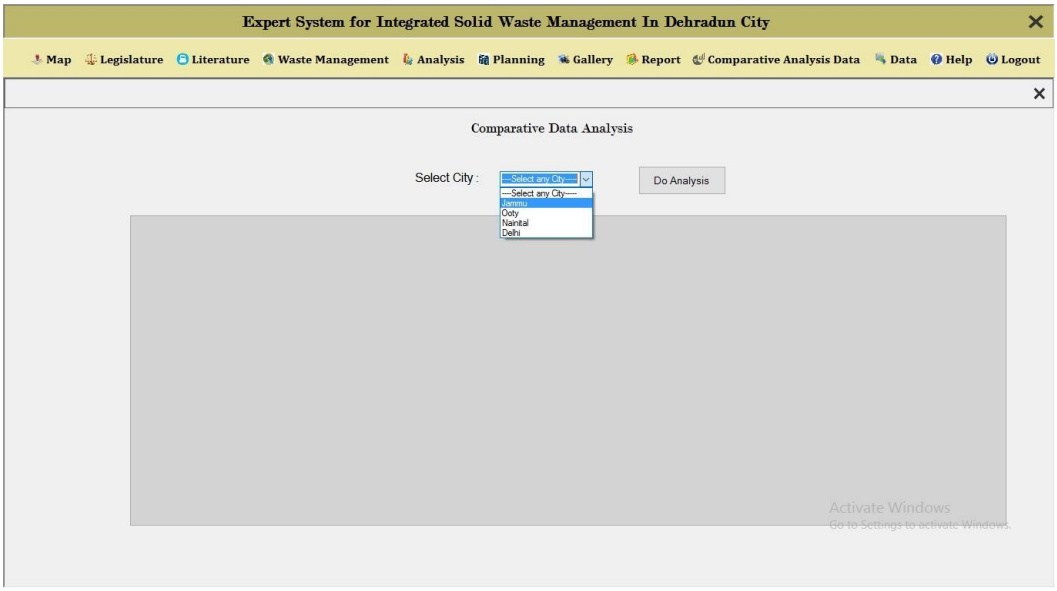


Fig. 4.68: Comparative Analysis module

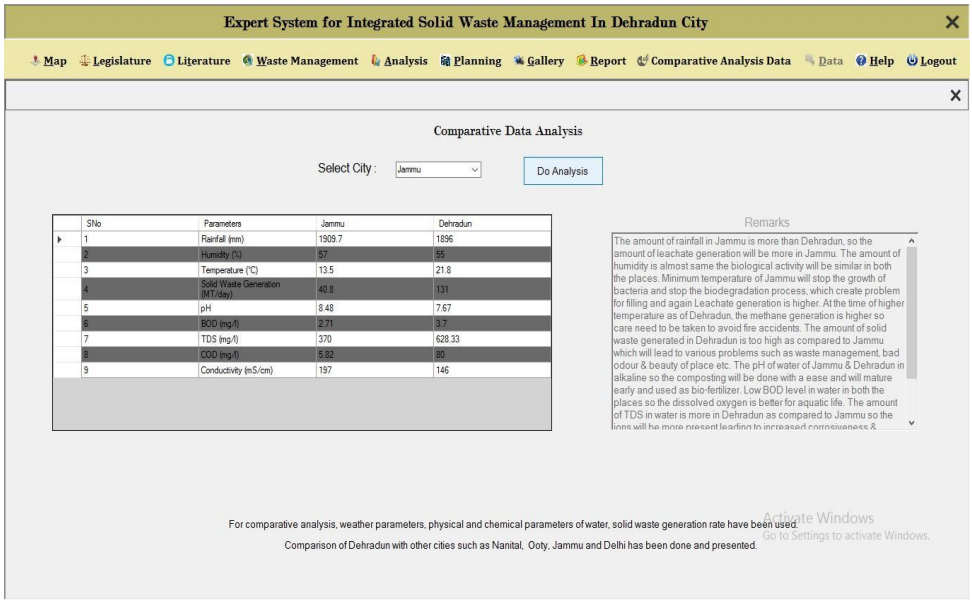


Fig. 4.69: Comparative Analysis sub-module

4.2.1.10 Data Module

This module presents a repository of data entered into the system. All the values entered in the analysis module are stored in the database for future use, reference and record.

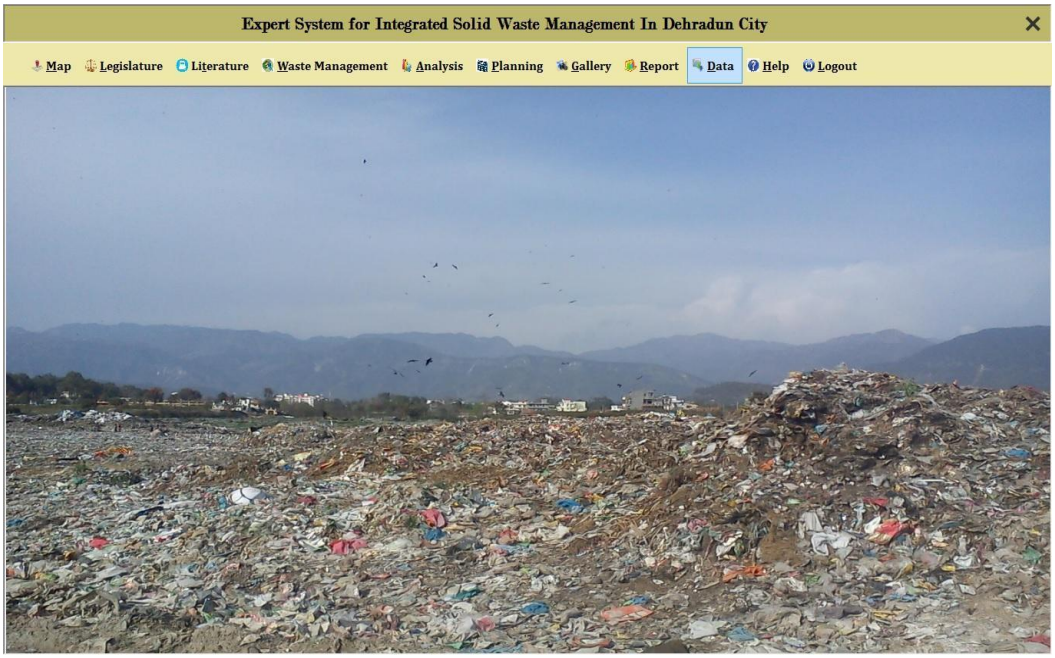
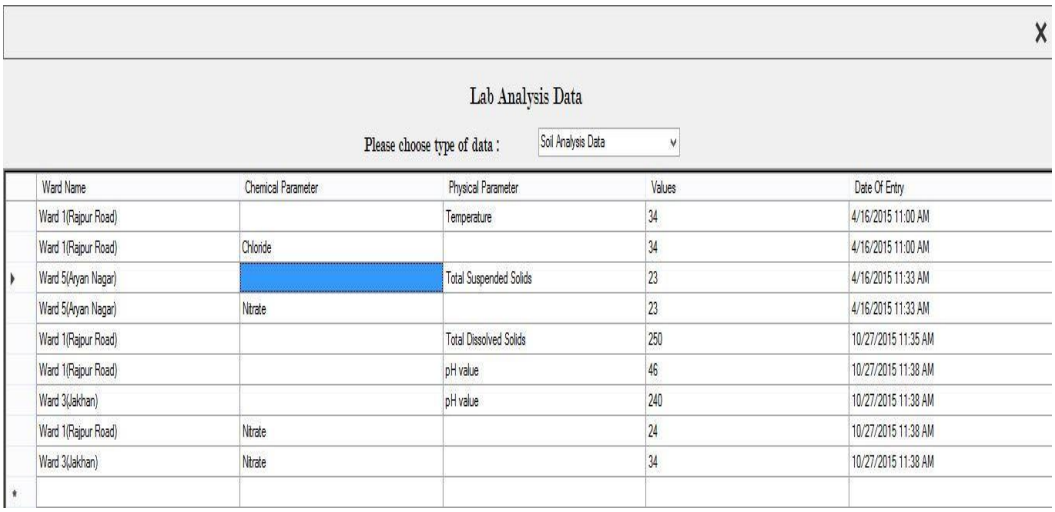


Fig. 4.70: Data module



Ward Name	Chemical Parameter	Physical Parameter	Values	Date Of Entry
Ward 1(Rajpur Road)		Temperature	34	4/16/2015 11:00 AM
Ward 1(Rajpur Road)	Chloride		34	4/16/2015 11:00 AM
Ward 5(Aryan Nagar)		Total Suspended Solids	23	4/16/2015 11:33 AM
Ward 5(Aryan Nagar)	Nitrate		23	4/16/2015 11:33 AM
Ward 1(Rajpur Road)		Total Dissolved Solids	250	10/27/2015 11:35 AM
Ward 1(Rajpur Road)		pH value	46	10/27/2015 11:38 AM
Ward 3(Jakhan)		pH value	240	10/27/2015 11:38 AM
Ward 1(Rajpur Road)	Nitrate		24	10/27/2015 11:38 AM
Ward 3(Jakhan)	Nitrate		34	10/27/2015 11:38 AM

Fig. 4.71: Database entries entered in analysis Sub-module

4.2.1.11 Help Module:

This module shows the Help regarding the different modules.

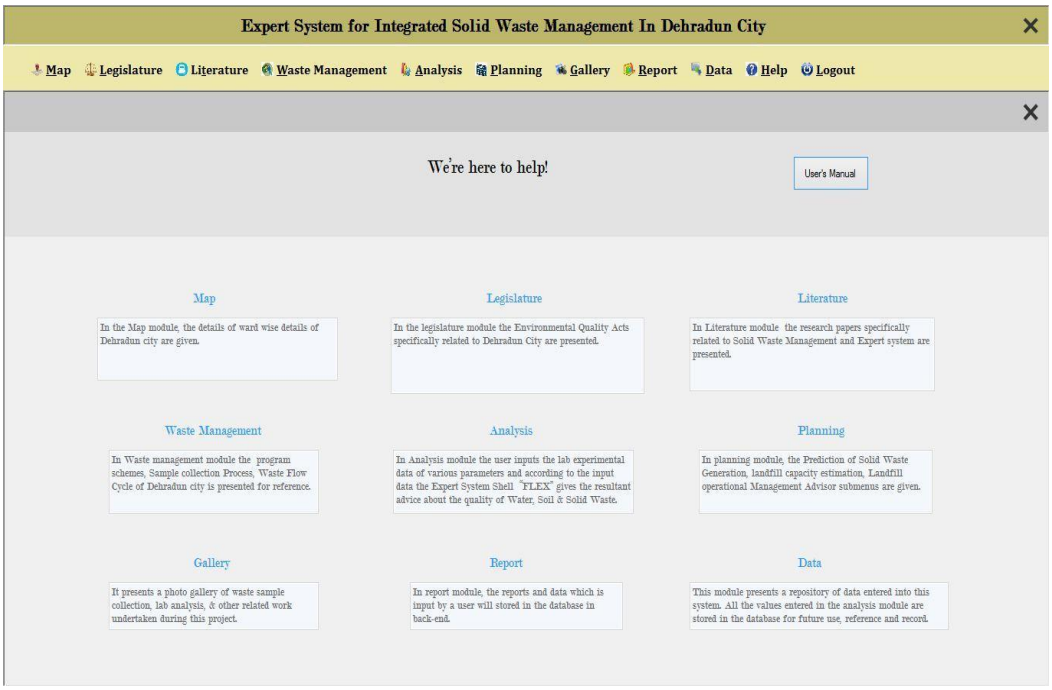


Fig. 4.72: Help module

CHAPTER: 5

CONCLUSION AND FUTURE RESEARCH

5.1 Advantages and comparison with the Existing Systems

1. SWES (Solid Waste Expert System):

Solid Waste Expert System is that it consists of many subforms via the use of that the user will acquire a entire historical previous understanding touching on to modern day solid waste administration in Kuala Lumpur, Capital of Malaysia. The subforms had been titled as literature, legislation, gallery, training, waste management, and at last the solid waste expert system itself. The user interface of the expert system was designed by using the Visual Basic.

2. BESTCOMP:

BESTCOMP has been developed across Sri Lanka by local authorities to provide a friendly professional platform for the better administration of solid waste composting. BESTCOMP, which was specialized in physical , chemical and agricultural composting, was primarily concerned with this. The aim was, on the other side, to provide the user with fashionable science and technology at a much cheaper cost.

The user has to access the knowledge from books, assessment articles , summary, audio , video, the web, contextual analyses and area specialists concerned with the management of solid waste, and that the user should get accurate understanding of the solid waste management.

3. URUSISA:

UrusSisa is a comprehensive structure for solid waste technology selection and designing. It can develop the techniques to find the most impressive developments in solid waste technology and create the preparatory design records of the technological know-how on solid waste. UrusSISA 's main information includes

an Analytical Hierarchy Process (AHP) precedence ranking and a prepared draft of the plan innovation. AHP comprises the organization of multiple choice order in hierarchy for determination of the relative value of these criteria and the identification of a typical ranking of alternatives. Solid waste research preparatory graph includes recycling, composting, incineration and waste disposal. The model design was tested using the case study.

4. BESTFill:

An expert system used to be created to aid fabulous utilization of landfill innovation in Sri Lanka. The cognitive content material used to be non inheritable through workbooks, guidebooks, specialized technical statement, analysis, publications and area specialists. An article oriented skilled device shell; ACQUIRE 2.1 was used to structure the prototype development. BESTFill knowledgeable device carries many sub modules by that the consumer will get a complete historical past of the domain. The output is anticipated to help advantageous built-in solid waste management.

5. DSS:

Most of the decisions made on waste management (WM) support systems (DSS) do not seem to be commonly promoted and have no good applications. This is due frequently to the amount of mathematical variables and complexities that accompany the assumptions and constraints required for decision making. The method developed by a number of DSS design researchers is to confine a number of key components that affect the DSS. This fragmented method does not provide the complex relations between the various parts identified with a radical understanding. In order to use a marketable framework that has realistic functionality, the various elements to designing the DSS must be integrated and optimized. The DSS used in aiding producers should be incorporated into a GIS system that is designed to offer strong GISs, forecasts the abundance of waste

characteristics and therefore the underlying instability of the waste generation and offers the best allocation of waste streams for recycling, composting, waste to energy and landfill.

Table 5.1: Comparison of Integrated Solid Waste Expert System (ISWES) with Existing Expert System

S. No	Existing Expert System	Features	Demerits	ISWES Advantages
1.	**Solid Waste Expert System (SWES)**	✓ The tool used for development of Expert System is Visual Basic Express Edition 2005. This expert system is developed for waste management in Kuala Lumpur. ✓ The main components on which the system is developed are: impact assessment, packaging requirement, label requirements recycling and recommendations. ✓ To know the	✓ Focus on Scheduled waste management in Kuala Lumpur. ✓ Its output is to support effective integrated scheduled waste management.	✓ Developed user- friendly, cost effective, environmentally acceptable technology solution for SWM. ✓ Knowledge Repository- SWM issues for all concerned SWM officials. ✓ Integrated Technology Solution: Expert System with Knowledge dissemination, Impact analysis,

		comprehensive background, numbers of sub-modules are also developed. ✓ Therefore, the user gets an extensive background of the domain through many sub-modules. ✓ The result will support the effective waste management.		Futuristic Planning. ✓ Recommend-ation of "Landfill Type" and its estimated capacity assisting in landfill planning. ✓ Advisory for handling landfill operational issues and helping in emergency response designing by landfill managers.
2.	**BESTFill**	✓ The needs of expertise in landfill are to be catered with the help of Bestfill. ✓ The tool ACQUIRE 2.1 is used for the development of this system. ✓ BESTFill technical tool has multiple sub-modules through which the user is able to acquire an overall history of the area. ✓ The expected	✓ Focus on expertise in landfill technology. ✓ The output is expected to support effective integrated solid waste management	

		output would help for effective waste management.		
3.	**BESTCOMP**	✓ BESTCOMP is a user friendly program for better administration of solid waste composting, established by the Sri Lankan authorities. ✓ The main focus is on physical, chemical and organic composting process behavior. ✓ The goal was to provide an effective tool with modern technologies for various users at cheaper cost.	✓ Enhance--ment of the administration of solid waste composting by the authorities in Sri Lanka. ✓ The aim is to provide various economical technologies with latest tools at cheaper cost.	
4.	**URUSISA**	✓ This system is developed for designing and selecting waste technologies.	✓ Focus on selecting and designing solid waste technology. The output	

		✓ This strengthens the way of selecting the most efficient technologies for solid waste and generates data of Solid waste management which are already available. ✓ The primary information focused on UrusSisa consists of an analytical hierarchy (AHP) prioritization of manipulation and a preliminary advice technology. ✓ AHP consists of structuring various selection criteria into a list, evaluating the relative relevance and deciding a general ranking of alternatives for those parameters. ✓ The composting, waste to energy, burning and landfill are the	consists of priority ranking using Analytical Hierarchy Process (AHP), and preliminary design of recommendat-ion technology	

		preliminary technologies of Solid Waste.		
5.	**DSS**	✓ The various Decision Support Systems (DSS) designed for waste are not used and marketed properly. ✓ The various elements in constructing the DSS to be integrated and improved for production of viable tool ✓ To order to provide a viable, realistic and marketable model, the various building elements of the DSS need to be incorporated and optimized. ✓ This tool is also integrated with GIS for assistance of users.	✓ Focus on the conceptual frame work of Decision Support Systems (DSS) for waste management. ✓ The DSS model's output is able to provide a strong forecast for users integrated with GIS, despite the inherent uncertainties of waste generation.	

		✓ It suggests various waste technologies available i.e. composting, waste to energy, landfill and incineration.		

Economic Analysis:

Table 5.2: Economic Analysis

S.N.	SWM	Existing System			ISWMES		
		Time (months)	Manpower	Cost (Lakhs)	Time months	Cost (Lakhs)	Manp-ower
1.	**Knowledge Acquisition & Distribution**	10	1	2.0	1	0.20	1
2.	**Impact Analysis**	6	1	1.20			
3.	**Planning of Solid waste generation Rate**	1	1	0.20			
4.	**Landfill Capacity estimation**	1	1	0.20			
5.	**Advisory for**	6	1	1.20			

	handling landfill operational problem						
	Total	24 Months	5	3.80	1	0.20	1
		Continuous process			**One time investment**		

5.2 Comparison of Conventional Ways of Solid Waste Management and Existing System (ISWMES):

Conventional Ways:

- **Knowledge Acquisition and Dissemination:**

  It includes acquiring knowledge through various sources such as visits and meetings with SWM officials, Knowledge sources: literature reviews, research publications, articles and reports, Sites visit to record details of current status of SWM, Knowledge about effects of weather and terrain parameters on MSW. Characterization of solid waste is required in evaluating a variety of tools, structures and management application and plans. It is based on a range of aspects, such as dietary nature, cultural conditions, and environmental and socioeconomic circumstances. The characteristic of garbage varies not only due to different cities but in the same city also and due to different seasons too. The status of garbage should be measured taking into account seasonal and zonal variations etc. Solid waste management should include the following ordinary steps: 1. Waste technology 2. Control, storage and processing on site 3.collection, sortation and recycling 4. Reuse and repair 5. Disposal technology.

- **Impact Analysis:** An Environmental expert deals with the study out of an impact on solid waste on water quality. It includes the work starting from the specimen collection to analysis in the laboratory. After analysis, the expert concludes the affect of solid waste on water quality.

- **Planning:** Planning includes the following:

a. **Solid Waste Generation Rate:** Technical specialist will decide the growth rate of solid waste generation through using the mathematical prediction approach.
b. **Estimation of Landfill Capacity:**The traditional waste-management resolution is the landfill. A government should confirm types of landfill and the procedures for gathering, transportation, consolidation, and disposal of waste are applicable for its community. There are number of rules from starting to end process that applies in every phase.
c. **Advisory for Handling Landfill Operational Problems:** A Technical expert working in the landfill who is expert of operational problems. By his or her experience, knowledge and data from monitoring instruments, the expert deals with the operational problems and generates advice regarding the problems that can occur while handling landfills.

5.3 Conclusion

The main reason for chaotic and haphazard approach in SWM is lack of domain expertise and a need for channelizing it with proper guidance (Nassereldeen, 2011). Hence, an integrated solid waste management (ISWM) expert system is developed with integrated modules to provide access to comprehensive background of the SWM domain, analyze and report impact of solid waste on water quality, identify land-fill operational

problems, provide control measures, generate advice facilitating development of emergency response plans by land-fill managers, projection of solid waste generated in the years to come, accordingly predict potential impact and affect on water quality, and to provide estimation of land-fill size needed.

The growing complexity of issues involved in integrated SWM demands knowledge-based tools and a very high degree of monitored implementation. Expert System is a tool that provides information which can be used by city authorities at various levels. It acts as a resource for advising personnel at the organization's strategic level and resource for training of new members of the staff of the SWM department. It is a tool for inexperienced/inefficient landfill managers. It assists in planning through its prediction modules by providing details such as the quantity of SW likely to be generated in the future, and the potential deterioration of water quality thereof. So, there is need for a well-rounded strategically planned approach integrated with domain knowledge targeted towards guided and monitored implementation.

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CURRICULUM VITAE

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Objective:

Want to become a part of an organization where I can use my insight and abilities for the advancement of the organization.

Academic Qualification:

Examination	Discipline	Board/University	Year of passing
PhD	HSE	UPES	Pursuing
M.Tech	HSE	UPES	2018
B.Tech-M.Tech	Biotechnology	LPU	2011
Senior Secondary (12^{th})	Medical	HPBOSE	2006
Matriculation (10^{th})	All Subjects	HPBOSE	2004

Project Undertaken:

- "**An Expert System for an Integrated Solid Waste Management for Dehradun City**" under the guidance of Dr. Neelu J Ahuja, Professor and Dr. Kanchan Deoli Bahukhandi, Assistant Professor at University of Petroleum & Energy Studies, Funded by Uttarakhand State Council for Science and Technology, Dehradun.

- **"Providing Project Development Support for Enhancement of Micro, Small and Medium Enterprises (MSME) Energy Efficiency at Dehradun Cluste**r" under the guidance of Dr. Pankaj Kumar Sharma, Professor and Principal Investigator of Project at University of Petroleum & Energy Studies, supported by World Bank & Global Environment Facility (GEF).

- **PRODUCTION OF AMYLASES FROM *ASPERGILLUS SPECIES* AND THEIR STABILIZATION USING VARIOUS ADDITIVES"** under the guidance of Dr. Giridhar Soni, Professor at Lovely Professional University, Phagwara, Punjab.

Publications:

- Kanchan Deoli Bahukhandi, **Ritesh Saini**, Neelu Jyoti Ahuja, Divya Thakur, Nihal Anwar Siddiqui, 2021 "*Assessment of the impact of the municipal solid waste on Hydrochemistry of the Surface and Groundwater quality of Dehradun district of Uttarakhand: Seasonal variation in water quality"* Himalayan Geology, Vol. 42 No. 1, pp. 175-188. ISSN:0971-8966.
- **Ritesh Saini**, Nihal Anwar Siddiqui, Kanchan Deoli Bahukhandi and Neelu J Ahuja, 2018 " *Study of effects of Municipal Solid Waste on water quality of Dehradun City*" Journal of Environmental Science, Computer

Science and Engineering & Technology, Vol.7 No. 3, 409-416. ISSN:2278-179X.

- **Ritesh Saini**, Neelu J Ahuja, Kanchan Deoli Bahukhandi, 2017 *"Futuristic projection of Solid Waste Generation in Dehradun City of Uttarakhand using supervised Artificial Neural Network-Non-Linear Autoregressive Neural Network (NARnet)"* International Journal of ChemTech Research, Vol.10 No.13, pp 283-299,, , ISSN: 0974-4290, ISSN(Online):2455-9555.

- **Ritesh Saini**, Neelu Ahuja and Kanchan Bahukhandi, 2016 "*Fuzzy logic based advisory for handling landfill operational problems for early warning and emergency response planning*" International Journal of Chem Tech Research, Vol.9, No.08:2016:282-297, ISSN:2455-9555.

- Neelu Ahuja, Kanchan Bahukhandi, **Ritesh Saini** and Aparna Narayanan, 2015 "*A Novel landfill capacity estimation model for Dehradun city*" Asian Journal of Microbiology, Biotechnology, Environmental Sciences, Vol-17, No.(3) :2015:255-264. ISSN-0972-3005

Paper Presented:

- Presented paper on "Conceptual framework of analytical module of Expert System for integrated solid waste management for Dehradun city: Working model of water analysis" at 8th Uttarakhand State Science and Technology Congress-2013 was held on 26th -28th Dec. 2013.

- Presented paper on " Quantification & Characterization of Municipal Solid Waste for Dehradun City-Physico-Chemical Analysis of Solid Waste" at 9th Uttarkhand State Science and Technology Congress-2014 was held on 26th -28th Feb.2015.

- Presented paper on "Study of effects of Municipal Solid Waste on water quality of Dehradun City" in National Seminar held at UPES on 4th April 2015.

Work Experiences:

S.No	Organization	Designation	Period
1.	Municipal Corporation Shimla, Department of Urban Development, Himachal Pradesh.	Sanitation Expert	1st Feb 2017 to till date

- Assisting in implementation of Solid Waste Management of MC Shimla.
- Assisting for Water Quality Monitoring in jurisdiction of MC Shimla.
- Implementation of door- to-door garbage collection, segregation and disposal through outsource agency SEHB Society.
- Assisting in formulations, floating and evaluation of tenders for procurement of various items.
- Providing support for up-gradation of Solid Waste Management Plans.
- Implementation of various components of Swachh Bharat Mission Project.
- Assisting MC Shimla for carrying out Swachh Survekshans.
- Coordinating with different departments to successfully carryout the above mentioned activities.

S.No	Organization	Designation	Period
2.	UPES Dehradun, Uttarakhand.	Laboratory Analyst	24th July 2015 to 31st January 2017

- Environmental Monitoring (Water and Air).

- Sampling, Analysis and Report Preparation (Water, Air and Solid Waste)
- Research and Development.
- Prepared Quality/Procedure Manual and supporting documents for NABL Accreditation of HSE laboratory.
- Lead Auditor- OHSAS 18001.
- Assisted in ISO 9001, ISO 14001 and OHSAS 18001 certification.

S.No	Organization	Designation	Period
3.	UPES Dehradun, Uttarakhand.	Junior Research Fellow	30th May 2013 to 29th May 2015

- Base Map Preparation and Site identification.
- Sampling, Analysis and Report Preparation (Water, Air and Solid Waste)
- Quantification and Characterization.
- Skill development towards using/programming in software/tools such as Expert System Shells, Prolog and Visual Programming (.NET).
- Expert System Development.
- Incorporation of analytical data into Expert System.
- Integration of prediction/statistical tools such as AHP etc. in expert system.
- Validation, Testing and Implementation.
- Documentation and Report Writing.

S.No	Organization	Designation	Period
4.	Zeon Lifesciences Ltd. Paonta Sahib	Production Officer	6th June 2012 to 29th May 2013

- Working according to cGMP guidelines.
- Handling In- Process Activities (Manufacturing).

- Handling BMR/BPR.
- Handling Manpower in Manufacturing process.

Other Experiences:

- Attended Water Quality Workshop: Monitoring, Assessment and Management held on 25th -26th November, 2015 organized and supported by Uttarakhand State Council for Science and Technology.
- Internal Auditor in University of Petroleum & Energy Studies for ISO 9001, ISO14001 and OHSAS 18001.
- Co-ordinated Meeting of Sub Expert Committee on "Women and Nutrition" Programme held on 19th and 20th June 2014 Funded by SEED, DST at University of Petroleum & Energy Studies, Dehradun.
- Co-ordinated "10th Uttarakhand State Science & Technology Congress" held on 10th to 12th February, 2016.
- Co-ordinated M.Tech Symposium during Ignite 2014, Annual Techno Legal Management Fest held on 20th & 21st Feb. 2014 at University of Petroleum & Energy Studies, Dehradun.
- Member of Reviewer Panel in International Conference on Intelligent Communication, Control and Devices-2016 organized by Department of Electronics, Instrumentation and Control Engineering at UPES, Dehradun on 2nd & 3rd April, 2016.

Technical Skills:

- **Hands on**: AAS, UV Spectrophotometer, Respirable Dust Sampler, Stack Monitoring, PM 2.5/10, Dosimeter, Carbon Dioxide Analyzer, Handy Sampler (Air), Noise Meter, Hardness of water, Alkalinity of water, Chloride of water, Dissolved oxygen in water, Conductivity of water,

Turbidity of water/waste water, pH value of water, WBGT Meter (Industrial Hygiene), Dosimeter (Industrial Hygiene).

- Environment Impact Assessment & Waste Management.
- Water, Air, Soil & Solid Waste Sampling and Analysis.

Computer Proficiency:

- Visual Basic, FLEX 4.8, MS-Office, Search Engines.

Personal Details:

Name	**:**	Ritesh Saini
Father's Name	**:**	Sh. N.L. Saini
Date of Birth	**:**	24-02-1989
Nationality	**:**	Indian
Sex	**:**	Male
Marital Status	**:**	Married
Address	**:**	V.P.O Ner-Chowk, Tehsil Balh, Distt. Mandi, Himachal Pradesh, India.

Declaration:

I hereby declare that the above-mentioned information is correct upto my insight and I bear the responsibility for the correctness of the above mentioned points of interest.

(RITESH SAINI)

PLAGIARISM CERTIFICATE

1. We Dr. Neelu J. Ahuja (Internal Guide), Dr. Kanchan Deoli Bahukhandi (Co Guide/ External Guide) certify that the Thesis titled Design and development of an expert system with emphasis on futuristic planning and impact analysis of municipal solid waste for Dehradun City of Uttarakhand submitted by Scholar Mr Ritesh Saini having SAP ID 500031478.

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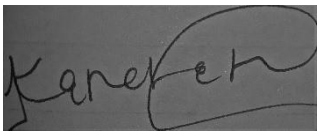

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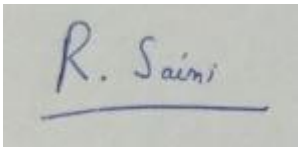

Signature of the Scholar

DESIGN AND DEVELOPMENT OF AN EXPERT SYSTEM WITH EMPHASIS ON FUTURISTIC PLANNING AND IMPACT ANALYSIS OF MUNICIPAL SOLID WASTE FOR DEHRADUN CITY OF UTTARAKHAND

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