Soil Infiltration Study:
Measuring the Difference in Leachate Quality Between Surface Compost Application and Incorporated Compost Application

A Senior Project

presented to

the Faculty of the Earth and Soil Sciences Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Soil Sciences; Bachelor of Science

by

Christopher Gallo and Kristin Roberts

June, 2010

APPROVAL PAGE

Title:	Measuring the difference in leachate quality and between surface compost application and incorporated compost application
Authors:	Christopher R. Gallo and Kristin N. Roberts
Date Submitted:	August 2010

Dr. Brent Hallock
Senior Project Advisor

Dr. Brent Hallock

Dr. Lynn E. Moody
Department Chair

Dr. Lynn E. Moody

Earth and Soil Sciences Department

ACKNOWLEDGEMENTS

Many people have helped to make this project possible, and each deserves their due recognition. Without the help of funding from the California Polytechnical State University Erosion Control Team sponsored by California Department of Transportation, this project never would have been completed.

Dr. Hallock has been a wonderful senior project advisor, and presented us the opportunity and freedom to express our soil science knowledge. We appreciate your guidance and critiques along the way.

Dr. Appel was generous with his knowledge and understanding toward the materials and methods needed in the analysis many of our samples.

Craig Stubler was extremely kind to take time from his busy schedule to help guide us through the lab analysis process and provide us with data.

Crystal Thoin and the Cal Poly Erosion Control Team for helping us collect soil and assist with minor data collection. You guys rock!

And all of our other family, friends, and professors, who have helped through our college careers and have prepared us for the next stage in our lives.

CONTENTS

PAGE

1. INTRODUCTION

In many cases, organic compost is used as a soil amendment in order to decrease water run-off and erosion potential of topsoil. It is also a way to provide the soil with necessary nutrients for a plant to germinate and sustain its life cycle (Environmental Protection Agency, 2010). In order to understand the physical properties of compost used as an erosion control measure and its other environmental effects, studies need to be conducted to measure the components of leachate materials from different application methods. Many erosion control solutions employ the usage of organic compost to hold water in the soil, increase soil fertility and prevent erosion of topsoil. This practice has been identified as a very efficient and useful practice, but there have been little efforts in the way of determining what nutrients make it through the soil profile and potentially into groundwater.

According to the California Department of Transportation, the benefits of compost include: reduced stormwater runoff volume and velocity, improved infiltration rate, improved soil water holding capacity, improved soil structural properties (soil structure, porosity, and texture), improved plant rooting depth, improved soil chemical properties (providing proper pH, carbon, nitrogen, potassium and phosphorus levels), improved soil biology (activity by bacteria, mycorrhizal fungi, nematodes, protozoa, microarthropod and earthworms), improved soil nutrient levels and nutrient cycling, and improved potential for vigorous long term vegetation coverage (California Department of Transportation, 2010).

These benefits have been sufficiently proven, therefore the use of compost has become a standard practice as an erosion control measure. But as environmental standards become more stringent, it is necessary to measure the type and quantity of nutrients that could potentially leach through the soil profile and into the groundwater supply. One of the main concerns when using compost is the leaching of nitrates into the groundwater supply. According to the Environmental Protection Agency (EPA), nitrates are considered to be a contaminant in the water supply and the maximum contaminant level goal is to be under 10 mg/L or 10 ppm NO_3-N (Environmental Protection Agency, 2010). These values represent the highest level the specific ions or concentration may be without posing a risk for people.

The soil used in this study was a granitic soil in the hydrologic soil group (A). This hydrologic soil classification means that the soil has low runoff potential when thoroughly wet and that water is transmitted freely through the soil with a high rate of infiltration (Natural Resources Conservation Service, 2007). The hydrologic soil group (A) was used in this study because of its high rate of infiltration, giving a more realistic situation in which nitrate leaching from compost would pose a threat to groundwater.

With this information, a clearer conclusion was made helping to determine which application method is most useful in holding water in the soil, but most importantly, holding nutrients in the soil as well. This was compared to water infiltration of bare soil as well as water infiltration of compost alone. In this way, the significance of compost usage was assessed and could be used as a resource in commercial application to prevent erosion and keep surface and groundwater as clean as possible. This is important because environmental responsibility is a pressing issue, and it is necessary to understand the consequences of all actions, even those originally believed to be beneficial to the environment.

The objectives of this experiment were to: i.) determine the differences in leachate material between compost applied on top of soil and compost incorporated into soil; ii.) determine the amount of nitrate leached through sandy soil from compost; iii.) determine the most effective application method of compost to sandy soil for low nitrate leaching; iv.) and to provide recommendations for future application methods.

2. LITERATURE REVIEW

2.1 Hydrologic Soil Groups

In the National Engineering Handbook, made by the National Resources Conservation Service (NRCS), the four hydrologic soil groups (HSG's) are clearly defined to provide a simpler way of classifying hydrologic soil groups (Natural Resources Conservation Service, 2007). This is a result of a multi-year collaboration between soil scientists and engineers. The reason this new system of classification was needed was because the old system involved a classification of HSG's based on soil series. The problem with this is that soil series are continually changing across the country so maintaining a consistent national list became virtually impossible. The new system ignores the soil series classification and focuses only on the hydrologic properties of the soil. These properties are then translated into four categories, classified by soil scientists, and used to assign soils as map units across the country.

The four groups in this classification (A,B,C and D) each have different hydrologic characteristics (Appendix A). In its simplest form, a HSG is determined by "...the water transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable (such as fragipan or duripan) or depth to a water table (if present)". Group A consists of soil with low runoff potential when thoroughly wet. This means that water is transmitted freely through the soil with high rates of infiltration. These soils are typically sandy soils with less than 10 percent clay. Group B consists of soil with moderately low runoff potential when thoroughly wet. These soils typically have 50 to 90 % sand with 10 to 20

% clay. Group C consists of soil with moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. These soils typically have less than 50 % sand with 20 to 40 % clay. Group D consists of soil having high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. These soils typically have less than 50 percent sand with greater than 40 percent clay. These soils also have high shrink-swell potential (Appendix A).

2.2 Certified Compost

In 1990, the United States Composting Council (USCC) was created to be dedicated to the development, expansion and promotion of the composting industry. The USCC has developed a program committed to testing, labeling and disclosing information regarding specific compost called the Seal of Testing Assurance, STA. This program ensures that compost suppliers provide information of what is contained in each collection of compost, which makes it easier to identify chemical composition and physical characteristics such as particle size (Appendix B). Certified compost products are tested for: pH, soluble salts, nutrient content (total N, P_2O_5, K_2O, Ca, Mg), moisture content, organic matter content, bioassay (maturity), stability (respirometry), particle size (report only), pathogen (Fecal Coliform or Salmonella) and trace metals (Part 503 regulated metals).

2.3 Safe Drinking Water Act

In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water that would pose no adverse health effects to the public. These health goals are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substance or matter in water.

The MCLG for nitrate is 10 mg/L or 10 ppm NO_3-N. EPA has set this level of protection based on the best available science to prevent potential health problems. EPA has set an enforceable regulation for nitrate, called a maximum contaminant level (MCL), at 10 mg/L or 10 ppm. MCLs are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies (Environmental Protection Agency, 2010).

The Phase II Rule, the regulation for nitrate, became effective in 1992. The Safe Drinking Water Act requires EPA to periodically review the national primary drinking water regulation for each contaminant and revise the regulation, if appropriate. EPA reviewed nitrate as part of the Six Year Review and determined that the 10 mg/L or 10 ppm MCLG and 10 mg/L or 10 ppm MCL for nitrate are still protective of human health. Individual states can choose to impose more rigorous standards for their drinking water; however, they cannot be any less stringent than the national standard set by the EPA (Environmental Protection Agency, 2010).

2.4 Related Studies and Articles

In an article entitled, *Leaching from Composted Biosolids,* by Charles Frink and Brij Sawhney (1995), the leaching of nitrates into groundwater was assessed by applying two inches of composted biosolids on turf plots and lysimeters. This study showed that the leaching of heavy metals into the groundwater supply was insignificant and well below drinking water standards with a nitrate level of 5.1 ppm. However, the leaching of nitrate through the turf plots and lysimeters was considerable with a nitrate level of 14.2 ppm. This nitrate infiltration was increased due to heavy rains caused by Hurricane Bob. Although this study found the leaching of nitrate to be considerable, the conclusion reached by Frink and Sawhney was that, "...the temporary pulse of nitrate from storage and one time use of composted sewage sludge at topsoil blending rates does not appear to pose any persistent threat to ground water."

An article entitled, *Leaching of Nitrate, Ammonium, and Phosphate from Compost amended Soil Columns,* by Y.C. Li and P.J. Stoffella (1997), set out to determine the amounts of nitrate, ammounium and phosphate that were being leached through sandy soils in the Florida area. This study was significant not only because Florida has several sandy soils throughout the state, but because the annual rainfall is high and the water table is relatively shallow. This means that if there is a significant amount of nitrate, ammonium and phosphate leaching into the water table, it would be contaminating the water supply for a large population and could be above the safe levels of these contaminants determined by the Safe Drinking Water Act of 1974. After conducting this study, the conclusion of Li and Stoffella was that nitrate should be a factor when compost rates and frequencies of application are considered because their data showed large amounts of leached nitrate higher than the standard. This should especially be considered when dealing with soils that are vulnerable to nutrient leaching.

In a recently published article entitled, *Strategies to reduce nitrate leaching into groundwater in potato grown in sandy soils: Case study from North Central USA,* Raj Shrestha, Leslie Cooperband and Ann MacGuidwin (2010) explore different methods in reducing the leaching of nitrate into groundwater, one of which is the application of organic matter. The authors quickly point out that in attempts to reduce leaching of nitrate from organic matter, there is risk of adding too much organic matter which could potentially lead to increased levels of leached nitrate in sandy soils. Other methods described as reducing nitrate are better management practices (BMP's) aimed at fertilizer application and irrigation practices. The preferred method in this study, however, was retaining the surface organic matter of the crop residue in order to increase the water retention capacity of a soil and thereby reducing nitrate leaching. This method also comes with a warning of not having too much organic matter because of the potential for leaching from mineralization, especially in sandy soils. It is important to realize that organic matter has many benefits, but using it properly is key to avoiding the adverse effects of nitrate leaching into groundwater.

A journal article written in 2007 entitled, *Movement of Nitrogen and Phosphorus Downslope and beneath a Manure and Organic Waste Composting Site,* by R.B. Confesor, J.M. Hamlett, R.D. Shannon and R.E. Graves (2007), analyzes the impacts that a composting site has, or may have, on the groundwater and the surface runoff from their site. The authors state that composting sites pose a problem to groundwater in the leaching of nitrates and they could contribute to contamination of storm water through the movement of phosphate in surface runoff, both of which create an environmental problem. Nitrate can be toxic to humans and livestock and phosphate often causes advanced eutrophication of surface waters. A common practice of composting sites is to store compost piles on heavily compacted gravel pads, which is intended to prevent leaching of pollutants. This study was conducted on such a pad to see how effective the compacted gravel is at restricting leaching. The conclusion of this study showed that the compacted gravel did not fully prevent the downward movement and accumulation of nitrate beneath the pad but the surface movement of nitrate was negligible. The data also showed that there was surface runoff and downslope transport of phosphorus from the compost site to the filter strip. The leaching tests indicated that mature composts pose a greater potential source of nitrate leaching than the young, freshly-mixed composts. Whereas, the freshly-mixed composts pose a greater potential source of phosphate than the older composts.

In the article entitled, *Impact of Organic Amendments on Groundwater Nitrogen Concentrations for Sandy and Calcareous Soils,* by F. Jaber, S. Shukla, P. Stoffella, T. Obreza and E. Hanlon (2005), the authors observe the impact of organic matter compared to inorganic fertilizers used in vegetation production in regards to groundwater concentrations of nitrogen. The different types of organic matter applied in this study consisted of: yard and food residuals compost, biosolids compost, a cocompost of the municipal solid waste biosolids, and inorganic fertilizer. Nitrate, ammonium nitrogen and total N concentrations were collected over a period of two years for both soils. Statistically there were no differences among the three treatments and the nitrate concentration for all three treatments was less than the maximum contamination level of 10 mg/L (ppm) NO_3-N . An interesting part of this study was that leached nitrate was more in calcareous soil than in sandy soil. But the conclusion of this study was that all the composts tested were comparable to the inorganic nitrogen fertilizer and performed as good or better in providing the necessary nutrients for plant growth.

3. MATERIALS

3.1 Site Description

The soil collection site is located in Santa Margarita next to the Calf Canyon Highway in California with GPS coordinates: latitude: 35.436791 longitude: -120.505678 (Figure 1). The site collection area was approximately 0.5 acres. Vegetation consisted of annual and perennial grasses, forbs, and areas of brush and oaks. Slopes ranged from 30-70 %. The aspect of the site was northwest. The sites parent material was residuum weathered from granitic rock. Annual precipitation ranges from 25-27 inches and the mean annual air temperature is about 60 degrees F. The soil that was collected is classified as a Cieneba-Andregg Complex, which is textured as a coarse sandy loam (WSS, 2009).

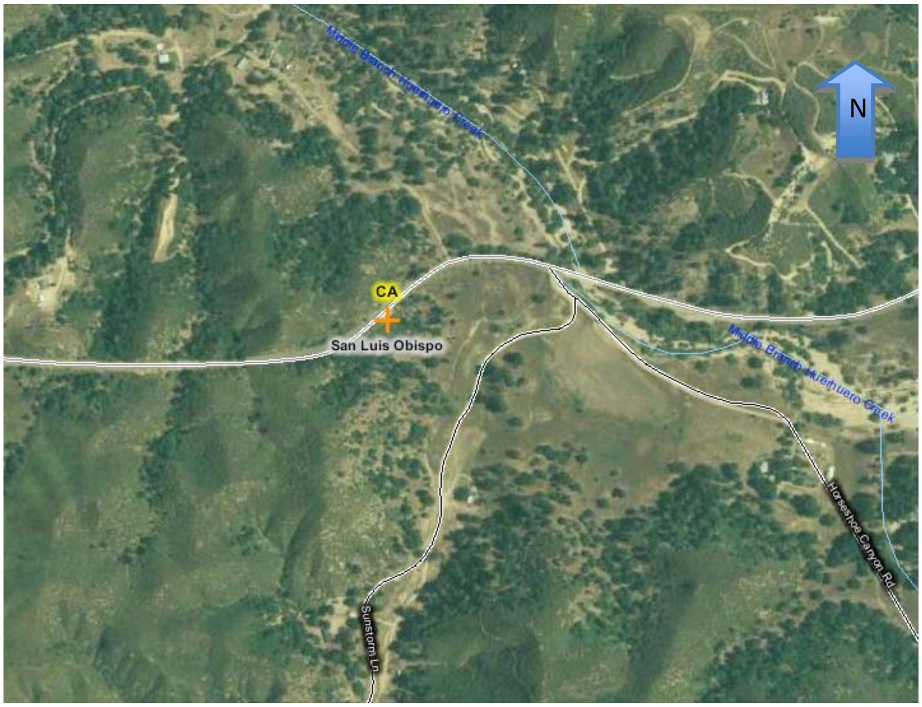

Figure 1. Map of site location, Santa Margarita, CA.

3.2 Soil Sampling

The Cieneba-Andregg Complex soil samples were collected from the backslope of the site by raking away the top 5 cm (2 inches) of vegetation and then digging to a depth necessary to collect the adequate amount of soil (Figure 2). Samples were collected in five-gallon plastic buckets with sealed plastic lids to be taken back to the lab. Soil samples were air dried, ground by mortar and pestle, and then passed through a 2 mm sieve. Particle size analysis was performed and concluded the Cieneba-Andregg Complex was a sandy loam with 70-13-17 sand, silt and clay.

Figure 2. Map of soil collection site, Santa Margarita, CA.

3.3 Compost

The experiment was designed using 10 cm (4 inches) diameter PVC pipe with a length of 46 cm (18 inches) for each sample. The soil column had a height of 30 cm (12 inches). This was intended to simulate the soil column and the depth of soil that is affected by use of compost. A

50/50 mix of fine (< ½ inch) and coarse (1/2-3 inch) was chosen from Santa Maria. This compost is USCC certified and is composed of green with biosolid waste (Appendix C). No animal manure. The different samples consisted of one bare soil (*bare*), one pure compost (*all*), one soil with 5 cm (2 inches) of compost on top (*surface*) and one soil with compost incorporated (*incorp.*) 25 % to Cal Trans standards (2" soil on bottom with added 6" soil with 2" compost incorporated on top of the original 2"). Tubes were uniformly compacted to Cal Tran standards with bare 90-95 % and the other three factors with compost were compacted to 80-85 %; all samples were ran in replicates of three for a total of 12 total soil columns.

3.4 Structure Design

The materials used in these simulations were 10 cm (4 inch) diameter PVC pipe with a drainage cap at the bottom, lined with filtration material and fiberglass window screen. The structure housing the tubes was built from 4" x 4" and 2" x 4" lumber (pine) with plywood used for top. Holes were cut into the plywood surface using a power drill and jigsaw. These holes provided a method for suspending the experimental tubes above the leachate collection beakers (Figure 3). For each sample, a constant amount of water was applied for each tube with the total amount of water applied being 1400 mL. The application of water was done using graduated cylinders and applying 100 mL at a time.

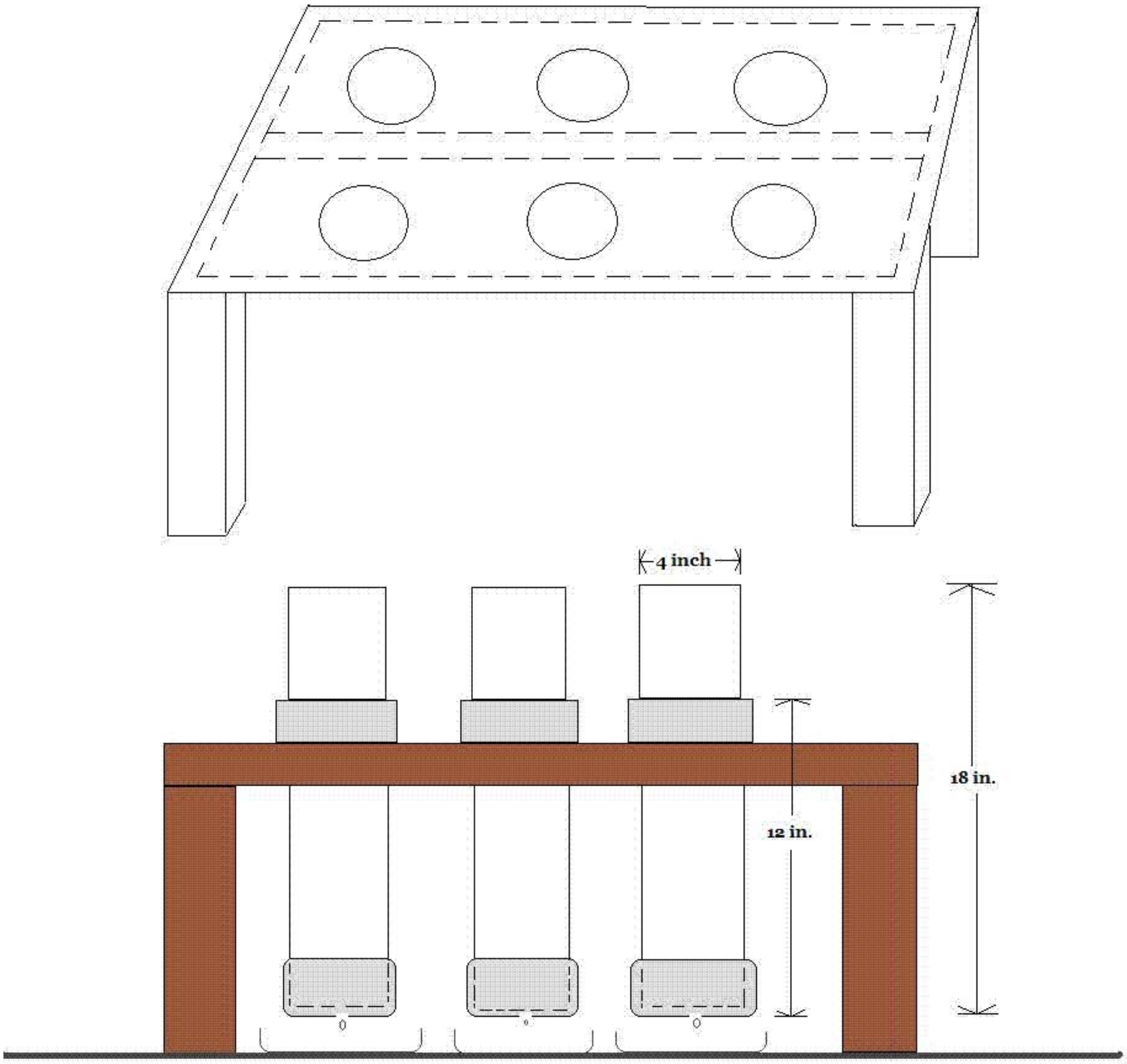

Figure 3. Experimental design support structure with tubes.

4. METHODS

4.1 Experimental Set-up

The 12 samples were run six at a time in order to have greater consistency in data collection and timing for statistical purposes. Once set-up was complete, water was applied in uniform amounts (100 mL) and continually added once water was fully infiltrated and no pooling was seen at the top of the tube until the entire 1400 mL was applied. Beakers were placed under the soil columns to collect leachate materials and time was taken at leachate breakthrough. The leachate materials were observed to assess the different rates of infiltration with the different treatments.

4.2 Leachate Materials Analysis

Leachate materials were examined and measured for total amount of leached quantities, quantities of total carbon and nitrogen, as well as EC, pH and NO_3-N.

4.3 Leached Quantities

Leached materials were collected with beakers and used to understand the total amount of infiltrated leached materials in mL.

4.4 Total Carbon and Nitrogen

In order to measure total C and N, a total of 14 samples (12 from leachate plus 2 pure DI water blanks) were prepared; 3000 mg of sea sand and 2000 μL of each collected leachate was added to a cleaned VarioMax graphite crucible. Two blanks were also prepared with 3000 mg of sea sand and 2000 μL of DI H_2O. The 14 samples were analyzed on the VarioMax CNS analyzer and C and N were reported as percentages.

4.5 EC

Electrical conductivity is measured using a YSI 3200 Conductivity Instrument (EC meter), which uses a glass bulb electrode. A small amount of leachate was poured into the cleaned electrode tip and a reading was taken from the meter after it was stable for 10 seconds. EC was measured in dS/m.

4.6 pH

In order to measure pH correctly, an AB15 Fisher Scientific pH meter with electrode was immersed into each leachate, separately. The pH value was recorded after the 100ths place and was taken after it was stable for a period of 10 seconds.

4.7 NO_3-N

In order to measure NO_3-N, 20 mL of each leachate was combined with 20 mL of 0.2 M $(NH_4)_2SO_4$ into a 50 mL beaker; a total of 12 samples prepared. Using a Corning potentiometer equipped with a proper nitrate selective electrode and reference electrode NO_3-N was reported in mV and converted to ppm using the calibration equation and line.

4.8 Quality Control

Many quality control measures were taken in order to ensure accuracy and precision for this experiment. In order to ensure accurate total C and N, EC and pH and NO_3-N measurements, initial calibration verification (ICV) was done at the beginning of each analysis. Continuing calibration verification (CCV), a replicate and a spiked sample were run after the 10th sample and a 80 – 120 % recovery was received. Lastly, the MDL was calculated using the previous blank samples that were run. All measurements ranged from 80 – 120 %, ensuring accuracy and precision for the experiment.

5. RESULTS AND DISCUSSION

5.1 Leachate Quantities and Qualities

After averaging the replicated sample treatments it is seen that for almost all factors *bare* had the lowest measured values for experimental analysis when compared to *surface*, *incorp.* and *all* treatments (Table 1 and Appendix B).

Table 1. Averaged treatments for recorded analysis procedures.

Average	Bare	Surface	Incorp.	All
Time of Breakthrough (hrs:min:sec)	3:15:23	2:23:12	1:24:35	0:22:08
Amount of leachate (mL)	450.00	466.67	461.67	530.00
pH	6.32	5.44	5.38	5.77
EC (dS/m)	0.28	12.91	11.93	34.01
NO_3-N electrode (ppm)	2.08	1131.97	1046.84	3424.16
% N	0.01	0.13	0.11	0.33
% C	0.06	0.07	0.07	0.17

From the results, *bare* has a greater time of breakthrough than the other treatments *surface, incorp.* and *all* (Table 1). This is expected because the tube was compacted to 90-95 %, which is relatively high compared to the other tubes being compacted to 80-85 %. This is also why it is consistent with the amount of leachate infiltrated because with the more compacted treatment *bare*, less leachate was infiltrated, whereas *surface, incorp.* and *all* had less compaction and more leachate infiltrated. In contrast, treatment *all* which was only compost had an extremely fast time of breakthrough and the highest amount of leachate. This is due to compaction and bulk density being related. When compaction increases, bulk density increases, which causes porosity to decrease causing less infiltrated leachate to be collected (Singer, 2006). Therefore, in treatment *all* the larger pore spaces, less compaction and non-uniform structure of the compost material caused the leachate to infiltrate quickly with the greatest volume collected.

It is also important to note that although *surface* and *incorp*. differ in measured values, they do not differ significantly (Table 1). This is important to note because they both have the same amount of applied compost (2 inches) in each of their test tubes, however their application method differed.

5.2 pH

Analysis shows *bare* was the highest pH value with 6.32, roughly one whole number above the lowest pH value (*incorp.* with 5.38). This can be due to the other treatments containing humic materials with humic acid, which lowers the pH values (Singer, 2006). Further analysis shows that there is no significant difference between the treatments, when looking at the standard deviation of the average (means) of each treatment (Figure 4). Therefore, there was no significant difference found from the pH data that would conclude any difference between the four treatments and therefore pH was not a factor in this experiments conclusion.

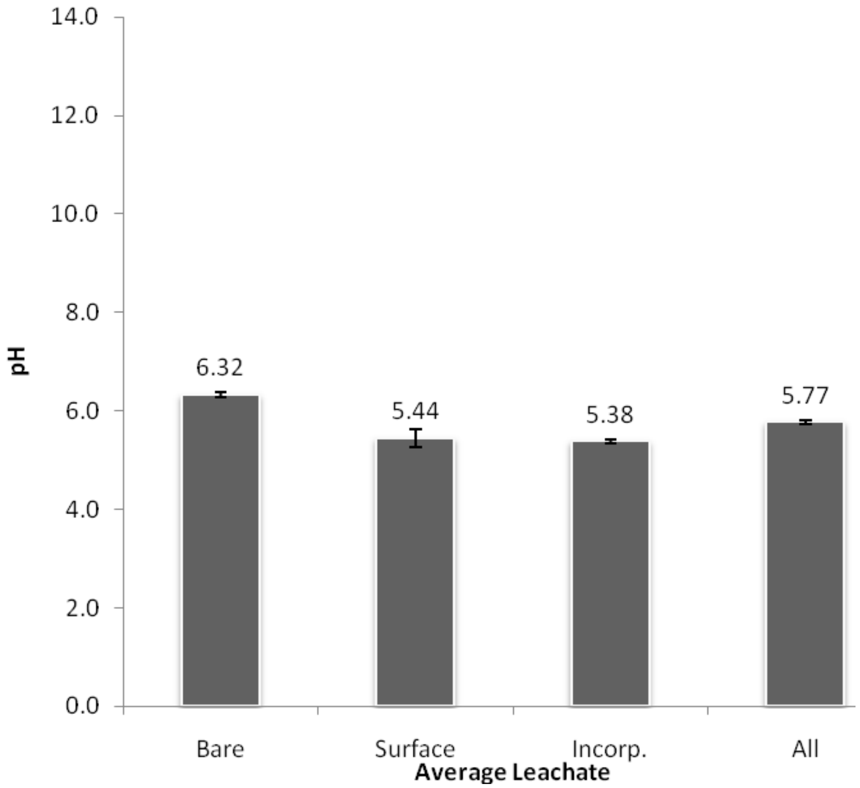

Figure 4. Average pH values from leachate with error bar of standard deviation of the means.

5.3 NO_3-N

The analysis that is highly important to recognize is the averaged values of NO_3-N (Figure 5). These values range from greatest to lowest with *all* > *surface* > *incorp.* > *bare*. Note that *incorp*. has roughly 523 times more NO_3-N than *bare* and *all* has roughly 3 times more NO_3-N than *incorp.*. *Surface* has roughly 1.08 times more NO_3-N than *incorp.*.

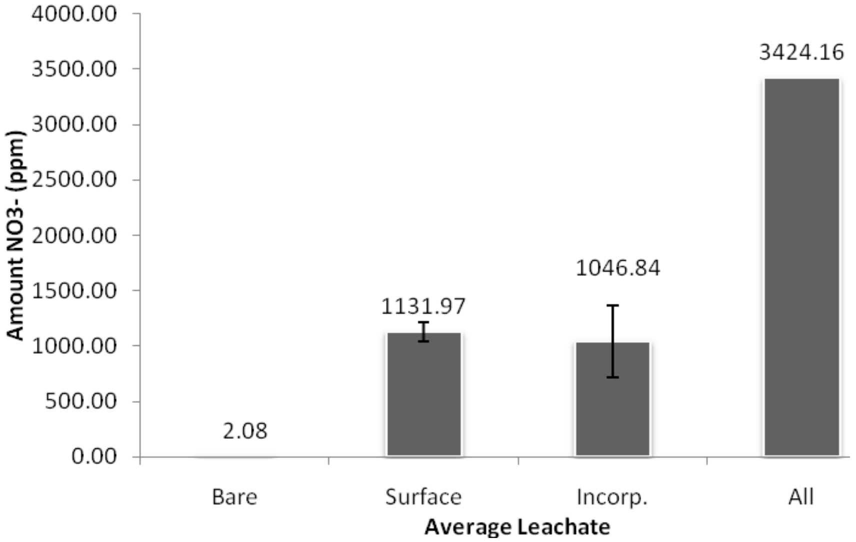

Figure 5. Average NO_3-N collected from leachate.

When observing NO_3-N data, *bare* is well below the EPA standards for MCL, however *surface, incorp.* and *all* containing compost highly exceed the MCL 10 ppm standard. In the context of this experiment, it is important to note that these numbers are high because of the relatively low volume of soil in the tube and height of the soil column. These numbers show that high amounts of NO_3-N leach from the tubes with compost application, which is expected from compost due to its humic composition used as a soil amendment.

Another factor to be considered is observing the standard deviation from the original replication of treatments. For example, the standard deviation of the three test replicates for *incorp*. was 324.28, whereas *surface* was 85.31. This is believed to be primarily due to human error by method of application, set-up or inconsistencies. However, it is important to notice the averaged treatment values between *surface*: 1131.97 and *incorp*.: 1046.84 not being significantly different. This leads to the conclusion that the two treatments with soil and compost *surface* and *incorp*. do not differ between NO_3-N leaching and therefore, should not be the primary factor when considering compost application method.

5.4 Other Trends

In observing the data of pH, EC and total N and C a trend can be observed in the similarities between *surface* and *incorp.*. This is expected because the properties of the tube contain the same amounts of soil and compost. Therefore, the infiltrated leachate should have similar measured results if there was no alteration to the application method. This would imply that there is no significant difference in leachate material between *surface* and *incorp.*.

6. CONCLUSION

This study was conducted to evaluate the potential difference in leachate material between the application method of four different treatments *bare, surface, incorp.* and *all*. All treatments provided data to draw the conclusion that soil with compost application *surface* or *incorp.* is more effective as an erosion control measure than both bare soil or all compost.

Furthermore, this study was conducted to evaluate the potential difference between compost on top (*surface*) to compost incorporated (*incorp.*). The data indicate that there is no significant difference in leachate material between the two treatments *surface* and *incorp.*. Therefore, further research should be conducted to evaluate which method of application should be used in standard practice.

In the findings of this study, the NO_3-N concentrations of soil with compost were significantly higher than the EPA standards for MCLs for NO_3-N. This is a concern for possible leaching of NO_3-N into groundwater, which can lead to concerns in environment. Further research for understanding this specific concern would need to be addressed, but for the purpose of this study this data was sufficient to draw conclusions that NO_3-N does leach from the treatments with soil and compost. Furthermore, NO_3-N leaching should not be the only factor to consider when choosing an application method for soil and compost.

Though, it was found that NO_3-N does leach from the treatments with compost, compost is still a widely used material that has many benefits. Some of these benefits include: reduce stormwater runoff volume and velocity, improve soil water holding capacity and improve soil structural properties (California Department of Transportation, 2010). Future research should investigate the roll of vegetation in NO_3-N phytoremediation.

7. REFERENCES

California Department of Transportation. 2010. Compost (Incorporate). Available at http://www.dot.ca.gov/hq/LandArch/ec/organics/compost_incorporate.htm (accessed 21 July 2010). California Department of Transportation, Sacramento, CA.

Confesor, R.B., J.M. Hamlett, R.D. Shannon, R.E. Graves. 2007. Movement of nitrogen and phosphorus downslope and beneath a manure and organic waste composting site [Online]. Available at http://www.lib.calpoly.edu/ (accessed 22 July 2010). Compost Science & Utilization. Vol. 15 (2):119-126.

Environmental Protection Agency. 2010. Basic information about nitrate in drinking water. Available at http://www.epa.gov/safewater/contaminants/basicinformation/nitrate.html (accessed 21 July 2010). Environmental Protection Agency, Washington, DC.

Environmental Protection Agency. 2010. Environmental Benefits- Composting. Available at http://www.epa.gov/osw/conserve/rrr/composting/benefits.htm (Accessed 25 August 2010). Environmental Protection Agency, Washington, DC.

Frink, C., B. Sawhney. 1995. Leaching from composted biosolids [Online]. Available at http://web.ebscohost.com.ezproxy.lib.calpoly.edu (accessed 21 July 2010). Biocycle. Vol. 36 (4):31.

Jaber, F.H., S. Shukla, P.J. Stoffella, T.A. Obreza and E.A. Hanlon. 2005. Impact of organic amendments on groundwater nitrogen concentration for sandy and calcareous soils [Online]. Available at http://lib.calpoly.edu/ (accessed 21 July 2010). Compost Science & Utilization. Vol.13 (3):194-202.

Li, Y.C., P.J. Stoffella. 1997. Leaching of nitrate, ammonium, and phosphate from compost amended soil columns [Online]. Available at http://web.ebscohost.com.ezproxy.lib.calpoly.edu (accessed 21 July 2010). Compost Science & Utilizatio. Vol. 5 (2):63.

National Resources Conservation Service. 2007. National Engineering Handbook: Hydrology. Available at http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba (accessed 22 July 2010). USDA, Washington, DC.

Shrestha, R.K., L.R. Cooperband, A.E MacGuidwin. 2010. Strategies to reduce nitrate leaching into groundwater in potato grown in sandy soils: Case study from North Central USA [Online]. Available at http://www.lib.calpoly.edu/ (accessed 22 July 2010). Am. J. Pot. Res. 87:229-244

Singer, M.J. and D.N. Munns. 2006. Soils: An Introduction. P. 39, 54. Pearson Prentice Hall, Upper Saddle River, New Jersey.

United States Composting Council. 2010. Seal of Testing Assurance. Available at http://www.compostingcouncil.org/programs/sta/ (accessed 21 July 2010). USCC, Rokonkoma, NY.

WSS – Web Soil Survey. 2009. Web Soil Survey. Available at http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx. USDA-NRCS, Washington, DC.

8. APPENDICES

Appendix A Table of Parameters for Hydrologic Soil Groups

Table 7–1 Criteria for assignment of hydrologic soil groups when a water impermeable layer exists at a depth between 50 and 100 centimeters [20 and 40 inches]

Soil property	**Hydrologic soil group A**	**Hydrologic soil group B**	**Hydrologic soil group C**	**Hydrologic soil group D**
Saturated hydraulic conductivity of the least transmissive layer	>40.0 µm/s (>5.67 in/h)	≤40.0 to >10.0 µm/s (≤5.67 to >1.42 in/h)	≤10.0 to >1.0 µm/s (≤1.42 to >0.14 in/h)	≤1.0 µm/s (≤0.14 in/h)
	and	and	and	and/or
Depth to water impermeable layer	50 to 100 cm [20 to 40 in]	50 to 100 cm [20 to 40 in]	50 to 100 cm [20 to 40 in]	<50 cm [<20 in]
	and	and	and	and/or
Depth to high water table	60 to 100 cm [24 to 40 in]	60 to 100 cm [24 to 40 in]	60 to 100 cm [24 to 40 in]	<60 cm [<24 in]

Table 7–2 Criteria for assignment of hydrologic soil groups when any water impermeable layer exists at a depth greater than 100 centimeters [40 inches]

Soil property	**Hydrologic soil group A**	**Hydrologic soil group B**	**Hydrologic soil group C**	**Hydrologic soil group D**
Saturated hydraulic conductivity of the least transmissive layer	>10 µm/s (>1.42 in/h)	≤10.0 to >4.0 µm/s (≤1.42 to >57 in/h)	≤4.0 to >0.40 µm/s (≤0.57 to >0.06 in/h)	≤0.40 µm/s (≤0.06 in/h)
	and	and	and	and/or
Depth to water impermeable layer	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]
	and	and	and	and/or
Depth to high water table	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]	>100 cm [>40 in]

Appendix B Table of Physical Requirements for USCC STA Program

Table 1. Physical Requirements for Compost

Parameter	Range	Testing Method
pH	5.0-8.5	TMECC 4.11A
Soluble Salt Concentration	< 10dS/m	TMECC 4.10-A
Moisture	30-60% wet weight basis	SMEWW 2540B
Organic Matter	30-65% dry weight basis	TMECC 5.07-A
Particle Size	98% pass through ¾" screen or smaller	TMECC 2.02-B
Stability (Carbon Dioxide evolution rate)	>80% relative to positive control	TMECC 5.08-B
Maturity (Seed emergence and seedling vigor)	>80% relative to positive control	TMECC 5.05-A
Physical contaminants (man made inerts)	<1% dry weight basis	TMECC 3.08-A
Chemical contaminants	Meet or exceed US EPA Class A standard, 40 CFR § 503.13, Tables 1 and 3 levels:	
Arsenic	< 41ppm	TMECC 4.06-AS
Cadmium	< 39 ppm	TMECC 4.06-CD
Copper	< 1,500 ppm	TMECC 4.05-CU
Lead	< 300 ppm	TMECC 4.06-PB
Mercury	< 17 ppm	TMECC 4.06-HG
Molybdenum	< 75 ppm	TMECC 4.05-MO
Nickel	< 420 ppm	TMECC 4.06-NI
Selenium	< 100 ppm	TMECC 4.06-SE
Zinc	< 2,800 ppm	TMECC 4.06-ZN
Biological contaminants (pathogens)	Meet or exceed US EPA Class A standard, 40 CFR § 503.32(a) levels:	
Fecal coliform	< 1,000 MPN per gram, dry weight basis	TMECC 7.01
Salmonella	< 3 MPN per 4 grams, dry weight basis	TMECC 7.02

Recommended compost testing methodologies and sampling procedures are provided in Test methods for the Examination of Composting and Compost (TMECC)[1], and Standard Methods for the Examination of Water and Wastewater[2].

Appendix C Caltrans Requirements for Compost (incorporated)

Physical and Chemical Requirements

Property	Test Method	Requirement
pH	TMECC 04.11-A Elastometric pH 1:5 Slurry Method pH Units	6.0–8.0
Soluble Salts	TMECC 04.10-A Electrical Conductivity 1:5 Slurry Method dS/m (mmhos/cm)	0–10.0
Moisture Content	TMECC 03.09-A Total Solids & Moisture at 70+/- 5 deg C % Wet Weight Basis	30–60
Organic Matter Content	TMECC 05.07-A Loss-On-Ignition Organic Matter Method (LOI) % Dry Weight Basis	30–65
Maturity	TMECC 05.05-A Germination and Vigor Seed Emergence Seedling Vigor % Relative to Positive Control	80 or Above 80 or Above
Stability	TMECC 05.08-B Carbon Dioxide Evolution Rate mg CO_2-C/g OM per day	8 or below
Particle Size	TMECC 02.02-B Sample Sieving for Aggregate Size Classification % Dry Weight Basis	Inches % Passing 3 99% 3/8 < 25% Max. Length 4 inches
Pathogen	TMECC 07.01-B Fecal Coliform Bacteria < 1000 MPN/gram dry wt.	Pass
Pathogen	TMECC 07.01-B Salmonella < 3 MPN/4 grams dry wt.	Pass
Physical Contaminants	TMECC 02.02-C Man Made Inert Removal and Classification: Plastic, Glass and Metal % > 4mm fraction	Combined Total: < 1.0
Physical Contaminants	TMECC 02.02-C Man Made Inert Removal and Classification: Sharps (Sewing needles, straight pins and hypodermic needles) % > 4mm fraction	None Detected

NOTE: TMECC refers to "Test Methods for the Examination of Composting and Compost," published by the United States Department of Agriculture and the United States Compost Council (USCC).

Appendix D Table of Experimental Set-Up with Three Statistical Replicates

	Controls		Treatments	
Tube	All Compost	All Soil	Soil + Incorp	Soil + surf app.
1	**x**			
2	**x**			
3	**x**			
4		**x**		
5		**x**		
6		**x**		
7			**x**	
8			**x**	
9			**x**	
10				**x**
11				**x**
12				**x**

Appendix E Raw Data from Analysis

	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3
Time of Breakthrough (hrs:min:sec)	3:03:45	3:26:25	3:16:00	2:49:53	3:56:40	0:23:02	1:03:15	1:35:11	1:35:20	0:19:44	0:17:55	0:28:44
Amount of leachate (mL)	470	480	400	500	500	400	485	440	460	550	500	540
pH	6.27	6.31	6.39	5.55	5.54	5.23	5.43	5.36	5.35	5.72	5.77	5.81
EC (dS/m)	0.27	0.29	0.29	12.54	12.84	13.34	8.72	13.86	13.22	35.55	33.23	33.24
NO3- electrode (ppm)	2.23	2.05	1.97	1082.72	1082.72	1230.48	677.32	1284.08	1179.11	3424.16	3424.16	3424.16
% N	0.001	0.006	0.003	0.129	0.127	0.139	0.080	0.140	0.121	0.341	0.326	0.335
% C	0.055	0.067	0.049	0.074	0.068	0.071	0.058	0.089	0.075	0.169	0.161	0.173