COMPARATIVE EVALUATION OF FULLER'S EARTH & CHINA CLAY FOR THE CONTROL OF LEACHATE GENERATED FROM MUNICIPAL SOLID WASTE

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SUBMITTED BY:

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UNDER THE GUIDANCE OF

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to the

DEPARTMENT OF CIVIL ENGINEERING

BABU BANARASI DAS UNIVERSITY

LUCKNOW (INDIA)
MAY, 2019

CERTIFICATE

This is to certify that **Ms. Akansha** has carried out his research work presented in this thesis entitled **"Comparative Evaluation of Fuller's Earth & China Clay for the Control of leachate Generated From Municipal Solid Waste"** for the award of Master of technology in 'Environmental Engineering' from Department of 'Civil Engineering', Babu Banarsi Das University, Lucknow, under my supervision. The thesis embodies results of original work and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University.

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DECLARATION

I hereby certify that the work which is being presented in this thesis entitled **"COMPARATIVE EVALUATION OF FULLER'S EARTH & CHINA CLAY FOR THE CONTROL OF LEACHATE GENERATED FROM MUNICIPAL SOLID WASTE"** in partial fulfilment of award of degree of Master of Technology in **Environmental Engineering** submitted in Department of Civil Engineering, Babu Banarasi Das University, Lucknow is an authentic record of my own work carried under the supervision of **Mr. Anupam Mehrotra**, Associate Professor, BBD University, Lucknow, India.

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ABSTRACT

Leachate generation is a major problem for municipal solid waste (MSW) landfills and causes significant threat to surface water and groundwater. Leachate is defined as a liquid, which passes through a landfill and has extracted dissolved and suspended matter from it. Leachate is the outcome from precipitation entering the landfill from moisture that exists in the waste when it is composed. A comparative evaluation between the china clay and fullers earth is performed to control the leachate, generated from the solid waste.

Permeability and type of bonding are the major factors, which are affecting the water movement from surface to below the clay liners. In this study the effect of china clay and fuller's earth clay are compared to control the leachate from MSW. The china clay has advantages over fuller's earth.

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(*Akansha Dinkar*)

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LIST OF ABBREVIATIONS

MSW	**Municipal Solid Waste**
MSWM	**Municipal Solid Waste Management**
MTs	**Metric Tonnes**
LMAI	**Local Municipal Authority in India**
mg/l	**Milligram per litre**
BOD	**Biochemical Oxygen Demand**
COD	**Chemical Oxygen Demand**
VFAs	**Volatile Fatty Acids**
TOC	**National Highway Traffic Safety Administration**
GCLs	**Geosynthetic Clay Liners**
AMC	**Ahmedabad Municipal Corporation**
PMC	**Pune Municipal Corporation**
OC	**Organic Compound**
DOC	**Dissolved Organic Compound**
GIS	**Geographic Information System**
TC	**Total Coliform**
FC	**Faecal Coliform**
FVC	**Forced Vital Capacity**
RS	**Respiratory Systems**

CO_2	**Carbon dioxide**
CH_4	**Methane**
Cd	**Cadmium**
PVC	**Poly Vinyl Chloride**

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Waste management is one of the major challenges faced by municipality officials, public health engineers and environmentalists in their quest to protect and preserve our environment. The wastes that generate in cities dispose their wastes in different ways. Historically waste is disposed of unscientifically leading to the development of many waste dumps around. These general natural anomalies in the ground where trash is disposed of with very little or no environmental regulations. One of the major pollution problems caused by the municipal solid waste landfill leachate can be defined as a liquid that is generated when water or another liquid comes in contact with solid waste. It contains number of dissolved and suspended materials. After municipal solid waste landfill site is closed, landfill will continue to produce contaminated leachate process could last for 30-50 years. Due to increase growth of population and development of the industry, the landfill leachate problem becomes increasingly serious. Leachate has potential to contaminate ground and surface water and threaten human health which migrating from the landfill and contaminates surrounding lands and water. Once the leachate enters the water bodies, it is very difficult and expensive to clean up the contaminated water.

The design and maintenance of landfills for waste disposal are the concerns over the last few decades due to increasing awareness towards environment protection issues, such as ground and ground water protection. For last few decades, the landfill liner construction has developed and advanced technology has emerged such as the addition of engineered clays, synthetic lining material and designing of more sophisticated leachate collection systems etc. The main aim of these technology and methods are to improve the landfill liner performances as a hydraulic resistant and to minimize or prevent the migration of landfill leachate into surrounding environment. Clay minerals are available in bulk, these are inexpensive, and are safe materials for environmental applications. Because of their high porosity, surface charge, large specific surface area, and surface functional groups, clay minerals function as adsorbents, filters, flocculates, and carbon stabilizers.

Fuller's earth (palygorskite) and china (kaolin) clay are taken for the clay liner. Fuller's earth is any clay material that has the capability to decolorize oil or other liquids without chemical treatment. Fuller's earth typically consists of palygorskite or bentonite. Palygorskite is hydrated Mg-Al silicate material. This mineral actually resembles the amphiboles more than it does clay minerals, but has a special property that smectite lacks - as a drilling fluid, it is stable in salt-water environments. When drilling for offshore oil, conventional drilling mud falls apart in the presence of salt water. Fuller's earth (palygorskite) consists primarily of hydrous aluminium silicates (clay minerals) of varying composition. Common components are montmorillonite, kaolinite and attapulgite. Small amounts of other minerals may be present in fuller's earth deposits, including calcite, dolomite, and quartz. In some localities fuller's earth refers to calcium bentonite, which is altered volcanic ash composed mostly of montmorillonite. Kaolinite is this clay mineral is the weathering product of feldspars. It has a white, powdery appearance. Kaolinite is named after a locality in China called Kaolin, which invented porcelain (known as china) using the local clay mineral. The ceramics industry uses it extensively. Because kaolinite is electrically balanced, its ability of adsorb ions is less than that of other clay minerals.

1.2 What is Municipal Solid Waste?

Municipal solid waste, also called garbage or trash, is non-hazardous refuse generated by households, institutions, industries, agriculture, and sewage. It is made up of waste, compostable, and recyclable materials, with the municipality overseeing its disposal. Typically, this refuse is collected, separated and sent to either a landfill or a municipal recycling centre for processing. In some cases, what is defined by a community as municipal solid waste will vary by jurisdiction.

MSW has changed alongside with society. In the past, refuse from communal refuse was mostly made up of ash, wood, bone, and vegetable waste. Dumps were mainly filled with pottery or tools that could no longer be repaired as early humans would feed most biodegradables to their livestock or leave it to decompose. As humanity continued to develop, the refuse created by communities became more complicated with the introduction of metals like copper, aluminium, and steel; new materials like plastic; and the introduction of hazardous substances.

1.2.1 WASTE GENERATION VOLUME PROJECTION IN INDIA

Growing economy, soaring urban population, rising living standards and increasing consumption levels – is what trending in the emerging economies across the globe. With India flourishing on the same grounds, an increase in the purchasing power parity has led to more affordability, accessibility to resource use and a rapid surge in the waste volumes as well. Like many developing countries, India too is struggling with the straining waste management systems adversely impacting the ecological health. Having said that, these increasing waste volumes in the country are formulating a new business segment for the value chain players – making solid waste management all together a different industry practice. The total waste generation in India presently hovers around 60-65 MTs per annum, of which only 20 percent is actually treated. Municipal solid waste (MSW) holds a significant chunk, 75 percent of the total waste generated in the country. However, due to lack of efficient waste management systems in majority of the municipalities, significant volume of MSW produced in Indian cities remains un treated. It is pertinent to note that in India only 22-28 percent of the collected MSW is processed and treated, which is quite low.

Fig: shows the volume of the generation of Municipal Solid Waste in metric tonnes per year in cities in India up to the end of 2020 and 2030. A significant increase in volume in MSW, which will be a big challenge for LMAI (local municipal authorities in India).

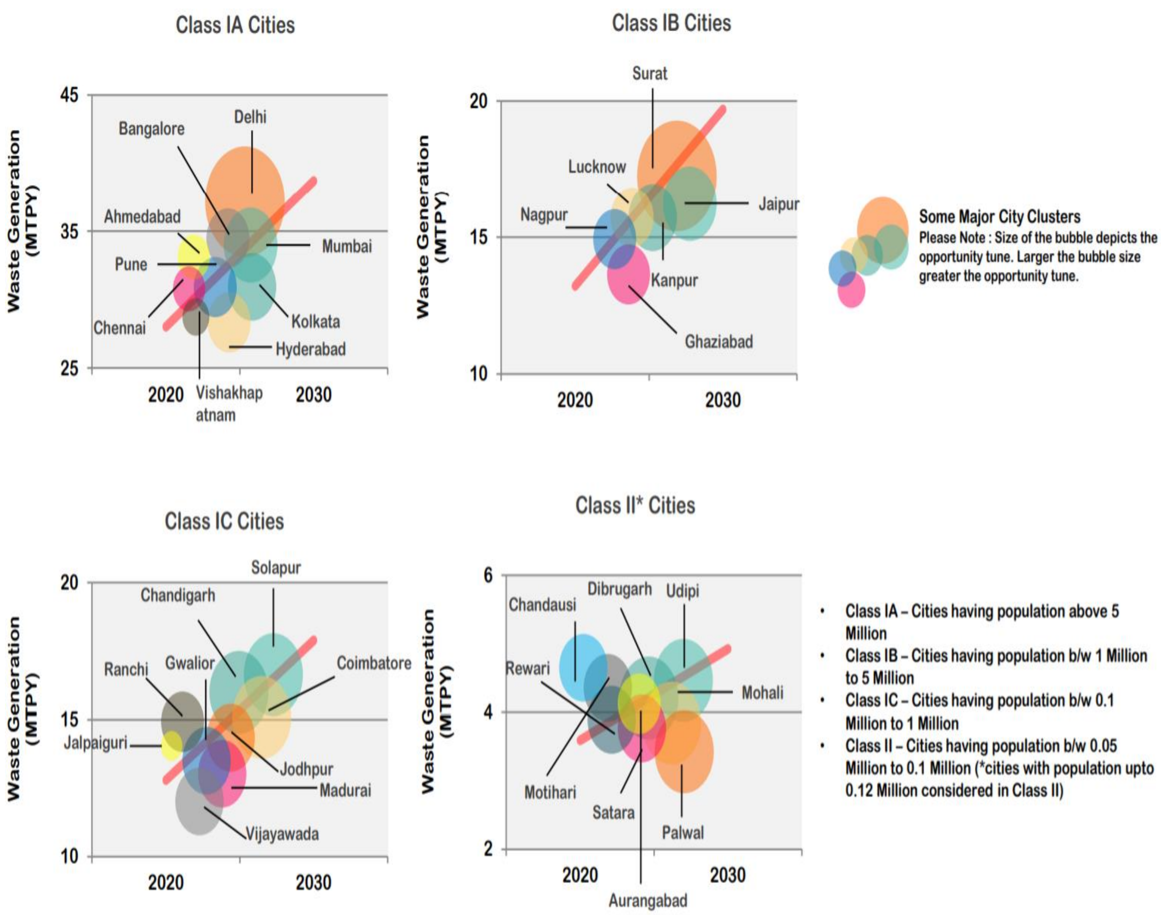

Fig. 1.1 Generation of MSW in India by Size of Cities – Till 2020 and 2030 Ref [11]

1.3 LEACHATE

Disposal of waste in an acceptable manner has been growing concerns to the public. One of the most significant concerns has been the possible contamination of groundwater from leachates generated by wastes. Landfilling is one waste management strategy adopted to dispose the waste in an effective and safe manner. Liner in a landfill plays an important role to prevent contaminant migration in to groundwater.

Leachate is defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it. In most landfills, the liquid portion of the leachate is composed of the liquid produced from the decomposition of wastes and liquid that has entered the landfill from external sources such as surface drainage, rainfall, groundwater and water from underground springs.

One of the major pollution problems caused by the MSW landfill is landfill leachate, which is generated as a consequence of precipitation, surface run-off and infiltration or intrusion of groundwater percolating through a landfill, biochemical processes and the inherent water content of wastes themselves. Leachate is the liquid residue resulting from the various chemical, physical and biological processes taking place within the landfill.

Landfill leachate is generated by excess rainwater percolating through the waste layers in a landfill. A combination of physical, chemical and microbial processes in the waste transfer pollutants from the waste material to the percolating water. After a landfill site is closed, a landfill will continue to produce contaminated leachate and this process could last for 30-50 years. Generally, leachate may contain large amounts of organic matter (biodegradable, but also refractory to biodegradation), as well as ammonia nitrogen, heavy metals, chlorinated organic and inorganic salts, which are a great threat to the surrounding soil, groundwater and even surface water. The compositions of leachate can be divided into four parts of pollutants. Organic matter such as: COD (chemical oxygen demand) and TOC (total organic carbon); specific organic compounds, inorganic compounds and heavy metals. However, the organic content of leachates is often measured through analyzing sum of parameters such as COD, BOD (biochemical oxygen demand) and TOC and dissolved organic carbon.

The composition of landfill leachate, the amount generated and the extraction of potential pollutants from the waste depend upon several factors, including solid waste composition, degree of compaction, absorptive capacity of the waste and waste age, seasonal weather variations, levels of precipitation, landfill temperature, size, hydrogeological conditions in the vicinity of the landfill site, engineering and operational factors of the landfill, pH, landfill chemical and biological activities.

A simplified water balancing equation takes all of these factors into account and allows designers to predict an amount of leachate that will be produced by the landfill.

Canziani and Cossu created this equation in particular:

L = P - R - DUs - ET – Duw

L = leachate production

P = precipitation

R = surface run-off

Us = change in soil moisture

ET = actual evaporative losses from the bare-soil/ evapotranspiration losses from a vegetated surface

Uw = change in the moisture content of the refuse components

The production of leachate also varies widely through the successive aerobic, acetogenic, methanogenic and stabilization stages. The degradation process of the waste in a landfill passes through different phases. The first phase which is normally short is characterized by the aerobic degradation of organic matter. When the oxygen is depleted, the degradation continues anaerobically. The anaerobic degradation process consists of two major fermentation phases, the acidogenic phase generating "young", biodegradable leachate and the methanogenic phase, generating "old", stabilised leachate. During fermentation organic molecules are broken down into simpler substances in an energy yielding process. Some physico-chemical characteristics are typical for each phase whereas other parameters are not specifically phase dependant. "Young" leachate from the early acidogenic phase contains large amounts of readily biodegradable organic matter. The complex organic compounds are fermented anaerobically, yielding mainly soluble organic acids such as free volatile fatty acids (VFAs), amino acids, other low molecular weight compounds and gases like H_2 and CO_2. The concentration of VFAs can be quite significant, representing 95% of the TOC, leading to low pH (around 5). Typical COD values are 3,000-60,000 mg/l. High ratio BOD_5/COD values of 0.5-0.7 indicate large amounts of biodegradable organic matter. During this phase the metals are more soluble because of lower pH and the bonding with the VFAs, leading to relative high concentrations of Fe, Mn, Ni and Zn. "Old" leachate from the methanogenic phase is partially characterized by the lower concentration of VFAs. This is due to their conversion into CH_4 and CO_2 as gaseous end products during this second fermentation period. As the content of VFAs and other readily biodegradable organic compounds in the leachate decreases, the organic matter in the leachate becomes dominated by refractory compounds, such as humic like compounds and fulvic acid like substances, thus a low ratio BOD_5/COD, most often close to 0.1, is a characteristic value for stabilised leachates. The humic substances give a dark colour to stabilised leachates. The decrease of VFAs results in an increase in pH. A characteristic pH value for stabilised leachates is around 8. The concentration of metal ions is in general low due to the decreasing solubility of many metal ions with increasing pH. However, lead is an exception, since it forms very stable complexes with the humic acids. Besides the effect of the shifting pH on metalions, there is the reduction of sulphate to sulphide during this phase, which increases the precipitation of metals ions. In general, the strength of leachate decreases with time due to biological breakdown of organic compounds and precipitation of soluble elements such as heavy metals. Due to its biodegradable nature, the organic compounds decrease more rapidly than the inorganic compounds with increasing age of leachate production. Therefore, the ratio of total volatile solids to total fixed solids (VS/FS) decreases with the age of the landfill. Three main groups of landfills are classified as young (less than five years), intermediate (5-10 years), and old or stabilized (more than 10 years). **Table 1.1,** summarizes the typical characteristics of leachate according to age of landfill. The typical chemical concentrations in young and old landfill leachates comparing with sewage and groundwater are also shown in **Table 1.2**.

Table 1.1 Comparison of parameters of leachates

Parameter	Young	Intermediate	Old
Age (Years)	<5	5-10	>10
pH	6.5	6.5-7.5	>7.5
COD, mg/l	> 10,000	4,000-10,000	<4,000
BOD5/COD	<4,000	0.1-0.3	<0.1
Organic Compounds (OC)	80% volatile fat acids (VFA)	5-30% VFA+ humic and fulvic acids	Humic and fulvic acids
Heavy metals	Low-medium	Low	Low
Biodegradability	Important	Medium	Low

Normally, young landfill leachate (the acid phase landfill, <5 years) contain large amounts of biodegradable organic matter. More than 95% of the dissolved organic carbon (DOC) consists of volatile fatty acids, and little of high molecular weight compounds. In mature landfills (the methanogenicphase landfill), the organic fraction in the leachate becomes dominated by refractory compounds, and the DOC content consists of high molecular weight compounds. According to the study of Diamadopoulos, the concentration of the organic substances and the ratio of BOD to COD are generally higher during the active stage of decomposition and decrease gradually due to leachate stabilization.

Table 1.2 Comparison of parameters of leachates with sewage concentration

Parameter	Young Leachate Concentration	Old Leachate Concentration	Typical sewage concentration	Typical groundwater concentration
COD	20,000-40,000	500-3,000	350	20

BOD5	10000-20000	50-100	250	0
TOC	9000-25000	100-1000	100	5
Volatile fatty acids	9000-25000	50-100	50	0

1.4 CLAY MINERALS

1.4.1 FORMATION OF CLAY MINERALS

A soil particle may be a mineral or a rock fragment. A mineral is a chemical compound formed in nature during a geological process, whereas a rock fragment has a combination of one or more minerals. Based on the nature of atoms, minerals are classified as silicates, aluminates, oxides, carbonates and phosphates.

Out of these, silicate minerals are the most important as they influence the properties of clay soils. Different arrangements of atoms in the silicate minerals give rise to different silicate structures.

Fuller's earth, any fine-grained, naturally occurring earthy substance that has a substantial ability to adsorb impurities or colouring bodies from fats, grease, or oils. Its name originated with the textile industry, in which textile workers (or fullers) cleaned raw wool by kneading it in a mixture of water and fine earth that adsorbed oil, dirt, and other contaminants from the fibres.

Fuller's earth consists chiefly of hydrated aluminum silicates that contain metal ions such as magnesium, sodium, and calcium within their structure. Montmorillonite is the principal clay mineral in fuller's earth, but other minerals such as kaolinite, attapulgite, and palygorskite also occur and account for its variable chemical composition. Though similar in appearance to clay, fuller's earth differs by being more fine-grained and by having a higher water content. It also crumbles into mud when mixed with water, so it has little natural plasticity. The substance is found in a wide range of natural colours, from brown or green to yellow and white.

Fuller's earth is used to refine and decolourize petroleum products, cottonseed and soy oils, tallow, and other fats and oils. Its high adsorptive power also makes it commercially important in the preparation of animal litter trays and assorted degreasing agents and sweeping compounds. Fuller's earth usually occurs as a by-product of the decomposition of feldspar or from the slow transformation of volcanic glass into crystalline solids. Major deposits of fuller's earth have been found in England, in Japan, and in Florida, Georgia, Illinois, and Texas, U.S.

Kaolin, also called china clay, soft white clay that is an essential ingredient in the manufacture of china and porcelain and is widely used in the making of paper, rubber, paint, and many other products. Kaolin is named after the hill in China (Kao-ling) from which it was mined for centuries. Samples of kaolin were first sent to Europe by a French Jesuit missionary around 1700 as examples of the materials used by the Chinese in the manufacture of porcelain.

Natural state kaolin is a white, soft powder consisting principally of the mineral kaolinite, which, under the electron microscope, is seen to consist of roughly hexagonal, platy crystals ranging in size from about 0.1 micrometre to 10 micrometres or even larger. These crystals may take vermicular and book like forms, and occasionally macroscopic forms approaching millimetre size are found. Kaolin as found in nature usually contains varying amounts of other minerals such as muscovite, quartz, feldspar, and anatase. In addition, crude kaolin is frequently stained yellow by iron hydroxide pigments. It is often necessary to bleach the clay chemically to remove the iron pigment and to wash it with water to remove the other minerals in order to prepare kaolin for commercial use.

When kaolin is mixed with water in the range of 20 to 35 percent, it becomes plastic (i.e., it can be molded under pressure), and the shape is retained after the pressure is removed. With larger percentages of water, the kaolin forms a slurry, or watery suspension. The amount of water required to achieve plasticity and viscosity varies with the size of the kaolinite particles and also with certain chemicals that may be present in the kaolin. Kaolin has been mined in France, England, Saxony (Germany), Bohemia (Czech Republic), and in the United States.

Kaolin is used extensively in the ceramic industry, where its high fusion temperature and white burning characteristics makes it particularly suitable for the manufacture of whiteware (china), porcelain, and refractories. The absence of any iron, alkalis, or alkaline earths in the molecular structure of kaolinite confers upon it these desirable ceramic properties. In the manufacture of whiteware the kaolin is usually mixed with approximately equal amounts of silica and feldspar and a somewhat smaller amount of a plastic light-burning clay known as ball clay. These components are necessary to obtain the proper properties of plasticity, shrinkage, vitrification, etc., for forming and firing the ware. Kaolin is generally used alone in the manufacture of refractories.
Substantial tonnages of kaolin are used for filling rubber to improve its mechanical strength and resistance to abrasion. For this purpose, the clay used must be extremely pure kaolinite and exceedingly fine grained. Kaolin is also used as an extender and flattening agent in paints. It is frequently used in adhesives for paper to control the penetration into the paper. Kaolin is an important ingredient in ink, organic plastics, some cosmetics, and many other products where it's very fine particle size, whiteness, chemical inertness, and absorption properties give it particular value.

1.4.2 BASIC STRUCTURAL UNITS

Soil minerals are formed from two basic structural units: tetrahedral and octahedral. Considering the valency of the atoms forming the units, it is clear that the units are not electrically neutral and as such do not exist as single units.

The basic units combine to form sheets in which the oxygen or hydroxyl ions are shared among adjacent units. Three types of sheets are thus formed, namely silica sheet, gibbsite sheet and brucite sheet.

Isomorphous substitution is the replacement of the central atom of the tetrahedral or octahedral unit by another atom during the formation of the sheets. The sheets then combine to form various two-layer or three-layer sheet minerals. As the basic units of clay minerals are sheet-like structures, the particle formed from stacking of the basic units is also plate-like. As a result, the surface area per unit mass becomes very large.

1.4.3 STRUCTURE OF CLAY MINERALS

The tetrahedron is one of the solid geometric forms used to represent the arrangement of atoms in clay mineral crystal structures. It is formed by connecting the centres of the four oxygen anions surrounding a central cation. In the clay minerals the predominant central cation of the tetrahedron is silicon. A limited number of tetrahedral are occupied by aluminium and occasionally ferric iron or other elements. A silicon, or aluminium, ion is surrounded by four oxygen ions to form a tetrahedron as shown in the Fig. 1.2. The isolated tetrahedron has a net negative charge of -4 (Si with 4+ charges and four O with 2- charges). The tetrahedral rest on triangular face and the four triangular faces of the tetrahedron are formed by joining the centres of the anions. Only two of the faces are visible in the polyhedral illustration on the Fig. 1.3. In clay minerals, the three oxygens at the base of the tetrahedron are shared with adjacent tetrahedral and only the apical oxygen retains a charge of -1. Al may freely substitute for the silicon ions.

A supplemental view on the Figure 4 emphasizes that the cation (blue) occupies the centre of the tetrahedron (blue lines), and that it is bonded (brown rods) to four anions which would be located at the corners of the tetrahedron.

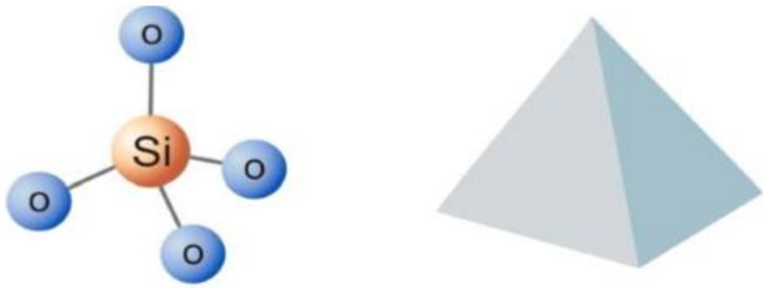

Fig. 1.2 Tetrahedral Structure

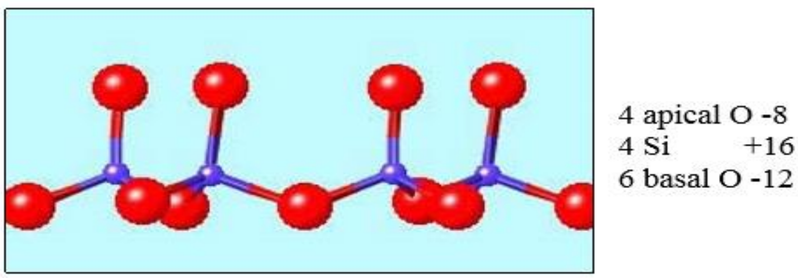

Fig. 1.3 Side View Showing Tetrahedral

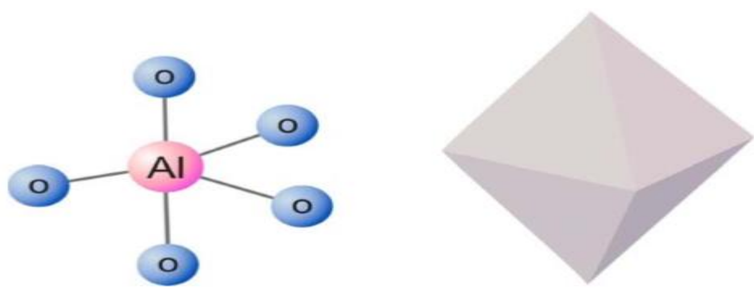

Fig. 1.4 Octahedral Structure

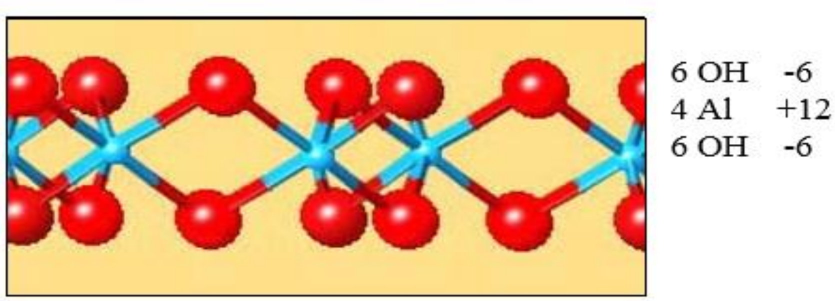

Fig. 1.5 Side View Showing Octahedral

The second structural unite is the octahedral sheet, in which the hydroxyl atoms (OH) in the corners and cations in the centre. The cations are usually aluminium (Al), iron (Fe), and magnesium (Mg) atoms. The octahedral sheet is comprised of closely packed oxygens and hydroxyls in which Al, Fe, and Mg atoms are arranged in octahedral coordination. The net charge on an isolated Al-OH octahedron is -3 (Al 3+ and six OH with 1- charge). In the octahedral sheet the charge is reduced through the sharing of anions by adjacent octahedral. A single octahedron can be recognized by following the bonds from the small blue balls (Al atoms). Three of them are directed upwards and are each connected a hydroxyl group as indicated by the arrows, shown in Fig. 1.4. The remaining three bonds are directed downwards to other hydroxyl groups. When aluminium with positive valence of three (Al +3) is present in the octahedral sheet, only two-thirds of the possible positions are filled in order to balance the charges. When only two octahedral sites filled with trivalent cations is a dioctahedral sheet. When magnesium with a positive charge of two (Mg+2) is present, all three positions are filled by divalent cations is a trioctahedral sheet.

When magnesium with a positive charge of two (Mg+2) is present, all three positions are filled by divalent cations is a trioctahedral sheet. The octahedral sheet is formed by sharing all hydroxyl groups at the corners of an octahedron with neighbouring octahedral. When you view the octahedral sheet from the side as shown in Fig. 1.5, they contain four aluminium atoms, six lower plane hydroxyls, and six upper plane hydroxyls. These rectangles are the same size as the planar motif outlined for the tetrahedral sheet. The formula for this unit is: $Al_4(OH)_{12}$ and the net charge is ZERO.

1.4.4 TWO-LAYER SHEET MINERAL

1.4.4.1 KAOLINITE MINERAL

The basic kaolinite unit is a two-layer unit that is formed by stacking a gibbsite sheet on a silica sheet. These basic units are held together by hydrogen bonds. The strong bonding does not permit water to enter the lattice. Thus, kaolinite minerals are stable and don't expend under saturation. Kaolinite is most abundant constituent of residual clay deposits.

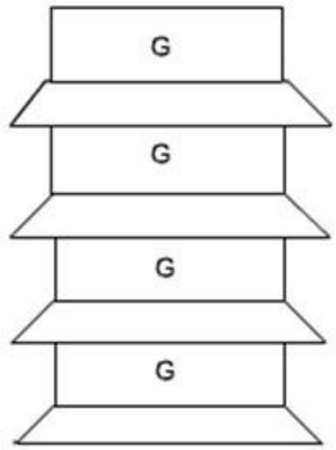

Fig. 1.6 Kaolinite Minerals

1.4.4.2 HALLOYSITE MINERAL

The basic unit is also a two-layer sheet similar to that of kaolinite except for the presence of water between the sheet.

1.4.5 THREE LAYERS SHEET MINERALS

Montmorillonite and illite clay minerals are the most common. A basic three-layer sheet unit is formed by keeping one silica sheet each on the top and at the bottom of the gibbsite sheet. These units are stacked to form a lattice.

1.4.5.1 MONTMORILLONITE MINERAL

The bonding between the three-layer units is by van der Waals forces. This bonding is very weak and water can enter easily. Thus, this mineral can imbibe a large quantity of water causing swelling. During dry weather, there will be shrinkage.

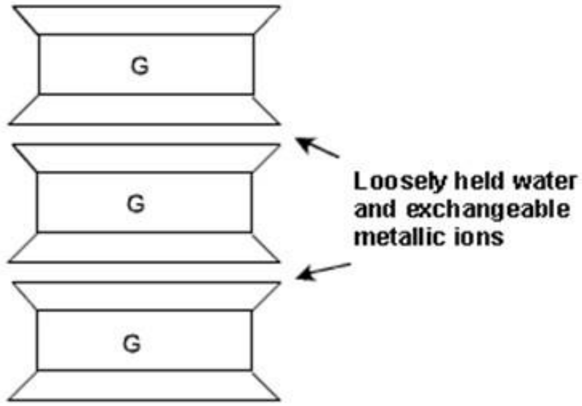

Fig. 1.7 Montmorillonite Mineral

1.4.5.2 ILLITE MINERAL

Illite consists of the basic montmorillonite units but are bonded by secondary valence forces and potassium ions, as shown. There is about 20% replacement of aluminium with silicon in the gibbsite sheet due to isomorphous substitution. This mineral is very stable and does not swell or shrink.

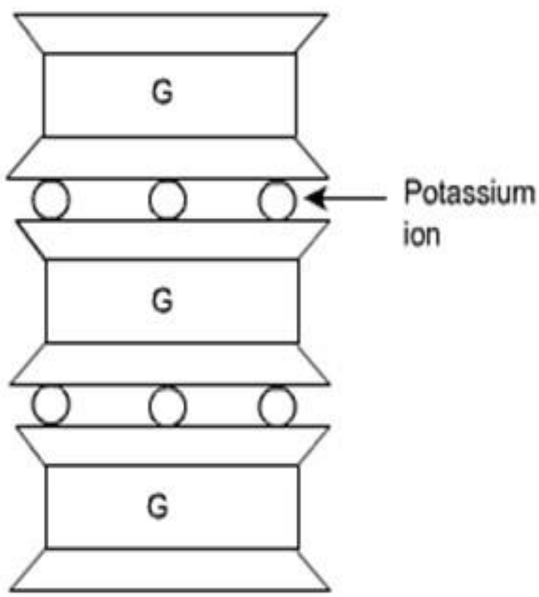

Fig. 1.8 Illite Mineral

The current study is experimental based study. In this study waste is collected from home dustbin and leachate is prepared. The equal amount of soil, china clay and fuller's earth clay are collected and then water is poured in to the clay and soil containers. When clay and soil is settled down, leachate (with liquid) poured in to the containers and effect of leachate is analysed and flow of leachate in china clay and fuller's earth are compared.

1.4.6 EQUILIBRIUM ADSORPTION AND ION EXCHANGE

The typically small grain size (<2 μm) of clay minerals results in the presence of large surface areas. These surface areas are available for exchange of ions and molecules between the solids and surrounding solutions. Exchange of ions involves adsorption and desorption which are commonly fast (on geological time scales). Adsorption takes place because of the attraction of ions to a surface. The strength of the bonding varies from weak van der Waals (physical adsorption) to moderate absorption (electrostatic adsorption) to strong chemical bonds (chemisorptions), henceforth simply referred to as adsorption. This process involves neutral species (H_2O, H_4SiO_4, organic molecules) and ions.

Example of kaolinite: Notice in the schematic diagram below that for 1:1 structure, positive ions are attracted to the light-blue tetrahedral basal oxygen surface. At the same time, negative ions are attracted to the dark-blue octahedral hydroxyl surface.

Example of vermiculite or smectite. The case for low-charge 2:1 structures is notably different from 1:1 structures. The schematic diagram below shows that 2:1 structures have mostly positive ions are attracted to the light-blue tetrahedral basal oxygen surfaces.

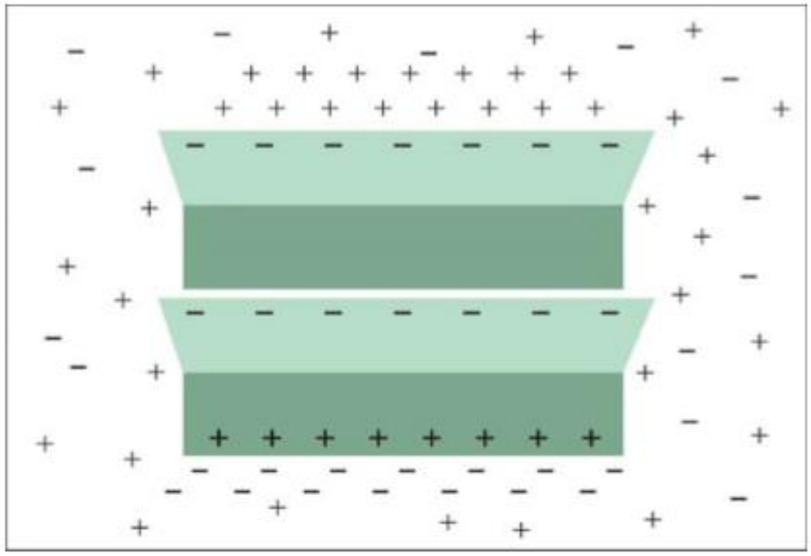

Fig. 1.9 Kaolinite ions

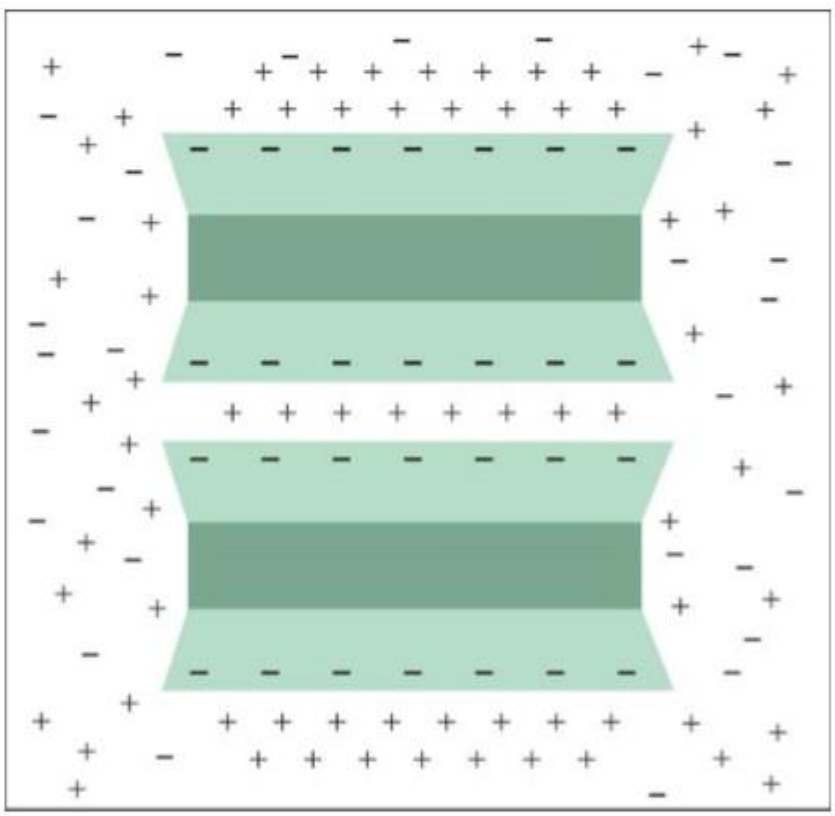

Fig. 1.10 Vermiculite or Smectite ions

Clay minerals have high sorption capabilities. They may absorb large quantities of compounds in the interstices between the particles much like a paper towel absorbs water. Clays also adsorb ions due to the electrostatic charges generated by atomic substitutions in their crystal structure and other processes. Adsorbed ions may be firmly attached to clay surfaces or readily hydrated and exchanged. In some instances, ions may be fixed in structural positions within the silicate layers. Organic matter and oxides/hydroxides also contribute significantly to the sorption capacity of clay-rich materials.

Cation exchange reactions often dominate the adsorption reactions. They are mostly dependent on the permanent negative charge of the 2:1 type layer. Johnston (2002) has listed six of the active sites influencing the sorption of organic molecules on clays.

1) The neutral siloxane surfaces of the 2:1 clay where no isomorphism substitution has occurred function as a Lewis base site.

2) Permanently charged sites (usually negative) are localized where isomorphism substitutions occur in the tetrahedral or octahedral sheets.

3) Exchangeable metal cations or metals in isomorphism substitution sites may interact directly with adsorbed molecules.

4) Polarized water molecules coordinated to exchangeable cations or under coordinated metal ions at flake edges serve as sites of surface acidity.

5) Organic molecules adsorbed on clay surfaces may create hydrophobic surfaces or serve as molecular pillars for exchange molecules.

6) Broken edge sites associated with under coordinated metal ions form surface hydroxyl groups which are among the most active of sites.

In the current study the experimental work is performed. The flow of leachate through soil, china clay and fuller's earth clay are analysed and the best solution is obtained to reduce the contamination of ground water.

CHAPTER 2

LITERATURE REVIEW

Control of leachate generation is big challenge in the modern Indian municipal corporation. There is continuous increase in population of India and lack of available water resources. Because of these it is paramount important to prevent water from contamination. The main source of the water is ground water. Near the landfill region where the municipal solid wastes are present, the possibility of contamination of ground water is more and the risk of health issues are more people living near these areas.
Several researches were conducted methods are suggested to control the leachate near the landfill. Many clay minerals are used as a clay liner to prevent the leachate to reach below the ground level.

Ali S. M. et. al , evaluated the physico-chemical parameters and heavy metals of leachate and quality of nearby groundwater collected from Hand-pumps and Tube-wells. The groundwater samples were examined for physico-chemical, microbiological parameters and heavy metals. It is observed that the physico-chemical parameters leachate sample has high contamination of oraganics, salts and heavy metal. The groundwater results shows that Mg^{2+}, F^- and Cr^{6+} exceeds permissible limit in groundwater give proof that quality of groundwater notably affected by percolation of leachate. The presence of TC in groundwater samples indicates possible contamination. Scientific management strategies should be adopted to prevent the future contamination of groundwater by leachate.

The leachate collected from the Dubagga municipal open dumping ground shows high values for the physicochemical parameters. Chromium were present at low level in leachate and Cadmium is below detection limit in leachate sample. The impact of leachate permeation is obvious on the encompassing groundwater. The groundwater results showed that Mg^{2+}, F- and Cr^{6+} exceeds permissible limit in groundwater give proof that quality of groundwater notably affected by percolation of leachate. The presence of TC in groundwater samples indicates possible contamination.

Swati et al, addressed the problems, both environmental and toxicological, associated with the landfills, the challenges faced in the current scenario, and the possible measures that can be taken to deal with the problem of municipal solid waste management successfully. In the paper the toxic nature of leachate is explained, the unsegregated waste that ends up in landfill contains lot of toxic substances which include waste from industries, pharmaceutical companies, hospital, e-waste, etc. These substances are highly recalcitrant and pose a great risk to human life and environment. With increased industrialization, the usage of mechanical devices and machinery is also increasing such as television, batteries, and computers which contain the substances like lead, arsenic, cadmium, PVC (Poly Vinyl Chloride), acids, and others. The improper disposal of these materials into the landfill leads to the accumulation of toxic substances in landfill. Other toxic substance that is frequently detected in landfill is mercury which is found to be released from fluorescent light bulbs. Even a small amount of mercury vapor poses a great risk to human kidneys and lungs. Eventually, these substances leach into groundwater and soil and cause pollution.

Case studies were considered and found that Many states are actively involved in managing waste and trying different methods and technologies available for developing sustainable waste management program as per the need of the area and the state. The Pune Municipal Corporation (PMC) has collected and segregated about 56% of waste with the help of SWACH (an NGO) and ragpickers. About 80% of the segregated waste has been treated and well processed (PEARL 2015). A number of composting unit and waste-to-energy plants were also established by PMC in different localities by involving private vendors into the business. The private partnership involvement has not only saved 150 lakhs annually to the PMC but also reduced the cost associated with environment degradation. The Ahmedabad Municipal Corporation (AMC) has achieved a milestone by collecting 98% waste. It has been possible because of the robust system developed by the

AMC. By keeping an eye on the projections of waste generation, AMC has developed a detailed master plan for waste management in the state. It has developed the first mobile court which deals with the violation of sanitation and health laws (SWMD, AMC 2014). The AMC is spending ₹2,500 per metric ton of solid waste which is not possible for the other municipalities and smaller cities. This became a constraint for other states and cities. Some other NGOs and civil society organizations are actively involved in waste collection and management program in conjunction with the municipalities of the state. Stree Mukti Sanghatana, a Mumbai-based NGO, organized 3,000 waste pickers that cover around 10,000 household of the city. Similarly, waste pickers in Pammal town of Kancheepuram district, Tamil Nadu, collect 994 MT of waste monthly which belong to Exnora Green Pammal (EGP) NGO.

Uma S M et. al , Comprehensive review of geosynthetic clay liner and compacted clay liner; Human activity inevitably produces waste materials that must be managed. Some waste can be reused. However, many wastes that cannot be used beneficially must be disposed of ensuring environmental safety. One of the common methods of disposal is land filling. The most common problems of the landfill site are environmental degradation and groundwater contamination caused by leachate produced during the decomposition process of organic material and rainfall. Liner in a landfill is important components which prevent leachate migration and prevent groundwater contamination. Earthen liners have been widely used to contain waste materials in landfill. Liners and covers for municipal and hazardous waste containment facilities are often constructed with the use of fine–grained, low plasticity soils. Because of low permeability geosynthetic clay liners and compacted clay liners are the main materials used in waste disposal landfills. These paper summaries the important geotechnical characteristics such as hydraulic conductivity, liquid limit and free swell index of geosynthetic clay liner and compacted clay liner based on research findings. This paper also compares geosynthetic clay liner and compacted clay liner based on certain criteria such as thickness, availability of materials, vulnerability to damage etc.

Lestari D. I. et al, studied the effect of reduction of the coefficient of permeability in soil modification (using mixed kaolinite and mixed bentonite on saturated soils) in order to reduce the pollution of the leachate on the surface and groundwater. The research is done in the laboratory with observing the characteristic of the soils that will be used, after that the permeability test will be conducted using a consolidation cell (rowe cell) with vertical direction and one back pressure system. The result showed that the greater the amount of kaolinite and bentonite on the soil will obtain a smaller coefficient of permeability itself, therefore the water will be difficult to pass through the pores inside the soil, hence the use of kaolinite and bentonite as clay barriers to prevent the pollutants (leachate) to pollute the rivers, groundwater, and environment.

Oluwapelumi et. al, Geotechnical Characterization of some Clayey Soils for Use as Landfill Liner; Waste management is one of the major challenges faced by municipality officials, public health engineers and environmentalists in their quest to protect and preserve our environment. Construction and operation of an engineered sanitary landfill ensures proper waste management with the protection of human and ecosystem health. This paper presents the results of geotechnical investigation carried out on clayey soils from three selected pottery areas in Oke Ogun, Oyo State; to assess their suitability for use as landfill liner. Samples were collected at three locations namely: Ajetunmobi village, sample A; Adegbite area, sample B; and Arigangan area, sample C. Basic index characterization tests conducted on the samples revealed percentage fines for samples A,B and C were 32.7%, 28.3% and 37.0% respectively. Specific gravity ranged between 2.71 and 2.74. Sample A had Cation Exchange Capacity (CEC) value of 10.58 milli-equivalents/100g (Meq./100g), sample B had CEC value of 11.76 (Meq./100g) and sample C had CEC value of 12.18 (Meq./100g) Geotechnical tests conducted on samples resulted in hydraulic conductivity (k) of 1.86 for sample A ; for sample B and, for sample C. The results obtained from the study show that sample A is the best material for a landfill liner based on the hydraulic conductivity criterion, however all the other samples are also useful and can be improved by addition of little percentage of bentonite. The compaction and compressibility characteristics needed in the specifications for the construction and operation of an engineered landfill using these clayey soils are presented.

Jun H el. al, Effects of leachate infiltration and desiccation cracks on hydraulic conductivity of compacted clay; Both cracks in clay liner and the complex composition of landfill leachate might have effects on the hydraulic conductivity of a compacted clay liner. In this study, the hydraulic conductivities of natural clay and bentonite-modified clay with and without desiccation cracks were measured, respectively, using three types of liquids as permeating liquid: 2 500 mg/L acetic acid solution, 0.5 mol/L $CaCl_2$ solution, and tap water. When tap water was adopted as the permeating liquid, desiccation cracks resulted in increases in the average value of hydraulic conductivity: a 25-fold increase for the natural clay and a 5.7-fold increase for the bentonite -modified clay. It was also found out that the strong self-healing capability of bentonite helped to reduce the adverse impact of cracks on hydraulic performance. In contrast to tap water, simulated leachates (acetic acid and $CaCl_2$ solutions) show no adverse effect on the hydraulic conductivities of natural and bentonite-modified clays. It is concluded that desiccation cracks and bentonite have more significant effects on hydraulic performance than simulated leachates.

Liu.Y et al, Hydraulic performance of geosynthetic clay liner to sulfuric acid solutions; The ability of geosynthetic clay liners (GCLs) to contain acidic mining leachates is examined. The results of saturated hydraulic conductivity (k) of two GCLs permeated with sulfuric acid solutions (H_2SO_4) at 0.015 M, 0.125 M and 0.5 M concentrations are reported. Also, the saturated k values of consolidated (35 kPa) bentonite cakes made from sodium bentonite extracted from both GCLs were compared to a commonly used magnesium sodium form bentonite. Chemical compatibility and effects of pre hydration and effective stress were assessed as part of this study. Results indicated that an increased acid concentration (ionic strength) increased the k of all tested specimens. The ratio of the k0.5 values for non-pre hydrated specimens permeated with

0.5 M H_2SO_4 to the kw values for specimens permeated with deionized (DI) water (k0.5/kw) ranged from 10 to 110. Pre-hydration (50e140% water content) and effective stress (35e200 kPa) improved the performance of GCLs (lower k). Strong correlations were observed between k and liquid limit and swell index parameters independent of pre-hydration and effective stress in this study. However, care should still be taken when using these correlations to evaluate hydraulic performance because the intrinsic micro-structure properties of bentonite, such as porosity, should also be considered. This work showed that, for example, high SI of bentonite does not translate necessarily to a better hydraulic performance of GCLs.

Archana et al, In the present study an assessment is made of the existing situation of municipal solid waste management (MSWM) in Lucknow city, UP (India). The current status of MSWM as per the MSW Rules, 2000 has also been appraised and an action plan for better management has been formulated. The quantitative and qualitative characteristics of MSW along with basic information have been evaluated for Lucknow city. The geographic information system has also been used to digitize the existing MSW dumping sites. The present study has showed that there are many shortcomings in the existing MSWM practices. The Lucknow city is one of the most densely populated, commercialized and urbanized cities of India. This city is also adding on commercial centres and new urban extensions which are providing additional housing services and employment opportunities to increasing population resulting into generation of huge quantity of MSW.

The inhabitants of Lucknow presently generate approximately 1500 tonnes of MSW every day. In the absence of sanitary landfills or other protected and lined dumping places, the MSW is transported to the various dumpsites, near fun republic mall Gomti Nagar, Telibagh Bhattha Maidan, Ghaila (Dubbga) Hardoi-Kanpur Ring Road and Ramdaskheda, Kursi Road. Such open dumping poses environmental and health hazards as leachate from open dumps are becoming major sources of groundwater contamination in the subsequent years of dumping MSW.

Srivastava R. et al, had characterised the waste generated in municipality of Varanasi, the most populated city in the state of Uttar Pradesh, India. Municipal Solid waste (MSW) is a heterogeneous waste and composition of the waste varied from place to place. The objective of the paper was to study the amount of solid waste generated during one year (2012-2013) of study period at four different places in Varanasi and evaluation and recommendations made on data collected in order to improve the current Solid Waste Management System of Varanasi City. The research gathered data from two main sources namely: secondary and primary sources. The three main techniques employed in gathering the primary data were: preliminary field investigation, questionnaire survey and face-to-face interview. Characterization of municipal solid waste shows Varanasi waste comprise maximum food waste (31.9 %) followed by plastic (22%), textile (10.6%), paper (9.6%), glass (6.7%), cardboard (6.2%), ash (5.3%), leather (5.7%) and minimum metals waste (2.8). Surveys showed that per capita MSW waste generation rate is 800 MT per day, 0.217kg/person/day. Sample from Ordalibazar showed the highest amount of energy content according to Modified Dulong Formula with a value of 254524.46 KJ/Kg followed by Daphi 167545.84 KJ/Kg, Nakhighat 96455.80 KJ,/Kg Puranapull 16147.11 KJ/Kg. Orderlybazar site have highest energy capacity compared to other sites and we can obtain more methane from NakiGhat site. Thus, on the basis of this study we may conclude that solid waste management and recycling is major issue of Varanasi district. We can reuse various types of waste depending upon the nature of waste. We can also make alternate use of that waste like energy production.

Xue Q. et al, 'Experimental study on anti-seepage grout made of leachate contaminated clay in landfill; In the study, leachate-contaminated clay was used as the base material, where cement and the self-developed clay curing agent were added to form an anti-seepage grout that can repair the leachate-contaminated clay in landfills, exhibit low permeability, and retard pollutants in the leachate. The effect of grout formula on the concentration of leaching pollutants, concretion rate, compressive strength, and permeability coefficient of concretion bodies was studied through a series of laboratory experiments. The efficiency of concretion bodies in retarding the leachate pollutants was investigated through a permeability test. The results indicated that the pollutants in the leachate-contaminated clay were controlled effectively. At 20% cement, 2% clay curing agent, and 1:1 water–soil ratio, the permeability coefficient of the concretion bodies after 7 days is ~ 10^{-7} cm/s, with > 1 concretion rate and > 1.2 MPa unconfined compressive strength. In addition, the concretion bodies reached > 85% retardation rate for COD in the leachate and > 99.8% for NH_3-N (including heavy metals such as Pb and Cd, among others). The retardation rate of the concretion bodies for the heavy metals is proportional to the ionic radius. As the cement content increased (clay curing agent = 10% cement), the concretion rate and permeability of the concretion bodies decreased, whereas its compressive strength increased.

Francis R. C. et al, studied Solid Waste Management and Characteristics in Lucknow, Uttar Pradesh, India; Increasing population levels, rapid economic growth and rise in community living standard accelerates the generation rate of municipal solid waste (MSW) in Indian cities. Improper management of SW (Solid Waste) causes hazards to inhabitants. The objectives of the study are to determine the quantitative and qualitative characteristics of SW along with basic information and to create GIS maps for Lucknow city. The samples have been randomly collected from various locations and analysed to determine the characteristics of SW. A questionnaire survey has been carried out to collect data from inhabitants including SW quantity, collection frequency, satisfaction level etc. The Geographic Information System (GIS) has been used to analyse existing maps and data, to digitize the existing sanitary ward boundaries and to enter the data about the wards and disposal sites. The total quantity of MSW has been reported as 800 ton/day, and the average generation rate of MSW has been estimated at 0.65 kg/capita/day. The generated Arc GIS maps give efficient information concerning static and dynamic parameters of the municipal solid waste management (MSWM) problem such as the generation rate of MSW in different wards, collection point locations, MSW transport means and their routes, and the number of disposal sites and their attributes.

Raghab S. M. et. al, Treatment of leachate from municipal solid waste landfill; Leachate generation is a major problem for municipal solid waste (MSW) landfills and causes significant threat to surface water and groundwater. Leachate can be defined as a liquid that passes through a landfill and has extracted dissolved and suspended matter from it. Leachate results from precipitation entering the landfill from moisture that exists in the waste when it is composed. This paper presents the results of the analyses of leachate treatment from the solid waste landfill located in Borg El Arab landfill in Alexandria using an aerobic treatment process which was applied using the mean of coagulation flocculation theory by using coagulant and accelerator substances for accelerating and improving coagulation and flocculation performance. The main goal of this study is to utilize a natural low-cost material "as an accelerator additive to enhance the chemical treatment process using Alum coagulant and the accelerator substances were Perlite and Bentonite.

The performance of the chemical treatment was enhanced using the accelerator substances with 90 mg/l Alum as a constant dose. Perlite gave better performance than the Bentonite effluent. The removal ratio for conductivity, turbidity, BOD and COD for Perlite was 86.7%, 87.4%, 89.9% and 92.8% respectively, and for Bentonite was 83.5%, 85.0%, 86.5% and 85.0% respectively at the same concentration of 40 mg/l for each.

Bhalla B., studied the Characterization of Leachate from Municipal Solid Waste (MSW) Landfilling Sites of Ludhiana, India: A Comparative Study; The paper discusses the characteristics of leachate generated from municipal solid waste land filling sites of Ludhiana City, Punjab (India). Leachate samples were collected and analyzed for various physico-chemical parameters to estimate its pollution potential. This study aims to serve as a reference for the implementation of the most suitable technique for reducing the negative environmental effects of discharge leachate. All the three landfilling sites of Ludhiana city are non-engineered low-lying open dumps. They have neither any bottom liner nor any leachate collection and treatment system. Therefore, all the leachate generated finds its paths into the surrounding environment. It has been found that leachate contains high concentrations of organic and inorganic constituents beyond the permissible limits. While, heavy metals concentration was in trace amount as the waste is domestic in nature. The data presented in this study indicated that the age of the landfill has a significant effect on leachate composition. In older landfills, the biodegradable fraction of organic pollutants in the leachate decreases as an outcome of the anaerobic decomposition occurring in the landfill. The concentration of leachate contaminants at Jamalpur and Noorpur belt landfilling site were comparative greater than that of Jainpur landfilling site which is older than both. Based on the characterization of landfill leachate, Jamalpur and Noorpur belt landfilling site demonstrated low bio-degradability i.e. BOD5/COD=0.19 and BOD5/ COD=0.20 compared with Jainpur landfilling site i.e. BOD5/COD=0.24. Indiscriminate dumping of municipal solid waste without proper solid waste management practices should be stopped or some remedial measures were required to be adopted to prevent contamination.

Mor S. et al, insisted for proper management of waste in Delhi. Leachate and groundwater samples were collected from Gazipur landfill-site and its adjacent area to study the possible impact of leachate percolation on groundwater quality. Concentration of various physical-chemical parameters including heavy metal (Cd, Cr, Cu, Fe Ni, Pb and Zn) concentration and microbiological parameters {total coliform (TC) and faecal coliform (FC)} were determined in groundwater and leachate samples. The moderately high concentrations of $C^{l-,}$ $NO^{3-,}$ $SO4^{2-,}$ $NH^{4+,}$ Phenol, Fe, Zn and COD in groundwater, likely indicate that groundwater quality is being significantly affected by leachate percolation. Further they proved to be as tracers for groundwater contamination. The effect of depth and distance of the well from the pollution source was also investigated. The presence of TC and FC in groundwater warns for the groundwater quality and thus renders the associated aquifer unreliable for domestic water supply and other uses. Although some remedial measures are suggested to reduce further groundwater contamination via leachate percolation, the present study demand for the proper management of waste in Delhi.

Taie L. A., study is based on four papers related to the performance of near-surface low-level water (LLW) repositories (landfills) focusing on construction and performance of clay liners in the cappings. The first paper discusses the source of hazardous wastes, their location and their impact on public health. The paper also discusses the scientific basis of the selection of the isolation of such wastes taking in account also cost issues. The paper also shows rules and principles of composing and constructing isolation of such waste according to American and German regulations. The second paper deals with the criteria for locating plants for processing and disposal of hazardous waste in Iraq with special respect to environmental, geological and socio-economic factors. Referring to these criteria a potential disposal site in the Al-Jezira desert is assessed in the paper. The third paper describes the properties of two candidate Iraqi smectite clays of potential value for isolating hazardous wastes. These clays have been and are still being examined in order to determine their performance and usability for waste isolation. The fourth paper, finally, discusses in detail the hydration-dehydration processes in clay liners in cappings of waste landfills in desertic climates. It also deals with construction issues.

Athanasiou et al, studied the respiratory health of the municipal solid waste workers. One hundred and eighty-four municipal employees of Keratsini (104 MSWWs and 80 controls) participated in a cross-sectional study. All participants were asked to fill in a slightly modified version of the Medical Research Council questionnaire. Lung function was evaluated by spirometry. Spirometry revealed reduced mean forced vital capacity (FVC) and forced expiratory volume in 1 s (as a percentage of predicted values) in MSWWs compared with controls. After adjustment for smoking status, only the decline in FVC was statistically significant. Prevalence of all respiratory symptoms was higher in MSWWs than in controls. After adjustment for confounding factors, the difference reached statistical significance (P ,0.05) for morning cough, cough on exertion and sore throat. The results of this cross-sectional study indicate a higher prevalence of respiratory systems (RS) and a greater decrease in lung function in MSWWs. A number of limitations such as the relatively small size of population and the 'healthy worker' effect should be taken into account.

Jayasekera S. et al, studied the effects of municipal landfill leachate on basaltic clay soil. The duty was to investigate the effects of landfill leachate on the performance of a compacted basaltic clay soil, over a period of time. For this purpose, a typical Melbourne basaltic clay with varying percentages of montmorillonite clay was selected and a synthetic leachate was developed based on the composition of typical municipal waste landfill leachate reported in the literature. The clay - leachate interactions were allowed take place under controlled anaerobic laboratory conditions. Samples were then tested at different time periods to identify possible variations of engineering properties such as volume change, consistency and grain size distribution due to the effect of leachate over time, since variation of these soil properties can affect the hydraulic conductivity of a clay soil. The analysis of test results suggests that the behaviour of a basaltic clay liner could be significantly affected by clay leachate interactions over time, due to possible alterations to physical and mineralogical properties of the clay.

Problem Statement

A leachate is any liquid that, in the course of passing through matter, extracts soluble or suspended solids, or any other component of the material through which it has passed. Leachate is a widely used term in the environmental sciences where it has the specific meaning of a liquid that has dissolved or entrained environmentally harmful substances that may then enter the environment. It is the most commonly used in the context of landfilling of putrescible or industrial waste. Leachate from a landfill varies widely in composition depending on the age of the landfill and the type of waste that it contains. It usually contains both dissolved and suspended material. The generation of leachate is caused principally by precipitation percolating through waste deposited in a landfill. Once in contact with decomposing solid waste, the percolating water becomes contaminated, and if it then flows out of the waste material, it is termed leachate. Additional leachate volume is produced during this decomposition of carbonaceous material producing a wide range of other materials including methane, carbon dioxide and a complex mixture of organic acids, aldehydes, alcohols and simple sugars. The risks of leachate generation can be mitigated by properly designed and engineered landfill sites, such as those that are constructed on geologically impermeable materials or sites that use impermeable liners made of geomembranes or engineered clay.

Human activities create waste, and it is the way these wastes are handled, stored, collected and disposed of, which can pose risks to the environment and to public health. In urban areas, especially in the rapid urbanizing cities of the developing world, problems and issues of Solid Waste Management (SWM) are of immediate importance. This has been acknowledged by most governments, however rapid population growth overwhelms the capacity of most municipal authorities to provide even the most basic services. One two thirds of the solid waste generated is not collected. As a result, the uncollected waste, which is often mixed with human and animal excreta, is dumped indiscriminately in the streets and in drains, so contributing to flooding, breeding of insect and rodent vectors and the spread of diseases. Furthermore, even collected waste is often disposed of in uncontrolled dumpsites and/or burnt, polluting water resources and air.

Predicting the amount of leachate is a critical design parameter when designing a landfill. The amount of leachate generated will impact operating costs for leachate collection and treatment. The treatment plant must he sized to handle the peak period of leachate flow. These calculations will also directly influence the amount of money that may have to he placed into an escrow account for long-term care after me landfill is closed.

The quantities of leachate generated will also a factor in determining the leachate system, which is installed at the base of the landfill. The volume of leachate produced, is assumed to equal the volume of percolating water. A lag may occur between me time percolating water enters the fill material and the time leachate emanates continuously from the base of the fill. During this period, the solid wastes are increasing in moisture content. Initially, some leachate will generate intermittently due to water channelling through the wastes. After a several year period, leachate production should be more consistent. Although the quantity of leachate may be predicted by the water balance equation, it's time to reach the base of the landfill is less predictable and will lag behind precipitation events by a period dependent upon the moisture capacity of the waste. In addition, the permeability of intermediate soil layers within the landfill will control the downward migration rate. The actual detection of leachate reaching the landfill will depend upon the design of the site and the availability of monitoring equipment. At a site where leachate collection lines are installed, the onset of leachate flow can he detected by observing flow in the collection system.

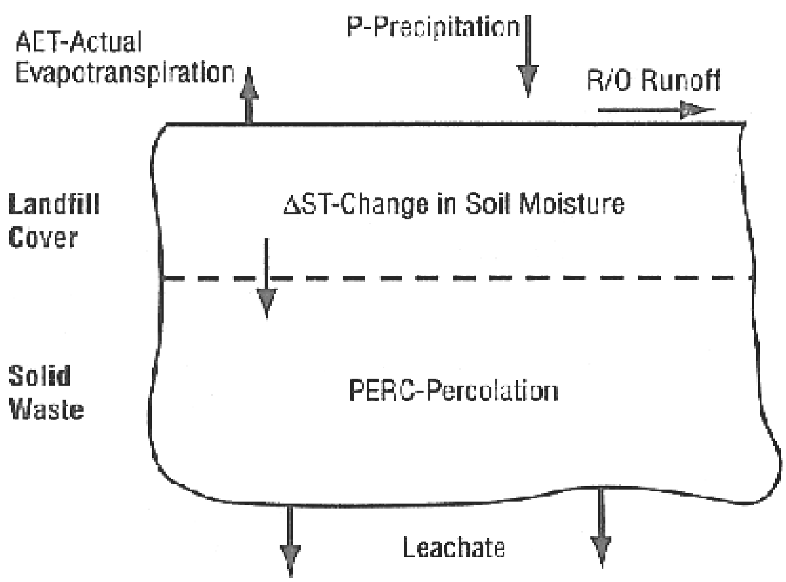

Fig. 2.1 Leachate at landfill region

CHAPTER 3

DESIGN METHODOLOGY

3.1 OVERVIEW

The sources of wastage form household are around 40-45% in Lucknow, which is the maximum as compared to others as shown in the Fig 1

Table 3.1 Percentage of sources of waste

Source of waste	Percentage
Households	40-45
Restaurants	28-30
Market	9-10
Shops & Workshops	7-8
Street Sweeping	7-8
Offices	5-6
Hospitals	3-2
Hotels	1-1.5

The movement of leachate, generated from the landfilled solid wastes depends upon site circumstances and landfill design features. It is especially important to plan for leachate control during the development of the landfill rather than after the landfill is constructed, since the control techniques are usually employed beneath the waste. Interrelations between topographical, hydrological, and geological factors must be considered to select the site for maximum natural containment of leachate. If a landfill site does not have suitable sub-surface hydrology for natural attenuation, the bottom of the landfill is lined with clay or silt, bentonite, kaolinite membrane liners, or other rather impermeable materials. It prevents the movement of leachate into the soil below the landfill. A prime consideration when installing a liner is its effectiveness in preventing leachate movement.

The clays can be analysed for particle size distribution, liquid limit, plastic limit, and plasticity index. In addition, other tests such as field density, field water content, void ratio, and porosity can be conducted, and the classification group symbol and group name can be determined. permeability of the soil can be examined to measure field hydraulic conductivity

3.2 PERMEABILITY

Permeability is commonly measured in terms of the rate of water flow through the soil in a given period of time. This characteristic is usually expressed as a permeability rate (coefficient of permeability or hydraulic conductivity k) in centimetres per second. Soils are permeable because of the existence of interconnected voids, through which water can flow from high-energy to low-energy points. The study of the water flow through permeable soil media is important in soil mechanics. In 1856, Darcy published a simple equation for the discharge velocity of water through saturated soils, which may be expressed as, (Das and Sobhan, 2014)

where

v = discharge velocity, which is the quantity of water flowing in unit time. However, the actual velocity of water (that is, the seepage velocity) through the void spaces is greater than v.

k = hydraulic conductivity (otherwise known as the coefficient of permeability)

i = Hydraulic gradient

The quantity of flow q through a cross-section of area A is stated as

$q = kiA$

Darcy's equation considered flow only through homogeneous soils. In reality, soils are stratified or layered with different soil types. In calculating flow through layered soils, an average or equivalent hydraulic conductivity representing the whole soil mass is determined from the hydraulic conductivity of each layer. The value of k is influenced by the void ratio, pore size, interconnected pore space, particle size distribution, homogeneity of the soil mass, properties of the pore fluid, stress level, and the amount of undissolved gas in the pore fluid (Budhu, 2015). Most natural soils are anisotropic with respect to the coefficient of permeability, and the degree of anisotropy depends on the type of soil and the nature of its deposition. In most cases, the anisotropy is more predominant in clayey soils compared to granular soils. In anisotropic soils, the directions of the maximum and minimum permeabilities are generally at right angles to each other, maximum permeability being in the horizontal direction. It is sometimes difficult to obtain undisturbed soil specimens from the field. For large construction projects, it is advisable to conduct permeability tests in situ to fined field coefficients of permeability (Das, 2014).

3.3 HYDRAULIC CONDUCTIVITY

Hydraulic conductivity test method covers field measurement of limiting values for vertical and horizontal hydraulic conductivities (also referred to as coefficients of permeability) of porous materials. This test method is utilized for natural deposits above the water table by ordinary borehole tests. However, its resulting value is the apparent conductivity. For this test method, a distinction must be established between "saturated" (Ks) and "field-saturated" (Kfs) hydraulic conductivity. True saturated conditions seldom occur in the vadose zone except where impermeable layers result in the presence of perched water tables. During infiltration events, a "field-saturated" condition develops. True saturation does not occur because of entrapped air. The entrapped air prevents water from moving in air-filled pores that, in turn, may reduce the hydraulic conductivity measured in the field by as much as a factor of two compared with conditions in which trapped air is absent. This test method simulates the "field saturated" condition. The values stated in SI units are to be regarded as standard unless other units are specifically provided. In U.S. practice, hydraulic conductivity is reported in cm/s, although the common SI units for hydraulic conductivity are m/s (ASTM, 2011).

The bonding between the clay layers and permeability is paramount important and major factors affecting the flow of leachate.

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 STEPS INVOLVED IN EXPERIMENT

The experimental setup is shown in Fig. 4.1 The major steps involved in the experiment are explained below,

Step 1: The left side of the container is filled with soil; Middle container is filled with china clay and right container is filled with fuller's earth clay. Three trays are kept below the containers to collect the passing leachate as shown in Fig. 4.5.

Step 2: The water is added in all containers to increase the humidity.

Fig. 4.1 Clay and Soil Containers

Fig. 4.2 Soil and Clays conditions after a day

Step 3: After waiting for a day when water is absorbed as shown in Fig. 4.2, the soil and clays is compressed and more water is added to the containers as shown in Fig. 4.3

Step 4: After two days water is added again as shown in Fig. 3.4 and left the container for two more days.

Fig. 4.3 Soil and Clays conditions after two days

Fig. 4.4 Soil and Clays conditions after 5 days

Step 5: After two more days (after 5 days from step 1) the water is absorbed by the soil and the clays as shown in Fig. 4.5

Fig. 4.5 Soil and Clays condition after seven days

Fig. 4.6 Diluted leachate

Step 6: Leachate is collected from garbage bin and diluted using water and 500 ml leachate is prepared as shown in Fig. 4.6 and Fig. 4.7

Fig. 4.7 Leachate (500 ml)

Fig. 4.8 Clays after 2 days of leachate addition

Step 7: Equal amount of water is poured into the containers and kept for two days as shown in Fig. 4.8.

Step 8: The water collection in the bottom tray is analysed and observations are recorded.

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4.2 RESULT AND DISCUSSIONS

It is observed that the leachate is passed through the soil and collected in the tray below the soil container shown in the Fig. 4.9.

Fig. 4.9 Soil and Clays containers after five days of leachate addition

A small amount of leachate is collected in the tray below the fuller's earth container. No leachate is passing through the container, filled with china clay.

There are two major reasons for best performance of china clay. One of them is the unit that is formed by stacking a gibbsite sheet on a silica sheet. These basic units are stacked on top of other to form a lattice structure. The units are bound together by hydrogen bonding. This bond is strong enough to prevent water to pass from the lattice. Thus, kaolinite minerals are stable. The fuller's earth clay units are bond together with van der waals forces. These forces are weak and water easily enters into the lattice. Initially the soil and clay have a weight of 6kg. After adding leachate to the soils, the weight of the soil and clays has changed because of the permeability due to absorption of material from the leachate because of the leaching effect there is a variation in the soil mass. The soil mass which showed lower permeability doesn't exhibit change in the soil mass. However, the soil having greater permeability has shown change in the soil mass which can be detected as follows:

Table 4.1: Showing the initial and final weight

Landfill Liner	Initial Weight	Final Weight
Soil	6kg	6.3 kg
China Clay	6kg	6.13 kg
Fuller's Earth	6kg	5.8 kg

The second reason is the permeability of the china clay, which is lower than the fuller's earth. The typical average permeability of china clay is 4.439E-13 m/s and that of fuller's earth is 2.845E-12 m/s. Because of low permeability it is not easy to pass the water from the china clay.

Figure 4.8 shows the peak crush force evaluation of the sections with variation in rib central fillets. There is 37 % increment of the peak force value, when fillet radius of 5 mm is used over the results of the cross rib with 1.8 mm thick. When using fillet radius of 7.5 mm the percentage increase of peak crush force is 39% as compared to cross rib with same thickness (section thickness).

CHAPTER 5

CONCLUSIONS & FUTURE SCOPE

5.1 CONCLUSIONS

Leachate means any liquid percolated through the deposited waste and emitted from or contained within a landfill. The leachate consists of many different organic and inorganic compounds that may be either dissolved or suspended. They will bring potential pollution issues for groundwater and surface waters in nature. The landfill leachate is a secondary contamination related to landfills. Clay liners are useful to prevent passing of water from ground surface to the inner surface of the earth. depending upon the physical and mechanical properties of the clay liners. China clay is better than the fuller's earth clay in terms of water contents. Mixture of both clays can be used with soil modification to reduce the permeability.

5.2 FUTURE SCOPE

Leachate, generated from Municipal Solid Waste, is Front collision is paramount important in of crash analysis. In future more efforts will be made with mixture of different clays to reduce the permeability.

5.2.1 Past Work

A typical municipal landfill leachate used in few studies, which contained heavy metals and organic compounds.

A lot of survey-based work is done, which provides the information about the MSW management and leachate control methods.

5.2.2 Present Work

Experimental work is conducted using home wastes and leachate flow through soil, china clay and fuller's earth clay is analysed.

Performance of China clay is the best because of low permeability as compared to fuller's earth.

5.2.3 Future Work

Experimental work can be further extended using mixture of different clay i.e china clay-fuller's earth clay to reduce the permeability of the mixture.

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Appendix I

Clay The meanings of the terms, "clays" and "clay minerals", are important to be distinguishing before starting to read the book. A very brief note on general aspects of clay can be explained as follows:

The term "clay" refers to a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden when dried or fired. Clay usually contains phyllosilicates, it may contain other materials that impart plasticity and harden when dried or fired. Associated phases in clay may include materials that not impart plasticity and organic matter.

Clay and sand both indicate a specific grain size; however, it is often used to refer to a specific mineralogical composition of sediments. Figure 1 shows the classification of siliciclastic sediments (unconsolidated, loose) that are based on average grain size. We advise to use it only for grain size. An important point in this figure is that the boundary between sand and silt is 0.06mm and smaller than 0.004mm is clay. The current ISO (International Organization for Standardization) Standard 14688:1996 placed the boundary at 0.06 mm between sand and silt (Geological Society, London, 2006).

The term "clay mineral" refers to phyllosilicate minerals and to minerals which impart plasticity to clay and which harden upon drying or firing. Clay minerals are layer silicates that are formed usually as products of chemical weathering of other silicate minerals at the earth's surface. They are found most often in shales, the most common type of sedimentary rock. In cool, dry, or temperate climates, clay minerals are fairly stable and are an important component of soil. Clay minerals act as "chemical sponges" which hold water and dissolved plant nutrients weathered from other minerals. This results from the presence of unbalanced electrical charges on the surface of clay grains, in which some surfaces are positively charged (and thus attract negatively charged ions), while other surfaces are negatively charged (attract positively charged ions). Clay minerals also have the ability to attract water molecules. Because this attraction is a surface phenomenon, it is called adsorption (which is different from absorption because the ions and water are not attracted deep inside the clay grains). Clay minerals resemble the micas in chemical composition, except they are very fine grained, usually under microscope. Like the micas, clay minerals are shaped like flakes with irregular edges and one smooth side. There are many types of known clay minerals. Some of the more common types and their economic uses are described here:

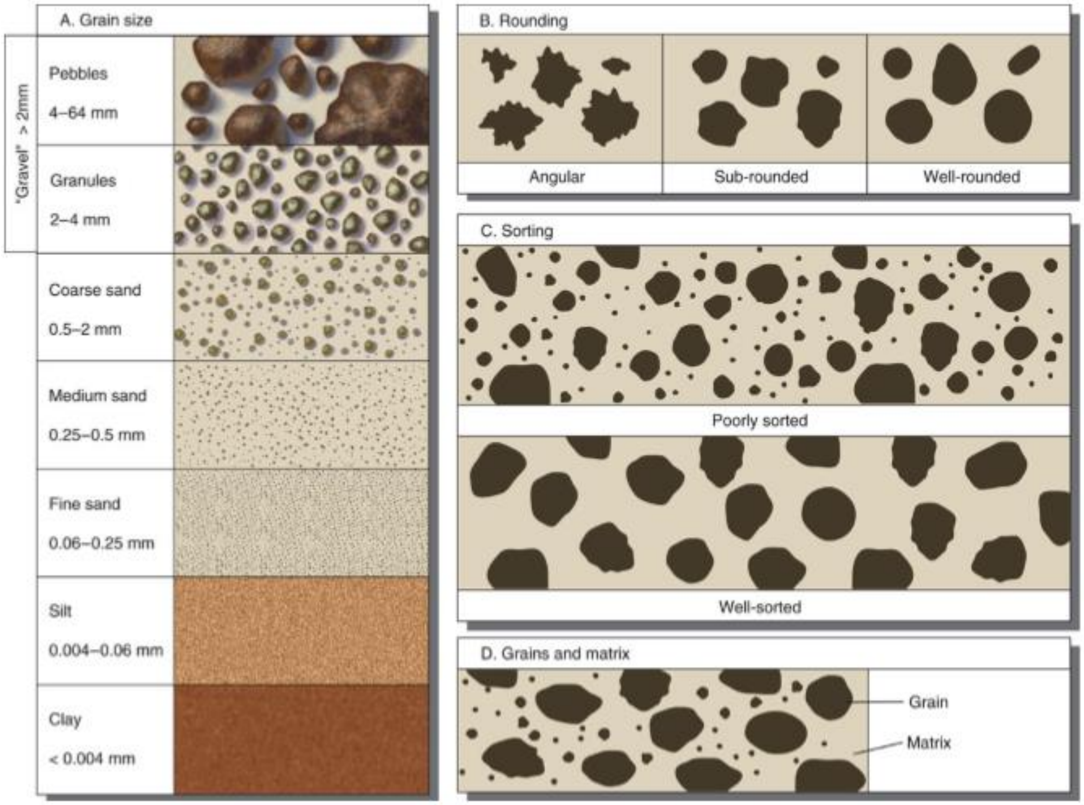


Fig. I.1 Clays Grain Size

Kaolinite: This clay mineral is the weathering product of feldspars. It has a white, powdery appearance. Kaolinite is named after a locality in China called Kaolin, which invented porcelain (known as china) using the local clay mineral. The ceramics industry uses it extensively. Because kaolinite is electrically balanced, its ability of adsorb ions is less than that of other clay minerals. Smectite: This clay mineral is the weathering product of mafic silicates, and is stable in arid, semi-arid, or temperate climates. It was formerly known as montmorillonite. Smectite has the ability to adsorb large amounts of water, forming a water-tight barrier. It is used extensively in the oil drilling industry, civil and environmental engineering (where it is known as bentonite), and the chemical industry. There are two main varieties of smectite, described in the following: Sodium smectite: This is the high-swelling form of smectite, which can adsorb up to 18 layers of water molecules between layers of clay. Sodium smectite is the preferred clay mineral for drilling muds, for creating a protective clay liner for hazardous waste landfills to guard against future groundwater contamination, and for preventing seepage of groundwater into residential basements. Sodium smectite will retain its water-tight properties so long as the slurry is protected from evaporation of water, which would cause extensive mud cracks. As a drilling mud, sodium smectite mixed with water to form a slurry which performs the following functions when drilling an oil or water well: 1) lubricates the drill bit to prevent premature wear, 2) prevents the walls of the drill hole from collapsing inwards, 3) suspends the rock cuttings inside the dense mud so that the mud may pumped out of the drill hole, and 4) when the dense mineral barite is added to drilling mud, it prevents blowouts caused by internal pressure encountered during deep drilling. Sodium smectite is also used as commercial clay absorbent to soak up spills of liquids. Calcium smectite: The low-swelling form of smectite adsorbs less water than does sodium smectite, and costs less. Calcium smectite is used locally for drilling muds.

Illite: Resembles muscovite in mineral composition, only finer-grained. It is the weathering product of feldspars and felsic silicates. It is named after the state of Illinois, and is the dominant clay mineral in mid-western soils. Chlorite: This clay mineral is the weathering product of mafic silicates and is stable in cool, dry, or temperate climates. It occurs along with illite in mid-western soils. It is also found in some metamorphic rocks, such as chlorite schist. Vermiculite: This clay mineral has the ability to adsorb water, but not repeatedly. It is used as a soil additive for retaining moisture in potted plants, and as a protective material for shipping packages.

Palygorskite (attapulgite): Palygorskite is synonymous terms for the same hydrated Mg-Al silicate material. The name specified by the International Nomenclature Committee is palygorskite. However, the name attapulgite is so well established in trade circles that it continues to be used by many producers and users. This mineral actually resembles the amphiboles more than it does clay minerals, but has a special property that smectite lacks - as a drilling fluid, it stable in salt water environments. When drilling for offshore oil, conventional drilling mud falls apart in the presence of salt water. Palygorskite is used as a drilling mud in these instances. Incidentally, palygorskite is the active ingredient in the current formula of Kaopectate.

Clay minerals form an important group of the phyllosilicates or sheet silicate family of minerals, which are distinguished by layered structures composed of polymeric sheets of SiO_4 tetrahedral linked to sheets of (Al, Mg, Fe) (O, OH)6 octahedral. The geochemical importance of clay minerals stems from their ubiquity in soils and sediments, high specific surface area, and ion exchange capacities. Clay minerals tend to dominate the surface chemistry of soils and sediments. Furthermore, these properties give rise to a wide range of industrial applications throughout the history of mankind. The use of clay for mainly clay figures, pottery and ceramics was already known by primitive people about 25000 years ago (Shaikh and Wik, 1986). Today clay is an important material with a large variety of applications in ceramics, oil drilling, liners for waste disposal, and the metal and paper industry. Clay is furthermore used as adsorbent, decolouration agents, ion exchanger, and molecular sieve catalyst (Murray, 1991). Despite their importance, the clay minerals form a difficult group of minerals to study due to their small size, variable structural composition, and relative slow kinetics of formation and alteration.

Occurrences of clay

Sedimentary rocks only make up 5% of the Earth's crust, but cover about 80% of the surface of the earth in which clays (including shales) form well over 40% of the sedimentary rocks. The raw material for sedimentary rocks comes from weathering. If we look at the volume of material at the earth's surface (Fig. 2), we see that clay minerals constitute about 16% of its total. 20 km is considered the surface of the earth because it is the region from which we extract natural resources (and dump our waste). Clay sediments are collected by the agencies of water (e.g. marine clays, alluvial clays, lacustrine clays), wind (Aeolian clays), or ice (e.g. glacial clay, till or boulder clay, as most clays in Finland). The majority of the common sedimentary clays, however, are the marine deposits typically comprising mixtures of coarser material with clay in which the clay mineral, illite, usually predominant (see chapter two for description of clay minerals).

Clay mineral-rich deposits can be formed in two other principle ways: • by weathering of parent minerals in situ to form a clay rich residual soil in which the clay mineral kaolinite frequently predominates, especially common in landscapes undergoing tropical weathering, and • by ascending fluids, i.e. by hydrothermal alteration of the host rock. Cornish china clay is a good example, the feldspar of the local granite having been converted mainly into clay minerals of the kaolinite group. For full discussion see chapter five.

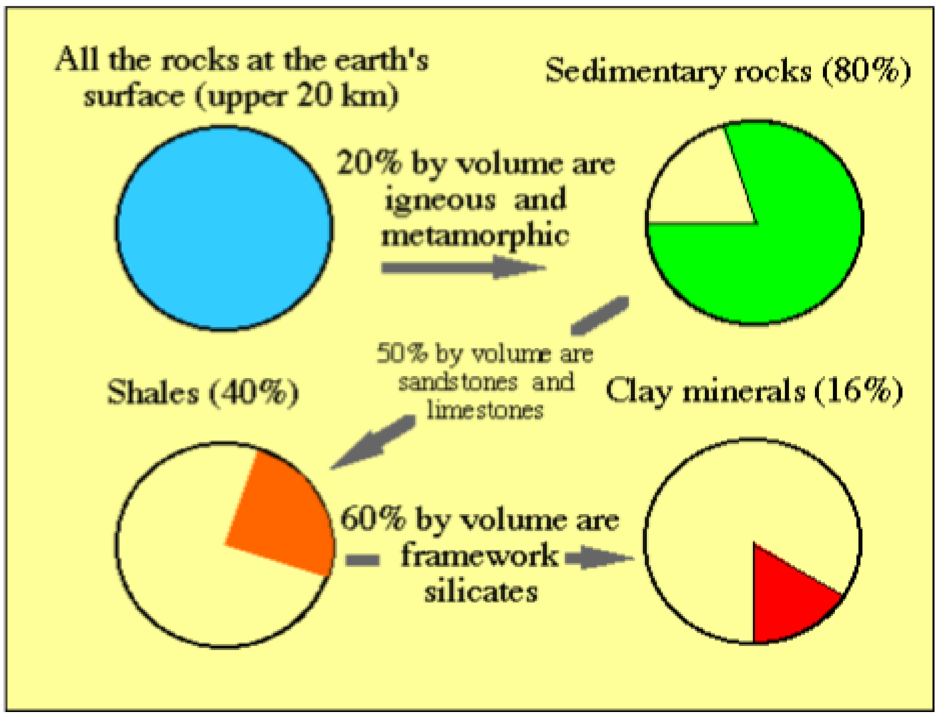


Fig. II.1 Clays Minerals and Rocks Percentage

INDUSTRIAL USES OF CLAYS

Clay minerals are some of the most important, if not the most important, of our industrial minerals. Millions of tons are utilized annually in a large variety of applications. These applications include uses in geology, the process industries, agriculture, environmental remediation and construction. This book focuses on the major applications of the clay minerals today and looks into the future growth and applications of certain specific clay minerals. Why are certain clay minerals used in specific applications? The reason is that the physical and chemical properties of a particular clay mineral are dependent on its structure and composition. As we explained in chapter two, the structure and composition of kaolins, smectites, and palygorskite and sepiolite are very different even though they each have octahedral and tetrahedral sheets as their basic building blocks. However, the arrangement and composition of these octahedral and tetrahedral sheets account for major and minor differences in the physical and chemical properties of kaolin, smectites and palygorskite.

The important characteristics relating to the applications of clay minerals are particle size and shape, surface chemistry, surface area, surface charge, and other properties specific to particular applications, including viscosity, colour, plasticity, green, dry and fired strength, absorption and adsorption, abrasion and pH. In all applications, the clay minerals perform a function and are not just inert components of the system. Several authors those discuss clay mineral applications and, although some are historical, they are essential to our present understanding of how and why the clay minerals have such an extensive industrial utilization. Some of these are Murray & Lyons (1956), Grim (1962), Clem & Doehler (1963), Haden (1963), Jordan (1963), Konta (1995), Murray (1984, 1991, 1986), Grimshaw (1971), Grim & Guven (1978), Robertson (1986), GalaÂn (1996), Elzea & Murray (1994), Heivilin & Murray (1994), Pickering & Murray (1994), Keith & Murray (1994) and Murray (2007).

Table (9) shows some of the properties of kaolin, smectite and palygorskite that account for many of their applications. Specific applications are discussed under the headings kaolin, smectite, and palygorskite and sepiolite.

6.1 Kaolin

Kaolin is soft, white plastic clay consisting mainly of the mineral kaolinite which is a hydrated aluminium silicate Al_2 Si_2 O_5 $(OH)_4$. It is formed by the alteration of feldspar and muscovite. Kaolin deposits are classified as either primary or secondary. Primary kaolins result from residual weathering or hydrothermal alteration and secondary kaolins are sedimentary in origin. Kaolin is an important industrial mineral, which is used in many industrial applications.

Smectite (Bentonite)

Smectite is the mineral name given to a group of Na, Ca, Mg, Fe, and Li-Al silicates. The mineral names in the smectite group which are most commonly used are Na-montmorillonite, Camontmorillonite, saponite (Mg), nontronite (Fe), and hectorite (Li). The rock in which these smectite minerals are dominant is bentonite. Bentonite is smectite clay formed from the alteration of siliceous, glass-rich volcanic rocks such as tuffs and ash deposits.

The sodium, calcium, and magnesium cations are interchangeable giving the montmorillonite a high ion exchange capacity. The industrial bentonites are generally either the sodium or calcium variety.

Bentonites are important and essential in a wide range of markets including drilling mud, foundry sand binding, iron ore pelletizing, pet waste absorbents, and civil engineering uses such as waterproofing and sealing. Bentonites have excellent rheological and absorbent properties. Sodium bentonite has a high swelling capacity, and forms gel-like masses when added to water. Calcium bentonite has a much lower swelling capacity than sodium bentonite but this can be improved by treatment with soda ash to produce sodium exchanged bentonite. Normally this sodium exchanged bentonites do not have as high swelling capacity as the natural sodium bentonites.

The largest sodium bentonite deposits are located in the Western United States in Wyoming, Montana, and South Dakota. These sodium bentonites are also called Western or Wyoming bentonite which means a high swelling sodium bentonite. Other smaller sodium bentonite deposits occur in Argentina, Canada, China, Greece, Georgia Republic, India, Morocco, South Africa, and Spain. Calcium bentonite deposits are much more common than sodium bentonite ones. In the United States calcium bentonites occur in Georgia, Alabama, Mississippi, Texas, Illinois, and Missouri. Elsewhere calcium bentonites occur in England, Germany, Spain, Italy, Greece, Turkey, Georgia Republic, Czech Republic, Ukraine, Japan, Algeria, Morocco, South Africa, China, India, Japan, Argentina, and Brazil. The world production of all types of bentonite was estimated by the USGS to be 11,800,000 tons, in 2007.

Bentonite has several important physical and chemical properties which make it important in a wide range of markets. In addition to its rheological and absorbent properties, bentonite has excellent plasticity and lubricity. Bentonite barriers in sealing nuclear waste

Over twenty-five years ago, bentonite was identified as a suitable material for use in sealing nuclear waste repositories in crystalline rock. The consideration of bentonite for this application was a natural consequence of its widespread use as a sealant in petroleum and civil engineering. The important properties of swelling, plasticity and low hydraulic conductivity were identified as key requirements for in filling materials that could be used around waste containers, as tunnel backfills and as seals for boreholes, drifts and shafts. Since that time, a greatly improved understanding has been developed of the basis for design and long-term performance assessment of bentonite barriers in geologic repositories.

Bentonite barriers are essential components of many repository designs for the geological disposal of highly radioactive waste. Considerable resources and time have been devoted to their study and testing, focusing on diverse aspects at different levels of detail, and different scale and time horizons. This effort is being pursued in a continuous pursuit of confidence building and optimisation, justified by the importance of bentonite barriers for the safety, and for the design, operation and closure of the repository systems.

Several European countries have integrated their skills, knowledge and experience in the BENIPA (Bentonite Barriers in Integrated Performance Assessment) project, within the Fifth Framework Programme of the European Union. The project was carried out from September 2000 to August 2003. Participants in the project are two National Agencies, responsible for national HLW management (ENRESA as Project Co-ordinator, from Spain and NAGRA, from Switzerland) and six Research Centres (GRS, from Germany; IRSN, from France; NRG, from The Netherlands; SCK-CEN, from Belgium; VTT, from Finland and ZAG, from Slovenia).

Other uses of Smectite (bentonite)

Drilling mud, or drilling gel, has bentonite as a major component. Drilling mud is crucial in the extraction of drill cuttings during the drilling process. Bentonite, when mixed with water, forms a fluid (or slurry) that is pumped through the drill stem, and out through the drill bit. The bentonite extracts the drill cuttings from around the bit, which are then floated to the surface. Taconite, a low-grade iron ore, has been developed as an economic source for iron. During processing, the taconite is ground into a very fine powder. The ground taconite is then mixed with small amounts of bentonite which serves as a binder to the taconite. This mixture is processed into balls or pellets. The process is finished when these pellets are sintered in rotary kilns that give the pellets a hard surface.

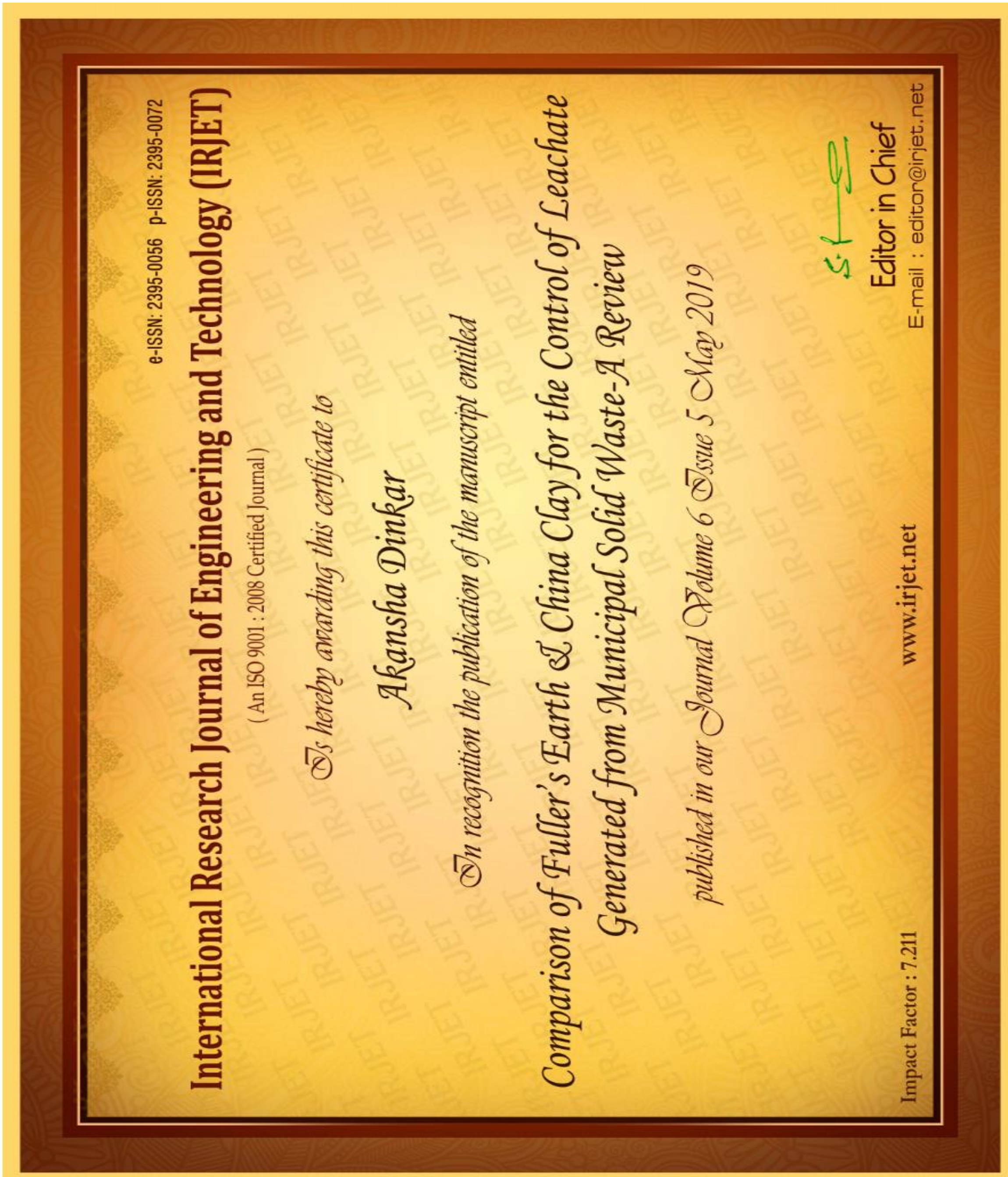
The metal casting industry needs bentonite as an economical bonding material in the molding processes associated with the metal casting industry. Bentonite, when mixed with foundry molding sands, forms a pliable bond with the sand granules. Impressions are formed into the face of the bentonite/sand mixtures. Molten metal is poured into the impressions at temperatures exceeding 2,800 F. The unique bonding characteristics of bentonite insure the durability of the mold during these high temperatures. Once the process is complete, the bentonite/sand mold can then be broken away from the casting face and reused. In recent years, bentonite has become a major component in the manufacturing of cat litter. Because of the unique water absorption, swelling, and odor (smell) controlling characteristics of bentonite, it is ideal for use in "clumping" types of cat litters, 95% of all cat litter is made from clay. Clumping cat litter has become widely accepted as an economical alternative to conventional non-clumping type cat litters. Because bentonite forms clumps when wet, the clumps can easily be removed and disposed of. The remainder of the unused material stays intact and can continue to be used. Clumping cat box litters will last longer with less frequency of changing. For many years bentonite has been used as a binder in the feed pelletizing industry. Small amounts of bentonite can be added to feed products to insure tougher, more durable pellets. Bentonite has also proved helpful in sealing freshwater ponds, irrigation ditches, reservoirs, sewage and industrial water lagoons, and in grouting permeable ground. In addition, it has been used in detergents, fungicides, sprays, cleansers, polishes, ceramic, paper, used as a base for cosmetics and medicines, and applications where its unique bonding, suspending or gallant properties are required.

Palygorskite – Sepiolite

Palygorskite is a term that is synonymous with attapulgite. The term attapulgite is largely used industrially even though the international mineral nomenclature committee ruled that palygorskite was first used and therefore is the preferred term. Both palygorskite and sepiolite are hydrated magnesium aluminium silicates. Sepiolite has higher magnesium content than palygorskite and has a slightly larger unit cell size. Both of these minerals are thin elongate chain type structures. When dispersed in water these elongate crystals are inert and non-swelling and form a random lattice capable of trapping liquid and providing excellent thickening, suspending, and gelling properties. These clays do not flocculate with electrolytes and are stable at high temperatures, which make them uniquely applicable for many uses. The term fuller=s earth is a term used for highly absorbent and natural bleaching clays. Thus the term includes both attapulgite and calcium montmorillonite, so there is a definite overlap in the use of the term fuller=s earth, with both attapulgite and calcium bentonite.

Palygorskite (attapulgite) and sepiolite deposits are relatively rare in comparison with the other industrial clays. A major occurrence of palygorskite is in the south eastern USA in southern Georgia and northern Florida, where major deposits of Palygorskite (attapulgite) occur. The major occurrence of sepiolite is near Madrid in Spain. Two other large occurrences of palygorskite are in Senegal near Theis, ~100 km east of Dakar and in China in Anhui Province, ~120 km northwest of Nanjing. There are also occurrences of sepiolite in Turkey

PUBLICATIONS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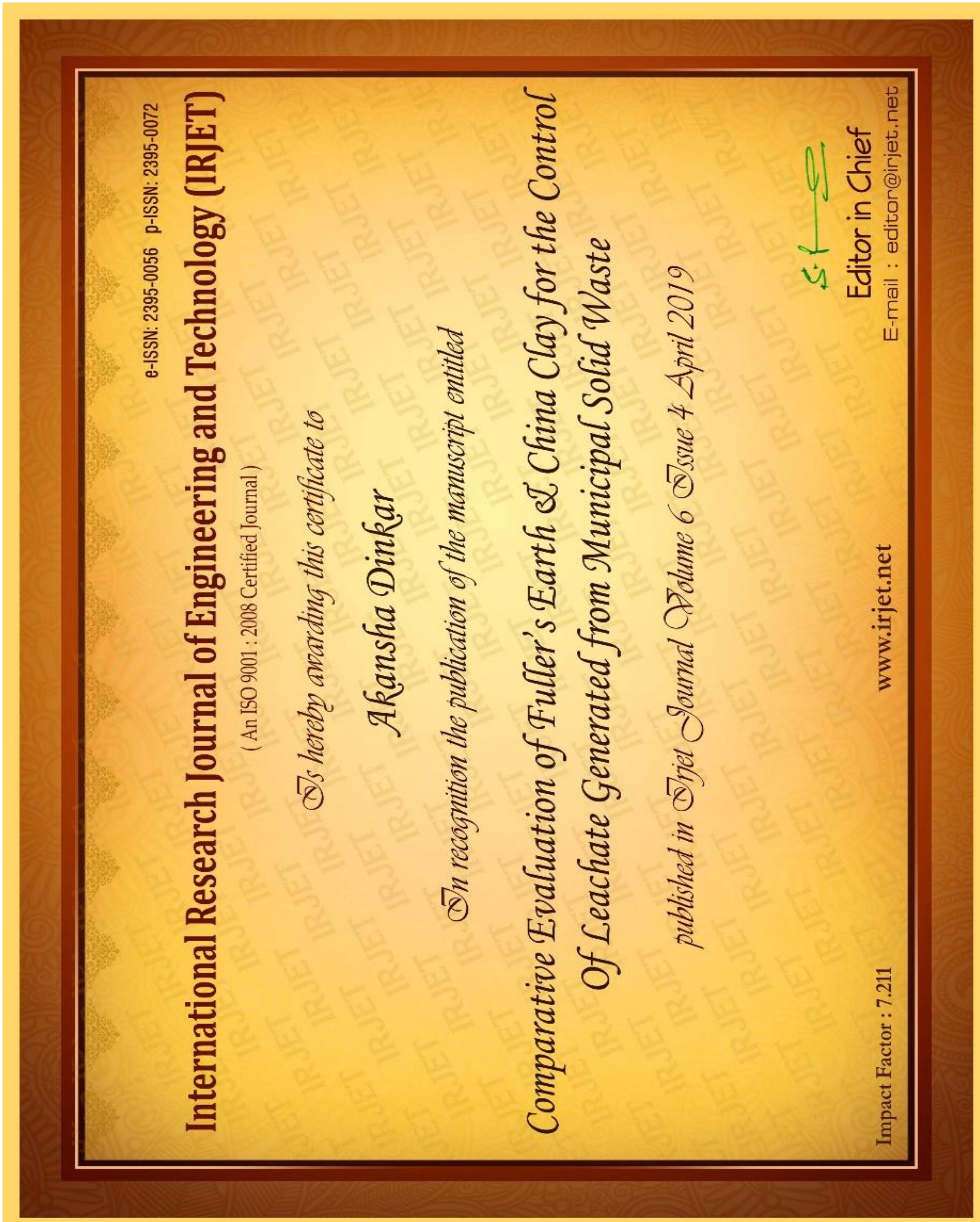
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