Journal of Environmental Pollution and Control
Volume 5 | Issue 3
ISSN: 2639-9288

Research Article Open Access

Permeable Rective Barrier Using Bottom Ash and Clay for The Removal of Contaminants Presesent in Leachate

J Jasmine[1] and V Rajagopalan[2*]

[1]PG student, Department of Civil Engineering, University College of Engineering (BIT Campus) Anna University, Tiruchirappalli-620024, India
[2]Assistant Professor, Department of Civil Engineering, University College of Engineering (BIT Campus) Anna University, Tiruchirappalli-620024, India

[*]**Corresponding author:** V Rajagopalan, Assistant Professor, Department of Civil Engineering, University College of Engineering (BIT Campus) Anna University, Tel: ; Email: vrgopalanaut@gmail.com

Citation: J Jasmine, V Rajagopalan (2022) Permeable Rective Barrier Using Bottom Ash and Clay for The Removal of Contaminants Presesent in Leachate. J Environ Pollut Control 5(3): 301

Abstract

The Rapid generation rate of solid waste due to increasing population and industrialization leads to open dumping of solid waste. This causes serious environmental risk of groundwater contamination due to landfill leachate, that consists of heavy metals and impurities. This affects the quality of the ground water. To identify the contaminant flow and implementation of remediation technology such as permeable reactive barrier (PRB) systems are highly demanded. A permeable reactive barrier (PRB) has been recognized as a cost effective method in removing heavy metals, organic and inorganic compounds from Landfill leachate. It is a barrier which allow some, but not all materials to pass through. PRB is an insitu treatment that passively captures a plume of contaminants present in leachate and releasing uncontaminated water to the ground. The reactive material selected for the PRB will depend on the types of contaminants present in the leachate. This work aims to investigate the ability of bottom ash which is a by-product from coal combustion and clay as permeable reactive barrier for restriction of movement of impurities from leachate. In this study PRB made of Bottom ash and Clay adsorbs the contaminants from leachate and permeate less contaminants of leachate to the ground. The presence of elements like carbon, oxygen, magnesium, aluminium, silicon, potassium, calcium,Titanium and iron in bottom ash will highly act as an effective adsorbent for removing impurities from leachate rather than it does not cause any harm to water and it does not detoriate the groundwater quality.

Keywords: Leachate; Contaminants; Ground water; Permeable reactive barrier; Bottom ash; Clay

List of Abbrevations

PRB: Permeable reactive barrier; XRD: X- Ray Diffraction; SEM: Scanning Electron Microscope; EDX: Energy dispersive X-Ray spectroscopy; TDS: Total Dissolved Solids; TA: Total Alkalinity; TH: Total Hardness; COD: Chemical oxygen demand; BOD: Biochemical oxygen demand

Introduction

As the world's population grows and more and more people move to cities, waste consumption and waste collection are increasing rapidly. Because of these developments, there is a challenge in the of disposal of waste. Open dumping is a common method used for the final disposal of municipal solid waste in most of the developing countries. Open dumping of solid waste causes a serious environmental impact on groundwater due to the formation of landfill Leachate [1]. Landfill leachate is the aqueous effluent generated as a consequence of rainwater percolation through waste [2]. This leachate consists of a variety of contaminants in the form of organic and inorganic compounds which can be hazardous. Organic compounds like, propanes, esters, ethanes and phenols etc. are immensely found in it. Inorganic compounds such as nitrogenous and phosphorous compounds are dominant. Due to the contamination of these pollutants, the quantity of safe groundwater on earth, which is already limited at the moment, is reducing rapidly. Landfill Leachate also generates several toxic materials including heavy metals. Heavy metals like Manganese (Mn), iron (Fe) Chromium (Cr), Nickel (Ni), Cadmium (Cd), Lead (Pb), Zinc (Zn), Copper (Cu), and Mercury (Hg) and toxic organic matters were found in the landfill leachate. In some cases, the heavy metal concentrations were exceeded their maximum effluent water quality standards. Once the heavy metals reach to the groundwater bodies, the bioaccumulation may occur and it leads to several health issues such as sweating, bleeding stomach disorders, congenital disabilities, kidney diseases, cancers, mental retardation in children and gastrointestinal disorders etc. The penetration of leachate causes serious groundwater pollution and contaminate the soil too. The contaminated water plume will spread through the aquifer along with the hydraulic gradient. Thus, the public and wildlife at the down streams become soft targets of this contaminated groundwater. In order to mitigate the ground water contamination and permeation of contaminants from leachate, Permeable Reactive Barriers (PRB) is used. (PRB) is defined as “PRB is an engineered treatment zone of reactive material(s) that intercepts a contaminant plume and transforms the contaminants into environmentally acceptable forms as they flow through it” [2].

Materials and methods Materials Leachate

Leachate samples used in this study was taken from Ariyamangalam Landfill site, Tiruchirappalli district, Tamilnadu.The layout of the Ariyamangalam landfill site is shown in Figure 1. Landfill leachate is formed when rain water filters through the wastes placed in a landfill. When this lquid comes in contact with buried wastes it leaches or draws out chemical constituents from those wastes and moving into subsurface areas. Landfill leachate contains dissolved organic matter, inorganic macrocomponents and heavy metals. Landfill Leachate can contaminate groundwater, surface waters and soil, potentially polluting the environment and harming human health causing variety of health problems.

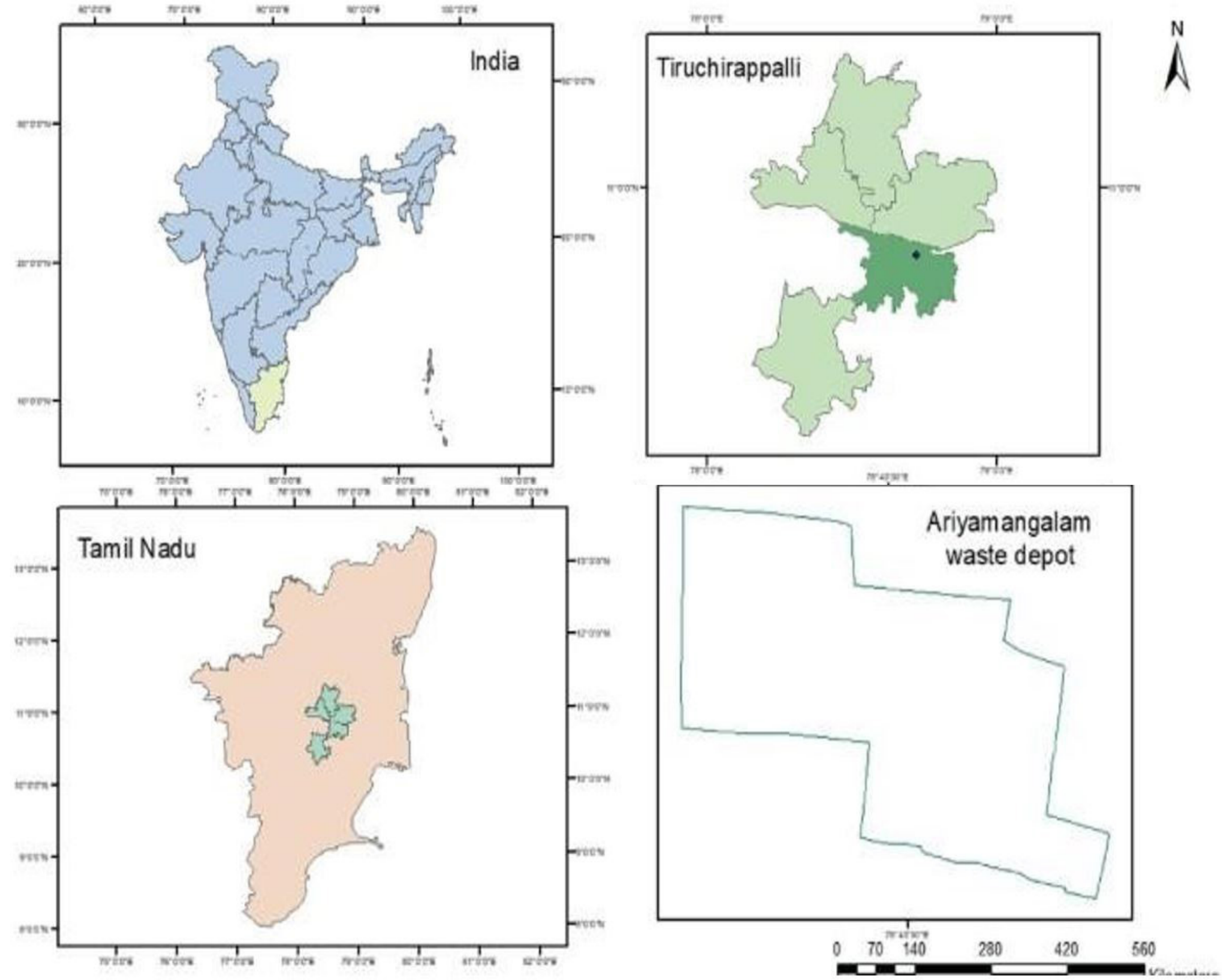

Figure 1: Layout of the Ariyamangalam landfill site

Bottom Ash

In this study bottom ash sample was collected from Thoothukudi Thermal Power Station (5 X 210 MW) which is located at Thoothukudi harbour estate, Tamilnadu. The layout of the Thoothukudi Thermal Power Station is shown in Figure 2.

The coal ash collected which is collected at the bottom of furnace is called as bottom ash. Bottom ash has rough surface. It is a granule spherical, grayish black dust, irregular and porous. The specific gravity of Bottom ash in India varies from 1.60 to 2.39 relies on chemical composition. The presence of Iron content in the Bottom ash can increase the bulk density. Experiments were conducted by several researchers and their coworkers and proved that BA can effectively use as an adsorbent from waste water. Leachate consists of heavy metals and organic and inorganic compounds which is removed by using Bottom ash as an adsorbent. Bottom Ash (BA) are produced from thermal power plants are which are useful in facing disposal and environmental problems CLAY Clay sample used in this study was collected from Cultivation land, Chinnalapatti, Dindigul District, Tamilnadu. Clay sample from Cultivation land is shown in Figure 3.

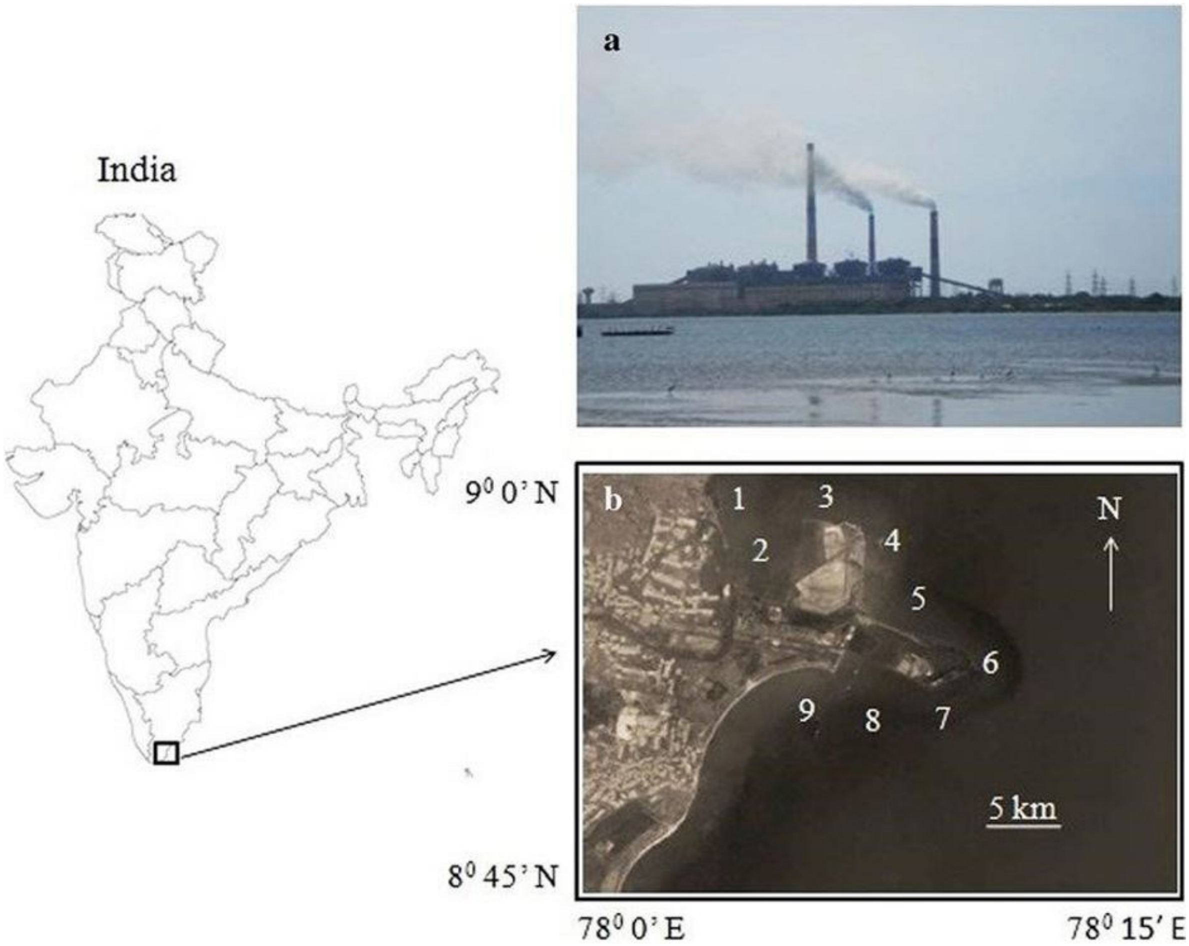

Figure 2: Thoothukudi Thermal Power Station

Figure 3: Clay from Cultivation land, Chinnalapatti

Clay is a small particle, that found naturally on the surface of the earth composed mainly of silica, alumina, water and weathered rock. Clay can be used as an effective adsorbent to trace heavy metal ions present in aqueous solution for past 10 years. Clay minerals Variety of clays and play can be used as an effective adsorbent material for the removal of toxic metal ions from water solution. Based on the qualities, clays are divided into various classes and groups such as smectites. (montmorillonite, saponite), mica (illite), kaolinite, vermiculite, serpentine, pylophyllite (talc), and sepiolite etc. Bentonite clay can be used as best adsorbent.

Methods Physicochemical characteristics of Leachate

The physicochemical characteristics of leachate such as Total Dissolved Solids (TDS), Total Alkalinity (TA), Total Hardness (TH) and Calcium (Ca2+) was determined by titrimetric methods, pH was determined by using pH meter, Chemical Oxygen Demand (COD) was estimated by closed reflux titrimetry method, Biochemical Oxygen Demand (BOD) was calculated by oxygen determination by Winkler titration and the heavy metals was analyzed using UV Spectrophotometer.

Batch adsorption Experiment for Leachate

Batch experiments are also known as static systems, are performed by adding a certain amount of solids to a solution that contains a special concentration of solids with a certain solid / liquid (S / L) concentration. These compounds are vibrated vigorously or shaken throughout the reaction time. For the total amount of adsorbent in which high adsorption occurs, 150 ml leachate is taken from a series of flasks with different amounts of adsorbent clay: 0.5, 1.0, 1.5 g, 2g and 2.5g. The leachate is stored in a moving incubator for 30 minutes at 120 rpm. After that time, the content was filtered and the absorption was detected using a visible UV spectrophotometer. Batch adsorption experiments was performed to determine the most effective dosage of both the adsorbent i.e., clay and to measure the maximum removal percentage of contamainants, pollutants and heavy metals from the leachate sample.

Characterization of Bottom ash

Before using bottom ash as an adsorbent the characterization of bottom was studied using X- Ray Diffraction analysis (XRD), SEM analysis (Scanning Electron Microscope) and EDX APEX analysis (Energy Dispersive X-Ray Spectroscopy).

Characterization of Clay

Before using clay as an adsorbent the characterization of bottom was studied using X- Ray Diffraction analysis (XRD), SEM analysis (Scanning Electron Microscope) and EDX APEX analysis (Energy Dispersive X-Ray Spectroscopy)

Results Characterization of Leachate

The physicochemical characteristics of collected leachate sample such as pH, Total Alkalinity, Total Dissolved Solid [TDS], Calcium, Total Hardness (TH), Chemical Oxygen Demand [COD] and Biological Oxygen Demand [BOD] and their heavy metal concentrations such as copper, cadmium, chromium, lead, zinc and iron was determined and provided in Table 1.

S.NO	PARAMATER	RESULT mg/l
1.	pH	6.9
2.	Total Alkalinity	11350
3.	TDS	3150
4.	Calcium	696
5.	Total Hardness	21227
6.	BOD	1562
7.	COD	12315
8.	Copper	0.81
9.	Cadmium	0.65
10.	Chromium	0.55
11.	Lead	0.71
12.	Zinc	1.23
13.	Iron	0.63

Table 1: Physicochemical Characteristics of leachate sample

Effect of adsorbent mass on adsorption using Batch adsorption experiment

The adsorption capacity of adsorbent for the clay sample, for the removal of contaminants, pollutants and heavy metal ions from the landfill leachate using batch experiments were done and the results are presented in the Table 2.

DOSAGE 150ml	COPPER mg/l	CADMIUM mg/l	CHROMIUM mg/l	LEAD mg/l	ZINC mg/l	IRON mg/l	% Removal
BLANK	0.112	0.112	0.112	0.112	0.112	0.112	_
0.5	0.503	0.024	0.027	0.47	1.50	2.341	41
1	0.52	0.014	0.031	0.50	1.61	2.670	53
1.5	0.645	0.035	0.045	0.62	1.69	2.80	69
2	0.711	0.041	0.051	0.68	1.781	3.54	76
2.5	0.74	0.043	0.55	0.74	1.83	3.901	89

Table 2: Effect of adsorbent mass on adsorption using Batch adsorption experiment for leachate sample

The dosage of the adsorbent and the percentage removal of the concentrations of the heavy metal ions were provided in the Figure 12.

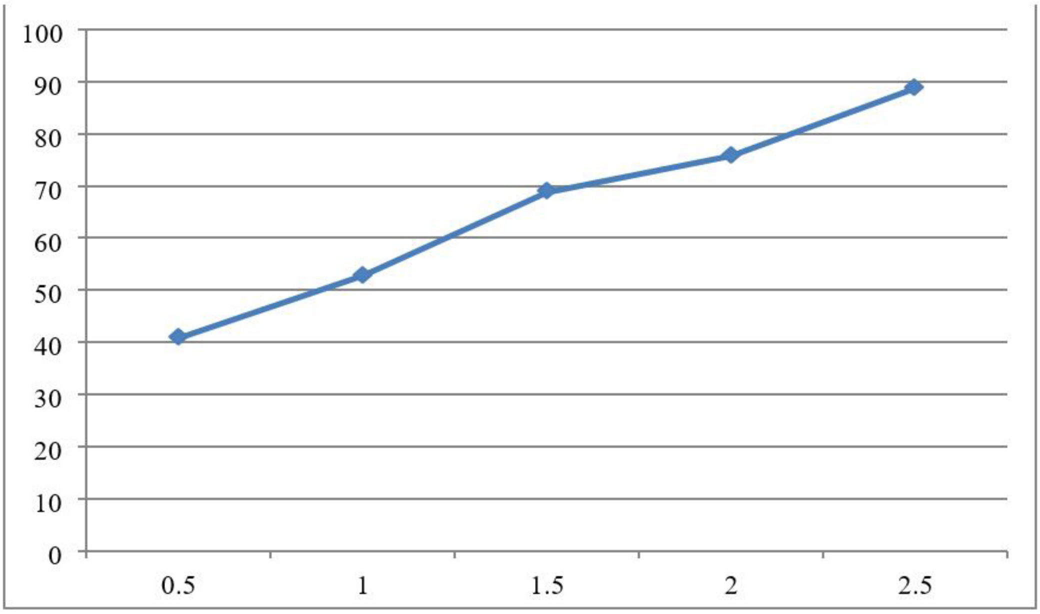

Figure 12: Dosage VS Removal obtained by conducting Batch experiments by using clay as an adsorbent

Characterization of Bottom ash

XRD Analysis of Bottom Ash

The XRD spectrum in Figure shows the mineral composition of bottom. It can be seen that only silicate minerals such as albite, biotite, microcline and quartz are existed within the bottom ash. The existence of silicate minerals within the bottom ash originating from the bubbling fluidized bed boiler is suitable when considering that the bed material of a fluidized bed boiler usually consists of silica sand. The silicate minerals in these bottom ash fractions might also be partly because of sand and soil particle contamination of forest residues during harvesting, transportation and handling. XRD Analysis of Bottom Ash were shown in Figure 4.

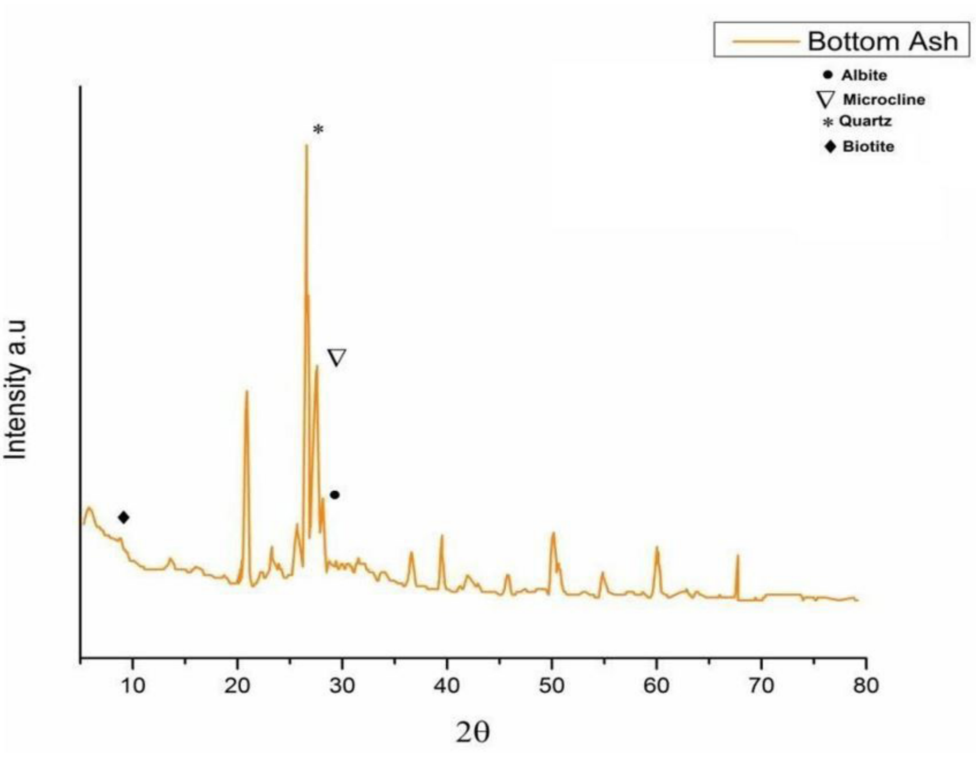

Figure 4: XRD Analysis of Bottom Ash

SEM Analysis of Bottom Ash

SEM images of bottom ash shows that the bottom ash spherical same like fly ash particle with glassy structure and its angular. Bottom ash particle seen much larger and porous with many small pores. These pores are micro pores. The water absorbed and adhered to surface, so that the little pores occurs. Since excess water may be damaging to the geo polymer properties, attention should be conducted while using bottom ashes. SEM Analysis of Bottom Ash was shown in Figure 5.

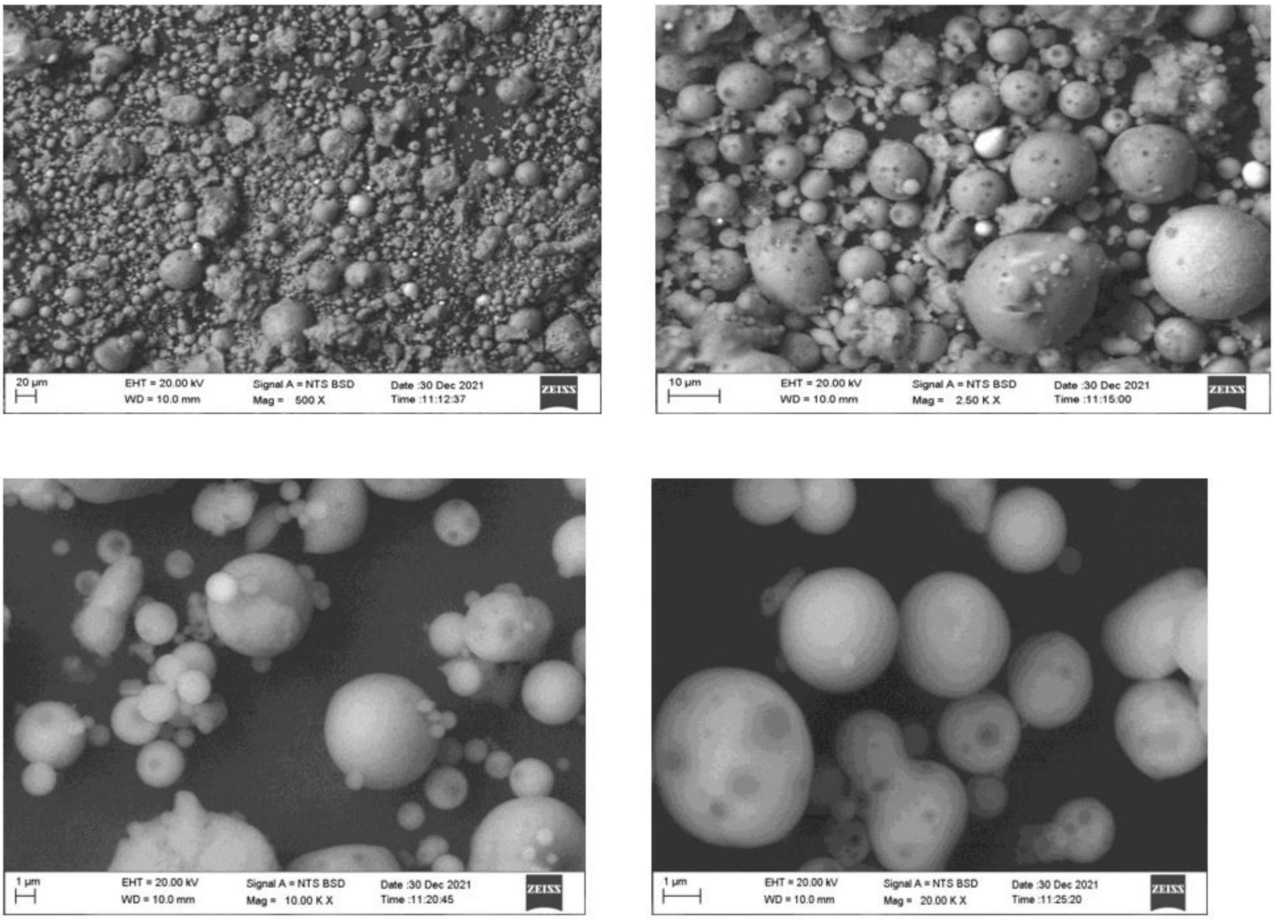

Figure 5: SEM images of Bottom ash

EDX APEX Analysis of Bottom Ash

Energy Dispersive X-Ray Spectroscopy is an analytical technique used for the basic elemental analysis or elemental composition or chemical characterization of a sample. It gives both the atomic mass and weight composition of the sample in percentage. It consists of variety of elements like carbon, oxygen, magnesium, aluminium, silicon, potassium, calcium, Titanium and iron with various Kratios. Oxygen, Silicon and Aluminium are the peak values in the bottom ash. Peak values of the bottom ash were shown in figure 6 EDX APEX Analysis of Bottom Ash was shown in Figure 7 and the smart quant results for the bottom ash are present in the Table 3.

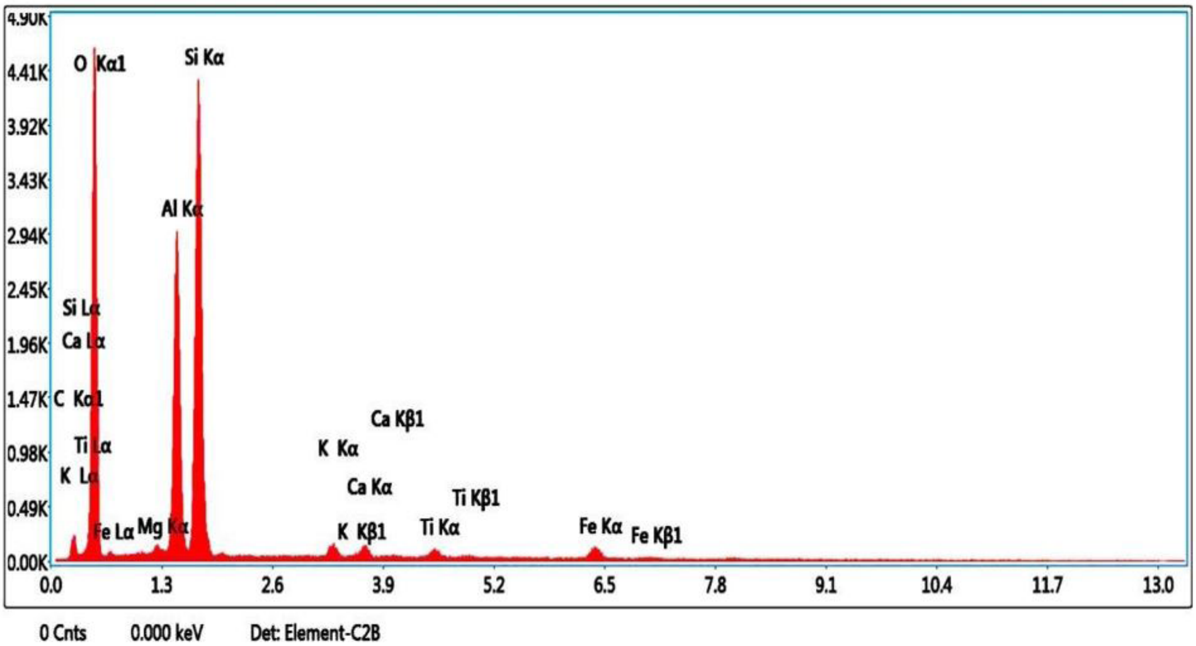

Figure 6: Peak Values for Bottom ash

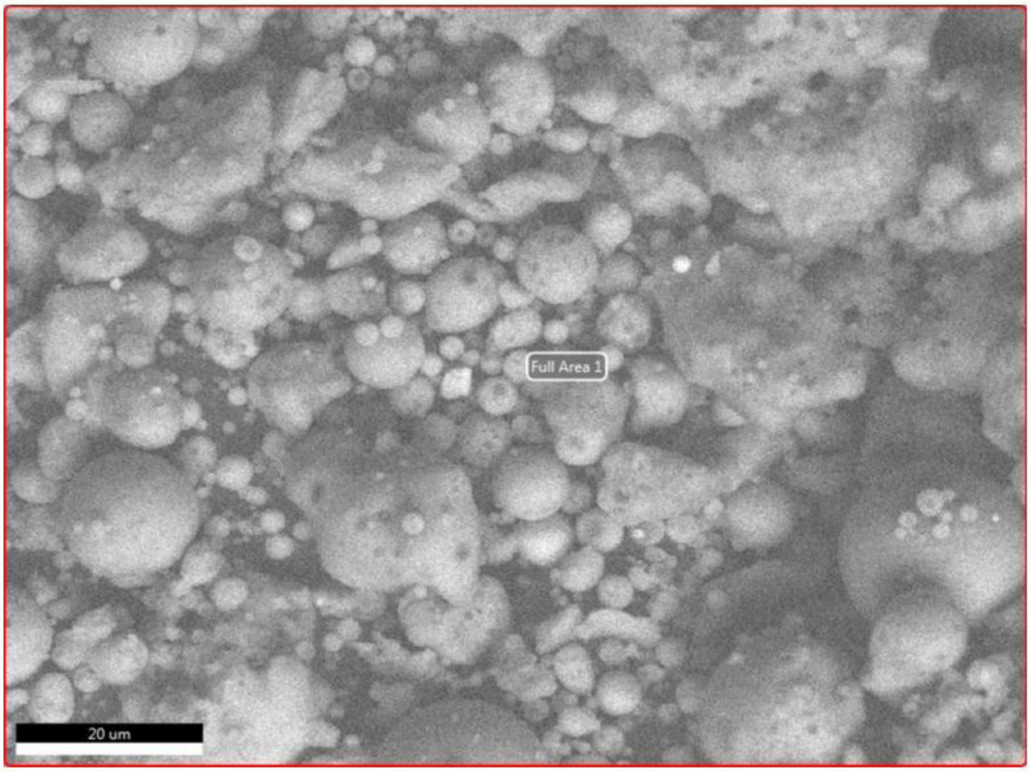

Figure 7: EDX APEX image of Bottom Ash

Element	Weight %	Atomic %	Error %	Kratio
C K	5.5	9.0	15.3	0.0085
O K	48.2	59.6	8.3	0.1605
MgK	1.0	0.8	10.7	0.0053
AlK	15.6	11.4	4.8	0.1009
SiK	23.5	16.5	4.9	0.1491
K K	1.1	0.5	14.1	0.0088
CaK	1.2	0.6	11.0	0.0099
TiK	1.2	0.5	10.6	0.0096
FeK	2.8	1.0	8.1	0.0242

Table 3: Smart Quant Results for Bottom Ash

Characterization of clay

XRD Analysis of Clay

The clay sample has a considerable presence of quartz (peaks around 4.29 ˚ A, 3.37 ˚ A, 2.13 ˚ A, 1.54 ˚ A, and 1.37 ˚ A). Felspars and sillimanite are in the sample too. For the first one, peaks were in 3.76, 3.20, and 3.02 ˚A, whereas sillimanite showed one signal at 4.51 ˚A. The sample also had contents of cristobalite (4.08 ˚A) and illite (10.14 ˚ A). XRD Analysis of Clay was shown in Figure 8.

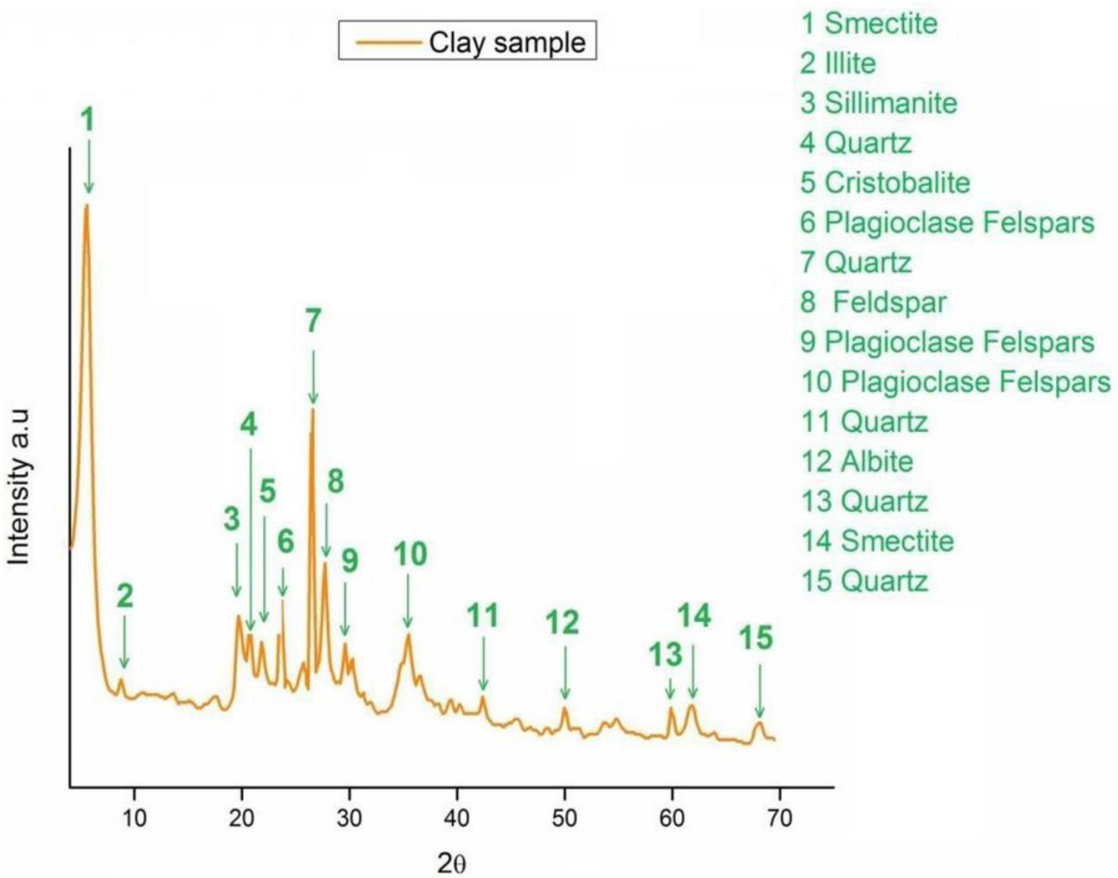

Figure 8: XRD image of clay

SEM Analysis of Clay

The SEM analysis of clay shows the morphological structure, texture, fabric, growth mechanism of crystals and crystallites. The large plates of clay appear to be composed of much smaller platelets. The features shown here include the variations in layer thickness, crystal habit, topotaxis. SEM Analysis of Clay was shown in Figure 9.

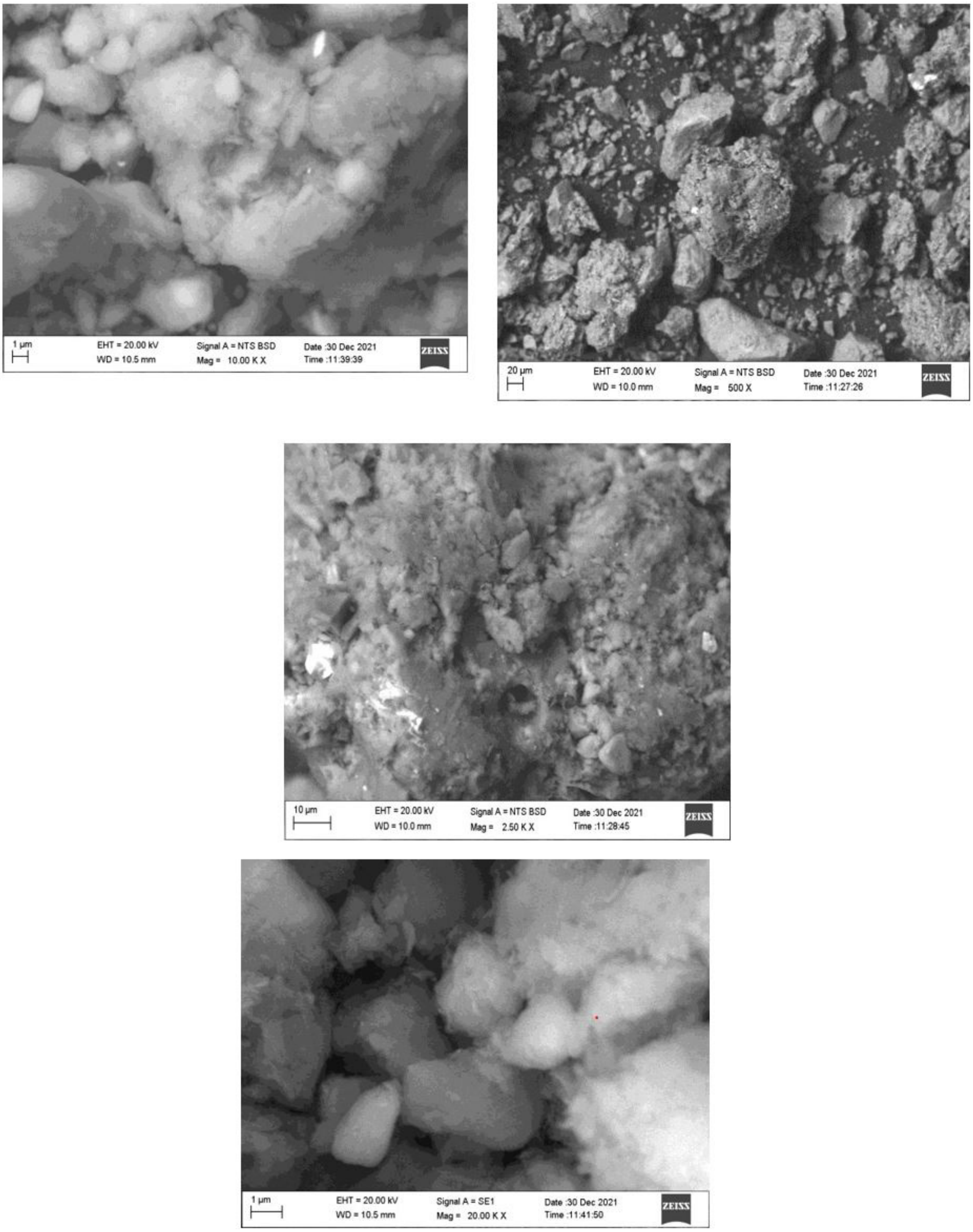

Figure 9: SEM images of Clay

EDX APEX Analysis of Clay

Energy Dispersive X-Ray Spectroscopy is an analytical technique used for the elemental analysis or elemental composition or chemical characterization of a sample. It gives both the atomic mass and weight composition of the sample in percentage. It consists of variety of elements like carbon, oxygen, sodium, magnesium, aluminium, silicon, potassium, calcium and Titanium with various Kratio. Oxygen, Silicon are the peak values in the clay. Peak values of clay shown in the figure 10. EDX APEX Analysis of Clay was shown in Figure 11. And the smart quant results for the bottom ash are present in the Table 4.

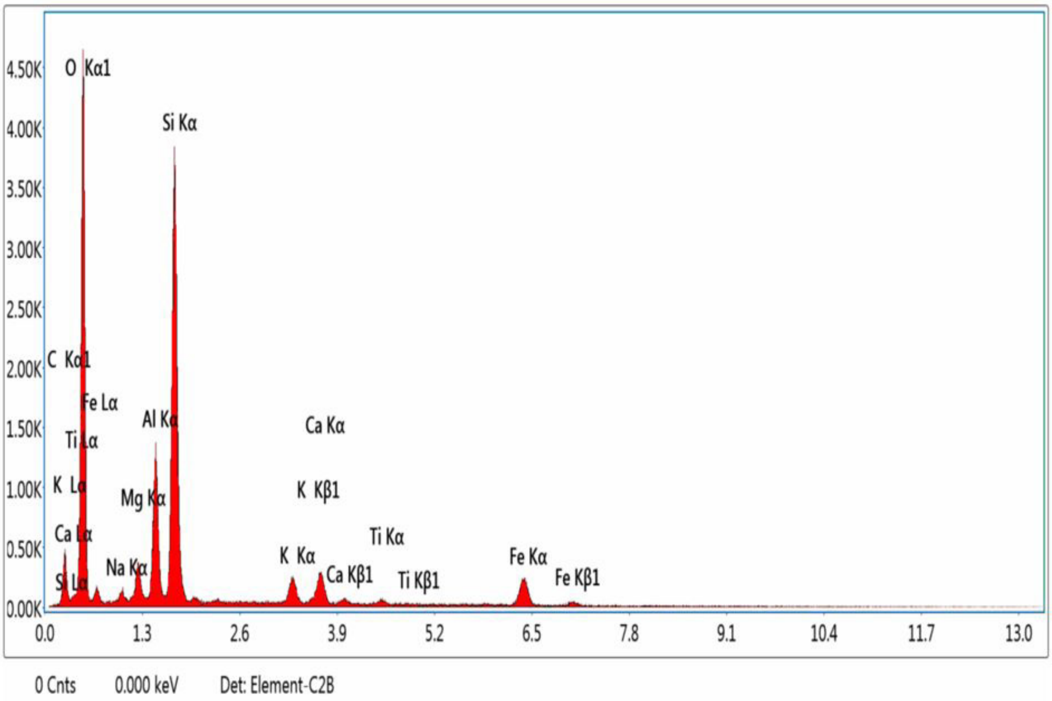

Figure 10: Peak Values for Clay

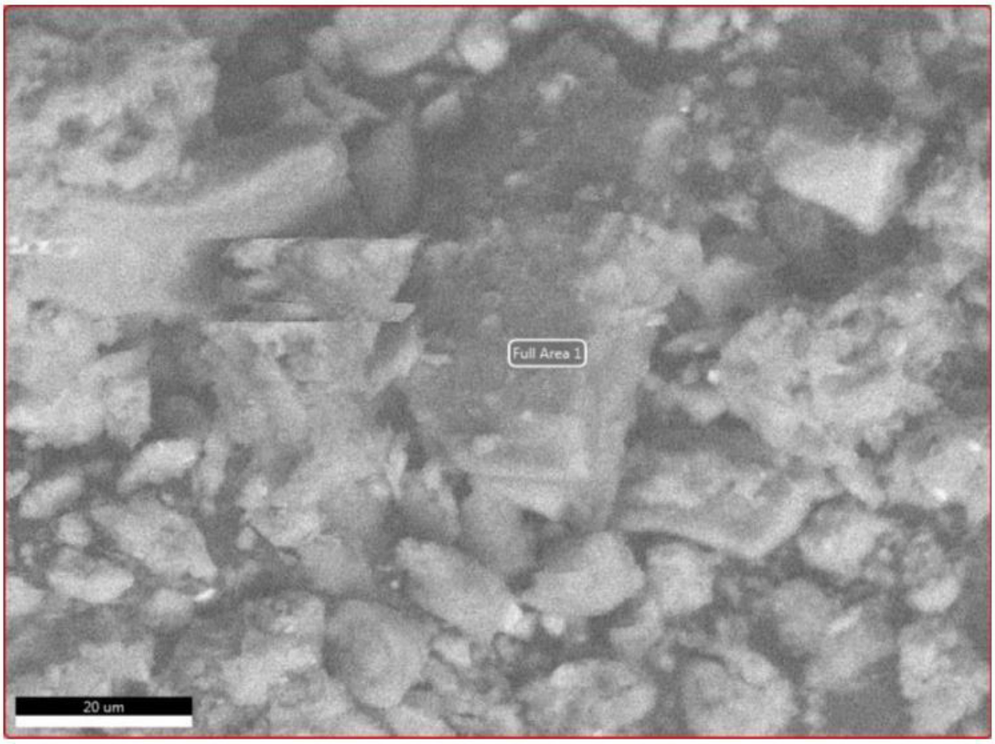

Figure 11: EDX APEX image of Clay

Element	Weight %	Atomic %	Error %	Kratio
C K	8.7	13.9	13.1	0.0163
O K	49.6	59.8	8.5	0.1557
NaK	1.1	0.9	17.6	0.0037
MgK	2.5	2.0	8.7	0.0122
AlK	7.3	5.2	5.9	0.0432
SiK	19.6	13.5	4.7	0.1297
K K	2.1	1.0	7.9	0.0172
CaK	2.9	1.4	5.8	0.0254
TiK	0.6	0.3	19.2	0.0052

Table 4: Smart Quant Results for Clay

Discussion

Characterization of Leachate

The pH of the leachate determined was 6.9, it is confirmed that the leachate is slightly alkaline in nature. According to WHO Standards, only the value of pH between 3.7 -6.5 within its permissible limits. The physicochemical characteristics and the heavy metal concentration of the leachate sample mainly depend upon the solid waste composition, compaction of waste, cover design, amount of precipitation and water content material of the municipal solid waste [23]. Other than pH, all other parameters are exceeding their permissible limits. The range heavy metal concentration such as copper, cadmium, chromium, lead, zinc and iron are very high.

Characterization of bottom ash

The presence of various elements such as carbon, oxygen, magnesium, aluminium, silicon, potassium, calcium, Titanium and iron with various Kratios have proved that bottom ash can be used as an effective adsorbent for the removal of contaminants, pollutants and heavy metals in the leachate. Besides bottom ash particle seen much larger and consists small pores. Hence it can be easily act as a permeable medium for the leachate. The presence of such elements in the bottom ash does not affect the quality of groundwater rather than it will act as effective adsorbent. The elemental composition of bottom ash consists of silicon, aluminium, iron, calcium, magnesium, carbon, chromium, oxygen, nitrogen, sulfur and other elements. These bottom ashes cannot be used as an adsorbent because it consists of heavy metal chromium and the presence of sulfur makes unfit for using this bottom ash as an adsorbent because sulfur is a secondary contaminant of water [22].

Characterization of clay

The presence of variety of elements like carbon, oxygen, sodium, magnesium, aluminium, silicon, potassium, calcium and Titanium with various Kratio. The large plates of clay appear to be composed of much smaller platelets can adsorb the contaminants present and heavy metals in the leachate. The presence of such elements possess very strength [23]. Hence this clay can be effectively used as an adsorbent.

Effect of adsorbent mass on adsorption using Batch adsorption experiment

The contaminants and the heavy metals present in the leachate that enters into the soil can contaminant the groundwater and make the water undesirable for drinking and other purposes. It can contaminate the soil too.It also affects both the humans and aquatic life [12]. It alters the properties of soil. The metal adsorption capacities generally increase with increase in initial metal concentration and decreases when the adsorbent masses are increased in the solution. There is a constant increase in percentage of removal of heavy metals with the increase in dosage of adsorbent.

Conclusion

From the Physico-chemical characteristics of the leachate sample, it is evident that the leachate sample collected from the landfill site is highly polluted and the parameters are exceeding their limits. If this leachate reaches the groundwater without treating the contaminants and heavy metals, it will surely contaminate the groundwater and makes the groundwater and surface water toxic. Due to the infiltration of leachate the properties of soil also affected.so the leachate sample collected should be treated before entering the groundwater and the soil. A permeable reactive barrier is an emerging and cost effective technology for treating the contaminated leachate. Permeable Reactive Barrier (PRB) is a wall constructed below the ground to clean up the contaminated leachate. Walls should not exceed the more than 50 feet. These walls are filled with reactive materials. These reactive materials react with the contaminants present in the leachate and makes the leachate less harmful and acceptable forms. And the permeation of the less harmful leachate takes place before entering the groundwater. Reactive materials like basalt dust, bone char, phosphatic compounds and waste foundry sand can be used. In this study bottom ash and clay have been used as reactive materials. The elements such as carbon, oxygen, magnesium, aluminium, silicon, potassium, calcium, Titanium and iron present in the bottom ash like and the existence of carbon, oxygen, sodium, magnesium, aluminium, silicon, potassium, calcium and Titanium with various Kratios have been proved that the bottom ash and clay can be used as a reactive materials i.e as an adsorbent for the removal of contaminants, pollutants and heavy metals in the leachate.

Acknowledgement

The authors sincerely thank Kalasalingam university, coimabatore for the characterization results (SEM and EDX APEX analysis) and also we thank Pondicherry university for the (XRD analysis). We also thank the Department of Civil Engineering, University college of Engineering, Tiruchirappalli for conducting tests for the Leachate sample.

References

1. AH Faisal, AH Sulaymon, QM Khaliefa (2018) "A review of permeable reactive barrier as passive sustainable technology for ground water remediation", A, International Journal of Environmental Science and Technology, 15: 1123-38.

2. DM. Kankanige, WKCN Dayanthi, IU Nagasinghe, AM Disanayakaand K Kawamoto (2019) ENGINEER, 02: 15-25.

3. Dr. Arup Kumar Mandal, OM Prakash Sinha (2014) "Review on current research status on bottom ash: an Indian prospective", Journal of the Institution of Engineers (India); Agricultural Engineering Division.

4. Crini G, Badot P-M (2010) "Sorption process and pollution, conventional and non- conventional sorbents for pollutant removal from wastewaters". Presses Univ. Franche-Comte.

5. Das BM (2012) "Introduction to Geotechnical Engineering", Cram101 Inc. publication and services; First Edition.

6. AM Disanayaka, K Kawamoto, IU Nagasinghe, DM Kankanige, IU Nagasinghe, et al. (2019) ENGINEER 02: 15- 25.

7. R Gandhimathi, S T Rammesh, V Sindhu, PV Nidheesh (2013) "Bottom ash adsorption of basic dyes from their binary aqueous solutions", Songklanakarin J. Sci, Technol, 35: 339- 47.

8. S Kanmani, R. Gandhimathi (2013) "Investigation of physicochemical characteristics and heavy metal distribution profile in groundwater system around the open dump site" 387-99.

9. Khan MR, Hedge RA, shabii mam (2017) M>A, "Adsorption of Lead by Bentonite clay".

10. Meral Yildirim Ozen, Nevin Aramahmut Memer, Funda Demir and Eme Moroydor Derun(2017), "Removal of As(V) by using bottom ash as adsorbent", International conference proceedings.

11. Mathur N, P Bhatnagar, P Bakre (2006) Assessing mutagenicity of textile dyes from Pali (Rajasthan) using ames bioassay,Applied Ecology and Environmental Research, 1:111-18.

12. J Mittal, D Jhave, H Vardhan, A Mittal (2013) "Utilization of bottom ash as a low-cost sorbent for the removal and recovery of a toxic halogen containing dye eosin yellow, Desalin, Water treat".

13. Omar Aldayel, Jameel, AA Hefne (2019) "Adsorptive applications of Montmorillonite clay for the removal of Ag(I) and Cu(II) from Aqueous medium" Journal of chemistry.

14. N Ott (2000), "Permeable reactive barriers for organics", National network of environmental management studies fellow for U.S Environmental Protection Agency -Office of solid waste and Emergency response -Technology Innovation office -Washington DC.

15. DH Phillips (2009) "Permeable reactive barriers: a sustainable technology for cleaning contaminated ground water in developing countries, Desalination" 248: 352-9.

16. Rifaqat Ali khan Rao, Mohammad Kashif Uddin (2012) "Adsorption studies of Cd(II) on ball clay: Comparison with other natural clays", Arabian Journal of chemistry.

17. BGN Sewwandi, , K Takahiro, K Kawamoto, S Hamamoto, S Asamoto, H Sato, et al. (2013) "Evaluation of Leachate Contamination Potential of Municipal Solid Waste Dumpsites in Sri Lanka Using Leachate Pollution Index. Sardinia".

18. NK Sharma, S Mitra, V Sengal, S Mishra (2012) "An assessment of physical properties of coal combustion residues with respect to their utilization aspects".

19. Shichi T, Takagi K (2000) "Clay minerals as photochemical reaction fields." J Photochem Photobiol C: Photochem Rev, 1:113-30.

20. Bonusa Nabila Huda, Endang Tri Wahyuni, Mudasir Mudasir (2021) "Eco-Friendly immobilization of dithizone on coal bottom ash for the adsorption of Lead(II) ion from water" 100221.

21. A Lakshumu Naidua, Dr. D Nageswara Rao (2013) "Studies on Characterization and Mechanical Behavior of Natural Clay" Accepted 02 July 2013, Available online 01 August 2013, ISSN: 2321-24.

22. Denutsui (2012) "Leachate characterization and assessment of unsaturated zone pollution near pollution near municipal solid waste landfill site at oblogo Accra-Ghana".Res J Environ Earth Sci, 4:134-41.

23. Abbas H, Sulaymon Ayad AH, Faisal Qusey M Khaliefa (2015) "Cement Kiln Dust (CKD)-filter sand permeable reactive barrier for the removal of Cu(II) and Zn(II) from simulated acidic ground water", Journal of Hazardous Materials.