Compost as an Adsorbent Media for Municipal Solid Waste Leachate

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2011-2015

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A Thesis Submitted in Partial Fulfillment of the Requirement for the Degree of

BACHELORS OF ENGINEERING

IN

ENVIRONMENTAL ENGINEERING

Institute of Environmental Sciences & Engineering (IESE)

School of Civil & Environmental Engineering (SCEE)

National University of Sciences & Technology (NUST)

Islamabad, Pakistan

2011-2015

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ACKNOWLEDGEMENTS

First of all we thank **ALLAH**, who gave us a chance to become out of only few percent Pakistanis to get higher education. After that we acknowledge our beloved **parents** and **family** who really encouraged us to continue our studies, financed us and supported us at every step whenever we needed them.

We want to acknowledge all our teachers who taught us throughout our study career, we are really thankful to our respected supervisor **Dr. Muhammad Anwar Baig** who supported and encouraged us during our project research and also for his kind guidance, expertise and connections. We would also like to thank our mentor **Mr. Hamid Iqbal** (Ph.D. Candidate) for his expertise, continuous support, guidance and efforts to make this research happen in all manners.

We would thank **Dr. Ishtiaq Qazi** (Associate Dean, IESE) for giving us a chance to get higher education in the most prestigious university of Pakistan. We will acknowledge **NUST** and **IESE** in regard of financing our undergraduate project.

We acknowledge **Mr. Hassan** (MS-Student) for providing us leachate initially and helping us regarding the leachate collection site during our project. We will acknowledge **Mr. Baber Abbas** (Lab Engineer) for providing us some helpful material and storage canisters. We will say thanks to **Mr. Noor Haleem** (Lab Assistant) for his help provided in XRF-Analysis. We are grateful to **Mr. Tahir Choudry** (Ph.D. Candidate) for his help with environmental chemistry lab equipment and their usage.

Undergraduate group

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ABSTRACT

Compost is used in bio-retention systems to mend soil quality, water permeation, and retention of contaminants. However, compost contains dissolved organic matter, nitrate, and phosphorus, all of which can leach out and potentially contaminate ground and surface waters. To lessen the leaching of nutrients and dissolved organic matter from compost, granular activated carbon (GAC) and sand may be mixed into the bio-retention systems. Objective of this study was to test whether granular activated carbon (GAC) and sand mixed into water washed vermi-compost can reduce the leaching of organic carbon, nitrogen, and phosphorus.

This study was divided into two phases. Phase-1 was control run in which pure media was used in the columns. Phase-2 was the main run in which two media combinations were used, compost + sand and compost + granular activated carbon. Both phases were run continuously for 24 hours and samples were collected after every 2 hours. Afterwards, samples were analyzed for different parameters, which include pH, electrical conductivity (EC), total dissolved solids (TDS), ortho-phosphates (OP), nitrates, organics and total organic carbon (TOC).

It was found that compost kept on leaching contaminants even after being washed by the de-ionized water and air dried. Granular activated carbon (GAC) and sand reduced the contamination flow from the compost itself but did not completely eliminate it. Further, granular activated carbon (GAC) and sand amendment decreased the non-humified material leaching from the compost. Granular activated carbon (GAC) amendment also significantly reduced organic carbon and ortho-phosphates leaching but did not have much effect on nitrate leaching in comparison to sand amendment.

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

During the last several decades, migration from rural to urban areas has increased in Pakistan. According to 1981 census, 87.6% people migrated to urban areas out of which 50% permanently settled in the cities. It is estimated that in the next ten years the major cities in Pakistan to double their population. These cities are generating solid waste which is increasing annually with the population growth. Apart from water and air pollution problems, now solid waste management has become a challenge for developing countries like Pakistan. Presently it is estimated that around 65,000 tons solid waste is generated in Pakistan per day (National study on privatization of solid waste management in eight cities of Pakistan, EPMC, 2010). For the cities to be clean 75% of these quantities must be collected. Unfortunately none of the cities have proper solid waste management system right from the collection up to the disposal. Also in Pakistan there is no single engineered landfill, all type of hazardous and nonhazardous waste is eventually disposed either in dumping grounds, rivers, and agricultural land. These dumpsites not only pose health risks for surrounding communities but also pollute ground water through leaching of contaminants.

As far as waste management is concerned, all over the world different treatment processes such as incineration, disinfection and land filling are being used to minimize the amount of waste. Incineration and disinfection are practiced in developed countries where technology and capital is not an issue. Disposal of waste in landfills is an adequate solution for developing countries when land is not a limiting factor. Therefore certain management and engineering practices are needed to be integrated in the design and construction phases of such infrastructure in order to avoid the propagation of pollution; as a matter of fact that ground water pollution is of a major concern because population in the urban areas is totally dependent on groundwater.

Keeping in mind the problem of leaching, research is being conducted on different materials that could possibly be used as bottom barrier layer in engineered landfills to minimize the mobility of leachate to groundwater. There is a wide range of liner materials. These materials actually retain the contaminants from the landfilled mass depending upon their respective adsorption capacity. Following are some definitions regarding solid waste, landfill, leachate and liner system.

Solid waste: It is defined as the materials which are discarded after use and no longer has value for the person who is responsible for it.

The most common type of waste that is generated in Pakistan is;

1. Municipal solid waste
2. Industrial waste
3. Agricultural waste
4. Hazardous waste

Sanitary Landfill: It is a disposal site in which different type of solid waste such as paper, glass, and metal, is buried between layers of dirt and other materials in such a way as to reduce contamination of the surrounding land. Modern landfills are often lined with layers of adsorbent material and sheets of plastic to keep pollutants from leaking into the soil and water.

Leachate: It is the water that contains certain concentrations of constituents like biological oxygen demand (BOD), chemical oxygen demand (COD), metals, etc. from the solid waste and percolates through the filled waste mass in the sanitary landfill. Figure 1 illustrates the difference between leaching emission, with and without retention media, in open dumpsites.

Liner System: A landfill liner is a low permeable barrier that is laid under engineered landfills which is aimed to reduce the migration of leachate to aquifers and nearby water bodies. Geo synthetic clay liners (GCL) are used nowadays for municipal solid waste landfills. This is quite a new technology and is preferred over conventional liners due to its easy installation, low permeability and its ability to self-repair when holes are caused by swelling. Other examples of liners can be granular activated carbon (GAC), natural excavated soils, plastic, etc.

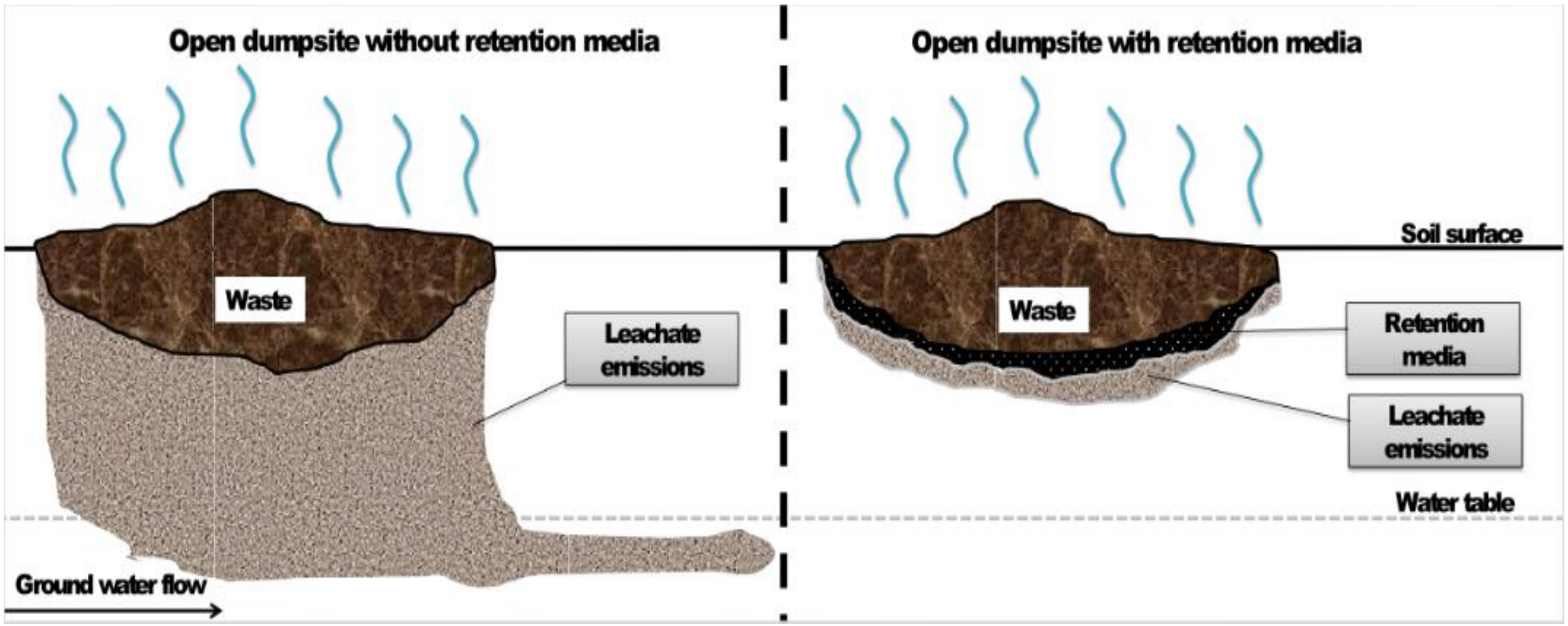

Figure 1 : Comparison of leaching emission with & without retention media (Iqbal Hamid. et al, 2015)

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1.2. HYPOTHESIS

1. Granular activated carbon (GAC) and sand may increase the adsorption capacity of compost
2. Compost + GAC mixture maybe an effective bio-retention media

1.3. OBJECTIVES

OBJECTIVE 1: To retain maximum amount of organics and other contaminants in leachate using water washed compost

OBJECTIVE 2: To measure the adsorption capacity of the contaminants for the following media:

1. Compost
2. GAC
3. Sand
4. Compost + GAC Mixture
5. Compost + sand Mixture

1.4. SIGNIFICANCE OF STUDY

Significance of this study is to introduce a low cost bio-retention media using compost for lining open dumpsites specifically in Pakistan where no engineered landfills are available, which would help reduce pollution due to leaching down of contaminants into the ground water. This study also analyzed possible amendments which could be used with compost in a lining material. This will help us analyze whether compost can be used as a cost-effective and efficient liner material for open dump sites nationally and internationally.

CHAPTER 2

LITERATURE REVIEW

2.1. GENERAL

Based on various site specific details and landfilled materials landfills have been categorized into four types;

1. Municipal solid waste (MSW) landfills: This type of landfills consist the domestic waste which is normally nonhazardous.
2. Industrial waste landfills: It consists the waste of industries which is hazardous
3. Inert waste landfills: Such types of landfills consist of ash, demolition waste and debris.
4. Abandoned landfills: are the mixture of above three types and the nature of the waste materials they consist are completely unknown. (Koerner & Soong, 2000)

2.2. LEACHATE

The landfill waste in developing countries consists 2-3 times more moisture content than developed countries. This moisture in the waste and rain fall over the landfills generates leachate. In addition to it several type of sewage treatment and industrial process sludge are being disposed with other type of waste in the landfills which have already high water content. It’s obvious that the areas which receive heavy precipitation will generate high quantities of leachate than arid and semi-arid areas. Leachate can be minimized or it can be added back to the waste mass in the form of leachate recirculation. This is practiced in Italy, and it is currently allowed in USA for MSW landfills.

Leachate, as a chemical substance, consists of the constituents of solid waste mass and takes it through which it flows. Thus there is no typical leachate, and the characteristics of leachate depend on the site specific waste. Leachate quality is an important consideration to avoid groundwater pollution when the liner material has more leakage chances or it is not that efficient to adsorb the contaminants. (Koerner & Soong, 2000)

2.3. GENERATION OF LEACHATE IN A YOUNG LANDFILL

The pilot-scale landfills built by SYSAV, the waste management company in the south-west of Sweden which are located at Spillepeng disposal site in Malmo were investigated with respect to soil cover and accumulation of water and rainfall-leachate flux relationship.

The average depth of the landfills was 6 m: 10 m at one end, sloping at 15% down to 2 m at the other end. A plastic was used as liner. The leachate was collected and the volume was being measured weekly. Given an average precipitation of 580 mm, the net water input, split into storage and leachate discharge, was 250 mm annually on average.

During a period of 6.5 years, the portion of the input water that became leachate increased from zero to about half and the moisture content in the waste increased to 180mm/m from its initial value. It was suggested that the observed short leachate flux response to a period of infiltration may indicate that a large part of the water is retained by surface tension as thin films in restricted channels, which is overcome by gravity when the input is suddenly increased. (Bendz et al., 1997)

2.4. LEACHATE COLLECTION AND REMOVAL

A typical leachate collection and removal system is installed at the base of an engineered landfill which is placed above the barrier layer. The leachate is collected down there and it is transmitted within the drainage system where it is gravitationally drains to a low point in the landfill where sump is located. The leachate is then removed from the sump through piping which are extended to the ground surface. The leachate is either treated, or disposed in an environmentally acceptable manner. This is a general method of leachate collection for engineered landfills but in case of abandoned landfills it is rare that such system for leachate collection is available. That's why the leachate in these landfills gravitationally drains through the waste mass and eventually develops head on the liner. It can accelerate leakage through the liner which is an undesirable situation. (Koerner & Soong, 2000)

2.5. LEACHATE QUANTITY AND QUALITY

From a landfill in Thessaloniki, Greece, 20 pollution parameters were examined in the leachate on seasonal basis. The composition of leachate varied widely depending upon degree of stabilization, seasonal production, and mainly upon influence of different climatic conditions. When the leachate was collected fresh all the parameters showed higher values markedly while the pH tended to increase from acidic to alkaline with time in the leachate that is older, therefore it was more stabilized. Likewise the concentrations of toxic metals were low in fresh samples of leachate and they were observed even lower in the older samples.

The maximum seasonal peaks of leachate production were observed in spring and in the end of winter. The amount of leachate generated may be proportional to the water that percolates through the waste in landfill and also it depends on the rainwater that the landfill receives. Therefore, there should be less water entering in the landfill in order to reduce the quantity of leachate generation. It was also found that leachate production is greater whenever the disposed waste is less compacted, since compaction was found to reduce the filtration rate. (Tatsi & Zouboulis, 2002)

2.6. LANDFILL LEACHATE IN ARID AREAS

Since the leachate generation in arid areas has long been neglected on the assumption that they receive less precipitation so less leachate could be generated. A study was conducted in Kuwait on two unlined landfills one of the two was active and the other was old (closed). The conceptual model is shown in Figure 2. The temperature in Kuwait is usually in the range of 20-50 degree centigrade and the average annual rainfall is 110mm. The analysis of data collected confirmed that leachates from both landfills were severely contaminated with organics, salts and heavy metals. And the organic strength of the leachate collected from the old landfill was reduced due to waste decomposition and continuous gas flaring. After assessing the water balance at these sites a model was presented which showed that the reason of leachate generation in arid areas could be capillary water, moisture content of the waste and rising of water table. Surface conditions such as Sand dunes and impact of dry wind conditions and humidity in summer can affect leachate generation. In arid areas rising water table alone can be a major factor for producing large quantities of leachate. The chemical composition of leachate in arid areas is difficult to understand because the characteristics of leachate do not show any trend with the type of waste dumped, thickness of waste layer and also with the age. (Al-Yaqout & Hamoda, 2003)

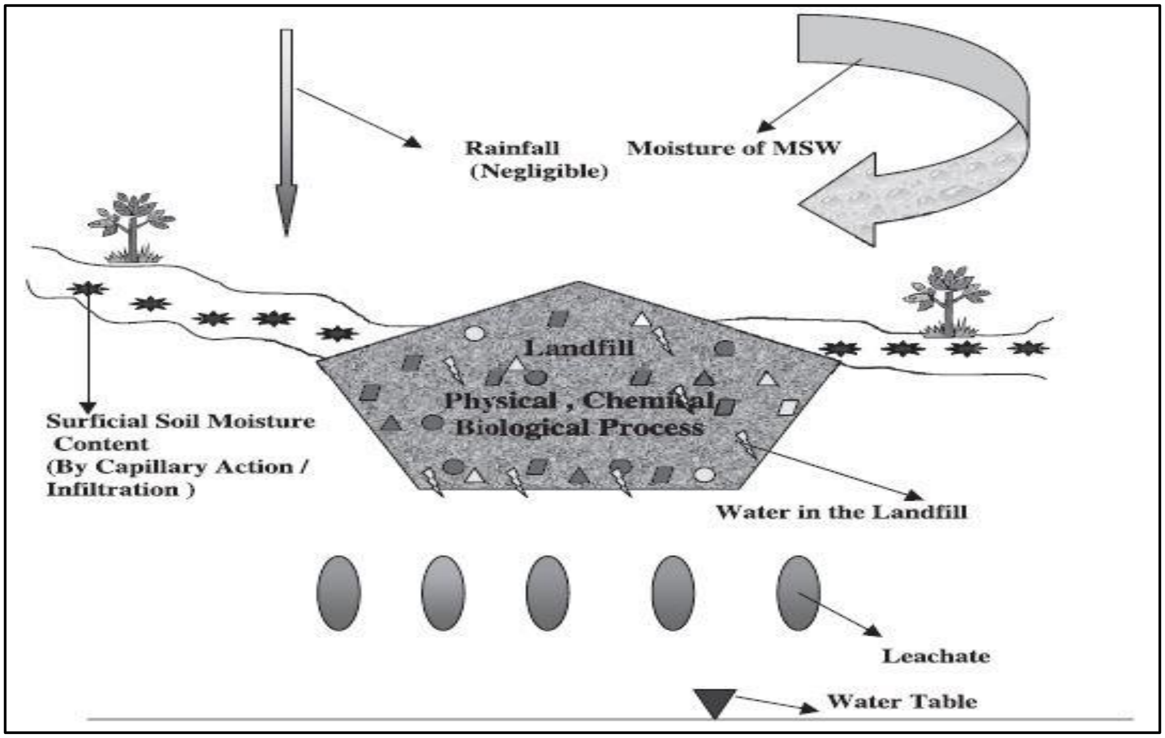

Figure 2 : A Conceptual model of leachate production in arid climate (Al-Yaqout & Hamoda, 2003)

2.7. LINER MATERIALS

Clay barriers can be used in public landfills for groundwater protection. It has showed the best retention capacity to be used as an adsorbent to retain metallic cations such as copper. Also the removal of heavy metals by adsorption is dependent on pH. (Bellir et al., 2005)

The crushed shales satisfy the basic properties of clay liners like they have low hydraulic conductivity to control leachate from the waste. And also the hydraulic conductivity does not increase by the reaction of species from the waste when the leachate comes in contact with the liner. The compacted shales show low compressibility for compactions of level. It has also sufficient shear strength to withstand the bearing capacity and slope failures. These requirements are satisfied by usually the natural clay materials but the highly plastic clays that desiccate are not preferred because the cracks due to desiccation result in the increase in amount of leachate. (Mohamedzein et al., 2005)

Silty soil excavated in construction projects can also be used as landfill liner material. It has been observed that leachate permeation do not change the hydraulic conductivity of the excavated soil. Also laboratory hydraulic conductivities are on the order of 10^{-9} m/s. thus it meets the 1.0E_08 m/s criterion in the Turkish regulations to be used it as liner. (Bozbey & Guler, 2006)

Mudstone material can also be applied as landfill liner. The liner must control the addition of water carefully because adding more or less water can increase the hydraulic conductivity of the liner. It is also concluded that when the mudstone liner contains more than 2.33 cm gravel and 1.79 cm sandy soil in thickness then the hydraulic conductivity of the liner will be less than 10^{-7} cm/s. (Sheu et al., 1998)

Table 1 shows discussed liner types and their functions.

Table 1 : Liner types and functions

Liner Types	Function	Reference
Clay Barriers	▪ Metallic Cations retention (e.g. copper) ▪ Ground water protection	(Bellir et al., 2005)
The Crushed Shales	▪ Continuous low hydraulic conductivity	(Mohamedzein et al., 2005)
Mudstone material	▪ Low hydraulic conductivity due to the presence of gravel and sand.	(Sheu et al., 1998)

2.8. BIO RETENTION MEDIA OPTIONS

Wood residues which are readily available from the forests and industrial activities are biomaterials that can be used as low-cost sorbents of aromatic hydrocarbons in remediation technologies. Lignin is the hydrophobic component of wood; it has a high sorption capacity towards the pesticides which it retains by different interaction mechanisms.

A column experiment was carried out in which the sandy loam soil for this study was selected from a province in Spain. There were two wood samples with different lignin content; oak (O) and pine (P) were used. The Leaching experiments were performed in glass columns of 3 cm (i.d.) × 20 cm (length) packed with the sandy loam natural soil (100 g) or with this soil with intercalated wood barriers.

The wood–soil columns were prepared by adding 90 g of soil, then 5 g of pine or oak sawdust (<1 mm) to prepare the barrier, and 5 g more of soil were added on top of the wood layer. The wood barriers were approximately 5 cm thick. Each column was previously over-saturated with an amount of water equal to six pore volumes (PV) and the excess of water was allowed to drain freely for 24 h, so the humidity conditions were equivalent to field capacity. TOC was released from the wood–soil mixtures (<0.1% TOC) after this treatment, indicating that water-soluble compounds from the woods were stabilized before leaching experiments began.

The pore volume of the packed columns was estimated by the weight difference between water-saturated columns and dry columns. Pesticide was applied by adding 1 mg dissolved in 1 mL of methanol (i.e. concentration of each pesticide was 1 mg mL^{-1}) to the top part of the columns saturated with water. Each experiment was carried out in triplicate.

The characteristics such as TOC, pH and surface area of the two wood samples were determined and at the end it was concluded that wood barriers can be very effective in the retention of pesticides like linuron which is hydrophobic and also the pine barriers were proved to be more effective than oak barriers because they showed maximum retention of the chemicals. (Cruz et al., 2011)

Compost is blended with the native soil available in arid areas and then this mixture is used as an infiltration barrier layer in landfill closure caps. The compost and native soils were mixed in the proportion of 60% compost and 40% native soil (dry weight). It was found that at this proportion the mixture gave minimum hydraulic conductivity of 2.0 to 3.0E-8 m/s at optimum moisture content of 26 %. It was also observed that thermal cycles had a significant effect on the hydraulic conductivity: the hydraulic conductivity of the mixture decreased at high temperature and increased at room temperature. Addition of compost with the soil actually increases the plastic nature of the soil that is amended. (Elshorbagy & Mohamed, 2000)

Table 2 summarizes the findings.

Table 2 : Bio-retention media liners and functions

Bio-retention media	**Function**	**Reference**
Wood Barrier	Pesticides retention	(Cruz, et al., 2011)
Pine Barrier	Chemical retention	
Oak Barrier	Chemical retention	
Mixture of compost and native soil	Low hydraulic conductivity at optimum moisture content	(Elshorbagy & Mohamed, 2000)

CHAPTER 3

MATERIALS AND METHODS

3.1. MEDIA CHARACTERISTICS

Sand was obtained from a construction site near School of Mechanical and Manufacturing Engineering (SMME), NUST. The sand was sieved using sieve number 10 and sieve number 16 to obtain a particle size between 1.18 mm & 2.00 mm. Sieved sand was washed and air dried. Vermi-compost was obtained from (National Agricultural and Research Centre (NARC), Islamabad. Vermi-compost was mixed with distilled water, and was kept on a mechanical shaker for 24 hours, after which it was removed and then air dried. Commercially available granular activated carbon (GAC) was obtained from the market and used as it is. Prepared media was weighed using ATY 224 Shimadzu analytical balance.

3.2. TREATMENTS AND COLUMN SETUP

Two types of treatment were used; control run (phase-I) and main run (phase-II). The control run used 3 different types of media. The media consisted of sand, vermi-compost and granular activated carbon.

Total 6 columns were used, 2 columns were filled with the same media with each media replicated 2 times. Two columns were filled up to a depth of 12.7 cm with sand, two columns were filled up to a depth of 12.7 cm with vermi-compost and two columns were filled up to a depth of 12.7 cm with granular activated carbon (GAC). The main run used 2 different media compositions. One composition was of sand and compost and the second media was a mixture of GAC and compost. Total 6 columns were used, 3 columns were filled with sand and compost and 3 were filled with GAC and compost. All 6 columns were filled with media to a height of 12.7 cm with ratio 2.33 to 1 (8.89 cm of GAC and 3.81 cm of sand).

6 columns of the same dimensions were used, having a length of 25.4 cm and diameter of 5.08 cm for the different types of media used in both control run (phase-I) and main run (phase-II). Before filling the column with media, the internal surfaces of the columns were roughened with sand paper. The columns used 6 identical shower heads, made of acrylic, which provide a constant flow rate to all the individual columns. Bottles at the end of the columns were used to collect the entire outflow from all the columns. The columns were sprinkled with shower heads of 5.08 cm external diameter and containing 12 needles (23 gauges).

The columns used had an internal diameter of 5.08 cm and a total height of 25.4 cm. The columns were filled with each media to the height of 12.7 cm as illustrated in Figure 3. The shower heads were connected to a self-made Marriott bottle (4.70 L) for constant head irrigation with the diluted leachate. The columns were made of polyvinyl chloride (PVC) pipes, covered with a mesh at the bottom of each of the column to hold the media in place. The shower heads were connected to the Marriott bottle (made of acrylic) which was connected to the main leachate reservoir (made of high density polyethylene, HDPE). The mesh was coarse enough to let the leachate pass, but retained all the media.

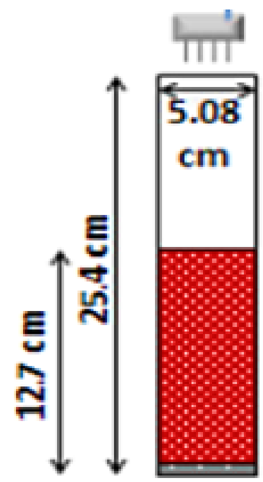

Figure 3 : Column dimensions and depth of media filling

3.3. COLUMN ADSORPTION EXPERIMENT

Leachate was sprinkled over the media in the columns using shower heads. The leachate used was obtained from IJP Road, Islamabad. The original leachate was diluted 40 times. The columns were irrigated with a flow rate of 11-13 ml/cm. The total duration of the control run (phase-I) was 24 hours and the total duration of the main run (phase-II) was also 24 hours. The samples were collected in DI washed polyethylene terephthalate (PET), and then stored in a cool place until further testing.

Figure 4 shows the schematic diagram & Figure 5 shows actual column adsorption setup.

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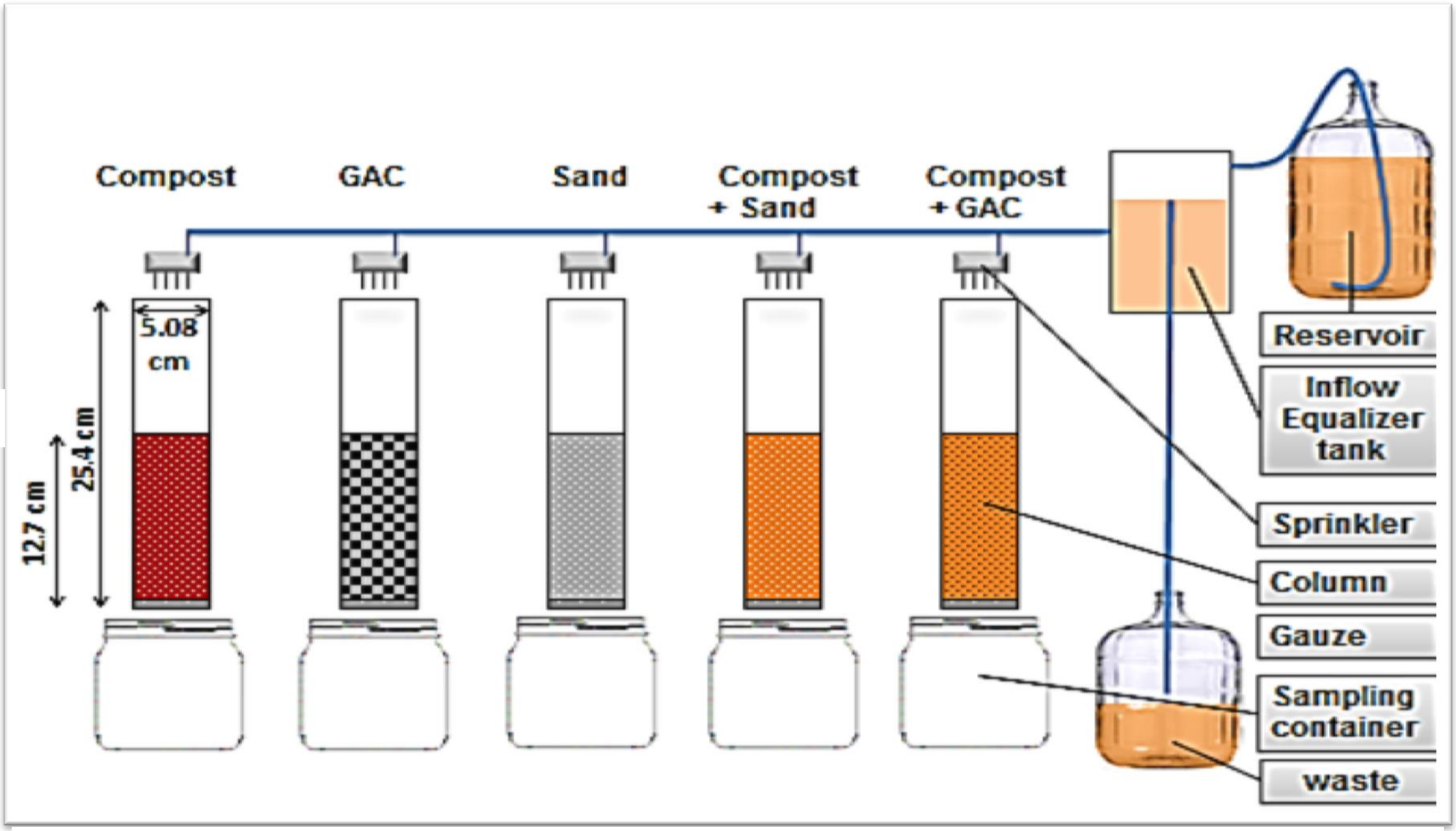

Figure 4 : Schematic of column adsorption setup

Figure 5 : Column adsorption setup installed in Air, Noise and Solid Waste Laboratory

3.4. LEACHATE CHARACTERIZATION

After collecting leachate from IJP road dump site, the leachate was filtered by using regular filter paper to remove large debris like leaves and soil particles.

Initial parameter testing was done on the leachate after diluting it 40 times. The leachate was tested for pH, electrical conductivity, total dissolved solids, nitrates, ortho-phosphates and total organic carbon (TOC). The leachate was filtered using a vacuum filtration assembly, with a filter paper of 1µm (Whatman® 1).

Absorbance of organic ratios was also tested against 3 different wavelengths which were 280nm, 472nm and 664nm. 3 different ratios were selected as:

$Q_{2/4}$ is the ratio of the absorbance at 280 nm divided by 472 nm.

$Q_{2/6}$ is the ratio of the absorbance at 280 nm divided by 664 nm and

$Q_{4/6}$ is the ratio of the absorbance at 472 nm divided by 664 nm.

TOC was measured using an Oasis Scientific UV/Vis Spectrophotometer T-60 UV PG, UK .The absorbance was measured against a wavelength of 465 nm. The result obtained for TOC was 21.755 mg/L. Ortho-phosphates were measured using an Oasis Scientific UV/Vis Spectrophotometer T-60 UV PG, UK. The absorbance was measured against a wavelength of 470 nm. The result obtained for ortho-phosphates was 0.362 mg/L

Nitrates were measured using an Oasis Scientific UV/Vis Spectrophotometer T-60 UV PG, UK. The absorbance was measured against a wavelength of 220 nm and 275 nm. The result obtained for nitrates was 0.182 mg/L.

pH was measured using an EU-Tech Cyber Scan pH 510 pH meter, USA .The result for pH was 7.24. Electrical conductivity was measured using inoLab WTW series pH/Cond 720 EC/TDS meter, Germany. The result for EC was 1070 µS/cm.

Total dissolved solids were measured using an inoLab WTW series pH/Cond 720 EC/TDS meter, Germany. The result for TDS was 1066 mg/L.

Ortho-phosphate concentration was found out using calibration curve shown in Figure 6.

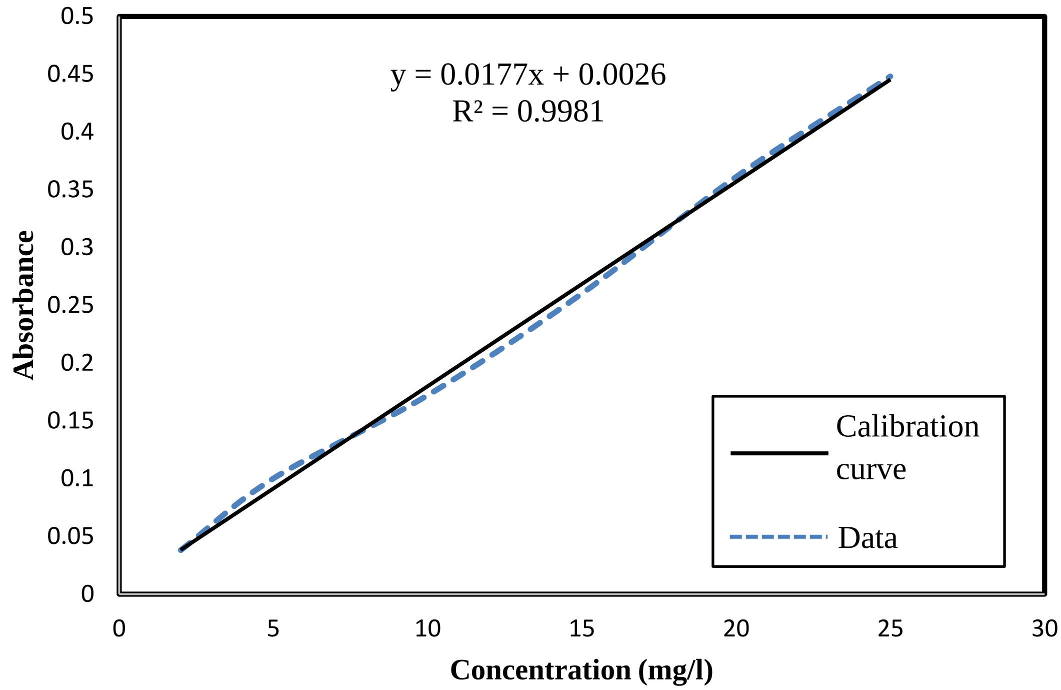

Figure 6 : Orthophosphate calibration curve

3.5. STATISTICAL ANALYSIS

Differences among treatments were analyzed by “Analysis of Variance” (ANOVA) and Tukey’s test ($p = 0.05$). The statistical analysis was done with R Version 3.0.2.

3.6. TESTED PARAMETERS

The following parameter tests were performed on the samples (also mentioned are the equipment used):

1. pH (EU-Tech Cyber Scan pH 510 pH meter, USA)
2. EC (inoLab WTW series pH/Cond 720 EC/TDS meter, Germany)
3. TDS (inoLab WTW series pH/Cond 720 EC/TDS meter, Germany)
4. Absorbance Ratios (Oasis Scientific UV/Vis Spectrophotometer T-60 UV PG, UK)
5. Ortho-phosphates (Oasis Scientific UV/Vis Spectrophotometer T-60 UV PG, UK)
6. Nitrates (Oasis Scientific UV/Vis Spectrophotometer T-60 UV PG, UK)
7. Total organic carbon (Oasis Scientific UV/Vis Spectrophotometer T-60 UV PG, UK)

CHAPTER 4

RESULTS AND DISCUSSIONS

Table 3 shows the analysis results of raw compost. Following parameters were tested on compost before being washed by deionized water and air dried.

Table 3 : Analysis of raw compost used in adsorption experiment

Parameters	**Value**
pH	6.5 – 7.5
Moisture Content (%)	20 – 30
N (%)	1 – 2
P (%)	0.2 – 0.3
K (%)	0.8 – 2
TOC (%)	>20
C:N	13 – 20
Cu (mg/g)	>0.02
Zn (mg/g)	>0.1
Fe (mg/g)	1 – 1.5
Mn (mg/g)	0.3 – 0.5

COMPARISON OF PARAMETERS BETWEEN DIFFERENT TREATMENTS

The following parameters were tested on the samples collected from different treatments. The figures below show parameters against cumulative flux measured in terms of depth (mm), which was calculated using the cross sectional area of the columns and flow rate. The parameters tested were pH, electric conductivity (EC), total dissolved solids (TDS), total organic carbon (TOC), ortho-phosphates and nitrates. These figures explain the concentration variations of different parameters for different treatments along with inflow leachate concentration.

4.1. pH & EC

As shown in Figure 7, in case of compost, pH dropped below inflow leachate pH of 7.24, to a range of 6.2-6.5 and did not change significantly throughout the experiment. This was also true for sand and GAC treatments and in both cases pH dropped to a range of about 6.5-6.7 and 6.5-6.8 respectively.

However in case of both compost + sand and compost + GAC treatments, pH rose significantly in the initial flux of 0.2 mm and then stabilized in the range of 6.9-7.2. This may have been due to release of some alkali salts like sodium carbonate (Na_2CO_3).

Influent EC was 1.07 mS/cm. For compost and GAC, EC was high in the initial flux of 0.1 mm in the range of 1.50-2.30 mS/cm but decreased sharply and stabilized in the range of 1.00-1.10 mS/cm. The initial high EC may have been due to the presence of salts that leached in the initial flux.

4.2. TOTAL DISSOLVED SOLIDS (TDS)

Figure 8 shows TDS variation for different treatments. Influent TDS was 1.07 g/l respectively. For compost and GAC, the TDS was high in the initial flux of 0.1 mm in the range of 1.5-1.8 g/l but decreased sharply and stabilized in the range of 1.00-1.10 g/l respectively. The initial high TDS may also have been due to the presence of salts that leached in the initial flux. The trend is similar to that of EC.

4.3. TOTAL ORGANIC CARBON (TOC)

Figure 9 shows TOC concentrations in samples. In case of compost initially the TOC concentration rose significantly in the early stages up to a range of 130 – 180 mg/l versus the inflow concentration of 21.7 mg/l and then decreased after initial flux of 0.2 mm to a range of 29-33 mg/l. This showed that compost released TOC initially. GAC showed adsorption as the inlet concentration of 21.7 mg/l dropped to a range of 9-21 mg/l and sand didn't show any adsorption capacity for TOC and all samples had concentrations equal to inlet.

For both compost + sand and compost + GAC treatments, initial concentrations of TOC were high as compost released TOC. In case of compost + sand treatment the concentration was as high as 150 mg/l after the initial flux of about 0.1 mm but then decreased sharply as in the case of compost. The compost + sand treatment didn't show any adsorption as the concentrations of TOC remained higher than the inlet concentration but in case of compost + GAC some adsorption was seen as the concentration in the outlet samples dropped after the initial flux of about 0.1 mm. The drop was faster than in pure compost column as the amount of compost in this treatment was lower.

4.4. ORTHO-PHOSPHATES

As seen in Figure 10, compost kept releasing ortho-phosphates but the concentration kept decreasing with increasing flux. The starting concentration ranged from 21-29 mg/l and finally after 1.5 mm flux it decreased down to 1.33-1.91 mg/l, which is still greater than the inlet concentration of 0.36 mg/l. GAC showed rapid adsorption of ortho-phosphates as all concentrations observed were lower than the inlet concentrations.

Surprisingly, the initial concentrations of samples for both compost + GAC and compost + sand treatments were higher than the pure compost treatments even though the amount of compost in pure compost treatment was higher than both. This showed that mixing sand and GAC with compost enhanced desorption of ortho-phosphates.

4.5. NITRATES

Figure 11 shows the nitrate concentrations in samples. Compost and sand show adsorption of nitrates while GAC released nitrates up to a concentration of 0.5 mg/l.

Compost + sand treatment released nitrates in a range of 6-8 mg/l while compost + GAC treatment released nitrates in a wide range of about 3-8 mg/l. Both the treatments showed that addition of either GAC or sand enhance desorption of nitrates from compost.

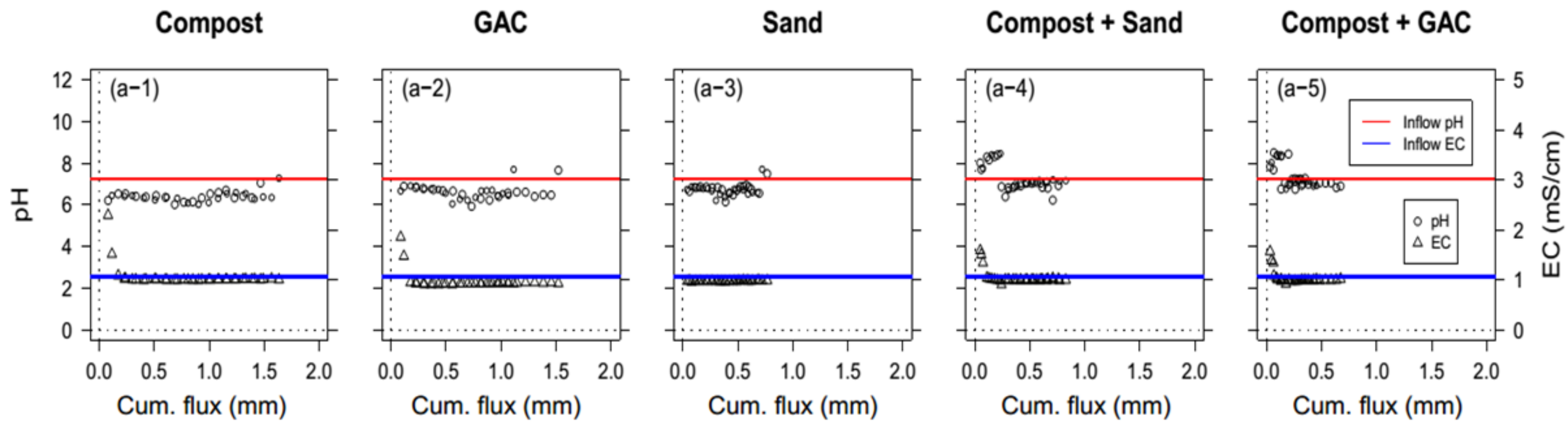

Figure 7 : Comparison of pH & EC against cumulative flux for different treatments

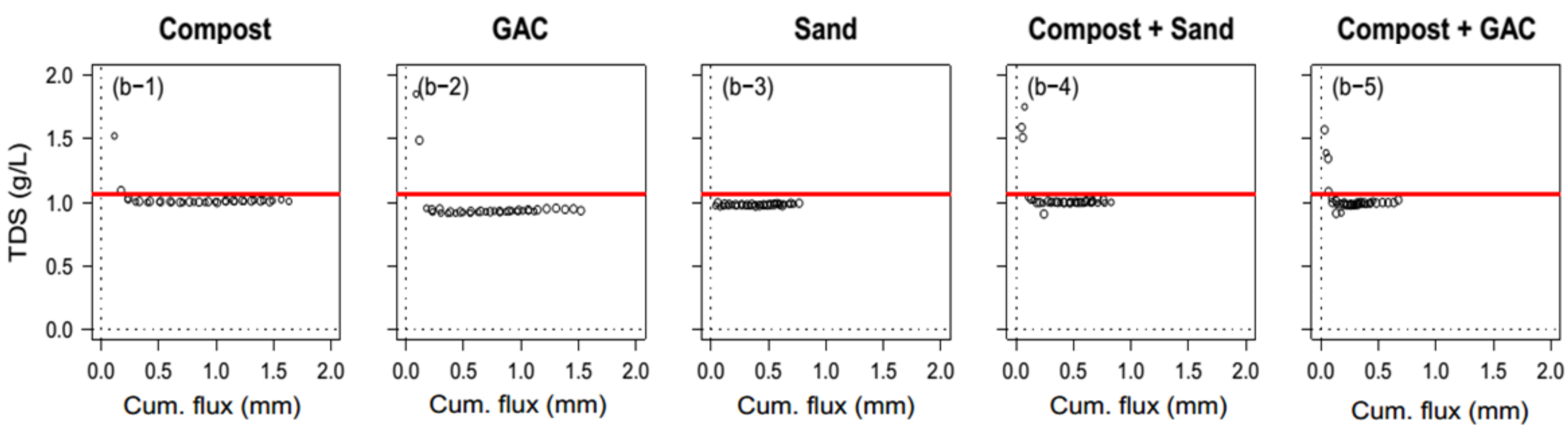

Figure 8 : Comparison of TDS against cumulative flux for different treatments

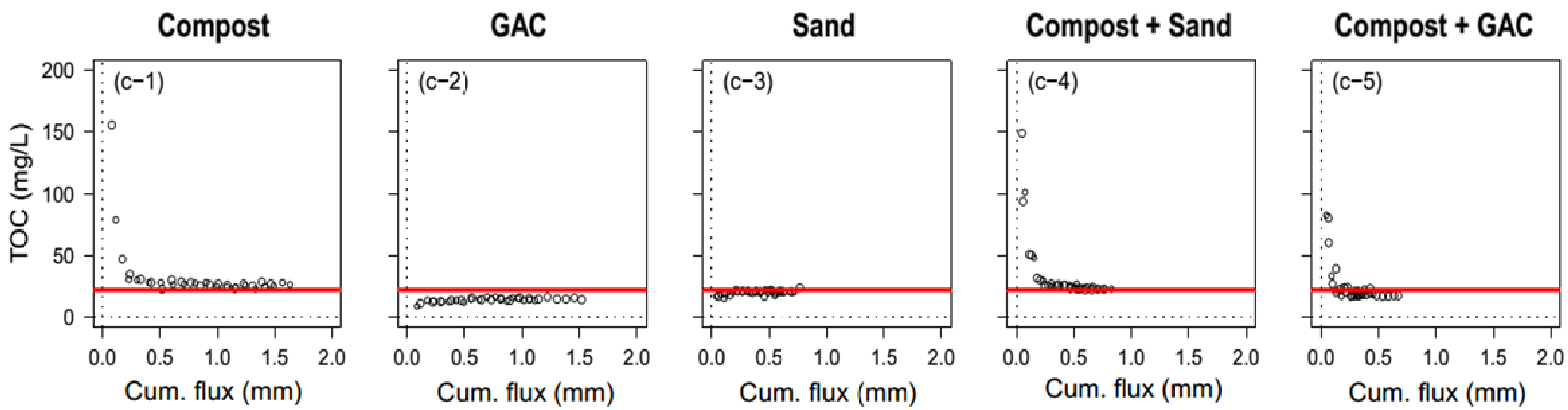

Figure 9 : Comparison of TOC against cumulative flux for different treatments

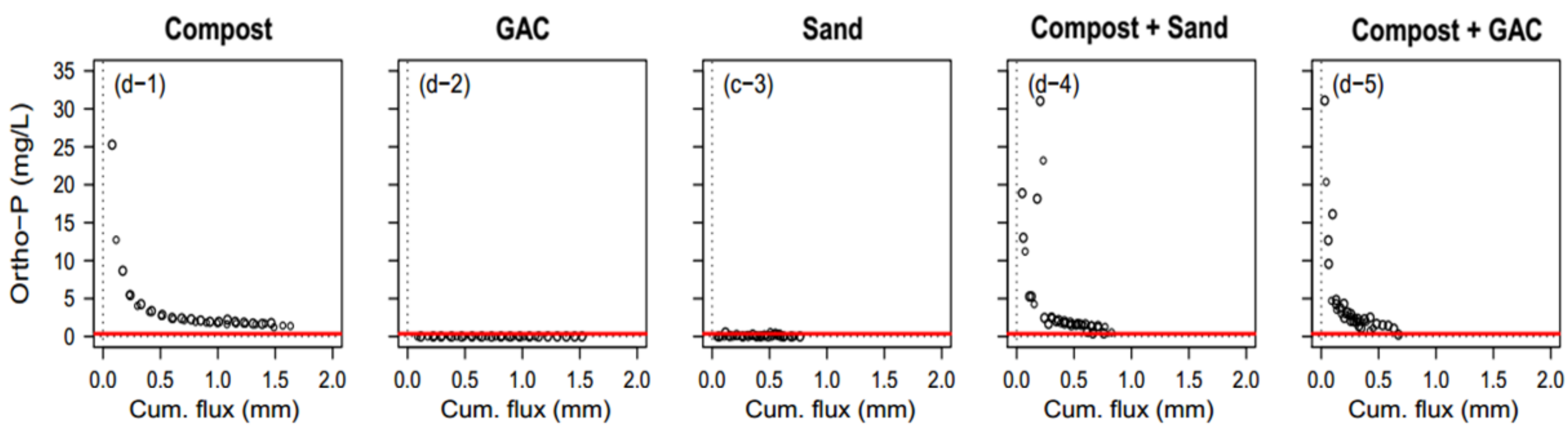

Figure 10 : Comparison of ortho-phosphates against cumulative flux for different treatments

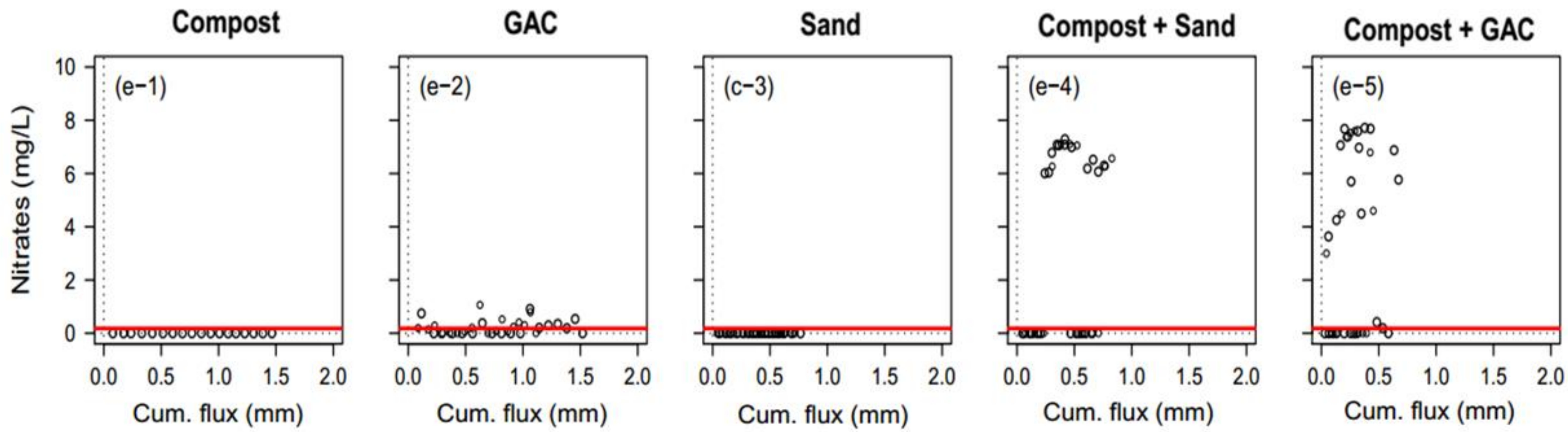

Figure 11 : Comparison of nitrates against cumulative flux for different treatment

4.6. CUMULATIVE FLUX

As shown in Figure 12, it was observed that outflow rate of compost and GAC treatments is the highest which is around 1200 mm^3/s and 1160 mm^3/s on average, respectively, followed by compost + sand treatment which is 900 mm^3/s on average and lastly compost + GAC and sand with 550 and 600 mm^3/s on average respectively.

Figure 13 shows the comparison of cumulative flux against time for different treatments. Both cumulative flux and outflow rate showed the same picture as flux was calculated from volume collected.

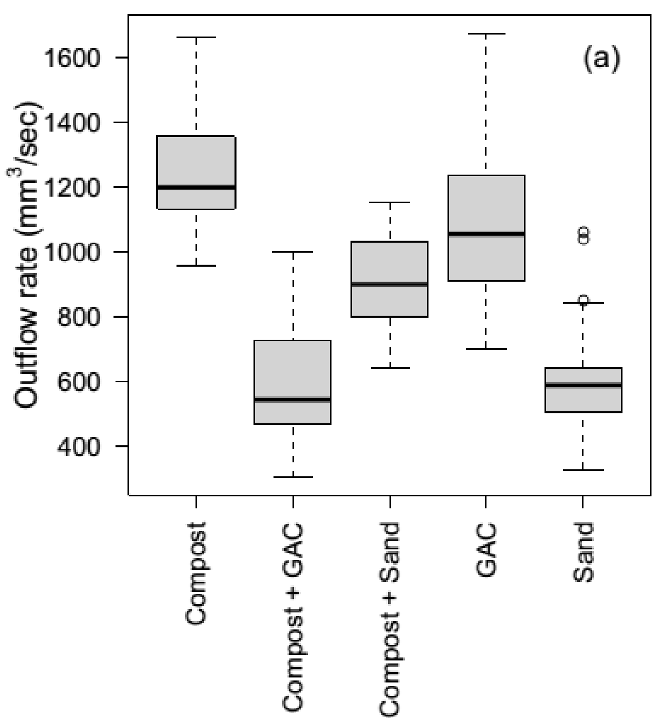

Figure 12 : Comparison of outflow for different treatments

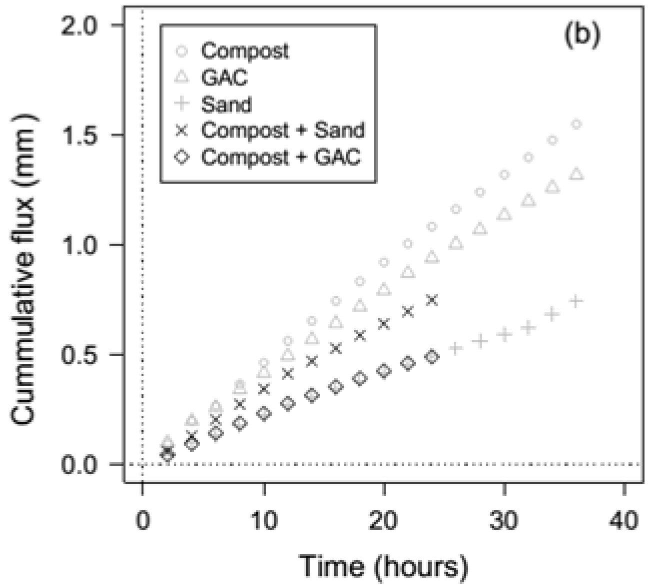

Figure 13 : Comparison of cumulative flux against time for different treatments

4.7. ABSORBANCE RATIOS

Absorbance was measured at 3 wavelengths for all substances as shown in Table 4, at 280, 472 and 664 nm. Absorbance at 280 nm was done for cellulose and lignin substances, 472 nm was done for fulvic like substances and 664 nm was done for humic substances. The dotted line in each of the ratios indicates respective values for standard humic acid for comparison.

Table 4 : Absorbance ratios

$Q_{2/4}$	$\frac{\text{Absorbance at 280nm}}{\text{Absorbance at 472nm}}$
$Q_{2/6}$	$\frac{\text{Absorbance at 280nm}}{\text{Absorbance at 664nm}}$
$Q_{4/6}$	$\frac{\text{Absorbance at 472nm}}{\text{Absorbance at 664nm}}$

4.7.1. ABSORBANCE RATIO $Q_{2/4}$

Figure 14 shows that the ratio of cellulose and lignin substances to fulvic like substances present in samples collected from each treatment. For compost we observed that the ratio is higher indicating that cellulose and lignin is present in a higher amount compared to fulvic substances. Sand treatment samples contained the highest amount of cellulose and lignin substances and GAC samples contained the lowest. For mixed treatments, compost + sand samples contained higher mounts of cellulose and lignin substances compare to lower numbers found in compost + GAC samples. This indicates that GAC suppressed the release of cellulose and lignin substances.

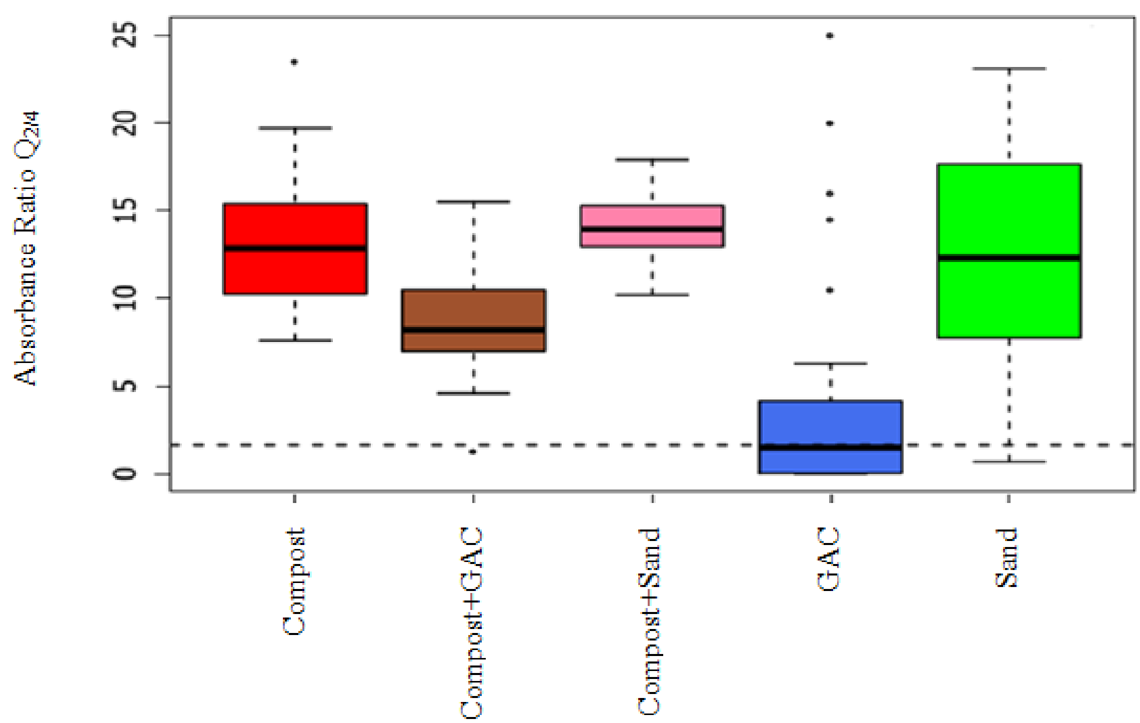

Figure 14 : Comparison of different treatments at absorbance ratio $Q_{2/4}$

4.7.2. ABSORBANCE RATIO $Q_{2/6}$

Figure 15 shows that the ratio of cellulose and lignin substances to humic substances. Compost samples contained the highest amount of cellulose and lignin substance compared to humic substances. On the other hand sand samples contained lower and GAC samples almost had no cellulose and lignin substances. For mixed treatments, compost + sand again contained higher amount of cellulose and lignin substances and in comparison compost + GAC samples contained very low amounts.

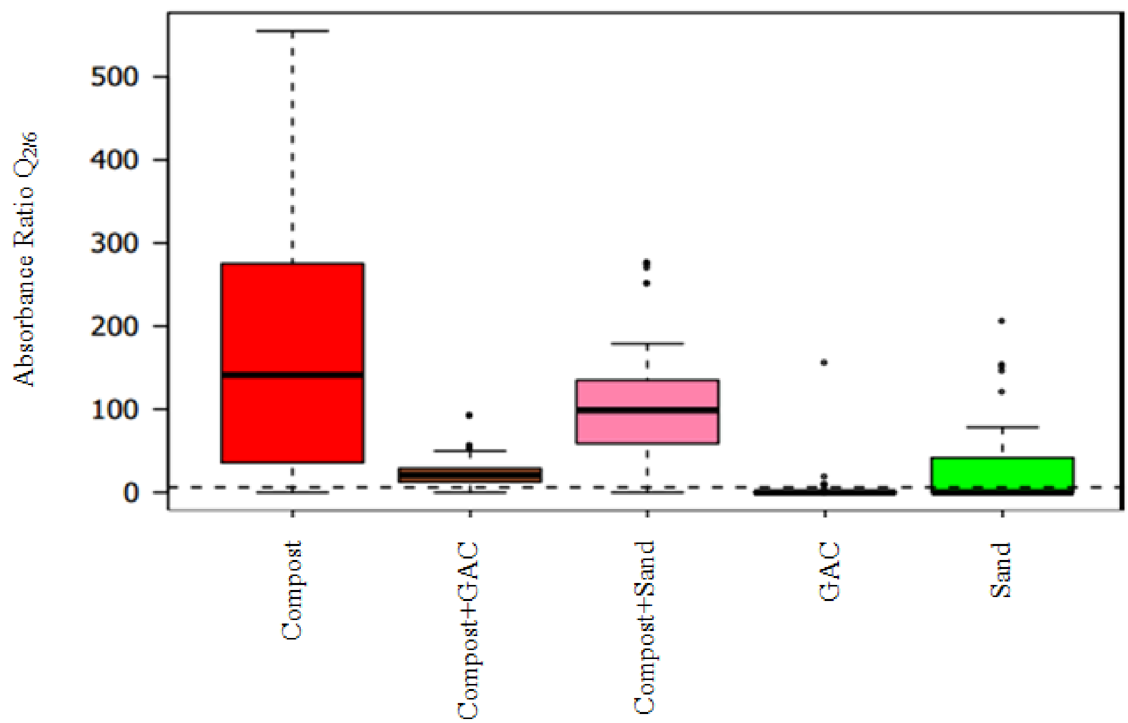

Figure 15 : Comparison of different treatments at absorbance ratio $Q_{2/6}$

4.7.3. ABSORBANCE RATIO $Q_{4/6}$

Figure 16 shows the ratio of fulvic substances to humic substances present in the samples. This ratio, also called humification index, was the most important factor as compost mostly contains fulvic or humic substances. Among the pure treatments, compost shows the highest ratio indicating that its samples contained the highest amount of fulvic substances compared to humic substances, followed by pure sand treatment and finally GAC. Among the mixed treatments, compost + sand samples again show higher amounts of fulvic substances compared to humic substances and on the other hand compost + GAC treatment shows the least ratio.

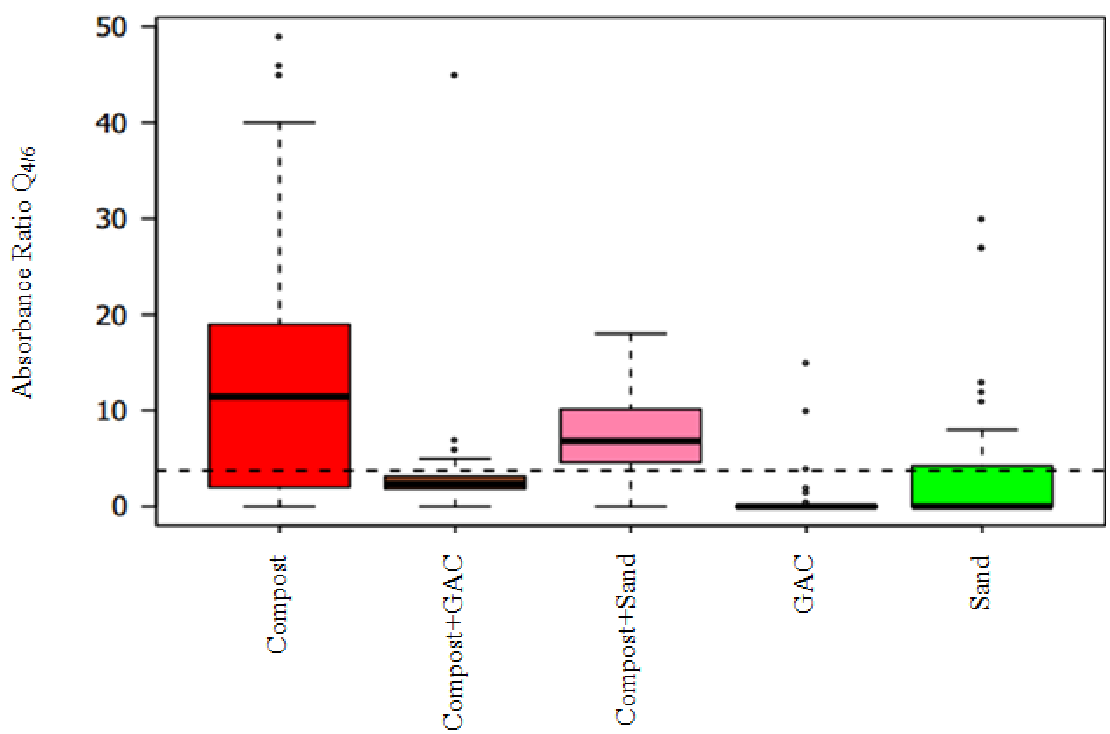

Figure 16 : Comparison of different treatments at absorbance ratio $Q_{4/6}$

4.7.4. COMPARISON OF ABSORBANCE RATIOS FOR DIFFERENT TREATMENTS

Comparing the 3 ratios, compost samples showed highest values in all 3 ratios indicating the release of most organics, followed by sand and lastly GAC which probably served as an adsorbent for organic materials and decreased non-humic leaching. Same trend can be observed for mixed treatments.

4.8. MASS BALANCE

Table 5 shows the mass of compost in each of the compost related treatments. Inflow masses of each of the 3 nutrients (TOC, P and N) is shown along with how much the media already had in it in the form of "substrate". Total outflow masses of the same 3 nutrients are also shown, over the entire duration of the experiment. Negative removal values indicate total leaching and positive values indicate total adsorption.

Table 5 also shows that compost leached out TOC and ortho-phosphates while adsorbing nitrates. For mixed treatments, compost + GAC showed overall adsorption for TOC and ortho-phosphates and both mixed treatments leached out nitrates.

Table 5 : Mass balance analysis for compost treatments

Mass of compost		Compost (g)	Compost + Sand (g)	Compost + GAC (g)
		322.2	96.7	94.9
TOC	**Inflow (mg)**	491.4	237.9	155.8
	Substrate (mg)	146484	44353	43537.8
	Outflow (mg)	743.8	377.1	80.6
	Removal (mg)	-252.4	-139.2	75.2
P (Ortho-phosphates)	**Inflow (mg)**	8.2	3.9	2.6
	Substrate (mg)	2.1	0.6	0.6
	Outflow (mg)	80.4	56.1	2.0
	Removal (mg)	-72.2	-52.2	0.6
N (Nitrates)	**Inflow (mg)**	4.1	2.0	1.3
	Substrate (mg)	1596.3	483.3	474.5
	Outflow (mg)	0	21.4	21.3
	Removal (mg)	4.1	-19.4	-19.9

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The column adsorption experiment was successfully operated for a time period of 24 hours for both control (phase-I) and main run (phase-II). Reliable, technical and meaningful data was collected during the column adsorption study. Some important conclusions that can be drawn from this study are:

- Compost keeps on leaching contaminants even after being washed by the de-ionized water
- GAC and sand reduce the contamination flow from the compost itself but do not completely eliminate it
- GAC and sand amendment decreases the non-humified material leaching from the compost
- GAC amendment significantly reduces total organic carbon and ortho-phosphate leaching

RECOMMENDATIONS

Although this study clarifies about the compost effects as a bio retention media, still further work can be done promoting good research opportunities for the students seeking research topics in this field.

- Pure compost may not be used as a bio-retention media as it leaches contaminants. It should be used in combination with GAC or sand amendments reducing the contaminants leaching from compost and the mixture will serve as a better bio-retention media.
- Alkali washed compost can be a promising bio-retention media as all the organics are washed by alkali.

REFERENCES

Al-Yaqout* A.F., M.F. Hamoda, (2003). Evaluation of landfill leachate in arid climate—a case study, *Environment International 29*, 593– 600.

Bellir K., M. Bencheikh-Lehocine, A.-H. Meniai*, N.Gherbi, (2005). Study of the retention of heavy metals by natural material used as liners in landfills, *Desalination 185*, 111–119.

Bendz D., V.P. Singh, M. Akesson, (1997). Accumulation of water and generation of leachate in a young landfill, *Journal of Hydrology 203*, I-10.

Bozbey Ilknur, Erol Guler, (2006). Laboratory and field testing for utilization of an excavated soil as landfill liner material, *Waste Management 26*, 1277–1286.

Chen Yunmin, Yuze Wang, Haijian Xi, (2015). Breakthrough time-based design of landfill composite liners, *Geotextiles and Geomembranes 43*, 196-206.

Elshorbagy W.A., A.M.O. Mohamed, (2000). Evaluation of using municipal solid waste compost in landfill closure caps in arid areas, *Waste Management 20*, 499-507.

Haijian XIE, CHEN Yunmin, KE Han, TANG Xiaowu, CHEN Renpeng, (2009). Analysis of diffusion-adsorption equivalency of landfill liner systems for organic contaminants, *Journal of Environmental Sciences 21*, 552–560.

Iqbal Hamid, Manuel Garcia-Perez, Markus Flury, (2015). Effect of biochar on leaching of organic carbon, nitrogen, and phosphorus from compost in bioretention systems, *Science of the Total Environment 521 –522, 37 –45.*

Koerner R.M., T-Y, Soong, (2000). Leachate in landfills: the stability issues, *Geotextiles and Geomembranes 18*, 293-309.

Mohamedzein*, Yahia E.-A., Amer A. Al-Rawas, Mohammed Y. Al-Aghbari, Ahmed Qatan, Abdul-Hamid Al-Rawas, 2005. Assessment of crushed shales for use as compacted landfill liners, *Engineering Geology 80*, 271–281.

Rodríguez-Cruz M.S., J.M. Ordax, M. Arienzo, M.J. Sánchez-Martín, (2011). Enhanced retention of linuron, alachlor and metalaxyl in sandy soil columns Intercalated with wood barriers, *Chemosphere 82*, 1415–1421.

Sheu Chyi, Tzong-Tzeng Lin, Juu-En Chang, Chih-Hung Cheng, (1998). The feasibility of mudstone material as a natural landfill liner, *Journal of Hazardous Materials 58*, 237–247.

Tatsi A.A., A.I. Zouboulis, (2007). A field investigation of the quantity and quality of leachate from a municipal solid waste landfill in a Mediterranean climate Thessaloniki, Greece, *Advances in Environmental Research 6*, 207-219.