USE OF FOUNDRY SAND IN HIGHWAY CONSTRUCTION

A THESIS

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

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Dr. Saurabh Rawat

(Assistant Professor)

By

Nitin Nautiyal(141645)

Hardik Goel(141646)

Himank Sen(141651)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled "***USE OF FOUNDRY SAND IN HIGHWAY CONSTRUCTION***" in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **NITIN NAUTIYAL(141645), HARDIK GOEL(141646), HIMANK SEN(141651)** during a period from July 2017 to June 2018 under the supervision of **Dr.SAURABH RAWAT** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

Date: - …..May,2018

Dr. Ashok Kumar Gupta	Dr. Saurabh Rawat	External Examiner
Head of Department	(Supervisor)	
Department of Civil Engineering	Assistant Professor	
JUIT, Waknaghat	Department of Civil Engineering	
	JUIT, Waknaghat	

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ABSTRACT

Waste Foundry Sand (WFS) is obtained from metal casting process in industries, metal is poured in the mould made of sand and subjected to very high temperature of about 1000ºC and above. Once used in mould it is of no further use therefore it is discarded. Our project deals in utilizing this waste foundry sand in sub-base layer of our pavement as it has already been done due to its suitability as a good replacement of traditional sand.

With our work we use the pavement model constructed in a Perspex box with four different layers being laid as per the guidelines in IRC-37 of flexible pavement design. Then our work included the collection of leachate through experimental setup pavement for a period of 150 days at a regular interval of 15 days, hence giving 10 different samples. These samples were taken for testing on it by performing tests like pH, Chlorides, Alkalinity, Acidity, DO, etc.

The most important of all test for our work was to determine the concentration of heavy metals seeping into the groundwater which we performed using TCLP (Toxicity Characteristic Leaching Procedure) test one of the most recognised and accepted test worldwide.

With above modelling and testing the main result obtain was the presence of Nickel metal beyond the maximum permissible range. Its excess presence is harmful as it causes hair loss, decrease body weight in animals and at higher concentration may even lead to skin cancer.

Keyword: *Waste Foundry Sand, Granular Sub-Base, TCLP*

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LIST OF ACRONYMS

WFS	Waste Foundry Sand
AC	Asphalt Concrete
GSB	Granular Sub-Base
WMM	Wet Mix Macadam
BC	Bitumen Concrete
EL	Embankment Layer
IMD	India Meteorological Department
TCLP	Toxicity Characteristics Leaching Procedure
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
NTU	Nephlometric Turbidity Unit

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CHAPTER 1

INTRODUCTION

1.1 General

Waste Foundry Sand or WFS is a waste material from casting industries which cannot be used again for the same purpose so WFS was used for construction purposes later on. Many scholars have studied the environmental impact of using WFS in construction but we have focused on its impact on groundwater when passed through pavement. In this chapter we have discussed about reuse of waste materials mainly foundry sand, its origin, physical properties and chemical properties.

1.2 Need of the Study

Waste Foundry Sand (WFS) is obtained from metal casting process in industries, metal is poured in the mould made of sand and subjected to very high temperature of about 1000ºC and above. Once used in mould it is of no further use therefore it is discarded.

Our project deals in utilizing this waste foundry sand in sub-base layer of our pavement as it has already been done due to its suitability as a good replacement of traditional sand.

Main objective of the project is to see the environmental impact of the replacement of sand with waste foundry sand. To what extent does it harm the groundwater is also one of our concerns. Mainly the heavy metals that are present in the waste foundry sand are of major concern for us. Also other physio-chemical parameters like chloride, total dissolved solids, pH, alkalinity, acidity are also look into and their presence in the acceptable range is checked.

For our project we included paper that had already done some work on waste foundry sand, leachate collection, etc. so from the papers we got a great deal about the direction in which we should focus mainly and were very helpful for the completion of the project. Many insightful ideas were provided in different fields needed for the project as foundry sand suitable for pavement design and 10% WFS is the best suited for highway design (S*ayeed Javed* , *1994*).

Have acceptable mechanical properties for sub-base layer and volumetric properties show that WFS can effectively replace conventional materials in HMA (*Tarek Abiehou et al., 2004)*.. CBR & mini CBR @60% had similar characteristics to that of lateritic sandy soil and 60% of WFS suitable for low volume traffic highway *(Luis Miguel Gutierrez Klinsky et al., 2006).* WFS from iron, steel and aluminum foundries are low contaminated matter making these safe to use beneficially *(Barbara S. Q. Alves et al., 2006)*. Clay bonded has 85-95% silica, chemically bonded 93-99% silica and WFS has no absorption quality and is non plastic *(Rafat Siddique et al., 2010)*.

1.3 Waste Materials

Materials which are unwanted or which cannot be used for the same purpose anymore are described as waste. There are many types of waste materials on the planet which can be categorized in numerous numbers of categories. But for the project we separated the waste materials which were only taken into consideration for the construction of roads. As we all know plastic has already been used in highway construction after so many years of studying and many researchers have found plastic to be beneficial for the same. So we decided to move further and we found that there are many more waste materials which can be used for construction of roads. Materials which were in consideration for the highway construction are:

- **Metals**: Metals as waste are generated in many industries but it is also generated during construction such as copper piping, aluminum siding, guttering and flashing, flashing and wire, steel and iron banding from bundles.
- **Drywall**: It is mainly used for the construction of wall in the U.S. for interior designs. Main constituent for drywall is gypsum which is covered from either sides with the help of a paper facing and paperboard backing.
- **Crumb Rubber (Scrap Tires)**: These are the by-products of tires of vehicles generated by friction and skid effect from the road, accidents and overusing of the tires.
- **Foundry Sand**: It is generated from casting industries and it is used again and again until its composition is unsuitable for further use. After that it is dumped as a waste. Metal is poured in the mould which is subjected to ver high temperature near about 1000 ºC.

- ❖ **Miscellaneous**: Cardboards and paper, paints, sealants, solvents, branches, trees from brush, old nickel cadmium batteries, etc. are the waste materials which can be used for the highway construction.

1.4 Reuse of Waste Materials

Waste materials can be used in many forms in daily life and are also being used as well. Many competitions are being held to use waste materials as creative as it can be for the betterment of the environment. Waste irrespective of type, its origin is very hazardous for the environment, surroundings, lands and for the living beings. Waste should be reused to save the planet and make the world a better place to live for the next generations otherwise there will be no resources left for the upcoming generations. But reusing waste doesn't says that use any type of waste anywhere without studying its effects on the environment. So the waste materials discussed above can be reused as:

- ❖ **Metals**: Metals can be used in numerous ways but it can also be used in highway construction as a reinforcing agent that can provide strength to the pavement if mixed with concrete in cement concrete roads.
- ❖ **Drywall**: scraps of drywall are used in the interior wall cavities during construction. It can also be used to provide support to gunite which is concrete sprayed on at high pressure. It can also be used in making new swimming pools.
- ❖ **Crumb Rubber (Scrap Tires)**: It is very usable in highway construction as it provides high shear strength which enables road to withstand imposed traffic load, improves resistance to skidding. It also reduces the frost penetration level during freezing and thawing cycles.
- ❖ **Foundry Sand**: As it is high quality silica sand and have high clay content, it was considered to be utilized in hot mix asphalt (HMA), sub-base embankments and as flowable fills. It provides strength to the pavement as it consists of metals from casting industries but the effect of these metals is the objective of the project because it is unknown after many studies too and it is site specific as well. It is found to be very useful when used in sub-base layer and it is very helpful for drainage so the layer responsible for drainage is also sub-base so it was found to be suitable.

- **Miscellaneous**: All the materials falling in this category can be used as a filler in the preparation of different layers as a replacement of dust.

1.5 Foundry Sand

Foundry sand is generated majorly from automobile and spare parts manufacturing industries. Constituents of WFS are of uniformly sized, high silica sand or lake sand which is mainly used during moulding process in casting industries mainly non-ferrous and ferrous metals moulds. Firsthand foundry sand is of very high quality than normal sand which is used in making moulds and it is used again and again until it looses its properties and is discarded for further use in casting industries. Then it is considered for the construction of roads as it is of very high quality than traditional sand used in highway construction. But the type of foundry sand generated depends on the industry it is generated from and its physical and chemical properties also varies with the same. The discarded sand after used multiple times for the moulding process of metals in casting industry is termed as Waste Foundry Sand (WFS).

1.5.1 Origin

Foundry sand consists mainly of fresh, same sized, top-quality silica sand or lake sand that's bonded to create molds for ferrous iron and steel, nonferrous copper, aluminum, brass metal castings. though these sands are rubbed before utilization, once casting they will contain ferrous iron and steel) plant account for about ninety five % of foundry sand utilized for castings. The trucks industry and its parts manufacturers are the main important consumers of foundry sand.

The most simple casting method in practice in the foundry plant is that the sand cast system just about all sand cast molds for ferrous castings are of the green sand sort. green sand consists of top-quality silica sand, (about ten % clay as the binder), 25 % water and about 5 % sea coal, a carbonous mold additive to enhance casting finish). the sort of metal being cast determines which additives and what gradation of sand was in use. The green sand utilized in the method constitutes upwards of ninety % of the molding materials used.

The annual manufacturing of foundry waste including (dust and spent foundry sand within the U.S. is believed in range from 9 to 13.6 million metric tons 10 to 15 million tons). Traditionally, near around one ton of foundry sand is utilized for every ton of iron or steel casting produced.

1.5.2 Disposal

Major portion of reused foundry sand from green sand operations is dumped on lands, often being employed as a supplemental cover material at dumping sites.

1.5.3 Market Sources

Foundry sand is collected straight from foundries, major of that are found in western countries, as well as Michigan, Illinois, Ohio, Wisconsin, and Pennsylvania. Foundry sand, before employing may be a similar graded metal. The spent material, however, often have metal from the moulding and outsized cast and main material having partially degraded filler. Employed foundry sand may have some leachable contaminants, as well as significant phenols that are consumed by the WFS through the casting methods. Significant high metals mainly found in non-ferrous compounds casted in non-ferrous industries are of major concern. Employed foundry sand from brass or bronze foundries, especially, could have high concentrations of Cadmium, lead, copper, nickel, and zinc.

1.5.4 Physical Properties of WFS

There are two types of WFS one is clay bonded or green sand which is black or grey in colour and second is chemically bonded which is whitish tan in colour the shape of particles of foundry sand appears to be semi-angular. Around 85% to 95% of the particles have size in the range of 0.6 mm to 0.15 mm. The grain distribution curve of waste foundry sand is uniform and 5% to 12% have size less than 0.075 mm. Physical properties od foundry sand is shown in table 1.2.

1.5.5 Chemical Properties of WFS

The chemical composition of the waste foundry sand depends on the casting industry it was being used, the type of binder used and the kind of metal moulds casted in the industry with type of combustible used all these account for the composition of waste foundry sand which can influence its efficiency. The residual foundry sand after use in the moulding process have traces of burnt carbon, silica sand and contains bentonite (residual binder) and foundry dust. All these factors discussed contributes to the chemical composition of Waste Foundry Sand. Chemical composition of foundry sand is shown in table 1.2.

Table 1.1: Physical properties of WFS

Property	Range	Method
Specific Gravity	2.39-2.55	ASTM D854
Bulk Relative Density(kg/m^3)	2589.45	ASTM C48/AASHTO T84
Absorption (%)	0.45	ASTM C128
Moisture Content (%)	0.1-10.1	ASTM D2216
Coefficient of permeability(cm/s)	10^{-3}-10^{-6}	AASHTO T215/ASTM D2434
Plastic Limit/Plastic Index	Non Plastic	AASHTO T90/ASTM D4318

Table 1.2: Chemical composition of WFS

Constituents	% in WFS
SiO_2	87.91
Al_2O_3	4.70
Fe_2O_3	0.94
MgO	0.30
K_2O	0.25
Na_2O	0.19
TiO_2	0.15

1.6 Environmental Impact of Waste

As soon as waste is generated it starts creating problem for everyone like where to dump, the gases leaked, the diseases it will spread and many more. When waste is generated it leaks a lot of harmful gas like methane, methane isocyanide and many more. Then it goes on to create problem where to dump because the place at which it will be dumped will be of no use as it spoils the land and the surroundings, the people living nearby and the air which it will pollute and it will be not just surroundings because air travels widely. All the resources are just being wasted on the waste which just identifies that nothing will remain if we keep moving on the same path. Our future generations will remain with nothing of resources because we are busy using them on wastes rather than using in something useful in different fields as natural resources are limited. If we cant keep our environment clean we don't deserve to live that's why we all are facing different diseases because we don't reuse waste and don't preserve our environment.

Figure 1.1 Waste dumped near river

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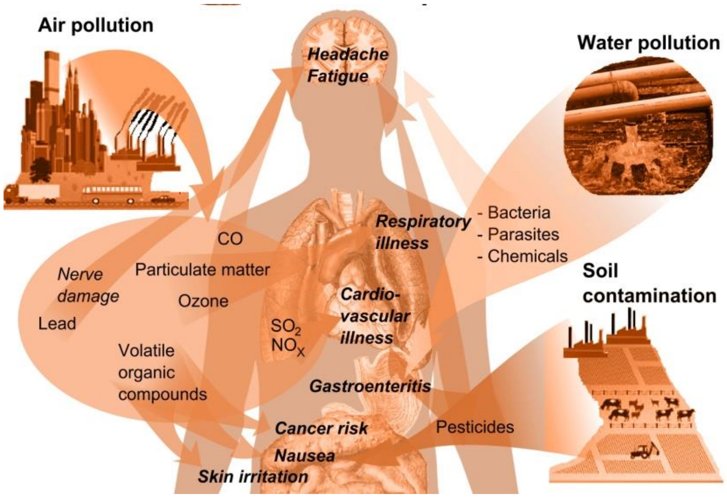


Figure 1.2 Impact of Waste

https://goo.gl/images/iEY3fv

As shown in Figure 1.1 waste is dumped nearby river causing water pollution, air pollution and land pollution which in turns harms us as shown in figure 1.2. So we need to take care of our home i.e The Earth.

1.7 Organizaion of Thesis

The project report is presented in five chapters. Brief description about each chapter is given below.

In chapter 1 we get to know the idea of what is waste foundry sand, origin and its environmental impact, it highlights the use of WFS as a suitable replacement for traditional sand keeping in mind the ill effects it can cause to groundwater.

In chapter 2 the literature of the work done by various researchers is discussed. It gives a brief but enough description about waste foundry sand, its environmental impact on groundwater when replaced with traditional sand in granular sub-base layer of pavement. Various research scholars have presented their work on its use and environmental impact which have been discussed in this chapter.

In chapter 3 methodologies is discussed and the primary goal of the research is to develop guidelines and technical specifications so as to check the possibility of utilization of waste foundry sand as a suitable replacement for traditional sand and its environmental impact on groundwater. Its environmental impact study is based on the physical modeling performed on it and tests such as TCLP which tells us the amount of heavy metals present in the leachate collected after passing water through the physical model.

In chapter 4 results are discussed and It was important to know the various physio-chemical properties of leachate to determine the presence of heavy metals and the possibility of these metals polluting the underground water source. The leachate was investigated for various tests like pH, turbidity, chlorides, specific conductivity, total solids, alkalinity, acidity, dissolved oxygen and TCLP.

In chapter 5 the conclusions are discussed and the Waste foundry sand from Rewari (Haryana) has been studied in detail for the checking of its impact on groundwater after being replaced with traditional sand in pavement. Various samples were taken at a regular interval for showing the time dependence impact of leachate on groundwater.

CHAPTER 2

LITERATURE REVIEW

2.1. General

This chapter summarizes the literature of the work carried out by various investigators. It gives a brief description about waste material ,reuse of waste foundry sand, its environmental impact on groundwater when replaced with traditional sand in granular sub-base layer of pavement. Various research scholars have presented their work on its use and environmental impact which has been discussed in this chapter.

2.2. Study on Waste Material

Aravind et al. (2008) in his work *"Industrial waste in highway construction"* confirmed the use of waste materials in pavement construction and showed the various possible ways to do it. He added in his work the acceptability criteria for the material to be used in highway construction. For conventional materials, a number of tests are conducted and their acceptability is decided based on the test results and the specifications. This ensures the desirable level of performance of the chosen material, in terms of its permeability, volume stability, strength, hardness, toughness, fatigue, durability, shape, viscosity, specific gravity, purity, safety, temperature susceptibility etc., whichever are applicable.

Klinsky et al. (2012) in his work "*Reuse of Waste Foundry Sand Mixed with Lateritic Clayey Soils in Pavement Bases and Sub-bases Courses*" included research work that assessed the feasibility of using Waste Foundry Sand mixed with clayey soils as a roadway sub-base and base course material. Lateritic clayey soils and chemically bonded WFS were used to assemble soil-sand mixtures. Mechanical properties of the soil-sand mixtures were investigated in a laboratory program. Also, Leaching Test was performed to investigate the environmental risks of their use. The laboratory results showed that soil-sand mixtures containing lateritic clayey soils and Waste Foundry Sand have mechanical properties similar to the commonly materials used in bases and sub-bases courses. Therefore, Waste Foundry Sand mixed with clayey soils could be reused as a partial substitute of commonly used materials.

2.3. Study on Foundry Sand

***Ojuri* et al. (2016)** in his work "*Geotechnical and Environmental Evaluation of Lime-cement Stabilized Soil mine Tailing Mixtures for Highway Construction*" Strength characteristics and environmental impact of the Lateritic Soil-Mine Tailings Binder Mix in highway construction was evaluated using a series of laboratory tests. Results of the geotechnical tests showed that the properties of the soil sample improved with the addition of mine tailings and binder. The results of the leaching test show that the binder was able to reduce the heavy metals in the leachate below the regulatory level, with the exception of barium and chromium. Mineralogical analysis done on the leached samples revealed that the binder was able to immobilize the mine tailing minerals that could adversely affect the environment in the soil matrix.

Arulrajah et al. (2016) in his work "*Recycled waste foundry sand as a sustainable sub-grade fill*" discussed that the particle size distribution curves indicate that the WFS was poorly graded and comprised essentially of sand sized particles. CBR values for WFS are greater than the typically specified within the range of 2% to 5%, which is the local road authority specification requirements for a structural fill material in road embankments. Leachate analysis results were obtained and compared with the requirements of regulatory authorities. Results indicated no environmental risks for using WFS in road applications, such as embankment fill and pipe bedding. The use of WFS instead of quarry sand will save embodied energy, as well as reducing carbon footprint.

Koyuncu et al. (2004) in his work "*An investigation of waste foundry sand in asphalt concrete mixtures*" included the result of the described experiments carried out on asphalt concrete samples, it can be concluded that the addition of WFS in quantities of more than 10% decreases the Marshall stability significantly, from 12.1 kN with 0% WFS to 10.9 kN with 10% WFS added. Hence for practical use, the portion of WFS as an additive material in asphalt concrete should be limited to 10% or less. The flow properties of WFS–asphalt cement mixtures measured show that the flow decreased as the percentage of WFS added was increased. All the experimental results of this study clearly indicate that using WFS as a partial replacement for fine aggregate in asphalt concrete should be limited to a maximum of about 10% in practical applications.

2.4. Study on Foundry Sand in pavement

Javed (1994) in his work "*use of foundry sand in highway construction*" tells us a great deal in making use of waste foundry sand in highway construction. His work signifies that foundry sand is suitable in pavement design. He also recommended field study, which should include the construction of a test embankment and a test section of sub-grade, with adequate monitoring devices, to measure the long term mechanical and environmental performance and development of correlations between the laboratory and field parameters. Further he claimed that its site specific nature makes every single work on it different and must be tested every time.

Abiehou et al. (2004) in his work "*Performance evaluation of highway embankment constructed with waste foundry sand"* shows foundry sand have acceptable mechanical properties for sub-base layer. Various applications of waste foundry sand includes embankment, retaining walls, sub-base flowable fills, barrier layers and HMA mixtures. Replacement of natural soil, aggregates and cement with solid industrial by-products is highly desirable. The preference being given to these by-products despite being inferior is cost effective nature of these materials. Some materials can also be added to it in order to increase the effectiveness of these by-products.

Partridge et al. (1996) in his work "*performance evaluation of highway embankment constructed with waste foundry sand*" was keen on reusing waste foundry sand and take benefits from waste material, he calculated Annual generation of waste foundry sand (WFS), a byproduct of the metal casting process, in the United States amounts to 5.4 million Mg, of which more than 408 000 Mg are produced in Indiana. Geotechnical laboratory investigations have been performed to determine the engineering properties of WFS . Research results indicated that WFS from ferrous foundries (which represents the majority of waste sand produced) is potentially suitable, from a geo technical standpoint, for various uses in highway construction, such as embankments, sub-grade, and flowable fill. Other uses have been proposed, including daily landfill cover and aggregate applications in concrete, asphalt, bricks, and tile.

2.5. Study on Environmental Impact Analysis

Guney et al. (2005) in his work "*geo-environmental behaviour of foundry sand amended mixtures for highway sub bases"* conducted a laboratory testing program on soil foundry sand mixtures amended with cement and lime to assess their as highway sub-base material. Environmental suitability of the mixture was evaluated by analyzing the effluent collected. The results of the study shows that strength of the mixture is highly dependent on the method and ways of compaction. Also his work showed that foundry sand is better in winters as compared to traditional sub-base material. He also concluded on the quality of groundwater when water would pass the layer and concluded that it would not degrade the quality of water beneath the pavement.

Alves et al. (2014) in his work "*Metals in Waste Foundry Sands and an Evaluation of Their Leaching and Transport to Groundwater*" tells while metal concentrations in TCLP leachates were also within report deranges, some of the concentrations were found to exceed drinking water and groundwater. This out come was expected because of the low pH conditions associated with the TCLP test. Land application of sands with a high metal leaching potential should be evaluated under realistic conditions if they are to be used in high rainfall, low evaporation areas. Under high rainfall, high evaporation and moderate rainfall, and moderate evaporation scenarios, only 3 of 16 WFSs were predicted to cause metal levels to exceed the limits for Ba and Mn.

2.6. Summary of Literature Review

From the studied literature, it can be summarized that waste foundry sand found its way into the field of civil engineering in the 1990s. From than a lot of research and experiments are under way so that foundry sand can be used in flexible or rigid pavement.

The literature brings to light that a lot of research work has been done on foundry sand and it is found to be suitable for pavement design. 10% WFS is best suited for highway design as per the study of **Javed (1994).** Foundry sand have acceptable mechanical properties for sub-base layer in pavement and volumetric properties show that WFS can effectively replace conventional materials in HMA as per the study of **Abiehou et al. (2004).** The study by **Klinsky et al. (2012)** shows that 10% of WFS should be used in asphalt concrete for better performance, also CBR & mini CBR @60% had similar characteristics to that of lateritic sandy soil. In further evaluation it was found by **Klinsky et al. (2012)** that 60% of WFS is suitable for low volume traffic highway. Authors like **Alves et al. (2014)** stated that clay bonded has 85-95% silica and chemically bonded 93-99% silica. WFS have no absorption quality and is non plastic.WFS from iron, steel and aluminum foundries are low contaminated matter making these safe to use beneficially.

Further **The Indian Meteorological Department's** rainfall data was analyzed to find the volume and time for the sprinkling of water on the designed pavement.

2.7. Objectives of the study

1) To fabricate a lab – scale pavement model using foundary sand in Granular sub – base layer (GSB) layer.
2) To evaluate the environmental impact of foundry sand in GSB layer by leachate testing through the pavement.
3) To charaterize the leachate through pavement model and its validation with published previous literature.

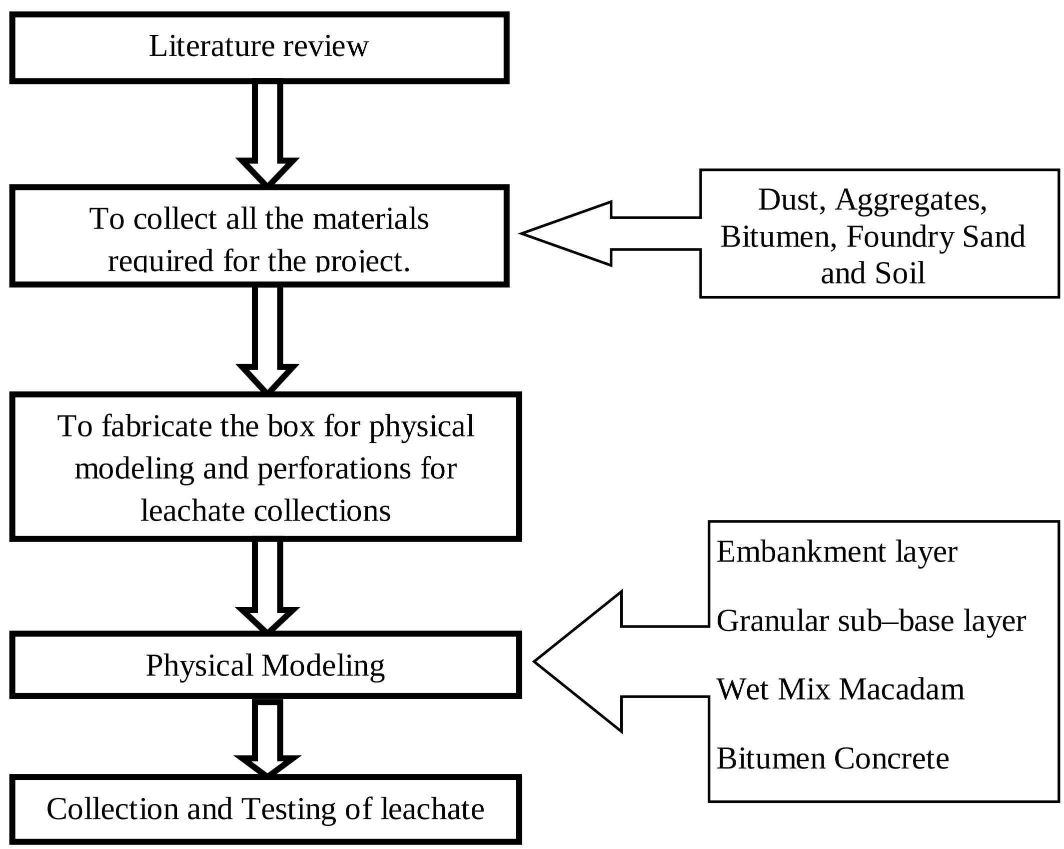
CHAPTER 3

METHODOLOGY

3.1. General

The primary goal of the research is to develop guidelines and technical specifications so as to check the possibility of utilization of waste foundry sand as a suitable replacement for traditional sand and its environmental impact on groundwater. Its environmental impact study is based on the physical modeling performed on it and tests such as TCLP which tells us the amount of heavy metals present in the leachate collected after passing water through the physical model.

3.2 Workplan



3.3. Pavement

The function of the pavement is to distribute the load that is being applied by the vehicles on the surface. Also it should provide smooth riding quality, better light reflection, proper skid resistance. For pavement to be called a good pavement it must fulfill all the above mention quality and also should last long with minimum maintenance cost during its life period.

There are two types of pavement specifically

- Flexile Pavement
- Rigid Pavement

For our project work we designed flexible pavement.

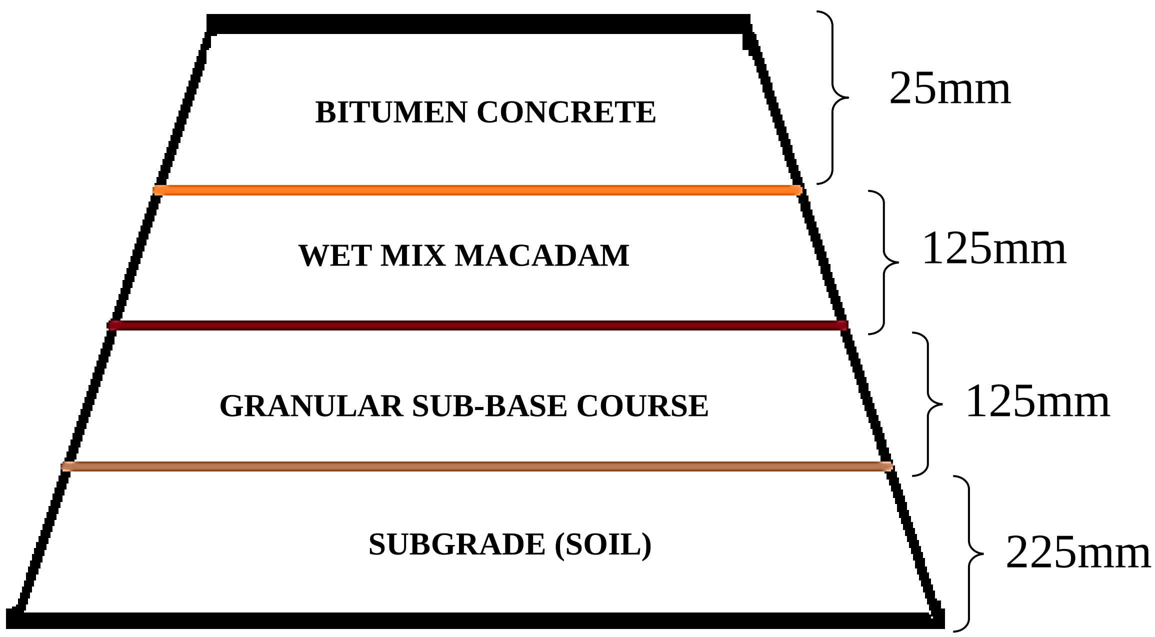


Figure 3.1 Layout of flexible pavement

3.4 Material Procured

The materials required for the project to be completed were procured from different places which were essential to construct the pavement model in a Perspex box (shown in fig. 3.2). Firstly, the Perspex box was made available on the site itself and the alloy stand on which the model was to be kept was built. Perforations beneath the box were done with the help of drilling machine.

Figure 3.2 Perspex Box

Figure 3.3 Dust

Dust (as shown in fig. 3.3) which is used in every layer of pavement as a filler or binder was procured from Panchkula (Haryana) having size of 0.84 mm. As stated it is used in every layer of the pavement i.e. Granular sub-base layer, Wet Mix Macadam and Bitumen Concrete.

Figure 3.4 Foundry Sand

Foundry Sand (shown in fig. 3.4) which is the main material for the project was procured from Rewari (Haryana). It was used in Granular Sub-Base Layer as a replacement of traditional sand with a proportion of 10% which came to be optimum for the pavement to have the strength that of a normal pavement constructed by traditional sand. Size used was medium to fine sand.

Figure 3.5 Aggregates

Aggregates (Shown in fig. 3.5) which provide strength to the layers of pavement were procured from Panchkula (Haryana). These are responsible for the strength, friction, and the thickness of layers. Different sizes of aggregates are used in different layers i.e. 40 mm is used in GSB, WMM; 20 mm is used in WMM; 13.2 mm used in BC; 10 mm used in GSB and 5.6 used in BC.

The binder material (shown in fig. 3.6) used in Bitumen Concrete layer which provides the colour of the road was procured from JUIT, Waknaghat and the grade mainly used in road was VG30 as it is most suitable for highway construction.

Figure 3.6 Bitumen

Figure 3.7 Soil

Soil (shown in fig. 3.7) used in embankment layer which is the utmost layer of road as it is the base of the highway which provides with the shape and is the backbone of the highway. It was procured from JUIT, Waknaghat and was used near around 125 kilograms. It was well graded soil having Specific Gravity (G) = 2.67, Cohesion (c) = 1.37 kPa and Angle of Internal Friction (ϕ) = 17.53°

Pavement Model Setup

- Surface Course (Bitumen Concrete)
- Base Course (Wet Mix Macadam)
- Sub-Base Course (Granular Sub-Base)
- Sub-Grade (Embankment Layer)

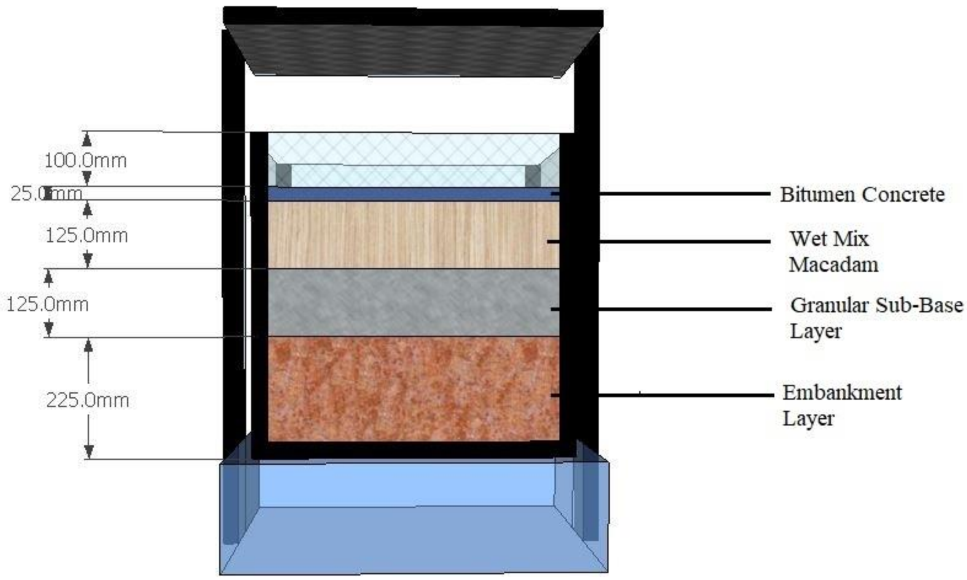


Figure 3.8 Pavement layers in Model

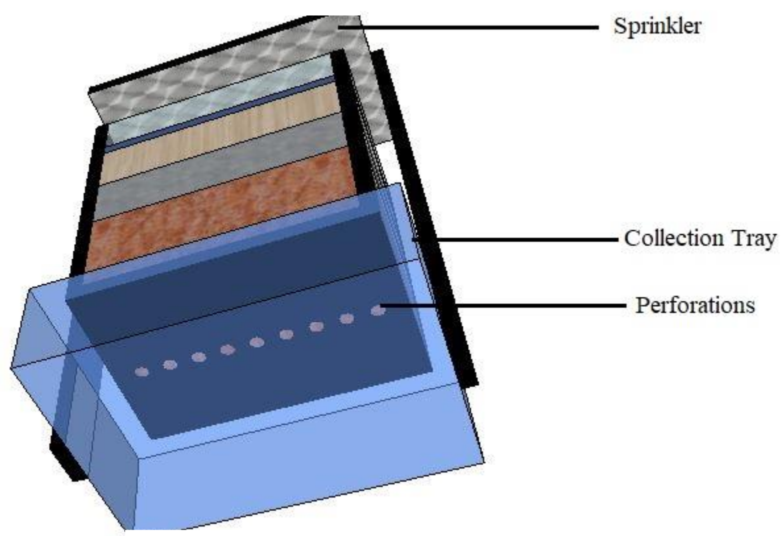


Figure 3.9 Components of Model

Surface Course

It is the topmost layer of the pavement having thickness of 25 mm (as stated in IRC-37) . It was prepared by making the mixture of aggregates (13.2 mm and 5.6 mm), dust and lime. Bitumen is heated in the oven at 150° C and the mixture is also heated at 150°C. Then the bitumen is mixed with the mixture part by part and it is laid immediately so that it does not get cold.

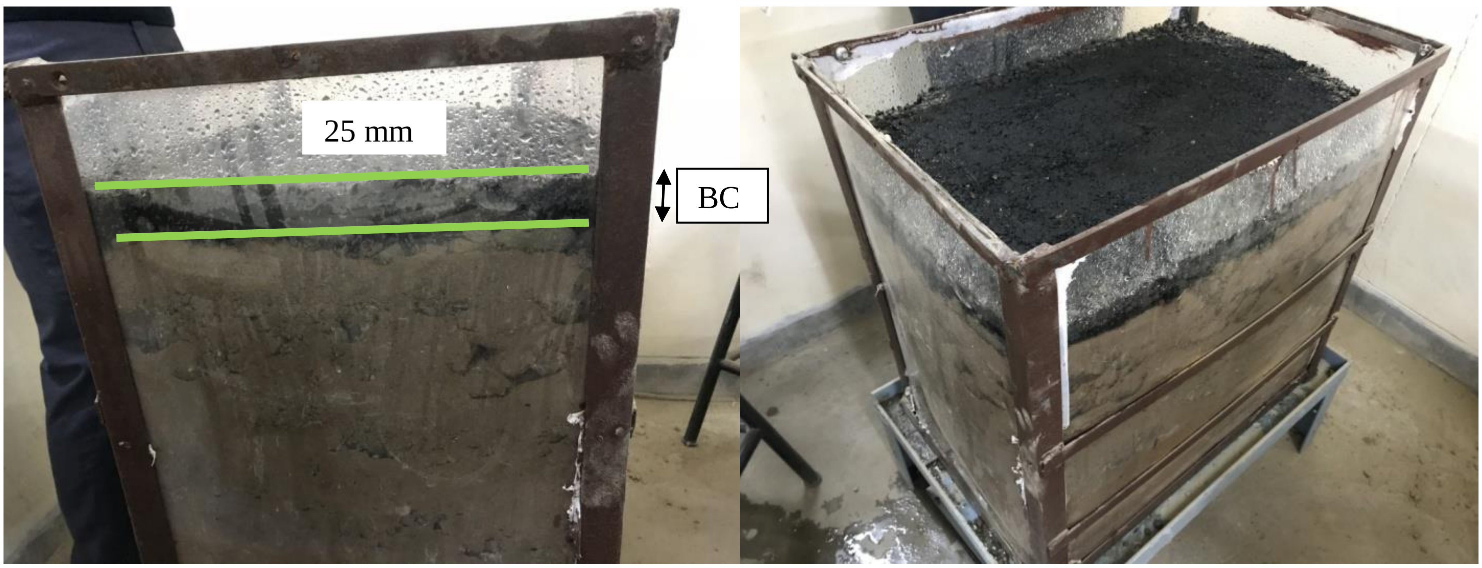


Figure 3.10 Surface Course (Bitumen Concrete)

Base Course

It is the layer named Wet Mix Macadam (WMM) prepared by the mixture of aggregates (40 mm and 20 mm) and dust. The layer thickness was 125 mm so it can be laid in a single go as minimum 150 mm is required for layer to be laid in two rounds. It was then compacted with the help of a round hammer. It helps in distributing load and drainage of the pavement. It is the second layer and have enough strength to pass traffic from it.

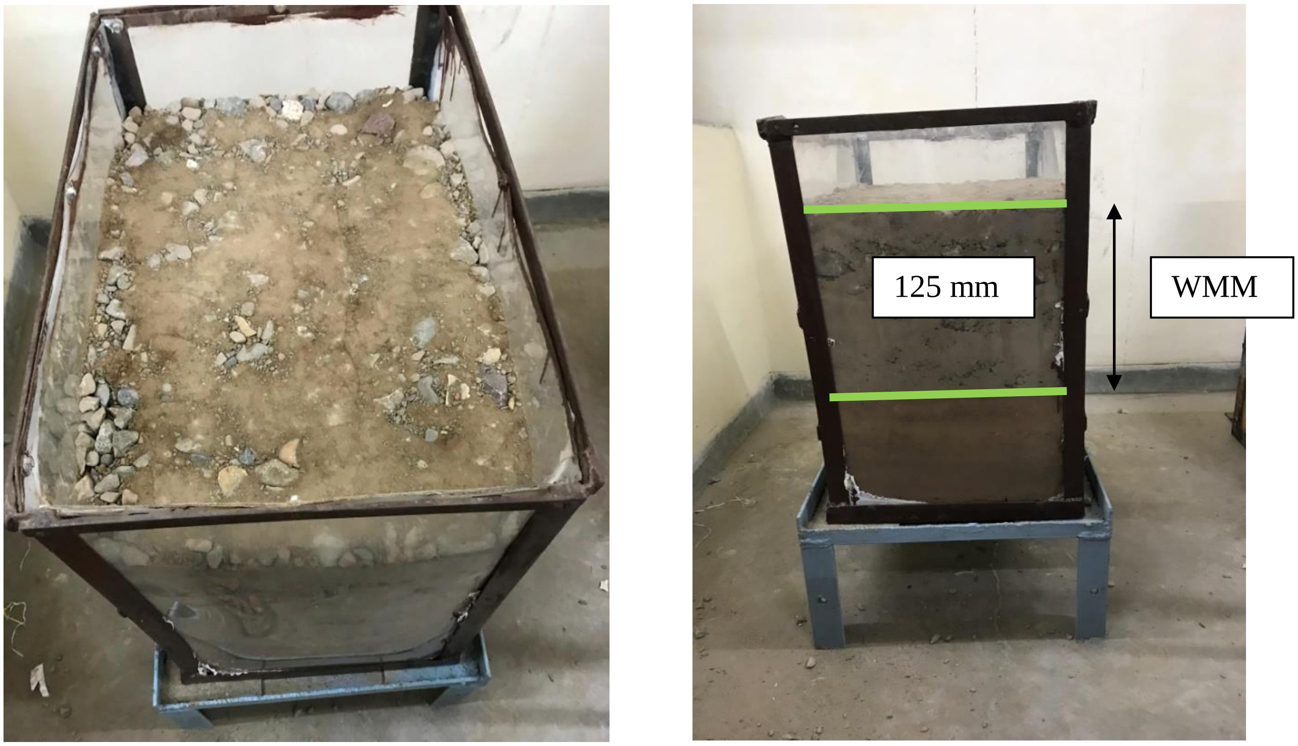


Figure 3.11 Base Course (WMM)

Sub-Base Course

It is the most important layer of the pavement as it consists of foundry sand among the aggregates (40 mm and 10 mm) and dust. 10% of foundry sand replaced the traditional sand in the layer and then the mixture was prepared according to the gradation. It was laid in a single round and was then compacted with the help of a round hammer. Thickness of the layer was 125mm.

Sub-Grade Course

It is the most important layer as it is the backbone of the pavement which provides the strength to the pavement. It was prepared by the soil procured from JUIT and the thicknes of the layer 225 mm according to IRC-37 and it was laid in two layers, one of 125mm and then it was compacted properly and the second was of 100 mm which was again compacted by the round hammer properly.

Figure 3.12 Sub-Base Course (GSB)

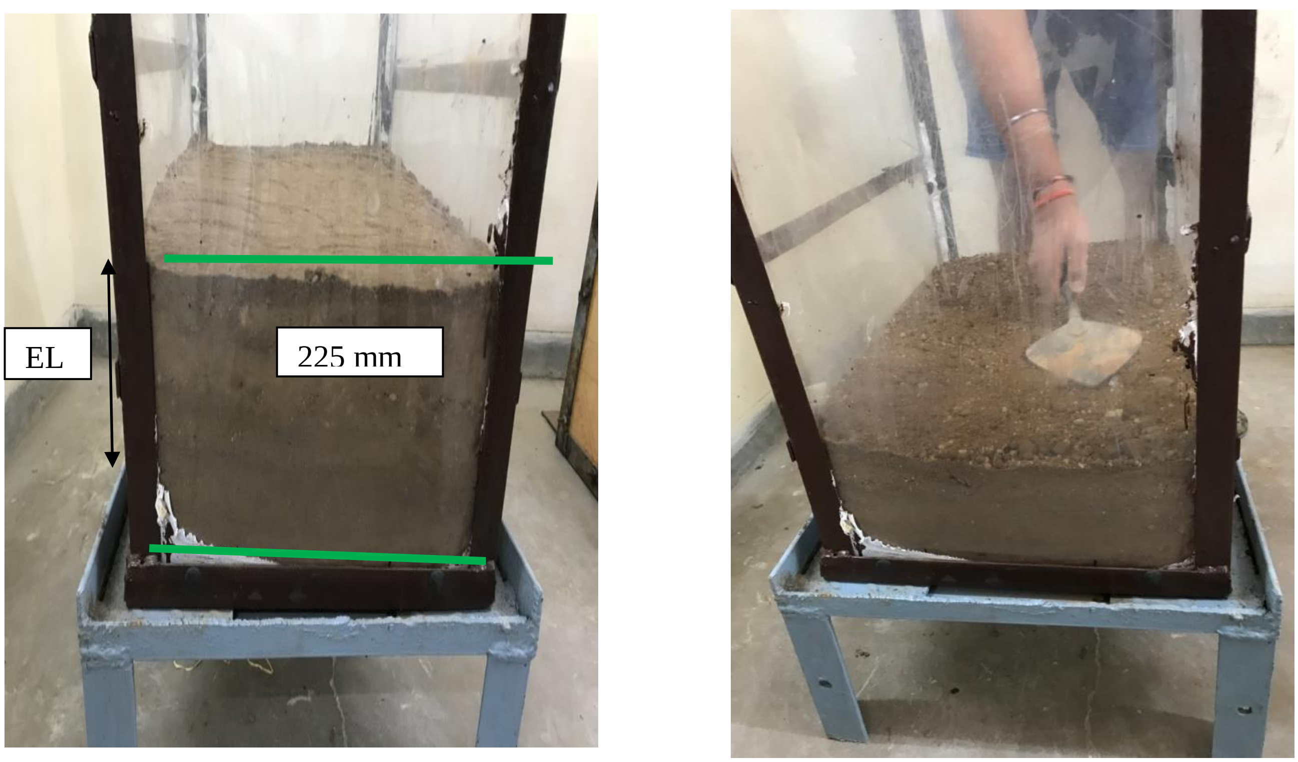


Figure 3.13 Sub-grade (Embankment Layer)

3.5. Rainfall Data

India meteorological Department is using the rainfall knowledge received from a network of quite 3500 rain-gauge stations and prepares the rain statistics, both in tabular as well as in graphical form. The statistics is ready for the administrative zones like districts, states and for the country. The statistics is also prepared for the thirty six meteorological subdivisions and for the four broad regions (North West India, Central India, South peninsula and, North & North East) of India. The rain is prepared at numerous temporal scales, like on weekly, monthly, seasonal and annual basis. Besides this, the hydro met division of IMD also monitors the sub-divisional rain on daily throughout the monsoon season

3.5.1. Methodology

The precipitation statistics is computed based on the receipt of precipitation data from about 3500 stations spread over the whole country. Based on daily precipitation data of these stations, the precipitation of all the districts are computed and using the precipitation of the districts, precipitation statistics for the meteorological subdivisions, states, the four broad regions and for the entire country have been computed.

As the study has been done in the state of Himachal Pradesh therefore seasonal and annual rainfall statistics are taken for the same as follows:

Table 3.1: Subdivision-Wise Seasonal & Annual Rainfall Statistics

Meteorological subdivisions	**winter**	**pre-monsoon**	**monsoon**	**post-monsoon**	**Annual**
Himachal Pradesh	249.8	131.3	774.2	61.6	1216.9

Table 3.2: Subdivision-Wise Monthly Rainfall (mm) - Year 2000-2015

Meteorological subdivisions	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Himachal Pradesh	76	174	75	25	31	240	219	245	68	21	16	25

To study further the subdivision-wise monthly rainfall (mm) was also taken into consideration from year 2000-2015 and with the help of these data the volume and time of sprinkling water for project was fixed. The data for subdivision-wise monthly rainfall is shown in table 3.4.

3.6. Leachate

"Leachate is also defined as the liquid that drains or leaches from the solid wastes that are disposed"(Henry and Heinke,1996).The leachate is generally generated as the result of waste being disposed off in open or nearby the landfills. The amount of leachate that will be produced will depend on the waste that is generated in the area and the time for which it is disposed off. The leachate contains dissolved and suspended particles therefore if this leachate seeps downwards to ground will definitely cause contamination and will make groundwater unfit for usage.

3.6.1. Composition of leachate

Leachate is also water based solution and has a little bad odour and contains colours like light reddish or light yellowish. It is acidic in nature as well as its odour, as it contains some chemicals like sulphur, nitrogen, hydrogen, etc and as the time period of sample increased the colour of the sample started to become same as normal water i.e colourless. Leachate could also be differentiated into two groups of contaminants as per the project, and they are:

a. Heavy Metals

b. Inorganic and organic compounds

In the groups mentioned, the heavy metals present in the leachate are the most important to take into account because heavy metals contaminate the groundwater the most and make it unfit for usage. In inorganic and organic group it has common +ions and –ions like zinc, aluminum, ammonia, sulphate, iron, chloride, total dissolved solids etc. These contaminants are very important to study to know the benefit use of foundry sand in pavement.

The collection of leachate was done after every 15 days and therefore changes in colour and contaminants was seen. The sample 1 having light reddish colour was obtained after first 15 days as shown in fig 3.8.

Figure 3.14 Collection of Leachate Sample 1

Figure 3.15 Collection of Leachate Sample 7

After 105 days sample 7 was collected and was found that the colour of the leachate was changing to colourless from light reddish to light yellowish and then to colourless as shown in fig 3.9.

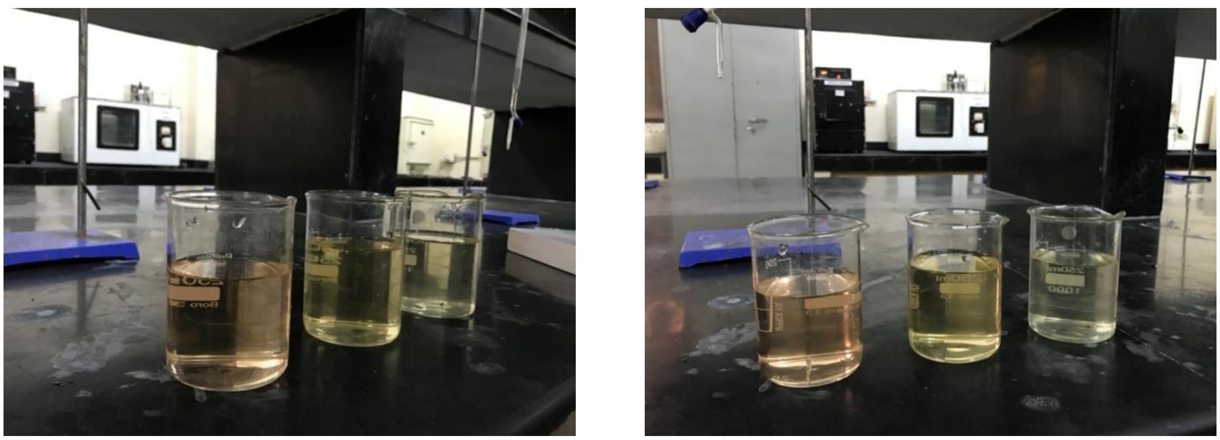


Figure 3.16 Collection of leachate from sample 1 to Sample 4 to sample 7

Leachate was collected after every 15 days and the totals days for which the leachate was collected was 150 days. Therefore all the samples collected and after number of days is shown in Table 3.5.

Table 3.3 Sampling with number of days

Samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Duration(days)	15	30	45	60	75	90	105	120	135	150

3.7. Leachate Characterization

3.7.1. PH of leachate

First of all, take the sample into the beaker and dip the pH strip into the sample to find the pH of the solution. The colour of the litmus paper varies from thick red for highly acidic waters to dark green for highly alkaline water and the colour changes as the solution changes its pH. Select a suitable narrow-range pH strip and compare the colour by using the same method as with wide-range Ph strips. Note down the pH of each sample from sample 1 to sample 10.

3.7.2. Turbidity Test

First of all, switch on Nephlometric turbidity meter and wait for few minutes till it warm up. Set zero of the instrument with turbidity free water using a blank solution & adjust 000 with the "Set Zero" knob as in fig 3.11. Now in another test tube take standard suspension just prepared as described. Take its measurement and set the display to the value of the standard suspension with the Calibrate knob. Now take samples of leachate in test tube as shown in fig 3.11. Shake thoroughly the sample and keep it for some time to eliminate the air bubbles. Take sample in Nephlometric sample tube and put the sample in sample chamber and find out the value on the scale. Now, note down the readings of each samples.

Figure 3.17 Nephlometric Turbidity Meter

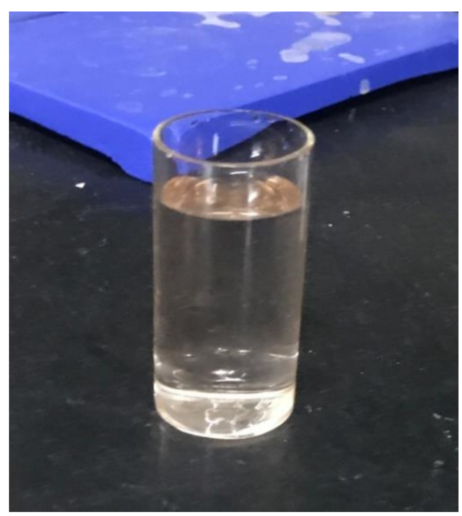


Figure 3.18 Leachate sample in Test Tube

3.7.3. Chlorides Test

To perform this test take 100 ml of leachate sample in conical flask. Add sulphuric acid or sodium hydroxide solution to get pH between 7.0 and 8.0. Now add 1 ml of potassium chromate indicator so that light yellow colour is obtained. Now titrate with standard $AgNO_3$ solution so that colour changes from yellow to brick-red. Volume of silver nitrate added is noted (A).For better accuracy, titrate 100 ml of distilled water after adding 1 ml of potassium chromate indicator to establish reagent blank. Volume of silver nitrate added for distilled water is noted (B).Now after doing calculations and chloride content is known.

3.7.4. Alkalinity Test

In a conical flask, take 100 ml of the leachate sample. For the removal of free residual chlorine (if present) and add one drop of 0.1 N sodium thiosulphate. Add 2 drops of php indicator to the sample so that sample turns pink. Titrate with 0.02 N standard sulphuric acid till the leachate solution becomes colorless. Note down the amount of H_2So_4 added to the solution (V_1).Add 2 drops of methyl orange indicator till sample turns to yellow. Titration is done till the color of the solution turns to pink. Total volume of H_2So_4 added is noted down (V_2).Therefore, alkalinity of sample is obtained.

3.7.5. Acidity Test

For this test pipette out one hundred ml of the leachate sample into a conical flask. Now add one drop of 0.1 N sodium thiosulphate solutions in the leachate solution to destroy any residual chlorine. Add two drops of methyl orange indicator. Now the sample turns pink. Titrate against 0.02 N standard sodium hydroxide solution till pink color changes to yellow. Note down the volume of the NaOH added (V1).Take another conical flask containing one hundred ml of leachate sample, add two drops of phenolphthalein. Proceed with titration till the sample turns pink. Note down the total volume of NaOH added (V2).This test will tell the acidity of the leachate sample.

3.7.6. Dissolved Oxygen Test

First of all for this test DO meter apparatus is required. Now take leachate sample in a beaker and put the reading end of apparatus into the sample as shown in fig 3.13. After sometime the DO meter will display the DO of that sample as shown in fig 3.14. Do this test for all the samples to get the DO of the leachate sample.

Figure 3.19 Dissolved oxygen test apparatus

Figure 3.20 DO meter

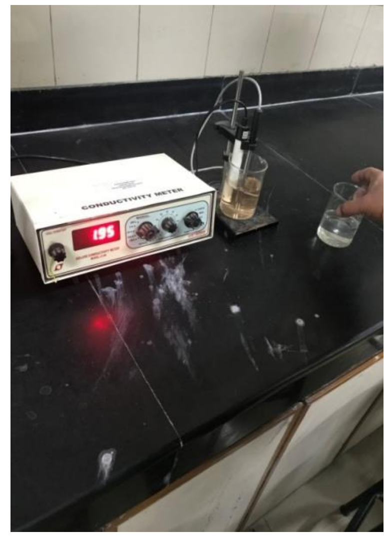


Figure 3.21 Specific Conductivity Meter

3.7.7. Specific Conductivity Test

To do this test switch on the conductivity meter for quarter-hour. Take out the conductivity cell dipped in H2O, now wash it with H2O and wipe it to dry with a tissue paper. Now Calibrate the cell with standard 0.1 N KCI solution of conductivity 14.12 mmhos at 300C. Take out the conductivity cell, wash it again thoroughly with H2O and wipe it dry. Now dip the cell into the leachate sample solution, swirl the solution and wait till to one minute for a gentle reading. Note down the instrument reading and additionally temperature by a thermometer (as shown in fig. 3.15). After this test the conducting nature of all the sample is known.

3.7.8. TCLP (Toxicity Characteristic Leaching Procedure) of Leachate

Toxicity Characteristics Leaching Procedure (TCLP) was made available to everyone in April 1985 (EPA, 1985).It tells quantity of the flow of inorganic & organic in different waste phases. If the liquid coming from leachate contains some compound at concentration more than permissible limit even after dilution from different fractions of extract, than that waste liquid is dangerous and require no further analysis.

For the waste having solids more than 0.5% solids or liquids, is separated inside from the solid phase & analysis is done later also the size of particle is decreased if possible. The phase of solid is extracted alongside the extraction fluid that is equal to 20 times the solid phase weight. The fluid is function of alkalinity of solid waste. A vessel specially made to test volatile analytes is used. After extraction, the liquid is separated from the solid by mean of filtration from a 0.6 – 0.8 μm glass fiber filter.

Figure 3.22 TCLP Apparatus

If compatible (i.e., different phases will not form after combination), the liquid phase initially taken of the waste is added to liquid extract, than together these are also analyzed. If than also these are incompatible, than the procured liquids are analyzed separately & results are combined mathematically to get a volume-weighted average concentration.

For the waste got from the liquid (i.e., those having less than 0.5% dry solid Materials), the waste, after the filtration through the glass fiber filter of the value 0.6 to 0.8 μm, is called the Toxicity Characteristic Leachate Procedure.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1. General

It is important to know the various physio-chemical properties of leachate to determine the presence of heavy metals and the possibility of these metals polluting the underground water source. The leachate was investigated for various tests like pH, turbidity, chlorides, specific conductivity, total solids, alkalinity, acidity, dissolved oxygen and TCLP.

As shown in chapter 3 various tests were performed on leachate collected and the results from these tests are:

4.2. Laboratory Results and Discussions

In order to determine the presence of heavy metals and the possibility of these metals polluting the underground water source leachate was investigated for various tests like pH, turbidity, chlorides, specific conductivity, total solids, alkalinity, acidity, dissolved oxygen and TCLP and the results obtained from the above tests are mentioned and discussed in the following section.

4.2.1 pH of leachate

pH of the sample collected throughout our experimental duration of 150 days shows that the fluctuation was between 6.5 to 7.5 which confirms with the works from other papers as well. pH is important for taking into consideration as groundwater is further used for drinking and other purposes which requires it to be around neutral level. If not so than we have to go for further process for treatment hence the advantage of using the cost effective foundry sand would not be useful.

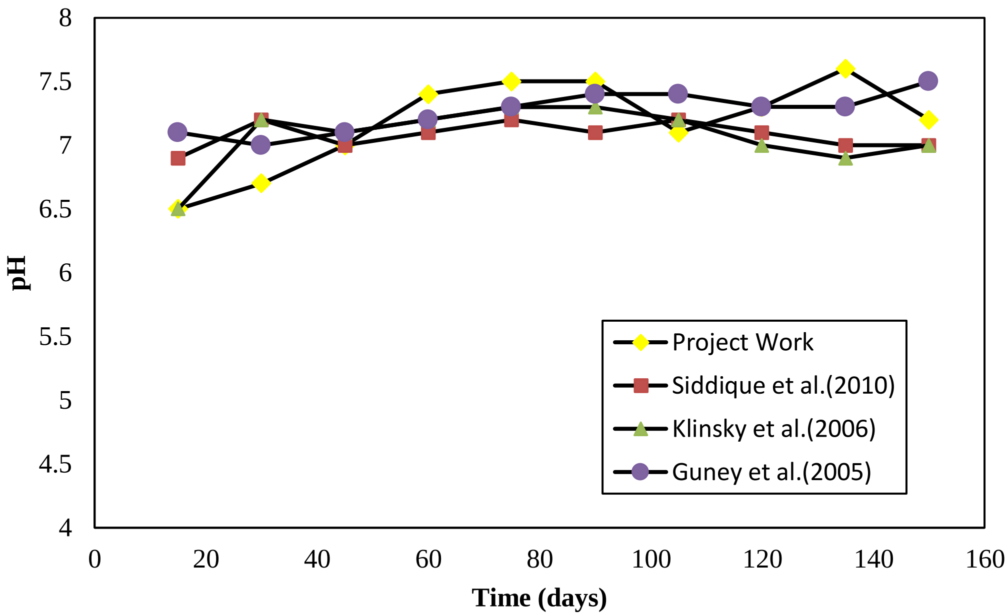


Figure 4.1 Variation of pH with time

Table 4.1 Comparison of pH samples with previously published literature

Samples	1	2	3	4	5	6	7	8	9	10
Project Work	6.5	6.7	7.0	7.4	7.5	7.5	7.1	7.3	7.3	7.2
Siddique (2010)	6.9	7.2	7.0	7.1	7.2	7.1	7.2	7.1	7.0	7.0
Klinsky (2006)	6.5	7.2	7.1	7.2	7.3	7.3	7.2	7.0	6.9	7.0
Guney (2005)	7.1	7.0	7.1	7.2	7.3	7.4	7.4	7.3	7.3	7.5

4.2.2. Chlorides in leachate

Chlorides of the sample given by the scholarly works of the past papers gave the range of chlorides between 30mg/l to 5mg/l. in our experimental set up the value for chlorides were within these ranges. Also with time the curve shows a gradual decrement in the concentration of chlorides and towards the later part showing straight curve tells that the concentration is now becoming constant. Similarity with the other papers in the pattern obtained validates the test.

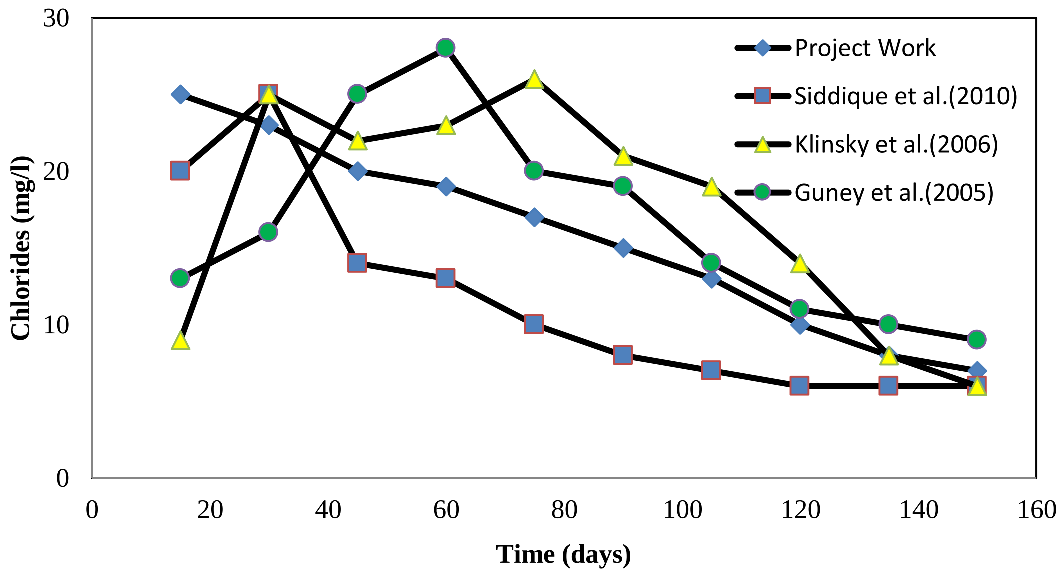


Figure 4.2 Variation of Chlorides with time

Table 4.2 Comparison of chloride samples with previously published literature

Samples	1	2	3	4	5	6	7	8	9	10
Project Work	25	23	20	19	17	15	13	10	8	7
Siddique (2010)	20	25	14	13	10	8	7	6	6	6
Klinsky (2006)	9	25	22	23	26	21	19	14	8	6
Guney (2005)	13	16	25	28	20	19	14	11	10	9

4.2.3. Specific Conductivity of leachate

Specific conductivity of the sample as done by many researchers for foundary sand tells that the site specific nature of the sample usually results in the variation of the values but the nature of the curve with time must show decrement in the value of specific conductivity. With our work we also got similar patterns. Also after analyzing the work of others the range found for specific conductivity was between .25-2.25 an

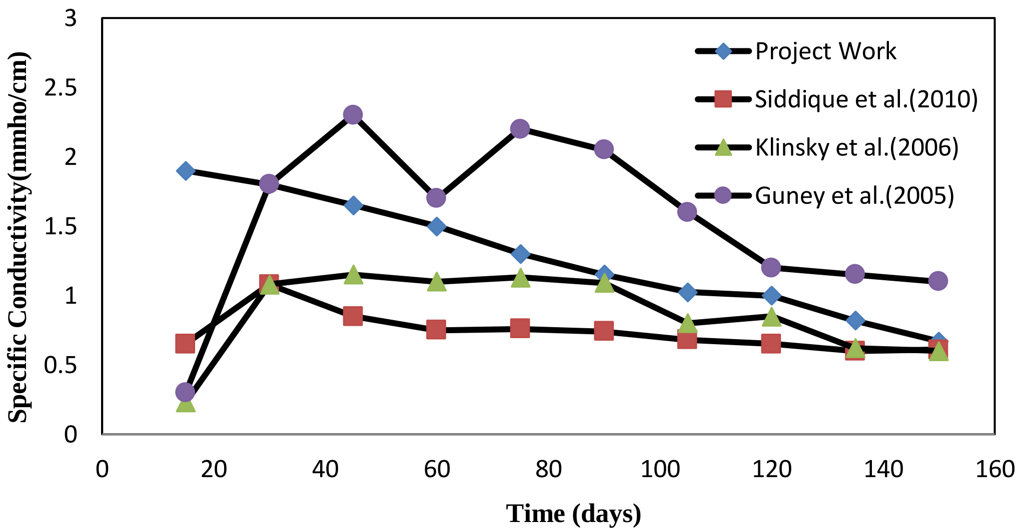


Figure 4.3 Variation of Specific Conductivity with time

Table 4.3 Comparison of Specific Conductivity with previously published literature

Samples	1	2	3	4	5	6	7	8	9	10
Project Work	1.95	1.80	1.65	1.50	1.30	1.15	1.025	1.0	0.81	0.67
Siddique (2010)	0.65	1.08	0.85	0.75	0.76	0.74	0.68	0.65	0.60	0.61
Klinsky (2006)	0.23	1.08	1.15	1.10	1.13	1.09	0.80	0.85	0.62	0.60
Guney (2005)	0.30	1.80	2.30	1.70	2.20	2.05	1.60	1.20	1.15	1.10

4.2.4. Total Solids in leachate

Total solids in the sample are a combination of both suspended as well as dissolved solids. From studying the previous work we got that its value decreases with time and eventually coming to a constant value towards the later duration. This can be due to the pores of the outlet being deposited with the solids. The range from the existing papers was found to be maximum up to 2400mg/l which keeps values of our work within range as shown in table 4.4.

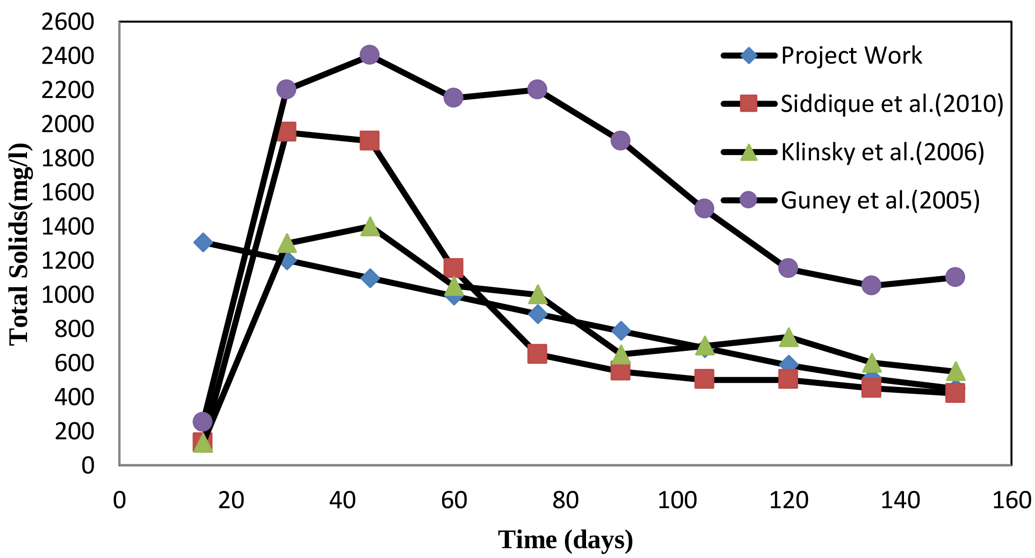


Figure 4.4 Variation of TDS with time

Table 4.4 Comparison of Total Solids with previously published literature

Samples	1	2	3	4	5	6	7	8	9	10
Project Work	1306.5	1200.5	1096.4	992.6	885.8	785.3	686.75	587.75	507.4	448.3
Siddique (2010)	130	1950	1900	1150	650	550	500	560	460	420
Klinsky (2006)	130	1300	1400	1050	1000	650	700	750	600	550
Guney (2005)	250	220	2400	2150	2200	1900	1500	1150	1050	1100

4.2.5. Alkalinity of leachate

Alkalinity of the sample depends upon the presence of the Hydroxide ions (OH-) in the sample. More alkaline water is also not suitable for usage therefore the alkaline range should remain in permissible limits and in our project throughout 150 days experiment shows a gradually decrease and gradually tends to become constant towards the later days as in fig. 4.5. These patterns show some similarity the work from other papers as shown in table 4.5.

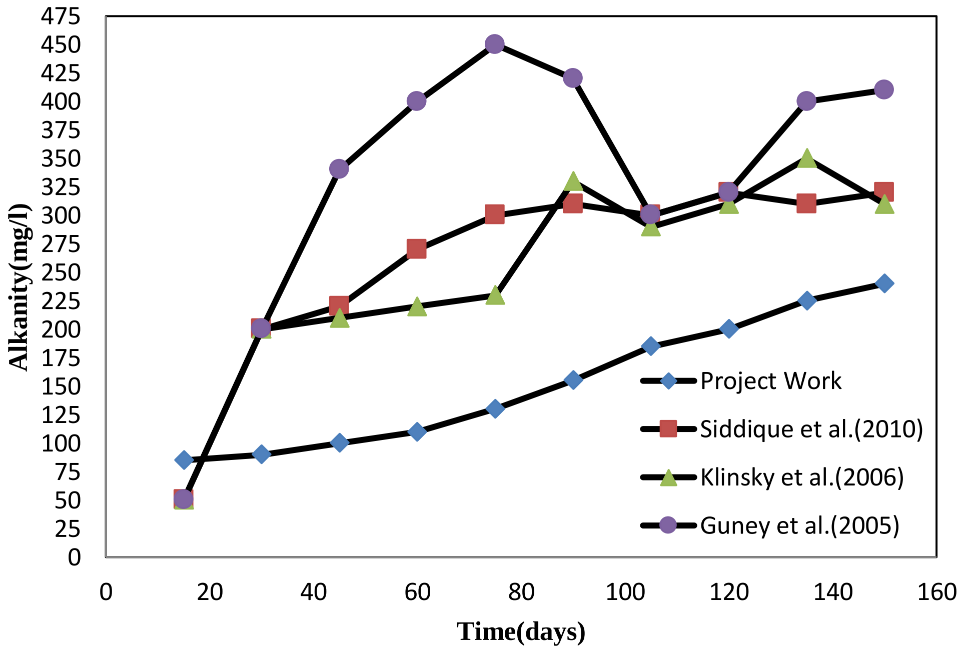


Figure 4.5 Variation of Alkalinity with time

Table 4.5 Comparison of Alkalinity with previously published literature

Samples	1	2	3	4	5	6	7	8	9	10
Project Work	85	90	100	110	130	155	1185	200	225	240
Siddique (2010)	50	200	220	270	300	310	300	320	310	320
Klinsky (2006)	50	200	210	220	230	330	290	310	350	310
Guney (2005)	50	200	350	400	450	420	300	320	400	410

4.2.6. Acidity Test

Acidity of the sample depends upon the Hydrogen ions (H+) present in the sample. These ions make Sample acidic which is not suitable for usage and in our project the acidity range was between 52-40mg\l. Acidity of the sample throughout 150 days of experiment shows a gradual increase and gradually tends to become constant towards the later days as in fig.4.6. These patterns show some similarity the work from other papers as shown in table 4.6.

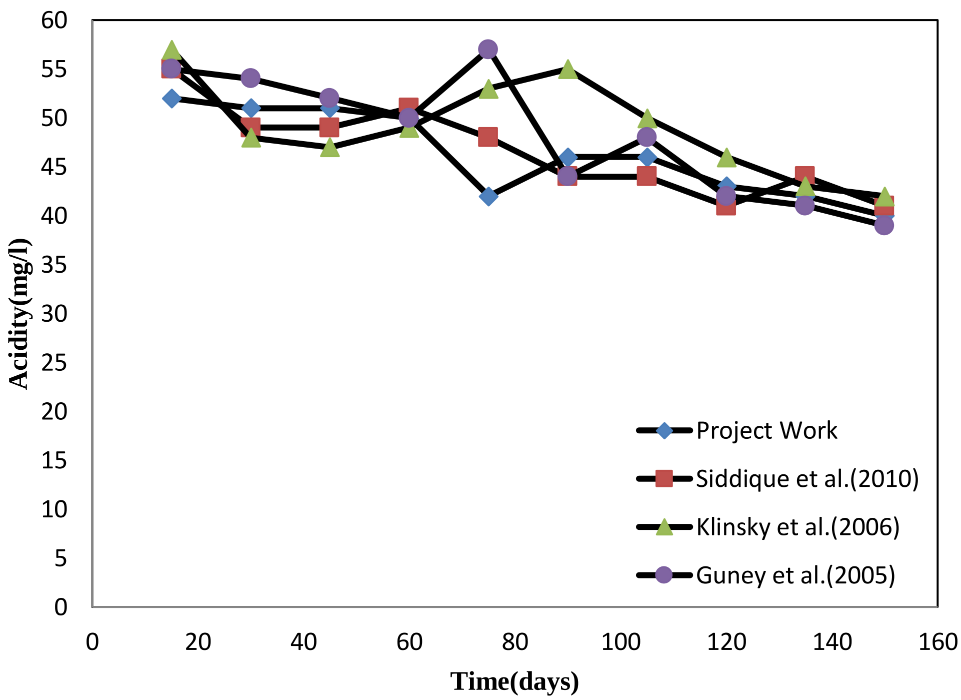


Figure 4.6 Variation of Acidity with time

Table 4.6 Comparison of Acidity of sample with previously published literature

Samples	1	2	3	4	5	6	7	8	9	10
Project Work	52	51	51	50	42	46	46	43	42	40
Siddique (2010)	55	49	49	51	48	44	44	41	44	41
Klinsky (2006)	57	48	47	49	53	55	50	46	43	42
Guney (2005)	55	54	52	50	47	44	48	42	41	39

4.2.7. Dissolved Oxygen Test

Dissolved Oxygen DO of the sample throughout 150 days of experiment shows a gradual decrease and gradually tends to become constant towards the later days as in fig. 4.7 .These pattern shows some similarity the work from other papers.

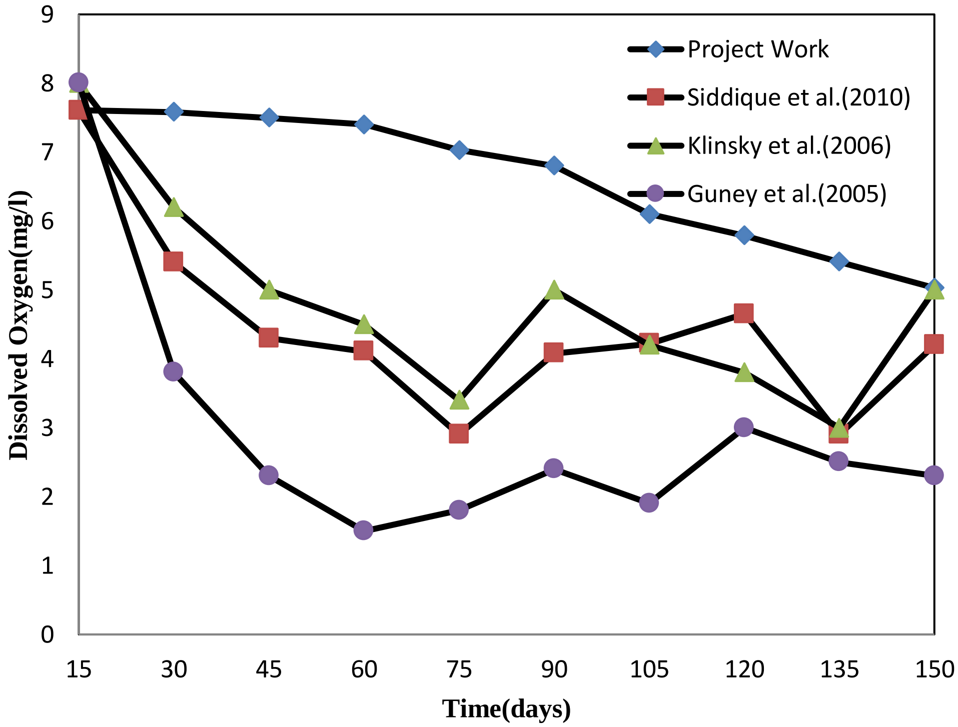


Figure 4.7 Variation of DO with time

Table 4.7 Comparison of DO with previously published literature

Samples	1	2	3	4	5	6	7	8	9	10
Project Work	7.61	7.58	7.50	7.40	7.03	6.80	6.10	5.79	5.41	5.03
Siddique (2010)	7.60	5.40	4.30	4.11	2.90	4.08	4.22	4.65	4.90	4.23
Klinsky (2006)	8.0	6.20	5.0	4.50	3.42	4.95	4.21	3.85	2.92	5.01
Guney (2005)	8.0	3.81	2.30	1.52	1.81	2.47	1.98	3.01	2.51	2.37

4.2.8. TCLP (Toxicity Characteristic Leaching Procedure)

TCLP test is the major test for our leachate collected as it is one of the most recognized and sophisticated test in determining the concentration of heavy metals present. Our experimental setup which we made, in it we carried out the collection and testing for a period of 150 days at a regular interval of 15 days, hence giving 10 different samples. The metals tested were then compared with the work of already existing papers for validation of our results.

Table: 4.8: _Metal concentration in TCLP Leachate from WFS Pavement (mg/L)

Element	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Ag	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Al	2.8	3.0	2.6	2.0	4.8	10	4.3	4.2	1.5	<0.03
As	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ba	0.76	0.93	0.39	0.22	3.9	2.0	0,97	1.5	1.3	1.1
Cd	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Cr	0.02	0.02	0.02	<0.01	0.01	0.21	<0.01	0.01	<0.01	<0.01
Cu	0.06	0.04	0.03	<0.009	0.05	0.05	0.04	0.07	0.04	<0.009
Hg	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Mn	0.64	0.57	0.46	0.65	0.41	1.8	0.63	0.56	0.36	6.1
Ni	0.03	0.03	0.02	0.02	0.03	1.10	0.03	0.03	<0.005	<0.005
Pb	<0.009	<0.009	<0.009	<0.009	0.17	0.04	<0.009	<0.009	<0.009	<0.009
Se	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009

4.3. Validation of TCLP (Toxicity Characteristic Leaching Procedure)

The following graphs shows the average presence of heavy metals throughout 150days of experimentation through TCLP test. Analyzing each heavy metals with the already existing works shows that the values of the metals were approximately similar which indicates that their presence is non toxic.

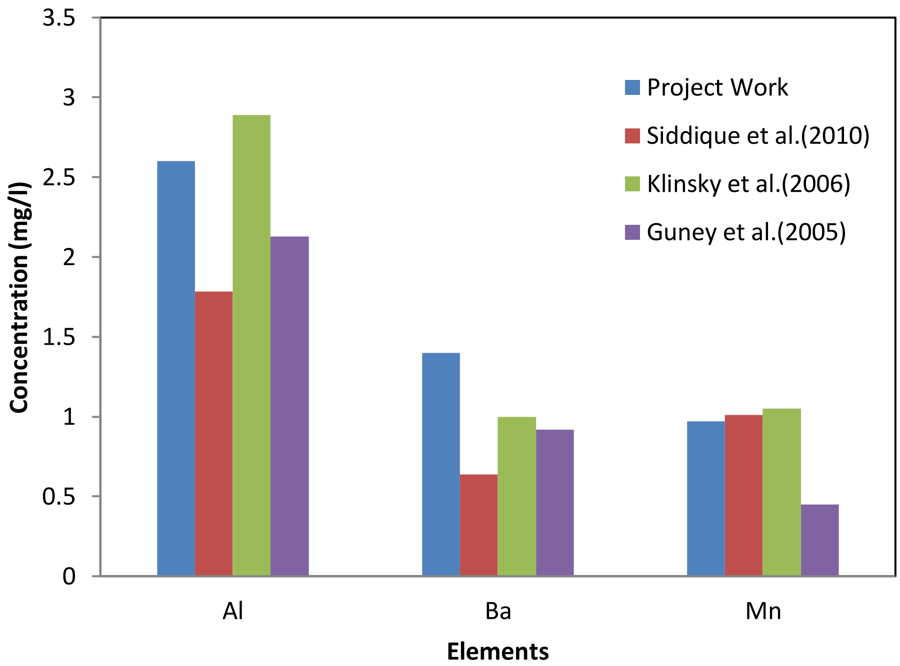


Figure 4.8 Comparisons of elements concentration (Al, Ba, Mn)

Table 4.9 Comparison of Al, Ba, Mn with previously published literature

Elements	Project Work	Siddique (2010)	Klinsky (2006)	Guney (2005)	Minimum	Maximum
Al	2.6	1.785	2.89	2.13	<0.03	10
Ba	1.4	0.639	1	0.92	0.22	3.9
Mn	0.97	1.009	1.05	0.45	0.07	6.1

Aluminum- Value of aluminum in our work lies within the range and syndicating no harmful effect on the environment. Excess of aluminum can effect human health by causing vomiting, mouth ulcers.

Barium - Value of barium in our work lies within the range and syndicating no harmful effect on the environment. Excess of barium can effect human health by increasing blood pressure, difficulty in breathing.

Manganese- Value of manganese in our work lies within the range and syndicating no harmful effect on the environment. Excess of manganese can affect human health by damaging nervous system, damages reproductivity.

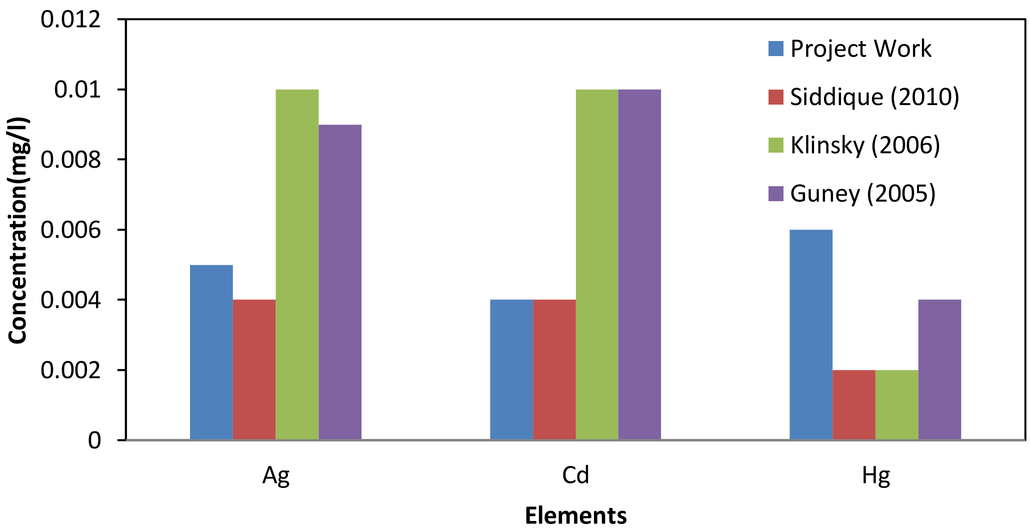


Figure 4.9 Comparisons of elements concentration (Ag, Cd, Hg)

Table 4.10 Comparison of Ag, Cd, Hg with previously published literature

Elements	Project Work	Siddique (2010)	Klinsky (2006)	Guney (2005)	Minimum	Maximum
Ag	0.005	0.004	0.01	0.009	<0.005	0.005
Cd	0.004	0.004	0.01	0.01	<0.004	0.004
Hg	0.006	0.002	0.002	0.004	<0.006	0.006

Silver- Value of silver in our work lies within the range and syndicating no harmful effect on the environment. Excess of silver can affect human health by causing gastrointestinal irritation due to its caustic action.

Cadmium- Value of cadmium in our work lies within the range and syndicating no harmful effect on the environment. Excess of cadmium can affect human health by damaging kidney.

Mercury- Value of mercury in our work lies within the range and syndicating no harmful effect on the environment. Excess of mercury can affect human health by damaging nervous system, and damages kidney.

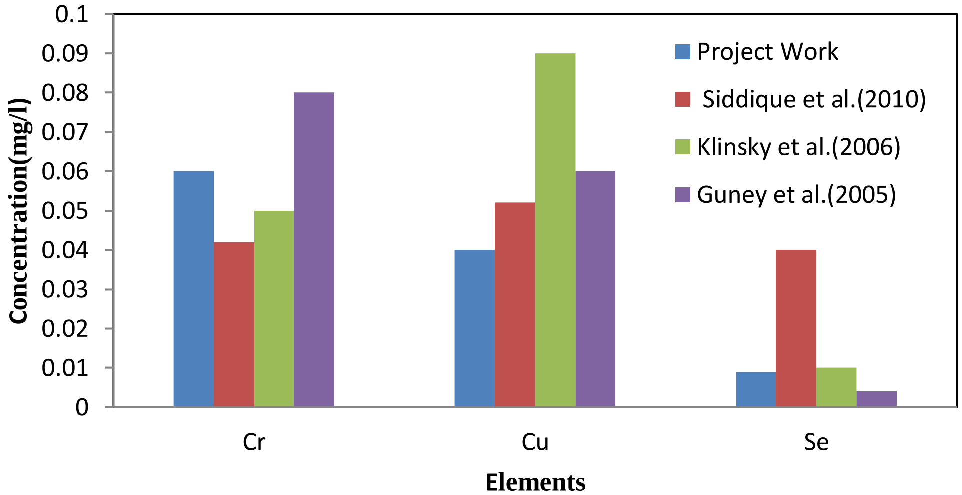


Figure 4.10 Comparisons of elements concentration (Cr, Cu , Se)

Table 4.11 Comparison of Cr, Cu, Se with previously published literature

Elements	Project Work	Siddique (2010)	Klinsky (2006)	Guney (2005)	Minimum	Maximum
Cr	0.06	0.042	0.05	0.08	<0.01	0.23
Cu	0.04	0.052	0.09	0.06	<0.009	0.11
Se	0.009	0.04	0.01	0.004	<0.009	0.009

<u>Chromium</u>- Value of chromium in our work lies within the range and syndicating no harmful effect on the environment. Excess of chromium can affect human health by causing skin irritation, ulcers and occupational asthma.

<u>Copper</u>- Value of copper our work lies within the range and syndicating no harmful effect on the environment. Excess of copper can effect human health by causing vomiting, mouth ulcers.

<u>Selenium</u>- Value of selenium in our work lies within the range and syndicating no harmful effect on the environment. Excess of selenium can affect human health by causing skin irritation and high blood pressure.

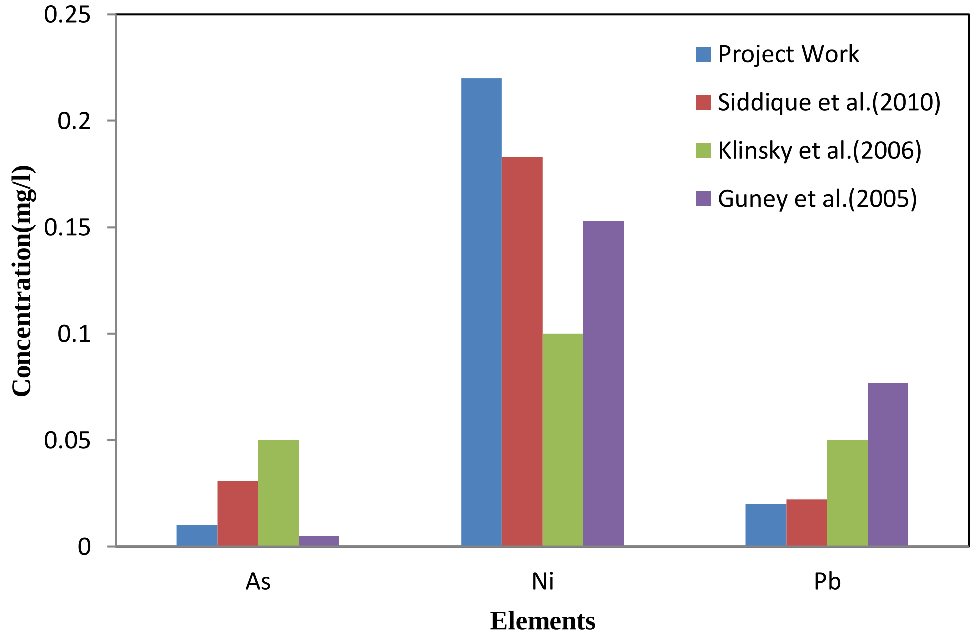


Figure 4.11 Comparisons of elements concentration (As, Ni, Pb)

Table 4.12 Comparison of As, Ni, Pb with previously published literature

Elements	Project Work	Siddique (2010)	Klinsky (2006)	Guney (2005)	Minimum	Maximum
As	0.01	0.031	0.05	0.005	<0.01	0.01
Ni	0.2	0.183	0.1	0.153	<0.005	0.12
Pb	0.02	0.022	0.05	0.077	<0.009	0.17

Arsenic- Value of arsenic in our work lies within the range and syndicating no harmful effect on the environment. Excess of arsenic can effect human health by causing eye irritation and cancer.

Nickel- Value of nickel in our work lies within the range and syndicating no harmful effect on the environment. Excess of nickel can effect human health by causing hair loss, decreases body weight of animals.

Lead.- Value of lead in our work lies within the range and syndicating no harmful effect on the environment. Excess of lead can effect human health by damaging nervous system and increase learning difficulties.

CHAPTER 5

CONCLUSIONS

5.1. General

Waste foundry sand from Rewari (Haryana) has been studied in detail for the checking of its impact on groundwater after being replaced with traditional sand in pavement. Various samples were taken at a regular interval for showing the time dependence impact of leachate on groundwater.

5.2. Conclusions

From the study undertaken, we can now conclude that the Waste Foundry Sand in Highway Construction is beneficial for future constructions. Following are the conclusion of our study.

1) As the Globalization and Urbanization is increasing therefore industries are also increasing which automatically increases the waste product in form of Waste Foundry Sand.

2) WFS is easily available near industrial areas and large quantity is also available. Mainly automobile industries are responsible for WFS as waste product.

3) Methodology adopted in the development of pavement is explained with detail of laying pavement in different layers.

4) Leachate characterization is explained with the test done on leachate like pH, Chloride, Alkalinity etc. All the results of tests were within permissible limits therefore indicating that the leachate is safe for groundwater.

5) Main test for leachate i.e. TCLP (Toxicity Characteristic Leachate Procedure) was performed at Lab in Panipat (Haryana).And result of TCLP indicates that heavy metals were also within range which means leachate contains permissible quantity of heavy metals which doesn’t affect groundwater.

6) Results from the tests on leachate are presented and compared with other papers. The comparison shows that the results are kind of similar to other paper or nearby their value.

7) Validation of results of heavy metals are presented and discussed thoroughly so that understanding of leachate from pavement constructed using WFS can be studied.

5.3. Scope of Future Work

After having concluded the study and validating the results of leachate collected, this chapter goes on further to discuss at length the scope for future work in the field of Waste Foundry Sand, WFS in different pavements, Leachate Characteristics.

In the current study of the suitability of waste foundry sand as the replacement for traditional sand has been determined and this helps in waste utilization of the surrounding to a beneficial use. But, the amount of WFS used in our project was limited, whereas a large amount of this sand can be used for future construction purposes.

As the study shows, the WFS is site specific therefore variety of tests can be done on WFS at different sites. This will help to study the waste sand in detail around the world which will ultimately benefit the environment and humans.

In our study, amount of rainfall in Himachal Pradesh was taken as standard but for further change in conditions in future quality of water can be changed to worst case scenario for extreme results. Also, rainfall rate can be varied depending upon the area or topography.

Also, this project deals with the leachate characterization and testing till 150 days but this duration can be extended for more sophisticated results. During this duration other tests on leachate can also be carried out to get more results about the leachate from WFS which at last can affect the groundwater.

The next set of future prospects for the study includes varying the kind of pavement in which WFS can be used at various sites. Different kind of pavement will show different time and quantity of leachate produced which will change the results of various leachate tests.

REFERENCES

1. Alves B. S. Q.,Dungan R. S., Carnin R. L. P., Galvez R., Pinto C. R. S. D. C. (2015) "*Metals in WFS and an Evaluation of their Leaching and Transport to Groundwater*",(2015)225:1963.

2. Rotti D., Gadag R. B. (2015) "*A study of Leachate Characteristics generated from Waste Foundry Sand and its Impact on Water Bodies*",(2015)2319-1163.

3. Kaur S., Purohit M. K. (2015) "*Rainfall Statistics of India*",02(2015)/18.

4. Siddique R., Kaur G., Rajor A. (2010) "*WFS and it's Leachate Characterisics*",54(2010)1027-1036.

5. Klinsky L. M. G., Fabbri G. T. P., Bardini V. S. D. S. (2006)." *Reuse of waste foundry sand mixed with lateritic clay soil in pavement bases and sub-bases courses*".

6. Bakis R., Koyuncu H., Demirbas A. (2006)." *An investigation of waste foundry sand in asphalt concrete mix*",24(2006)269-274.

7. Guney Y., Aydilek A. H., Demirkan M. M. (2005*)." Geoenvironmental behaviour of foundry sand amended mixtures for highway sub bases*",26(2006)932-945.

8. Javed S. (1994). "*Use of foundry sand in highway construction*",C-36-50N.

9. Abiehou T., Adil T. B.,Benson C. H., Bahiya H. (2004*)." Beneficial use of foundry sand by-products in highway construction*",31(2004)21091-4400.

10. IRC:37(2012),"*Guidelines for the Design of Flexible Pavements*", Indian Roads Congress, New Delhi

11. IS:10500(2012),"*Indian Standards for Quality of Drinking Water*",Bureau of Indian Standards Publication, New Delhi

12. Boothroyd P. (2008), "*Groundwater Contamination in the Highway Environment"*, University of Nottingham, Nottingham

13. Banks M.K., Schwab A.P. (2010) *"Evaluation of Toxicity Analysis for Foundry Sand Specifications"*

14. Aravind K., Das Animesh (2008) " *Industrial Waste in Highway Construction"*

15. Deng A., Tikalsky P.J. (2007) " *Geotechnical and Leaching Properties of Flowable Fill in incorporating Waste Foundry Sand"* ,Department of Civil Engineering, University of Hohai, Nanjing (China), Department of Civil and Environmental Engineering, University of Utah 28 (2007) 2161-2170

16. Partridge B.K. et al. (1996) "*Performance Evaluation of Highway Embankment Constructed with Waste Foundry Sand"* , Transportation Research Report 1619 (1996) 98-0838

ANNEXURE A

Table 1: Subdivision-Wise Seasonal & Annual Rainfall Statistics (mm)

METEOROLOGICAL SUBDIVISIONS	WINTER	PRE-MONSOON	MONSOON	POST-MONSOON	ANNUAL
A & N ISLAND	104.7	598.6	2152.1	902.4	3757.8
ARUNACHAL PRADESH	59.0	626.0	1165.9	192.0	2042.9
ASSAM & MEGHALAYA	10.6	503.6	1168.4	128.9	1811.5
N M M T	5.9	428.9	995.2	127.1	1557.2
SHWB & SIKKIM	26.7	443.4	1717.6	218.5	2406.1
GANGETIC WEST BENGAL	12.9	265.7	1167.7	358.3	1804.7
ODISHA	11.2	113.4	1115.6	392.2	1632.4
JHARKHAND	19.0	109.0	844.5	281.1	1253.6
BIHAR	27.7	122.4	722.2	197.5	1069.9
EAST U.P.	65.9	12.6	864.6	99.0	1042.1
WEST U.P.	89.7	7.2	758.6	70.4	925.9
UTTARAKHAND	261.3	65.0	1373.0	36.2	1735.4
HAR. CHD & DELHI	73.2	10.0	363.3	14.8	461.3
PUNJAB	59.4	18.6	479.7	28.9	586.6
HIMACHAL PRADESH	**249.8**	**131.3**	**774.2**	**61.6**	**1216.9**
JAMMU & KASHMIR	257.1	189.4	651.9	95.4	1193.8
WEST RAJASTHAN	30.4	8.9	339.0	11.1	389.4
EAST RAJASTHAN	23.1	4.6	775.0	32.2	834.9
WEST MADHYA PRADESH	32.8	11.7	1280.4	71.4	1396.3
EAST MADHYA PRADESH	45.4	23.9	1326.9	125.7	1521.9
GUJARAT REGION	1.1	5.7	1183.8	60.0	1250.5

SAURASHTRA & KUTCH	2.1	9.8	777.3	34.7	823.9
KONKAN & GOA	4.7	22.2	3498.4	159.6	3684.9
MADHYA MAHARASHTRA	5.3	12.4	881.5	63.1	962.4
MARATHWADA	10.9	16.9	745.3	114.8	888.0
VIDARBHA	19.6	7.0	1360.0	133.5	1520.0
CHHATTISGARH	22.3	56.0	1165.1	175.0	1418.3
COASTAL ANDHRA PRADESH	39.5	63.2	524.2	455.0	1081.8
TELANGANA	34.1	37.7	949.2	251.0	1272.1
RAYALASEEMA	22.2	69.1	420.4	165.5	677.2
TAMILNADU & PONDICHERRY	34.8	92.2	321.5	293.4	741.9
COASTAL KARNATAKA	19.3	124.1	3619.4	281.8	4044.6
N. I. KARNATAKA	7.3	75.7	534.9	105.2	723.2
S. I. KARNATAKA	10.6	142.0	827.1	131.0	1110.7
KERALA	43.9	218.5	2561.2	431.8	3255.4
LAKSHADWEEP	60.6	131.1	1057.0	177.6	1426.3

as per India Ministry of Meteorological Department

ANNEXURE B

Table 2 : Subdivision-Wise Monthly Rainfall (mm) - Year 2000-2015

METEOROLOGICAL SUBDIVISIONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
A & N ISLAND	67	38	43	46	509	777	565	337	474	456	354	92
ARUNACHAL PRADESH	19	41	115	175	336	290	330	230	316	164	13	15
ASSAM & MEGHALAYA	1	10	44	112	347	286	366	291	225	126	1	2
N M M T	0	6	20	60	349	207	256	291	241	126	0	1
SHWB & SIKKIM	3	24	32	114	297	405	588	416	308	200	16	3
GANGETIC WEST BENGAL	2	11	7	48	211	248	266	399	255	358	0	0
ORISSA	3	8	2	54	58	273	380	255	208	391	1	0
JHARKHAND	1	18	2	22	85	182	211	278	174	281	0	0
BIHAR	5	23	1	32	90	183	182	214	143	197	0	0
EAST U.P.	6	60	3	9	1	310	230	246	78	97	1	1
WEST U.P.	21	69	4	2	2	189	236	283	51	60	2	9
UTTARAKHAND	73	188	22	25	18	489	413	359	111	29	3	4
HAR. CHD & DELHI	21	52	5	3	1	62	97	162	43	11	2	2
PUNJAB	9	50	12	3	4	120	118	217	24	16	6	7
HIMACHAL PRADESH	**76**	**174**	**75**	**25**	**31**	**240**	**219**	**245**	**68**	**21**	**16**	**25**
JAMMU & KASHMIR	72	185	59	67	64	113	175	306	58	48	19	28
WEST RAJASTHAN	9	22	4	3	2	38	105	138	59	10	1	0
EAST RAJASTHAN	1	22	0	3	1	90	318	278	88	31	1	0
WEST MADHYA PRADESH	2	31	9	3	0	264	485	433	99	69	0	2
EAST MADHYA PRADESH	2	43	14	10	0	312	456	481	78	124	1	1
GUJARAT REGION	0	1	0	6	0	168	454	238	323	60	0	0

SAURASHTRA & KUTCH	2	0	0	10	0	159	209	100	309	35	0	0
KONKAN & GOA	0	5	0	0	22	1073	1555	517	353	156	3	1
MADHYA MAHARASHTRA	0	5	1	6	6	212	312	147	210	58	4	1
MARATHWADA	2	9	3	8	6	161	293	137	154	94	7	13
VIDARBHA	7	13	4	3	1	367	536	326	132	134	0	0
CHHATTISGARH	3	19	5	46	6	266	425	336	138	175	0	0
COASTAL ANDHRA PRADESH	1	38	5	37	22	101	158	127	138	384	67	4
TELANGANA	4	30	0	25	13	186	386	212	165	233	17	1
RAYALASEEMA	1	22	7	24	38	65	83	90	182	140	24	2
TAMILNADU & PONDICHERRY	4	31	30	20	42	55	43	111	114	128	112	53
COASTAL KARNATAKA	4	16	10	22	92	1044	1536	668	371	238	38	5
KERALA	4	40	50	49	119	1043	830	370	319	260	155	17
LAKSHADWEEP	26	34	38	5	88	426	296	154	180	73	78	27

as per India Ministry of Meteorological Department

ANNEXURE C

Table 3: Comparison of the TCLP results with groundwater maximum contaminant levels (mg /L)

Element	Minimum	Maximum
Ag	<0.005	
Al	<0.03	10
As	<0.01	
B	0.01	2.7
Ba	0.22	3.9
Be	<0.01	
Cd	<0.004	
Co	0.0025	0.04
Cr	<0.01	0.23
Cu	<0.009	0.11
Fe	0.61	384
Hg	<0.006	
Mg	0.33	55.7
Mn	0.07	6.1
Mo	<0.015	
Ni	<0.005	0.12
Pb	<0.009	0.17
Sb	<0.005	
Se	<0.009	
V	<0.015	0.03
Zn	0.14	5.4

as per Water Air Soil Pollution (2014) 225:1963