Evaluating the Performance of Tire Derived Aggregate (TDA) vs Natural Aggregate in Septic System

By

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Abstract

This research evaluated the performance of two materials, tire derived aggregate (TDA) and natural aggregate, in the septic field. A full-scale septic system was constructed in Manitoba to investigate the metal leaching effects of TDA in septic fields. The TDA was selected as an alternative to conventional natural aggregate. TDA is one of the repurposing materials made from scrap tires. At the end of its life, scrap tires became a stockpile in a landfill. These stockpiles serve as breeding grounds for diseases carried by mosquitoes and rodents that pose a risk to human health once ignited. The price of disposal of scrap tires led researchers to study beneficial waste tire reuse. A significant use is the use of TDA is to replacement for rock aggregate in different engineering applications. The type A nominal TDA made from off- the road tires was the aggregate chosen for this research. TDA and natural aggregates were implemented in a two-zone trench-style septic field, receiving wastewater from a two-compartment septic tank of a three-bedroom house. The system's effluent was monitored in the trenches as well as in the soil below the trenches (vadose) at depths of 1 ft and 3 ft. Results of comparison testing between both aggregates showed that the reductions in COD, phosphorous and ammonia concentrations were achieved in both systems without significant differences between the treatments. Concentrations of Ag, Al, Cu, Fe, and Zn in the vadose were below the National Secondary Drinking Water Regulations (NSDWRs). Mn was the only metal that exceeded the NSDWRs in both treatments at one foot below the trench base. Zn, Mn, Cu, Fe and Cr in soil samples were below or within ranges of uncontaminated soils in Manitoba or worldwide. Results suggest that TDA is a feasible substitute for natural aggregate in the septic field.

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Contents

List of Tables

List of Figures

List of Abbreviations

TDA	Tire Derived Aggregate
PLT	Passenger Light Tire
OTR	Off-the Road Tire
TCOD	Total Chemical Oxygen Demand
NH_4^+-N	Ammonium Nitrogen
PO_4-P	Orthophosphate
TSS	Total Suspended Solids
MCL	Maximum Contaminant Level
US EPA	United State Environmental Protection Agency
MR	Manitoba Regulation

1. Introduction

1.1 Conventional septic system

Since 800 BC, societies and governments have been striving to enhance the removal of human waste from residential areas and effectively treat that waste to decrease threats to public health and ecological resources (US EPA, 1980). At that time, human waste (i.e. discharge) was released into surface water to contaminate the lakes and rivers, which led to frequent outbreaks of diseases like cholera and typhoid fever (US EPA, 1980).

By the end of-1800s, The Massachusetts State Health Board and other state health organizations had documented linkages between disease and poorly treated sewage and suggested wastewater treatment through intermittent sand filtration and land use of the resulting sludge (US EPA, 1980). The septic system is also known by several other names such as onsite wastewater treatment system, decentralized wastewater treatment system, cluster system, package plant, on-lot system, individual sewage disposal system, and private sewage system (US EPA, 1980).

Nowadays, septic systems are a form of simple, low-cost wastewater treatment. The septic system is designed and installed to manage the wastewater produced from a rural location with no connection to a centralized wastewater system. Septic system is primarily used for single or multi-family residences to treat household wastewater.

1.1.1 Septic system components:

Typically, a septic system consists of a septic tank and a septic field. The solid waste within wastewater settles at the bottom of the septic tank, and the resulting clarified effluent is transferred out of the septic tank into the septic field and the surrounding soil. The septic tank effluent flows by gravity or is pumped to a distribution box or a header to a septic field.

For septic systems, the primary treatment takes place in the septic tank. The tank can be used as a holding tank or in combination with other processes before the wastewater is discharged into a septic field. The septic tank must be installed underground, and the manufacturing material can be concrete, fibreglass or polyethylene/plastic tank. One of the most critical design considerations is that the septic tank must be sufficiently large to provide a hydraulic retention time between 6 and 24 hours (US EPA, 1980).

The number of bedrooms, the number of people in the house, the dwelling's square footage, and water-saving fixtures dictate the size of the septic tank. A volume of 1,000 gallons is required for a three-bedroom dwelling with four inhabitants and no water-saving fixture (US EPA, 1980). The septic tank could comprise one or two compartment tanks. A two-compartment tank includes a sedimentation chamber and a control chamber. The role of the sedimentation chamber is to settle, store and stabilize the suspended solids in the raw wastewater (US EPA, 1980). In Manitoba, the capacity of the sedimentation chamber must be higher than 140% of the total daily sewage flow or a minimum capacity of 500 gallons. The minimum capacity of the control chamber must be higher than 75 gallons or 20% of total daily sewage flow (MR, 83/2003).

1.1.2 Septic field types

The septic field receives the effluent from the control chamber of the septic tank, either by gravity or pressure distribution. The most widely used methods of disposal of wastewater from a single residence can be classified into three groups: surface soil absorption systems, evaporation systems and treatment systems that discharge to surface water (US EPA, 1980). The most commonly installed septic field in Manitoba is the surface soil absorption system, which comprises total area fields, trench field using pipe and stones or wastewater effluent chamber and sand treatment mounds.

The shape of the total area fields is square or rectangular excavations filled with washed natural aggregate. The system is constructed by excavating 3.25 feet below the surface. Two feet of natural aggregate are placed into the excavated area and level. The perforated pipe is positioned in an evenly spaced pattern from a central distribution box. 4 to 6 inches of natural aggregate are placed on top of the perforated pipe and covered with a geotextile material to prevent the topsoil placed on top to clog the system. The system is covered with topsoil, sloped and seeded with grass. The total area field system cannot be installed when the percolation rate is slower than 60 min per inch (US EPA, 1980).

The trench type of disposal field is another conventional disposal system. The trench type consists of a series of trenches filled with natural aggregate and pipes or wastewater effluent chambers. The trenches are typically 3.25 feet deep and have a maximum width of 2-3.25 feet. The perforated pipe is placed out in the middle of the trenches and is covered 4 to 6 inches of natural aggregate. To prevent trench clogging, the trench surface is covered with a geotextile material. The trenches are covered with topsoil, sloped and seeded with grass. The trench field system cannot be installed when the percolation rate is slower than 120 min per inch (US EPA, 1980).

Another septic system used in Manitoba is the sand treatment mound. The sand treatment mound is used when the conventional soil absorption system is prohibited from installing. The limitations are slowly permeable soils, shallow permeable soils above creviced or porous bedrock, and high-water tables permeable soils (US EPA, 1980). For uniform effluent distribution, a pressurized effluent is required and is applied intermittently to the top of the sand layer of the mound. The top of the mound is narrow and long, which helps to maintain an aerobic condition in the mound. The width of the sand layer at the base of the mound varies from 3 to 10 feet (US EPA, 1980).

1.1.3 Septic tank treatment

The basic septic tank system is the most generally recognized primary treatment option for onsite wastewater treatment due to its numerous advantages. Septic tanks remove the majority of settleable particles and operate as an anaerobic bioreactor, allowing organic matter to be partially digested. The inadequacy of the soil and site features is the primary reason for their failure (Les & Ashantha, 2003). The system is cheap and easy to run and maintain; however, if left untreated for an extended period of time, sludge may create an odour issue (He, et al., 2012 Jun). Chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), and total Kjeldahl nitrogen (TKN) are all removed to a certain extent by the traditional septic tank (Andreadakis & Christoulas, 1982)

The first stage of the biochemical treatment of the wastewater is carried out in the sedimentation chamber. Oil, grease and floating solids form the scum layer at the top of the wastewater column. Settable solids form the sludge layer at the bottom of the sedimentation chamber. The removal rate of these solids ranges between 60-80% in this first stage (US EPA, 1980). The wastewater effluent characteristics vary on the influent characteristics and condition of the tank.

Total suspended solids (TSS) in domestic septic tank effluent may vary in quality according to the characteristics of the wastewater and if the tank is equipped with an effluent filter or not. The TSS effluent concentration leaving a septic tank, which is not equipped with an effluent filter, ranges from 40 to 140 mg/l; however, TSS concentration from a septic tank equipped with an effluent filter ranges from 20 to 55 mg/l (Crites & Tchobanoglous, 1998). Moreover, a well-functioning conventional septic tank would reduce TSS by 70 percent. Typically, effluent leaving a domestic septic tank, not equipped with an effluent filter, has a TSS concentration ranges from 49 to 161 mg/L (US EPA, 2002).

A septic tank serves as a primarily settling chamber under anaerobic conditions that contributed to the decrease of the wastewater of the organic and suspended solids (Goldstein & Wenk, 1972), (Carter & Knox, 1985). According to (Lawrence, 1973); (Carter & Knox, 1985); (Beal, Gardner, & Menzies, 2005), the environment within a septic tank is generally inefficient in decreasing the nutrient loading of wastewater, functionating solely to convert influent organic-N to ammonium and accomplishing minimal total_n removal throughout the process. Similarly, under the anaerobic conditions in the tank, convert the majority of the influent phosphorous, both organic and condensed phosphate, to soluble ortho-P, which is then eliminated with the effluent ((Bouma, et al., 1972); (Zanini, Robertson, Ptacek, Schiff, & Mayer, 1998); (Beal, Gardner, & Menzies, 2005).

According to (Henze , van Loosdrecht, Ekama, & Brdjanovic, 2008), nitrogen is one of the nutrients which is essential for the growth of the cells. Nitrogen presents in domestic wastewater in the form of organic nitrogen (10 mgN/L), ammonia (45 mgN/L), nitrate and nitrite (0.2 mgN/L). The sum of ammonium and organic nitrogen represents Total Kjeldahl Nitrogen (TKN). The excess of TKN in the receiving waters can be harmful to aquatic life. Therefore, removing nitrogen from wastewater is required to reduce the ammonium as well as the total nitrogen prior to discharge into receiving waters. The main components of the biological removal of nitrogen from wastewater are ammonification, nitrification and denitrification. (van Haandel & van der Lubbe, 2012).The conversion of the organic nitrogen into ammonium happens during the ammonification phase.

Under aerobic conditions, nitrification occurs, and ammonium is oxidized to nitrite and then nitrite to nitrate. The biological conversion of nitrate in anoxic reactors into nitrogen gas is called denitrification. The conversion of ammonium to nitrite and nitrate happens under aerobic conditions in the trenches. Organic nitrogen in the form of urea, dead cell material, amino acids and proteins represents the human excrete. Nitrogen removal in the septic tank could be achieved in the form of sedimentation and filtration of the particulate nitrogen that presents in the suspended solids. Under the anaerobic conditions in the septic tank, the organic nitrogen could be converted to ammonium. The concentration of total nitrogen in the septic tank effluent ranges between 33 and 171 mgN/L for domestic wastewater. The average TKN in the domestic wastewater from the septic tank effluent ranges between 39 and 82 mgN/L

Phosphorus in domestic wastewater presents in two forms: organic P contributed by human excreta; and inorganic P, which is contributed from detergents (such as laundry and dish soap) and cleaning products (Mary Lusk et al 2011). According to (USA EPA, 2002), the total phosphorus in the raw wastewater is sourced mainly from the toilet (59%), bath and toilet sink (37%), and the kitchen sink (4%). As particles build at the bottom of the septic tank, some P removal is anticipated. Any variations in total phosphorus concentrations between raw wastewater and septic tank effluent are often attributable to phosphorus buildup in residual sludge at the bottom of a septic tank. As particles sink to the bottom of the septic tank, about 20%–30% of P should be removed.

Consequently, septic tank effluent nearly invariably includes total phosphorus concentrations between 80% and 100% of those observed in raw wastewater (Lowe, et al., 2007); (McCray, et al., 2009) (Crites & Tchobanoglous, 1998). Otherwise, there are no effective methods for removing phosphorus from septic tanks. According to (Lowe, et al., 2007), the median concentration of total P in raw wastewater is 19 mg/L and in septic tank effluent is 10 mg/L. Comparing these figures indicates that the septic tank's P removal rate is close to 50%. P removal rates in the septic tank may is lower. The next chance for P removal occurs when septic tank effluent travels into the septic field, where it may react with soil components in various ways.

1.1.4 Septic field treatment

Soil is the element in the final treatment phase that facilitates biological and chemical processes that treat wastewater. Most of the treatment of effluent occurs in the soil underlying the septic field itself. As effluent enters this underlying soil, many of the disease-causing bacteria are filtered out. Smaller viruses are also absorbed by the soil until they are destroyed. The soil can also retain phosphorus and nitrogen, which can be utilized by plant life. However, the nitrate form of nitrogen can and does move down through the soil and may impact groundwater in granular soil and shallow aquifers (USA EPA, 2002).

A biological layer or biomat is formed in the trench by anaerobic bacteria. These bacteria secrete a gluey or sticky substance and anchor themselves to the soil or rock particles. This biomat forms first along the trench bottom, as the effluent from the septic tank begin to pond in the trench, along the soil surfaces on the sidewalls. When fully developed, the gray-to-black slimy biomat layer is about 1 inch (2.5cm) thick. Purification and hydraulic performance are complicated biogeochemical processes that have been found to be strongly affected by the biomat zone that develops at the soil–gravel interface along the base and wetted sides of septic trenches (Beal, Gardner, & Menzies, 2005).

1.2 On-site regulation

On-site Wastewater Management Systems (OWMS) is a program that administrates the Onsite Wastewater Management Systems Regulation (MR, 83/2003) under the Environment Act. In Manitoba, besides OWMS Regulation, the on-site certified installers must consider the Nutrient Management Regulation (MR, 62/2008) under The Water Protection Act. The purpose of the regulation is to monitor water quality by managing the discharge of harmful nutrients in the province. The Nutrient Management Regulation prohibits the installation, replacement, expansion or modification of OWMS in some regions of the province. Prior to installation, the certified installer must determine if the proposed septic system is in a Nutrient Management Zone N4 and within the Nutrient Buffer Zone.

Nitrogen and phosphorus are the two most essential constituents that exemplify wastewater strength in the septic system. The total phosphorus in domestic wastewater is reported to range between 6-20 mg/L (US EPA, 2002). The introduction of the Government of Canada Regulation Amending Phosphorus Concentration Regulation, P.C. 2009-947 June 2009, has essentially eliminated the use of phosphorus in household laundry and dishwasher detergents. Consequently, the phosphorus concentration in domestic wastewater is expected to decrease by 60% or more. EPA has established National Secondary Drinking Water Regulations (NSDWRs) that set non-mandatory water quality standards for 15 contaminants. EPA does not enforce these secondary maximum contaminant levels (SMCLs). They are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, colour and odour. These contaminants are not considered to present a risk to human health at the SMCL. Table 1 below shows the secondary water standards for 15 contaminants.

Table 1.1 Secondary maximum contaminant levels

Contaminant	**Secondary MCL**	**Noticeable Effects above the Secondary MCL**
Aluminum	0.05 to 0.2 mg/L*	colored water
Chloride	250 mg/L	salty taste
Colour	15 colour units	visible tint
Copper	1.0 mg/L	metallic taste; blue-green staining
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odour
Iron	0.3 mg/L	rusty colour; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown colour; black staining; bitter metallic taste

Odour	3 TON (threshold odour number)	"rotten-egg," musty or chemical smell
pH	6.5 - 8.5	low pH: bitter metallic taste; corrosion high pH: slippery feel; soda taste; deposits
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye
Sulphate	250 mg/L	salty taste
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; coloured water; staining; salty taste
Zinc	5 mg/L	metallic taste

*mg/L is milligrams of substance per litre of water.

1.3 Tire Derived Aggregate (TDA) leachability potential

Discarding scrap tires present a real concern in many regions of the world. At the end of its life, scrap tires are stockpiled in a landfill. These stockpiles serve as breeding grounds for diseases carried by mosquitoes and rodents that pose a risk to human health. Uncontrolled stockpiles are fire hazards for the environment. Once ignited, the tire stockpiles can burn out of control for months producing acrid black smoke and hazardous oil residue (US EPA, 1993).

In Manitoba, 1 million new tires hit the road every year, and the program responsible for scrap tire collection and disposal is Tire Stewardship Manitoba (TSM). Approximately 31,457 tonnes of scrap tire material was generated from the annual sales of new tires in Manitoba in 2017. However, only 18,364 tonnes of material were collected, which represents 86% of scrap tire material recovery. Recycling is an alternative to landfilling scrap tires. From the recycling products manufactured in Manitoba, 11 percent represent crumb, 12 percent represent cut, and 77 percent represent aggregate (TSM, 2017).

Tire derived aggregate (TDA) is one of the lightweight materials manufactured from scrap tires. TDA can be produced from passenger light tires (PLT) and off-the-road tires (OTR). There are two types of TDA based on the size: Type A with a maximum size of 3 inches (75 mm) and Type B with a maximum size of 12 inches (305 mm) (ASTM, 2009). In various civil engineering applications, including embankments, pavement structures, filling and septic systems, TDA has been used as a substitute for crushed rock aggregate. Type B TDA has already been utilized as lightweight fill for the reconstruction of many municipal roads in Manitoba. Scrap tire collected in Manitoba is repurposed in paving, landscape and roofing tiles and utilized as fill for road construction, sidewalls, crumb or blast mats.

1.3.1 Tire composition

The PLT tire's composition includes more synthetic rubber than natural rubber; truck tires consist of more natural rubber; and off-road (OTR) tires, including heavy mining tires, as well as agricultural and industrial tires, contain insignificant amounts of synthetic rubber. As a manufacturer, to be successful in the competitive market, the PLT’s rubber composition must reach very higher quality standards such as low rolling resistance, improved skid resistance and excellent wear. On the other side, OTR and truck tires have to deal with heavy loads and longer distances instead of high speeds (Pehlken & Essadiqi, 2005).

Table 1.3 Typical composition of passenger and truck tires in North America

Composition	Passenger Tire	Truck Tire
Natural Rubber	14%	27%
Synthetic Rubber	27%	14%
Carbon Black	28%	28%
Steel	14-15%	14-15%
Fibre, fillers, accelerators,antiozonannts, etc.	16-17%	16-17%

The tires manufacturer does not disclose the precise compositions of tires because they are a trade secret. All data are, therefore, assumptions and an average of all tires. There are two distinct roles of the steel used in tires. It is used in some tires for belting (below the tread at the tire's outer diameter) and in the circular metal part (bead) that is covered in rubber at the tire's inner diameter. The circular metal part helps to seal the internal diameter against the rim of the vehicle wheel. According to the Rubber Manufacturers Association, a typical passenger-car tire contains about 1.13 kg of steel. Goodyear tires contain a total of 0.9 kg steel in the most popular passenger car tire (P195/75R14) – 0.45 kg of steel in each of the belting and the bead (Pehlken & Essadiqi, 2005).

Table 1.3 Steel analysis (data from Rubber Manufacturers Association, 2004)

Constituent	**Steel Belts**	**Bead Wire**
Carbon	0.67-0.73%	0.60% min.
Manganese	0.40-0.70%	0.40-0.70%
Silicon	0.15-0.03%	0.15-0.30%
Phosphorus	0.03% max.	0.04% max.
Sulphur	0.03% max.	0.04% max.
Cooper	Trace	Trace
Chromium	Trace	Trace
Nickel	Trace	Trace
Coating	66%Copper	98%Brass
Coating	34% Zinc	2% Tin

Tires are made from different rubber compounds and carbon black concentrations, fillers like clay and silica, and chemicals & minerals that allow or accelerate vulcanization. The tires also contain several types of fabric and steel for reinforcement. The composition of PLT and OTR tires is shown in Table 1.4 (Evans A. , 2006).

Table 1.4 Tire composition PLT vs OTR

Constituents	**Passenger Light Truck Tire**	**Off-the-Road Tire**
Rubber/Elastomers	47%	47%
Carbon Black	21.5%	22%
Metal	16.5%	12%
Textile	5.5%	10%
Zinc Oxide	1%	2%
Sulphur	1%	1%
Additives	7.5%	6%
Total Carbon-based material	74%	76%

1.3.2 TDA leachability

The main challenge of using TDA in a septic system is its potential to leach metals and contaminate the groundwater. In North Yarmouth, Maine, a septic field was built under a secondary state highway to explore the impact of TDA above the groundwater table. The results show inorganic substances such as aluminum (Al), chromium (Cr), iron (Fe), lead (Pb), manganese (Mn), and zinc (Zn) that can potentially leach from tires were naturally present at low levels in groundwater (Humphrey & Katz, 2002). No evidence was found that tire shreds increased the concentration of chromium (Cr), copper (Cu) and lead (Pb), which should be low to maintain primary drinking water regulations. Similarly, no evidence was found that tire shreds increased the concentration of aluminum (AI) and zinc (Zn) to maintain secondary drinking water regulations. Iron (Fe) was found to exceed the secondary drinking water standard under some conditions. Tire shreds also increased the levels of manganese (Mn), which exceeded the secondary drinking water regulation. However, manganese only presents an aesthetic concern as it is naturally present in groundwater (Humphrey & Katz, 1999).

Much research has been done to resolve the leaching problem. Another field study was conducted to evaluate the water quality effects of TDA placed below the water table (Humphrey & Katz, 2002). The TDA was buried below the groundwater table and covered with three soil types: peat (P), marine clay (C), and glacial till (T). Aluminum (Al), Arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), Iron (Fe), manganese (Mn), and zinc (Zn) were compared with primary drinking water standards. The results conclude that TDA had an insignificant effect on the concentration of metals with the primary drinking water regulations; however, elevated levels of iron (Fe), manganese (Mn), and zinc (Zn) were found that may exceed the secondary drinking water regulations (Humphrey & Katz, 2002).

An experimental septic system was constructed at the Southern Idaho Regional Landfill (Burnell & MacOmber, 1997). Three trenches were constructed with TDA, natural aggregate and a half-tire gravel-less domed chamber. The landfill’s main office, a scale house, and a public restroom were the wastewater source for the septic system. Concentrations of Cd, Cr, Cu, Pb, Fe, and zinc Zn were determined from all three trenches and from the dosing chamber. For all samples, Cd, Cr, Cu and Pb were found under the detection limit. Iron (Fe) from the TDA trench was three times higher compared with the other two trenches and was above the secondary drinking water standards. The Zn concentration was seven times higher compared with the dosing chamber; however, the concentration was below the secondary drinking water standards.

Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) of the samples was also measured. The BOD decreased in all three trenches compared to the dosing chamber. The COD decreased in the trench filled with natural aggregate and half tire but remained approximately the same in the TDA trench and the dosing chamber. Low TSS values were found in all four cases.

Close to the Massachusetts Military Reservation Base in Falmouth, another study was performed on the full-scale septic system by the Massachusetts Alternative Septic System Test Centre (Sengupta & Miller, 2000). Three septic field trenches were installed; one was filled with natural aggregates, and the other two were filled with TDA. Each trench was lined with a geomembrane to collect and drain all the effluent through an outlet drain, which was then sent to the on-site wastewater treatment plant. After the installation, the septic tank effluent was gravitationally piped to a distribution box (D-box). The pH, alkalinity, BOD, fecal coliform, and ammonium nitrogen (NH4-N) parameters were collected from all three trenches and the D-box. For four months, the pH and alkalinity in the trenches were similar to the pH in D-box. After that, pH and alkalinity in the trenches were lower than the pH in the D-box. The BOD and fecal coliform in the TDA trenches produced a similar degree of wastewater treatment as the natural aggregate trench. Ammonium nitrogen in three tranches was almost negligible compared with the D-box.

1.4 Research objectives and hypotheses

The goal of this thesis is to evaluate the differences between the septic tank and two types of aggregate in the septic field, such as tire-derived and natural aggregate, over a period of 18 months. We want to evaluate the potential of tire-derived aggregate as an alternative to the natural aggregate in the septic field.

The report can be separated into three main sections:

1. The first section investigates the raw wastewater characteristics in the septic tank. The following parameters of the raw wastewater samples will be measured: ammonia, phosphorus (ortho-P), pH, TSS, temperature, TCOD and metal concentrations such as Ag, Al, Cu, Fe Mn and, Zn.
2. The second section presents a comparison of the two-treatment systems and determines the potential of tire-derived aggregate as a suitable alternative for natural aggregate in Manitoba. Treatment performance will be conducted by taking wastewater samples at one foot and three feet below the trenches using suction lysimeters. The following parameters of wastewater samples will be measured: ammonia, nitrite, phosphorus (ortho-P), pH, TSS, TCOD and metal concentrations such as Ag, Al, Cu, Fe Mn and, Zn to see if they meet the secondary drinking water standards.
3. The third section determines whether the tire-derived aggregate can contaminate the soil below trenches. Soil samples will be collected during the installation period and after one year of operation. The soil samples will be analyzed only for the metals (Cr, Cu, Fe, Mn, Zn and Ni) that make up the structure of a tire.

Hypotheses of this research are as follows:

1. The septic tank could reduce the concentration of suspended solids in the wastewater, which results in reducing the concentration of organic matter and nutrients by removing the particulate matter.
2. Both TDA and Natural aggregates could enhance the biological removal of organic matter and nutrients by creating the aerobic treatment conditions, which favours the activity of the microorganisms formed on the surface of the soil at the bottom and sides of the trenches (biomat).
3. The biological wastewater treatment could be achieved by the seepage of wastewater through the soil at the bottom of trenches. It is hypothesized that aerobic treatment could happen in the upper layer, and anaerobic treatment could be achieved in the lower layers.
4. It is hypothesized that the leaching of the metals from the tire-derived aggregates would not cause secondary drinking water contamination.

2.Materials and Methods

2.1 Site assessment

The site conditions were assessed on August 13, 2015. Two soil pits were excavated in a small wooded area close to the house. Each soil pit was excavated to a depth of 4 ft. Site assessment results, location of the soil pits and detailed soil profile descriptions are attached in *Appendix 1*.

2.2 Site location

The location of the septic system was in the RM of Siglunes in the Interlake area of Manitoba. A full-scale septic field was installed on September 16, 2016, by a certified installer. The role of the septic field is to provide a proper distribution of the liquid wastewater to the surrounding soil for effective treatment. Natural aggregate (stone) is typically used to distribute the wastewater to the surrounding soil in most septic field installations. Once the new system was installed, the existing septic system was dismantled. The solids and wastewater in the existing septic were pumped out and disposed of by the local hauler. The septic tank was then filled with sand. Manitoba Sustainable Development environment officer conducted the final field inspection on September 30, 2016. The system was allowed to warm up, and after one month, the first set of samples was collected.

Figure 2.1. An aerial photo of the septic system located in RM of Siglunes, Manitoba

2.3 Design criteria

The septic system was designed under the Environment Act (C.C.S.M. C. E125), Onsite Wastewater Management Systems Regulation (RM 83/2003). The design criteria for the three-bedroom house were calculated based on the number of bedrooms in the house, as is shown in the equation below.

Daily wastewater flow = (110 gallons/ bedroom) x 3 bedrooms =330 gallons.

In Manitoba, the capacity of the sedimentation chamber must be higher than 140% of the total daily sewage flow of 500 gallons. Therefore, a 1000-gallon septic tank was designed. The sedimentation chamber and pump chamber were designed to hold 500 gallons each.

Figure 2.2 Septic tank installation

Septic field size:

Based on the site assessment report, the depth of the trench was designed to be 2 ft. This was due to the best drainage and improved permeability and treatment of soil at this depth. The width of the trench was 2 feet.

$$Length\ of\ Trench = \frac{Daily\ Effluent\ Flow}{Application\ Rate * Application\ Area} \qquad \text{(Eq. 2.1)}$$

Where: Application rate =0.17 gal/ft² day

Daily effluent flow = 330 gal/day

Application area = 330 ft²

The total length of the trench was 647 ft (rounded to 640 ft for design/installation purposes). A total of 8 trenches were installed, and each trench was 80 ft. in length, 2 ft in width and 24 inches in depth below the ground. Four trenches were filled with 20 inches of natural aggregate.

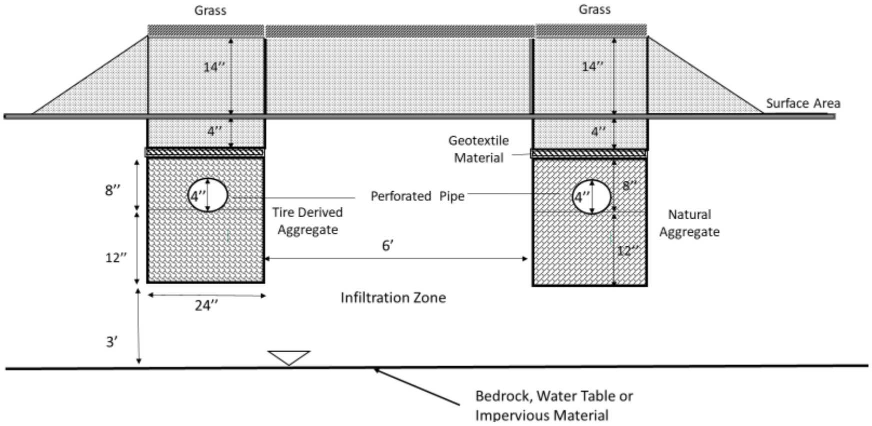

Figure 2.3 Trenches layout- not according to scale

Between TDA and natural aggregate, a layer of non-woven geotextile filter fabric was placed, and the trenches were covered with 18 inches of sandy loam soil, as shown in figure 2.3.

Figure 2.4 Trench installation

Cleaned and washed graded stone with the size ranging between 3/8 -3 inches were used as a natural aggregate. The other four trenches were filled with 20 inches of TDA. The TDA material used for the experiment was not screened and was manually sorted coming off the discharge conveyor. The TDA manufacturer provided a 2 to 4-inch nominal TDA, which represents 90 percent of the material used in the research project. 16.71 tonnes of TDA were used in the tranches compare to 60 tonnes of natural aggregate.

Figure 2.5 TDA vs Natural Aggregate

2.4 Septic System components

Three main components of the septic system are (1) a septic tank with an effluent filter, (2) a pump system with a control panel, and (3) a septic field.

2.4.1 Septic tank

One thousand-gallon fibreglass septic tank with two compartments and poly access risers over both manholes were installed. A PL-122 effluent filter by Polylok was installed between the two compartments of the septic tank. The effluent filter protects the pump in the second compartment and reduces the solid field loading. The septic tank was designed to be structurally sound, watertight and corrosion-resistant according to the CSA standards. The poly access risers were watertight and were fitted with secure poly lids. The tank was water tested in the field as per the manufacturers' specifications.

2.4.2 Pump system

A Liberty Pump (250 Series Submersible Effluent Pump) with 1/3 HP was installed in the second compartment of the septic tank. Floats with an On/Off and high-level alarm were also installed. The floats were secured to a floating bracket assembly constructed according to PVC Schedule 40 pipe. A Digital control panel (Friendly Series® -IFS In-Site® Single Phase Simplex) with an audible alarm was installed, which was also used to turn the pump On/Off. The high-level alarm float was connected to the control panel, which was installed on the house wall.

2.4.3 Septic field

Polyethylene pipe with a 2-inch diameter was used to connect the pump chamber to the distribution box (15-gallon Polylok 20”). The distribution box was designed with one inlet from the pump line, eight outlets with speed dials to adjust the flow and a removable lid with isolation. Each outlet was connected to a PVC distribution perforated pipe with a 4-inch diameter and 80 ft length. All pipes, fittings, valves and plumbing materials meet CSA or ASTM approval standards.

A total of 16 monitoring wells were installed in the field to observe system performance and monitor the wastewater in the trenches and high seasonal groundwater table levels. The PVC monitoring wells were 4.0 inches in diameter and were situated at the bottom of the trench. These wells were spaced 30 feet from both ends of the trench. The monitoring wells were perforated with 0.5-inch diameter holes in the bottom 6.0 inches of the pipes. The holes were covered with non-woven geotextile fabric. The wells were equipped with removable caps. Two monitoring wells per trench were installed. Sixteen lysimeters were installed during the trench excavation to extract the soil water from the saturated zone under the trenches. For each treatment, four lysimeters were installed at 1 foot deep under the trench base, and the other four were installed at 3 feet depth under the trench base. The layout of the system is shown in the figure below (not at scale).

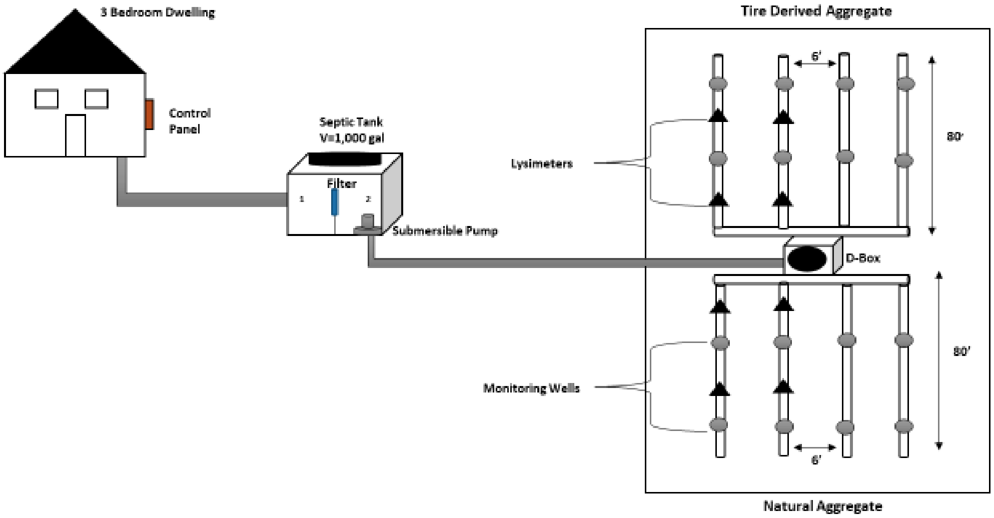

Figure 2.6 Septic system layout- not according to scale

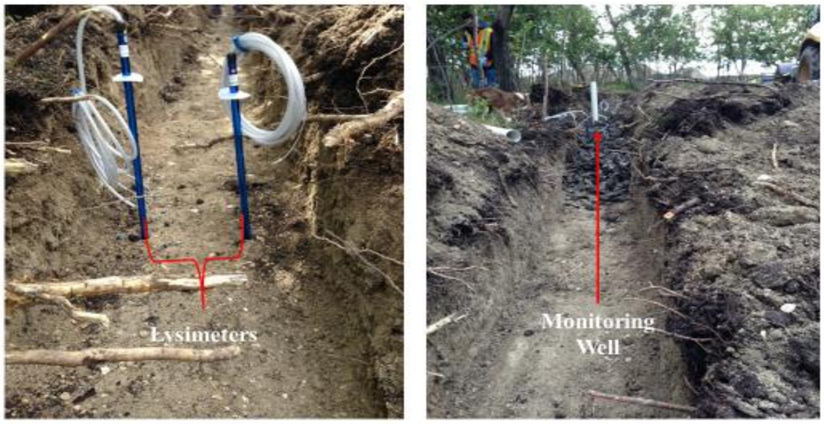

Figure 2.7 Lysimeter and Monitoring well installation

2.5 Septic system samples collection points and procedure

The wastewater samples from the septic field were stored and transported in an insulated cooler with ice packs to the Environmental Engineering Laboratory at the University of Manitoba and stored in a refrigerator at 4°C and analyzed within 24 hours.

The samples were analyzed for pH, temperature, NH4-N, NO3, PO4-P, TCOD, TSS and metal concentrations. From the lysimeters, the concentration of metals (Ag, Al, Cu, Fe Mn, Pb, Zn) was determined to see if they meet the secondary drinking water standards. Soil samples were collected during the installation period and after one year of operation. The soil samples were analyzed only for these metals that are included in tire composition, such as Cr, Cu, Fe, Mn, Zn and Ni. The pH and temperature were measured in the field. The temperature data was measured with a DO meter (Orion 3 star, Thermo Scientific, State, Country) and an accompanying probe. The sampling location can be seen in figure 2.8. The figure below shows the sampling location for different parameters.

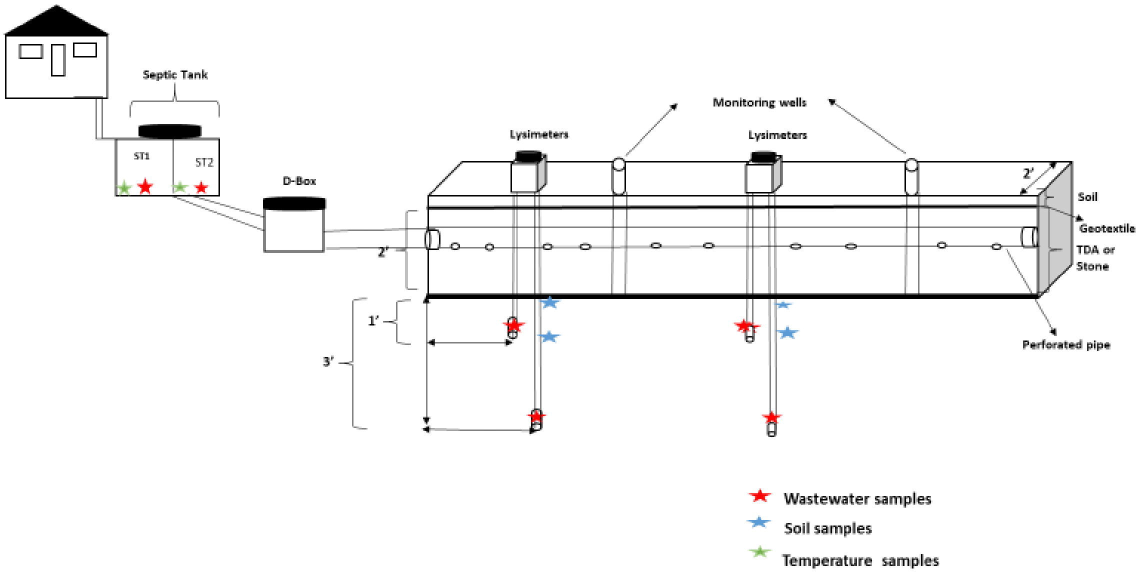

Figure 2.8 Sampling Location

Soil samples were collected during the system installation and trench excavation and were called initial soil samples. The initial samples were collected at the base of the trench and one foot below the trench, where the 1-foot lysimeters were installed, as shown in figure 2.9.

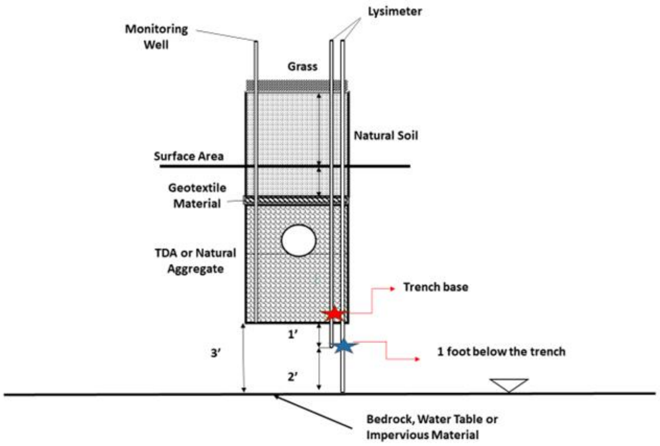

Figure 2.9 Soil Sampling Location

After one year of system operation, the sample locations were closed to the lysimeter boxes, as is shown in figure 2.10. The soil samples were taken from the same depth as the initial soil samples.

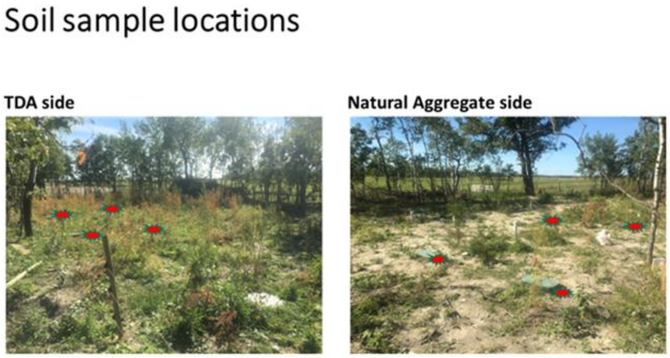

Figure 2.10 Soil Sampling Location in the Field

2.6 Analytical methods

Samples were also analyzed by a flow injection analyzer (Quick Chem 8500, Lachat Instruments, Loveland, CO), or FIA, for ammonia, nitrate and nitrite, and orthophosphate with the detection limit of 0.2 mg/L. The measurements were performed using filtered samples (0.45μm filters), which represent the concentration of soluble nitrogen and phosphorus. The ammonia was measured using the Berthelot reaction with the QuikChem® Method 10-107-06-1-I based on the standard methods for the analysis of water and wastewater 4500 NH3 H for FIA (Lachat Instruments, Loveland, CO). The nitrate and nitrite were measured using the cadmium reduction process with the QuikChem® Method 10-107-04-1-C based on the standard methods 4500 NO3-I for FIA (Lachat Instruments, Loveland, CO). The orthophosphate was measured using the ascorbic acid method with the QuikChem® Method 10-115-01-1-A based on the standard methods 4500-P G (Lachat Instruments, Loveland, CO).

The dissolved oxygen (DO) was measured in-situ at each sampling location by a DO meter (Thermo Scientific Orion 3 star) and an accompanying probe. A pH/conductivity meter (Accumet AP85, Fisher Scientific, Singapore) was used to measure the pH. TSS and VSS were measured according to the standard methods (APHA, 1998).

Soil samples were air-dried and ground using a pulverizer to pass through a 2-mm sieve. Phosphorous ($PO4_3$-P) and nitrogen in the forms of ammonium (NH_4^+-N were extracted from the soil samples using a wet oxidation method (Akinremi et al., 2003). Concentrations of phosphorus in soil (PO_4-P) and nitrogen in the form of ammonium (NH_4^+-N) were measured via an FIA (Quick Chem 8500, LACHAT Instruments, Loveland, CO).

Growth of total Coliform and E.coli was simultaneously determined using procedures adapted from APHA Method 9223B "Enzyme Substrate Coliform Test"... The samples were mixed with hydrolyzable substrates and then sealed in a 96-well packet. The packet was incubated at 35.0 ±0.5°C for 18 or 24 hours and then the number of wells exhibiting positive responses was counted. The results were obtained by comparing the number of positive responses to a probability table. The test was conducted at ALS Environmental Laboratory.

2.7 Statistical analyses

SAS software for Windows 10 (SAS 9.4, SAS Institute Inc., Toronto, ON, Canada) was used for the statistical analysis. The performances of the TDA and natural aggregate were compared using an analysis of variance (ANOVA) to account for the differences in performances by TDA leaching interference. For all statistical analyses, a significance level (p-value) of 0.05 was used.

2.8 Limitations

Temperature probes were installed at the base of the trenches in order to monitor the temperature in TDA tranches and natural aggregate tranches during the research period. After the installation, the temperature probes were not able to record the temperature, and they could not be fixed because they were installed at the base of the trenches with restricted access. The temperature in the trenches was measured in the wells; however, the results were not included in the present report.

The control panel was installed to record the flow received by the system during the research period. However, the control panel was unable to record any readings. It was changed twice (July 14, 2017, and January 25, 2018), and it was still not functional. On March 8, 2018, a flow meter was installed in the house to record the wastewater generated by the three-bedroom dwelling. The average monthly wastewater received by the field was 20,000 l/month. There were six readings recorded for six months.

The total wastewater received by the system during the 18 months (October 2016 until May 2018) was calculated by multiplying 18 months of study research with the 20,000 l/ month, which represents the average value recorded by the water meter. Based on the monthly average calculation, the total wastewater received by the system during the research period was 360,000 litres. Assuming the distribution box split the flow evenly in both field treatments, the average wastewater received by each side was 180,000 litres.

The treatment performances of the septic system were calculated using the equation as follows:

$$\%[\mathrm{NH4-N}]reduction = \frac{ST2\ effluent - TDA\ or\ NA\ effluent}{\mathrm{ST2\ effluent}} \qquad \text{(Eq. 2.2)}$$

Where:

ST2 effluent is the average effluent concentration from the pump chamber (mg/L)

TDA 1’ effluent is the average effluent concentration collected from the lysimeter at 1 foot under the trench (mg/L)

TDA 3’ effluent is the average effluent concentration collected from the lysimeter at 3 feet under the trench (mg/L)

NA (natural aggregate)1’effluent is the average effluent concentration collected from the lysimeter at 1 foot under the trench (mg/L)

NA (natural aggregate) 3’effluent is the average effluent concentration collected from the lysimeter at 3 feet under the trench (mg/L).

3. Results and Discussion

Leach fields from the natural aggregate and TDA were compared using wastewater effluent from the septic tank over 18 months. A variety of water quality parameters were tested using treated wastewater from stone (natural aggregate) and experimental TDA septic fields to determine if TDA can substitute natural aggregate.

3.1 pH

pH is a measure of the hydrogen ion concentration in water. Low pH indicates an increase in acidity, whereas a high pH indicates increasing alkalinity. The acidity or alkalinity of wastewater affects both the underlying treatment and the surrounding environment. The pH of domestic wastewater typically ranges from 6.5 and 8.0 (Canter & Know, 1985). The optimum pH for bacteria growth lies between 6.5 and 7. (Bitton, 1999), which is close to the typical range of 6.5 and 7.2 for residential septic tank effluent.

pH results for the septic tank (both chambers) and lysimeters are shown in Figure 3.1. The pH in the sedimentation chamber (ST1), pump chamber (ST2) and the septic field were statistically different. The pH results were not statistically different in the septic tank between ST1 and ST2. The average pH in the septic tank was 7.39 ± 0.08 and 7.49 ± 0.08, respectively. In the wells, pH results were not statistically different ($p<0.05$) between treatments; however, the pH in natural aggregates was statistically different ($p>0.05$) from that in ST1. The average pH in the wells was 7.59 ± 0.05 and 7.66 ± 0.04, respectively. As shown in Figure 3.1, in the same treatment, the average pH at one foot and three feet depth was not statistically different.

The pH of domestic wastewater typically ranges from 6.5 to 8.0 (Canter & Know, 1985) . Using the parameters for EPA secondary treatment guidelines, residential wastewater treatment systems require the pH of individual effluent samples to be between 6 and 9. The pH values measured from the system were between 6.5 and 8.5, which were in the range of the Secondary Drinking Water Standards. The pH in the natural aggregate field at three feet depth was statistically different compared to the TDA field in both depths. The limestone, which is present in the natural aggregate, essentially could increase the pH of the wastewater that infiltrates into the ground. Therefore, the use of TDA kept the pH levels below the tranches within the recommended regulations. According to (Lerner, Naugle, LaForest, & Loomis., 1993) the TDA tent to change the wastewater pH from acidic and neutral to alkaline conditions. They also conclude that the pH has little impact on leachability chemicals from TDA. Another study concludes that leaching metals from TDA could increase with decreasing pH (Sengupta & Miller , 1999).

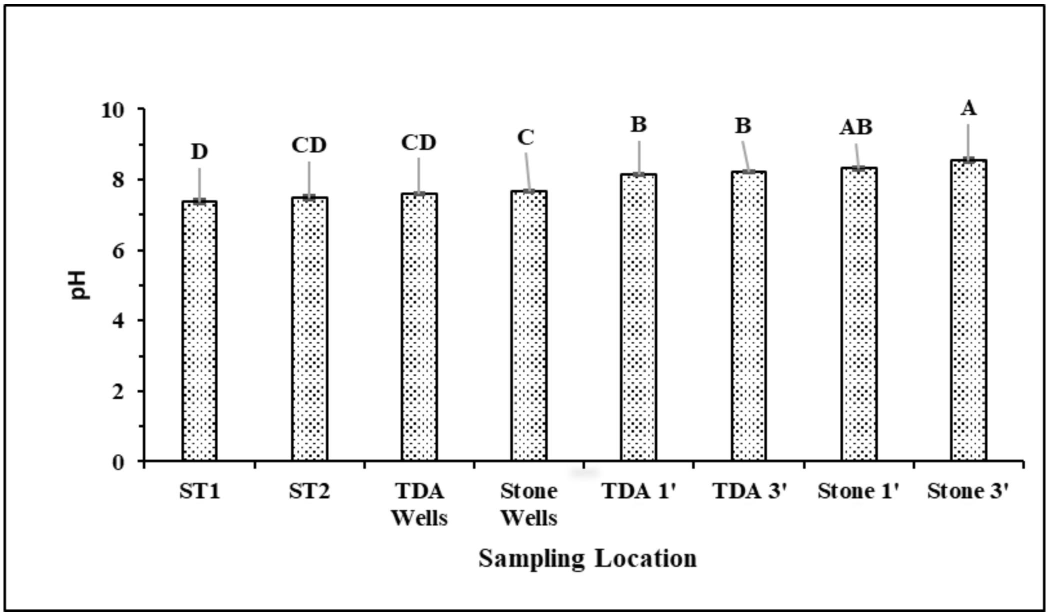

Figure 3.1: Average pH of both septic tank chambers and lysimeters

Note: Sharing the same letter between treatments represents no statistical difference. The error bar represents the standard error.

3.2 Temperature

Four temperature probes for each treatment were installed in the trenches in order to monitor the temperature in TDA and natural aggregate during the research period. When the first set of samples was collected, the temperature probes recorded an average temperature in TDA and natural aggregate trenches of 9.50℃ and 10.40℃, respectively. Temperature probes malfunction was noticed when the second set of samples was collected. The temperature probes could not be changed because they were installed in the trenches, with no access without disturbing the soil on top of the treatment field. The temperature data collected in the septic tank from both chambers are shown in Figure 3.2. Similar temperature values were found in both chambers in the septic tank. The temperature results were not statistically different ($p<0.05$) in the septic tank between ST1 and ST2. The average temperature in ST1 and ST2 was 12.91 ± 1.13 and 13.01 ± 1.13, respectively. A total number of 13 samples were collected during the research period for each chamber. During the research period, the ambient temperature ranged between 0.4℃ and 26℃.

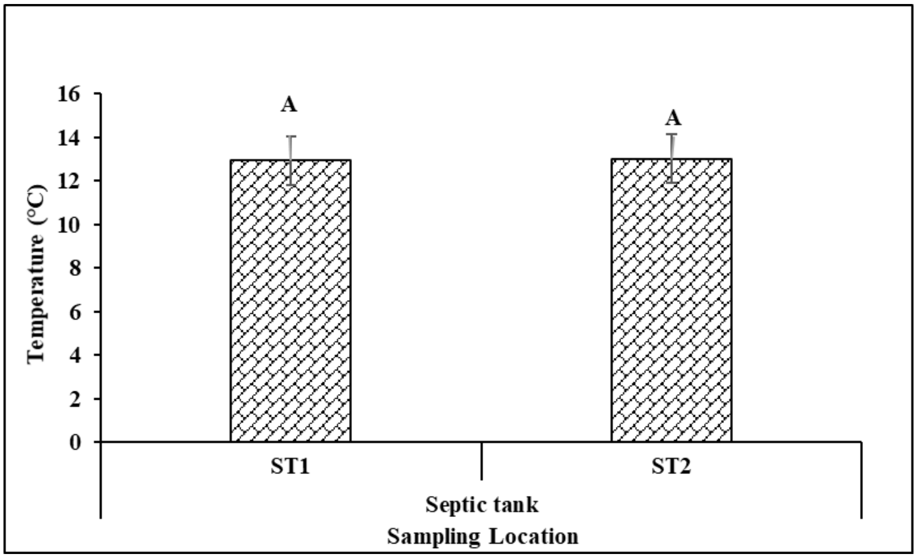

Figure 3.2: Average temperature in the septic tank chambers

Note: *Sharing the same letter between treatments represents no statistical difference. The error bar represents the standard error.*

3.3 TSS

TSS was measured in the septic tank in both chambers. The wastewater collected from the lysimeters did not register a TSS value due to the presence of a ceramic cap. Average TSS values of 853 mg/L and 81 mg/L were found for ST1 and ST2, respectively. Three sets of samples from each chamber were collected during the research period, and the samples were not statistically analyzed. The PL-122 filter by Polylok installed between the chambers in the septic tank led to a 90% TSS reduction in the ST2 pump chamber. According to EPA, a well-functioning conventional septic tank will reduce TSS by 70 percent (USA EPA, 2002). The quality of the septic tank effluent will differ depending on the wastewater characteristics and tank conditions. Typically, effluent leaving a domestic septic tank, and not equipped with an effluent filter, has a TSS concentration ranging from 49 to 161 mg/L (USA EPA, 2002).

3.4 Ammonium- N in the septic tank and lysimeters

In the septic tank's anaerobic environment, nitrogen exists primarily as Organic-N and NH_3-N/NH_4^+-N (TKN). Organic-N is transformed to NH_3-N/NH_4^+-N via ammonification, although some NH_3-N/NH_4^+-N is converted to Organic-N via bacterial cell growth. Therefore, there is a net increase of NH_3-N/NH_4^+-N in the effluent. Nitrogen can undergo several transformations within and below the subsurface soil absorption trenches (Ayres Associates, 1993). These transformations include: 1) adsorption of NH_4^+-N in the soil; 2) volatilization of NH_3-N in alkaline soils at pH above 8.0; 3) nitrification and subsequent movement of NO_3-N towards the groundwater; 4) biological uptake of both NH_3-N/NH_4^+-N and NO_3 -N; and 5) denitrification, if the environmental conditions are appropriate.

NH_4^+-N results from the septic field (both chambers), wells and lysimeters are shown in Figure 3.4.1. The average septic tank effluent concentration in ST1 and ST2 was 55 ± 3.4 mg/L and 54 ± 2.8 mg/L, respectively. The average concentration of NH_4^+-N was not statistically different ($p<0.05$) in the septic tank between ST1 and ST2, and they were within the typical range of 33 and 171 mg/L for domestic wastewater, as reported by WERF (2009). According to EPA, the average TKN in the domestic septic tank effluent ranges between 39 and 82 mg/L (USA EPA, 2002). The average NH_4^+-N concentration in wells was 20 ± 2 mg/Land 24 ± 2 mg/L, respectively. There were no statistical differences ($p<0.05$) in NH_4^+-N concentration between the samples collected from the wells on both sides; however, NH_4^+-N concentration in the septic tank was statistically different compared to the wells.

The average NH_4^+-N concentration under the TDA trenches at one foot and three feet depths were 1.31 ± 0.2 mg/L and 0.75 ± 0.1 mg/L, respectively. There were no statistical differences ($p<0.05$) between the average NH4+-N concentrations at different depths in the TDA field. The average NH_4^+-N concentration under the natural aggregate trenches at one foot and three feet were 3.42 ± 0.9 mg/L and 1.55 ± 0.4 mg/L, respectively. Similarly, no statistical differences ($p<0.05$) between different depths in the natural aggregate field were found. Overall, NH_4^+-N concentration under the trenches at one foot and three feet in both the treatment fields were not statistically different, as is shown in Figure 3.4.1 below.

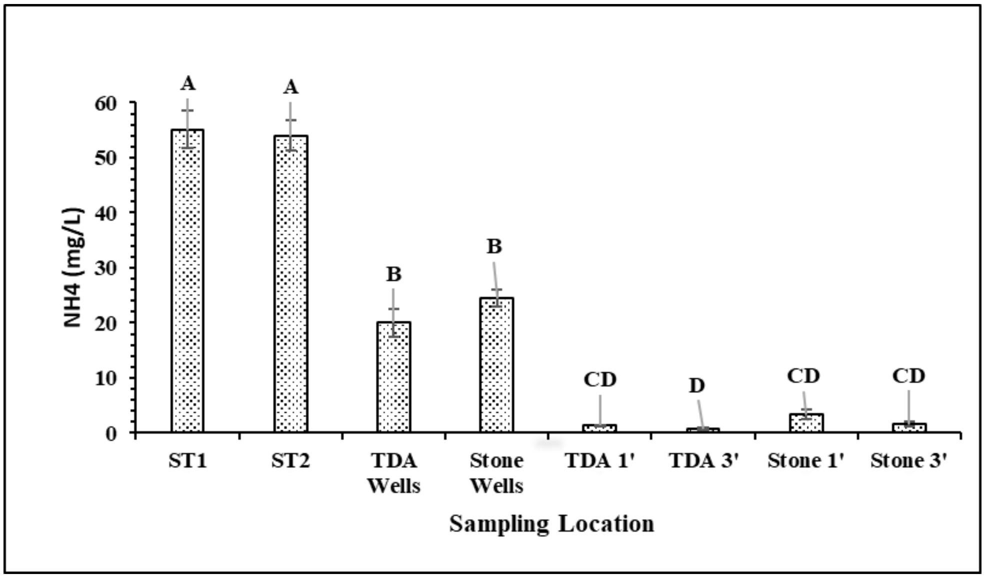

Figure 3.4.1 Average concentrations of NH_4^+-N in the septic system

Note: *Sharing the same letter between treatments represents no statistical difference. The error bar represents the standard error.*

Effluent NH_4^+-N concentration from the septic tank was converted to nitrate-nitrogen (NO_3-N) via the nitrification process in the presence of aerobic soil in the trenches (Humphrey, O'Driscoll, & Zarate, 2010). Measurements for nitrate-nitrogen (NO_3-N) were taken on three separate sampling dates under the trenches at one foot and three feet depths in both field treatments. The total number of samples was 48. There were no detectable NO_3-N (<0.2 mg NO_3-N/L). Concentration under the trenches at different depths in both field treatments. According to the OWMS 83/2003 regulation, the septic tank must be installed at a minimum of 26 feet from the water well. The disposal field must be installed at a minimum of 50 feet from the water well and 100 feet from a watercourse to allow for possible nitrogen concentration reduction by processes such as denitrification, dilution, and dispersion. According to EPA, the maximum contaminant level (MCL) for NO_3-N in ground and surface waters is 10 mg/L (USA

EPA, 2002). The risk for the blue baby syndrome is higher when the water supplies exceed the MCL.

The removal efficiency was calculated based on 180,000 L of wastewater received by the system during the 18-month research period for each treatment field. The rain precipitation, snow depth and soil evapotranspiration were not taken into consideration in the calculation. The removal rate in the TDA treatment was higher compared with the removal rate in the natural aggregate treatment, 98 percent vs 94 percent under 1-foot depth and 99 percent vs 97 percent under 3 feet depth, as shown in Figure 3.4.2.

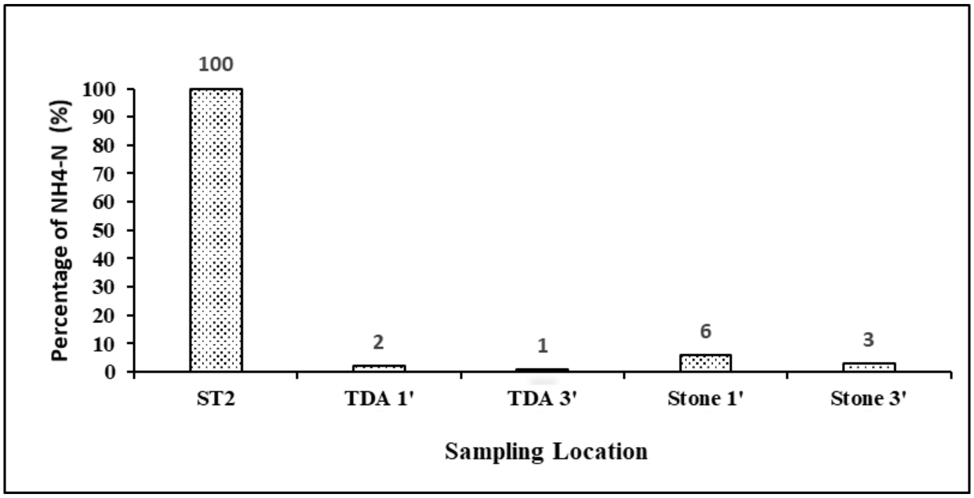

Figure 3.4.2 Ammonium-N reduction in the system

3.5 Orthophosphate in the septic tank and lysimeters

Typically, total phosphate (TP) concentration in untreated domestic wastewater can range between 5 mg/l and 20 mg/L, which also defines the strength of the wastewater. The TP concentrations around 5, 10 and 20 mg/l attributes to the weak, medium and high strength of the wastewater (Davis, 2011). For a typical residential dwelling equipped with standard water-saving fixtures, TP concentration ranges between 18-29 mg/L and Ortho-P concentration ranges between 6-24 mg/L (US EPA, 1980).

The average concentration of Ortho-P in ST1 and ST2 was 5.8 ± 0.4 mg/l and 5.1 ± 0.2 mg/L, respectively. Figure 3.5.1 shows that the Ortho-P concentration of wastewater in the septic tanks was below (US EPA, 1980) the threshold limits. One of the reasons can be the introduction of the Government of Canada Regulation Amending Phosphorus Concentration Regulation, P.C. 2009-947 June 2009, which essentially eliminated the use of phosphorus on household laundry and dishwasher detergents. The Ortho-P results were not statistically different in the septic tank between chambers.

The average Ortho-P concentration under the TDA wells and natural aggregate wells was 0.28 ± 0.04 mg/L and 0.56 ± 0.10 mg/L, respectively. The average Orth-P concentration under the TDA trenches at one foot and three feet depths were 0.3 ± 0.04 mg/L and 0.4 ± 0.09 mg/L, respectively. There were no significant differences ($p<0.05$) between different depths in the TDA field. The average Orth-P concentration under the natural aggregate trenches at one foot and three feet depths were 0.47 ± 0.1 mg/L and 0.2 ± 0.03mg/L, respectively. Overall, Ortho-P concentration under the TDA and natural aggregate trenches at one foot and three feet depth were not statistically different ($p<0.05$) than TDA and natural aggregate wells.

Phosphorus in the soil is rapidly chemisorbed onto mineral surfaces of the soil. As the concentration of phosphorus increases with time, precipitates may form with the iron, aluminum, or calcium naturally present in most soils (US EPA, 1980). Therefore, the movement of phosphorus through most soil types is slow. The unsaturated soil below the trenches between 2 ft to 4 ft is enough to remove bacteria and viruses to acceptable levels and nearly eliminate all phosphorus (US EPA, 1980). There were no statistical differences ($p<0.05$) at different depths in the natural aggregate field. Overall, Ortho-P concentration under the trenches at one foot and three feet depth in both the treatment fields was not statistically different, as shown in Figure 3.5.1 below.

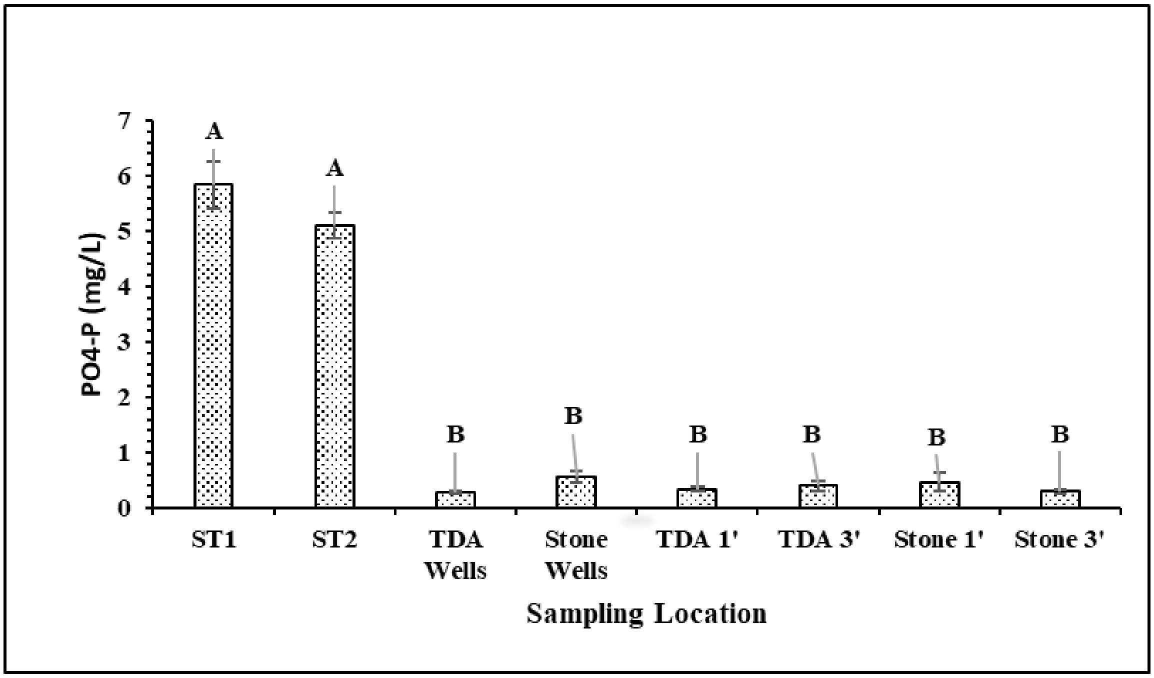

Figure 3.5.1 Average PO_4-P concentration in the septic system in the system

Note: *Sharing the same letter between treatments represents no statistical difference. The error bar represents the standard error.*

The removal efficiency was calculated based on 180,000 l received by the system during the 18-month research period for each treatment field. The rain precipitation, snow depth and soil evapotranspiration were not taken into consideration in the calculation. The removal rate in the TDA treatment was higher compared with the removal rate in the natural aggregate treatment, 93 percent vs 91 percent under 1-foot depth and 92 percent vs 94 percent under 3 feet depth, as shown in Figure 3.5.2.

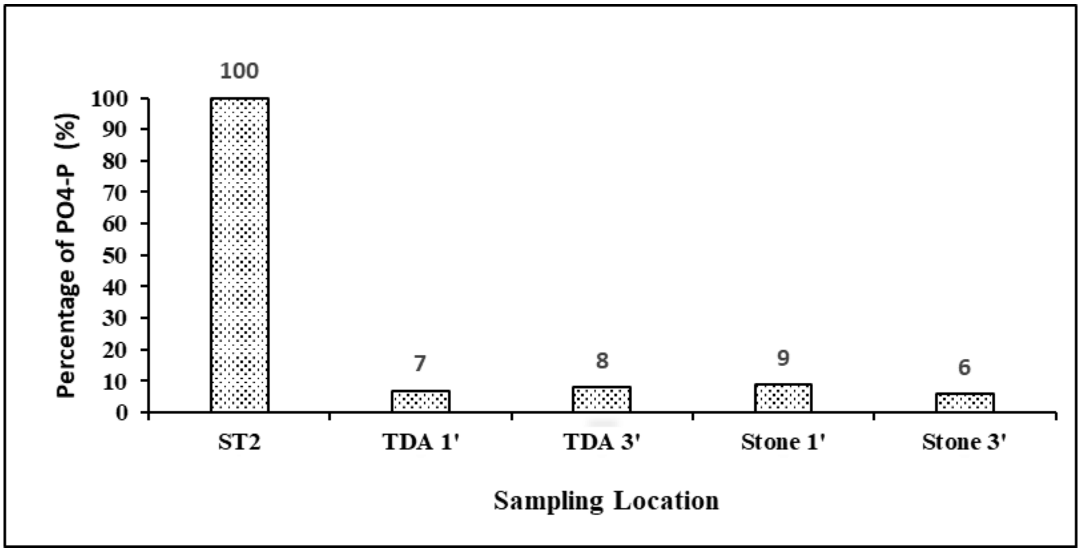

Figure 3.5.2 PO_4-P reduction in the system

3.6 TCOD in the septic tank and lysimeters

Total Chemical oxygen demand (TCOD) measures the total organic pollutants present in a wastewater sample. It is commonly used in the wastewater industry as a fast and reliable method of determining the quality of water after treatment. The principle behind the measurement of TCOD is that all the organic compounds can be converted to carbon dioxide and water by chemical oxidation. It is measured as the amount of oxygen required to chemically oxidize all the organic pollutants in a litre (L) of water and is expressed as mg/L or ppm.

TCOD is one of the parameters that convey the strength of the wastewater. Typically, TCOD in untreated domestic wastewater can range from 250 mg/l to 1000 mg/L. The domestic wastewater strength is weak if the TCOD is around 250mg/l, medium if the TCOD is around 500 mg/L, and strong if the TCOD is around 1,000 mg/L (Davis, 2011). The average TCOD in ST1 and ST2 were 723.68 ± 48.6 and 484.07 ± 32.2 mg/, respectively. The wastewater strength in ST1 is medium to strong; however, ST2 has medium strength wastewater (Davis, 2011). The

TCOD in ST1 was 32 percent higher than ST2. This can be attributed to the installation of the PL-122 effluent filter by Polylok between the two compartments of the septic tank. Figure 3.6 also shows the statistical differences between the chambers in the septic tank.

The average TCOD concentration under the TDA trenches at one foot and three feet depths were 94.99 ± 3.0 mg/L and 96.6 ± 3.1 mg/L, respectively. There were no statistical differences ($p<0.05$) at different depths in the TDA field. The average TCOD concentration under the natural aggregate trenches at one foot and three feet depths were 98.9 ± 5.4 mg/L and 89.6 ± 3.6 mg/L, respectively. There were no statistical differences ($p<0.05$) at different depths in the natural aggregate field. Overall, Figure 3.6 shows that TCOD concentration under the trenches at one foot and three feet depths in both the treatment fields were not statistically different. According to (US EPA, 1999) the wastewater travels through the soil profile reduce the TCOD to less than 10 mg/l. The TCOD samples in the US EPA study were collected from 12-13 feet below the septic field surface; however, for this research study: 1 foot below tranches represent 3 feet below the septic field surface and 3 feet below tranches represent 6 feet below septic field surface. Burnell and MacOmber's (Burnell & MacOmber, 1997) results showed that the TCOD decreased in the trench filled with natural aggregate; however, it remained approximately the same in the TDA trench and the dosing chamber.

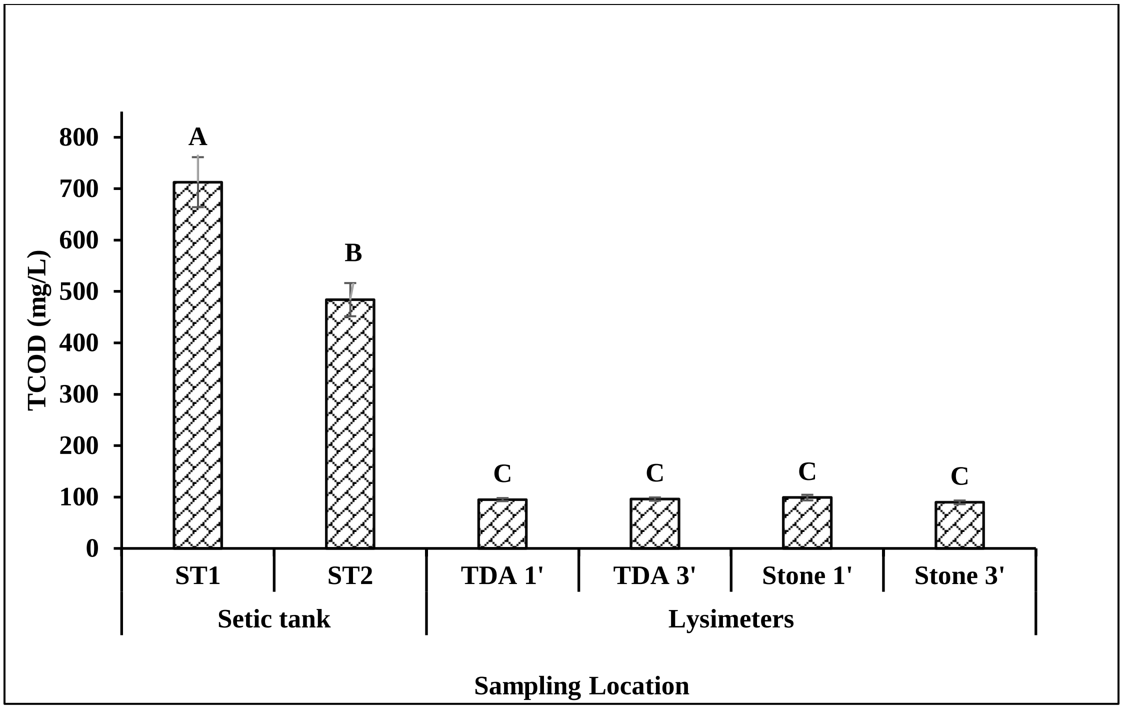

Figure 3.6 Average TCOD concentration in the septic system

Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error. TCOD – Total Chemical Oxygen Demand*

3.7 Metals in the septic tank and lysimeters

According to (Moriyama K. , Mori, Arayashiki, Saito, & Chino, 1989), various household sources of metal are food, tap water, detergents, cosmetics, sweat and dust, which enter in the wastewater stream from the lavatory, kitchen, laundry and bath. The characteristics of wastewater are also determined by the quality of the drinking water used in the house. Groundwater is the main source of water supply for lavatory, kitchen dishwasher, laundry and bath. The well's groundwater was never tested for the concentration of metals.

Ag is one of the metals that can cause skin discoloration and graying of the white part of the eye (sclera) if it is above 0.1 mg/L SMCL. For a total of 8 samples from the septic tank and 64 samples from both treatments at 1 foot and 3 feet depth, all measurements were below the detection limit. The same number of samples were also collected for other metals.

An Al concentration between 0.05- 0.2 mg/l (above the SMCL) results in discoloration of water. The average concentration in ST1 and ST2 were 0.09 ± 0.02 mg/l and 0.08 ± 0.2 mg/l, respectively. The average Al concentration under the TDA trenches at one foot and three feet depths were 0.04 ± 0.004 mg/L and 0.05 ± 0.004 mg/L, respectively. There were no statistical differences ($p<0.05$) at different depths in the TDA field. The average Al concentration under the natural aggregate trenches at one foot and three feet depths were 0.07 ± 0.007 mg/L and 0.08 ± 0.02 mg/L, respectively. Figure 3.7.1 shows no statistical differences ($p<0.05$) at different depths in the natural aggregate and TDA fields. The results show that the Al concentration in the septic tank was within the SMCL range; however, the Al concentration in the TDA tranches was below SMCL. According to (Humphrey & Katz, 2002) there was no evidence that the presence of TDA increases the level of Al in the septic field.

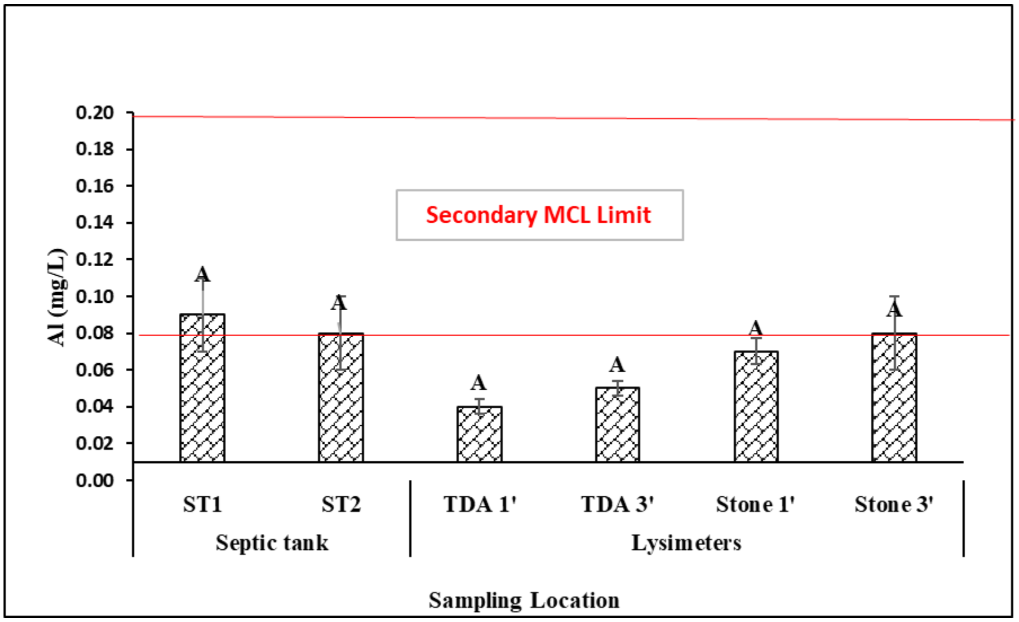

Figure 3.7.1 Al concentration in the septic system

Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

The concentration of Cu above 1.0 mg/l can result in blue-green staining and metallic taste. The average concentration in ST1 and ST2 were 0.09 ± 0.02 and 0.08 ± 0.2 mg/L, respectively. The average Cu concentration under the TDA trenches at one foot and three feet depths were 0.017 ± 0.002 mg/L and 0.018 ± 0.002 mg/L, respectively. There were no statistical differences ($p<0.05$) at different depths in the TDA field. The average Al concentration under the natural aggregate trenches at one foot and three feet depths were 0.014 ± 0.003 mg/L and 0.017 ± 0.02 mg/L, respectively. Similarly, no statistical differences ($p<0.05$) at different depths in the natural aggregate field were found. Overall, the Cu concentration in the system was below 1mg/l SMCL. According to (Humphrey & Katz, 1999) no evidence was found that tire shreds increased the concentration of copper.

The concentration of Fe above 0.3 mg/l can cause rusty colour staining, sediment, metallic taste and reddish or orange in water. The average concentration in sedimentation chamber ST1 was 0.22 ± 0.003 mg/L mg/l, and in the control chamber, ST2 was 0.15 ± 0.002

mg/L. The average Fe concentration under the TDA trenches at one foot and three feet was 0.08± 0.03 mg/L and 0.06 ± 0.03 mg/L, respectively. There were no statistical differences ($p<0.05$) between different depths in the TDA field. The average Fe concentration under the natural aggregate trenches at one foot and three feet was 0.04± 0.01 mg/L and 0.05 ± 0.02 mg/L, respectively. There were no statistical differences ($p<0.05$) between different depths in the natural aggregate field. Overall, the Fe concentration in the system was below 0.3 mg/l secondary MCL limit. According to (Humphrey & Katz, 2002) the results showed that iron levels might exceed the SMCL. Another study showed that Fe from the TDA trench was three times higher compared with the control trenches, and it was above the secondary drinking water standards (Burnell & MacOmber, 1997).

A noticeable effect of manganese Mn above 0.05 mg/l with the secondary MCL limit it is black to brown colour, black staining, bitter metallic taste in water. The average concentration in sedimentation chamber ST1 was 0.05 ± 0.02 mg/l, and in the control chamber, ST2 was 0.05 ± 0.2 mg/L, respectively. The average Mn concentration under the TDA trenches at one foot and three feet was 0.06 ± 0.004 mg/L and 0.04 ± 0.004 mg/L, respectively. There were no statistical differences ($p<0.05$) between different depths in the TDA field. The average Mn concentration under the natural aggregate trenches at one foot and three feet was 0.09 ± 0.007 mg/L and 0.04 ± 0.02 mg/L, respectively. Figure 3.7.2 shows there were no statistical differences ($p<0.05$) between different depths in the natural aggregate field and TDA; however, one foot below both treatments, the wastewater samples were above Secondary Drinking Water Standards. According to (Humphrey & Katz, 2002) Mn levels were higher on the TDA side compare with the control side and were likely to exceed SMCL; however, Mn naturally occurs in groundwater in many areas.

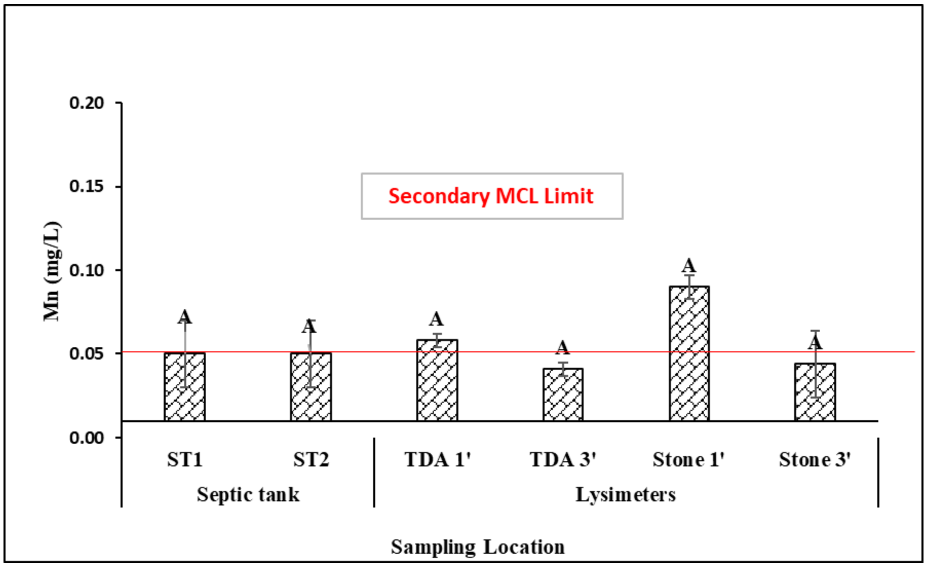

Figure 3.7.2 Mn concentration in the septic system

Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

Meat, tap water, laundry detergent and personal care products such as toothpaste, shampoo and deodorants are the primary sources of Zn in domestic wastewater (Sörme, 2002). According to Secondary Drinking Water Standards, the concentration of Zn above 5 mg/L can cause a metallic taste in the water. The average concentration in ST1 and ST2 were 0.03 ± 0.01 mg/l and 0.05 ± 0.2 mg/L, respectively. Zinc Oxide is one of the main components and represents 1% of passenger light truck tires and 2% of off-the-road tires (Evans A. , 2006). The average Zn concentration under the TDA trenches at one foot and three feet depths were 0.1 ± 0.009 mg/L and 0.02 ± 0.004 mg/L, respectively. The average Zn concentration under the natural aggregate trenches at one foot and three feet depths were 0.03 ± 0.02 mg/L and 0.02 ± 0.12 mg/L, respectively. There were no statistical differences ($p<0.05$) between different depths in the TDA field, as shown in figure 3.7.3. The Zn concentration was higher on the TDA side at 1 foot below trenches; however, overall, the concentration was below the SMCL. (Humphrey & Katz, 2002), find out that the Zn concentration was higher in the control side than the TDA side and conclude that there is no evidence that TDA increases the Zn levels. The higher level in the control section was because zinc is naturally present in the soil. According to (Burnell & MacOmber, 1997) the Zn concentration was found seven times higher compared with the dosing chamber; however, the concentration was below the secondary drinking water standards.

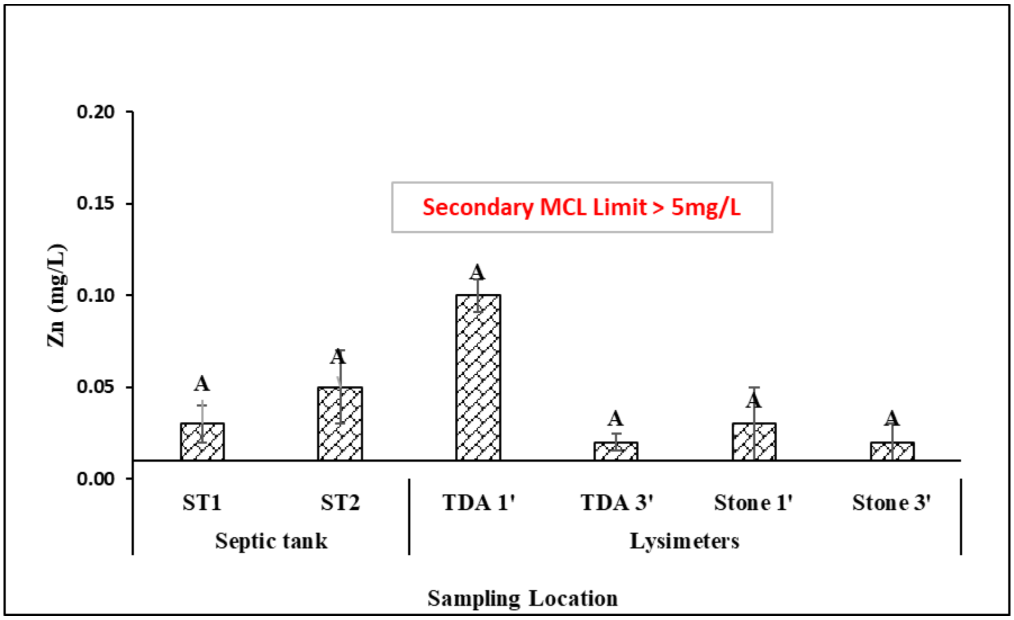

Figure 3.7.3. Zn concentration in the septic system
Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

3.8 Metals in the soil

The initial average Zn content under the TDA trenches at the base of the trench and one foot was 2.76 ± 0.6 mg/Kg and 1.65 ± 0.6 mg/Kg, respectively. After one year, the Zn content for the same treatment site and the same depth was 2.70 ± 0.6 mg/Kg and 2.04 ± 0.6 mg/Kg, respectively. The initial average Zn content under the natural aggregate trenches at the base of the trench and one foot was 1.89 ± 0.6 mg/Kg and 3.5 ± 0.6 mg/Kg, respectively. After one year, the Zn content for the same treatment site and the same depth was 2.43 ± 0.6 mg/Kg and 2.02 ±

0.6 mg/Kg, respectively. Overall, there were no statistical differences ($p<0.05$) between different depths in the TDA and natural aggregate field treatments, as shown in figure 3.8.1. According to (Haluschak, Eilers, Mills, & Grift, 1998), in southern Manitoba, the median Zn content in soil is 65 ppm; however, the Zn content ranges between 8 to 230 ppm. On a worldwide basis, the overall zinc content for uncontaminated soil ranges from 17 to 125 ppm (Kabata-Pendias & Pendias, 1992). Soil texture greatly influences the Zn content. When the content of clay increases, the average concentration of zinc in coarse-textured soils increases progressively from 32 to 105 ppm in fine-textured soils such when the Red River Plain and the Dauphin Lake Plain (Haluschak, Eilers, Mills, & Grift, 1998). The average Zn content in the septic field both treatments was found below southern Manitoba and the worldwide average for uncontaminated soils.

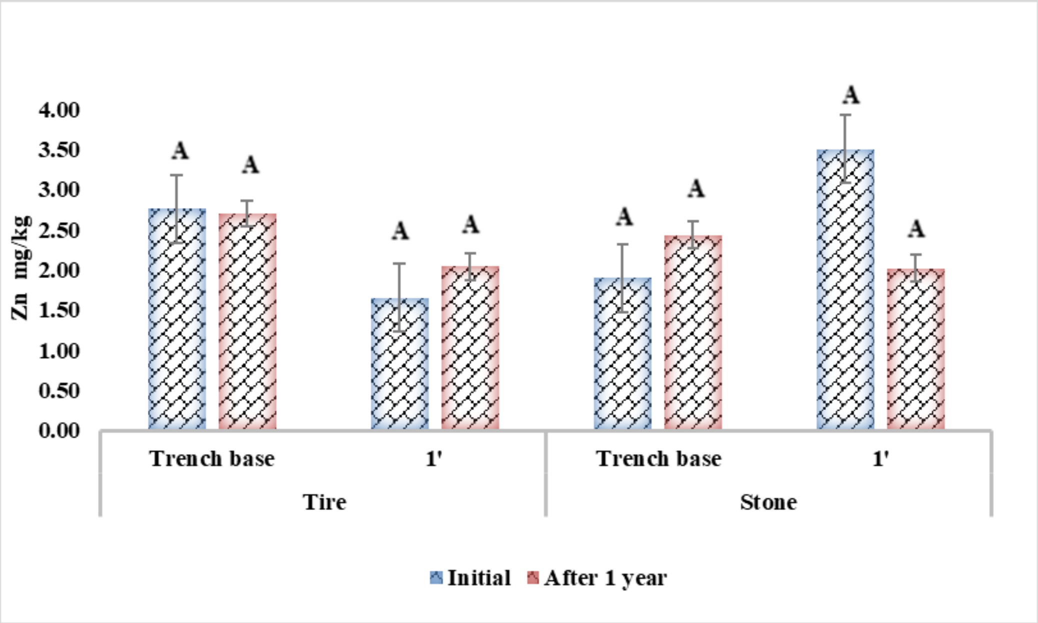

Figure 3.8.1 Zn content in the soil

Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

The initial average Mn content under the TDA trenches at the base of the trench and one foot was 16.47 ± 2.01 mg/Kg and 16.59 ± 2.01 mg/Kg, respectively. After one year, the Mn content for the same treatment site and the same depth was 23.63 ± 2.01 mg/Kg and 18.20 ± 2.01 mg/Kg, respectively. The initial average Mn content under the natural aggregate trenches at the base of the trench and one foot was 18.60 ± 2.01 mg/Kg and 16.95 ± 2.01 mg/Kg, respectively. After one year, the Mn content for the same treatment site and the same depth was 19.81 ± 2.01 mg/Kg and 18.68 ± 2.01 mg/Kg, respectively. Overall, there were no statistical differences ($p<0.05$) between different depths in the TDA and natural aggregate field treatments, as shown in figure 3.8.2.

According to (Haluschak, Eilers, Mills, & Grift, 1998), in southern Manitoba, the median manganese content in soil is 572 ppm; however, the manganese content ranges between 24 to 5200 ppm. On a worldwide basis, the overall Mn content in soil ranges from 7 to 9200 ppm, with a mean of 437 ppm (Kabata-Pendias & Pendias, 1992). In the Manitoba Plain, the average Mn content is less than 572 ppm (Haluschak, Eilers, Mills, & Grift, 1998). The initial Mn content in the septic field of both treatments was found below the lowest limit of southern Manitoba but in the range of the worldwide average. After one year, the Mn in TDA treatment slightly increases; however, the average Mn remains below the lowest limit of southern Manitoba, but still in the range of the worldwide average. The natural aggregate treatment followed the same pattern as the TDA treatment.

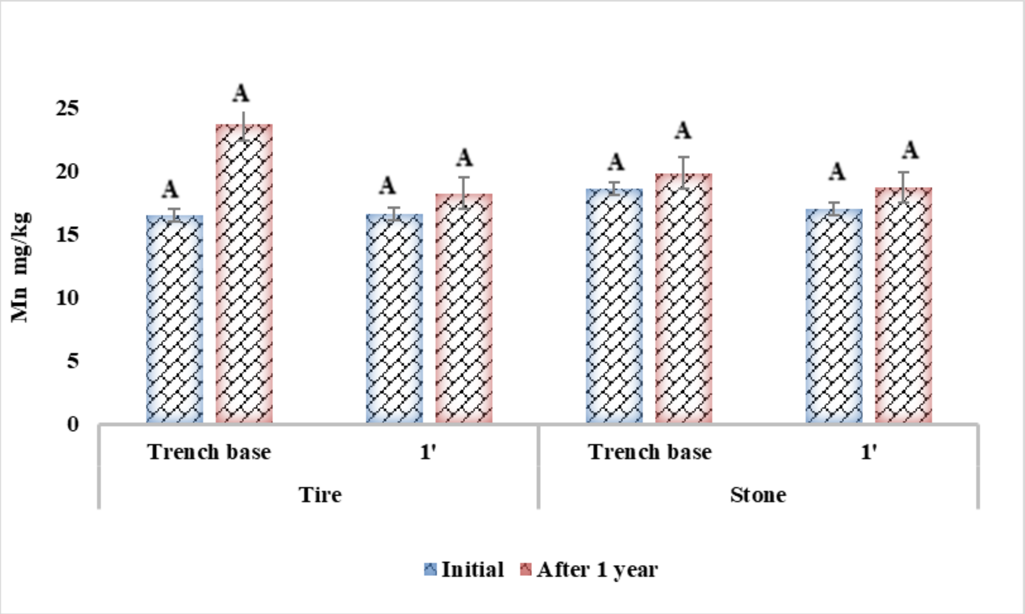

Figure 3.8.2 Mn content in the soil

Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

The initial average Cu content under the TDA trenches at the base of the trench and one foot was 4.88 ± 1.3 mg/Kg and 5.79 ± 1.3 mg/Kg, respectively. After one year, the copper content for the same treatment site and the same depth 2.04 ± 1.3 mg/Kg and 1.19 ± 1.03 mg/Kg, respectively. The initial average Cu content under the natural aggregate trenches at the base of the trench and one foot was 4.5 ± 1.03 mg/Kg and 7.2 ± 1.3 mg/Kg, respectively. After one year, the Cu content for the same treatment site and the same depth was 1.56 ± 1.3 mg/Kg and 1.25 ± 1.3 mg/Kg, respectively. Overall, there were no statistical differences between different depths in the TDA and natural aggregate field treatments, as shown in figure 3.8.3.

According to (Haluschak, Eilers, Mills, & Grift, 1998), in Manitoba soils, the Cu content ranges between 1 to 68 ppm. On a worldwide basis, the overall Cu content in uncontaminated soils ranges from 13 to 24 ppm (Kabata-Pendias & Pendias, 1992). In the coarse-textured soils, the low Cu average was 7 ppm; however, in the clays, the Cu content average was 33ppm

(Haluschak, Eilers, Mills, & Grift, 1998). The initial and after one-year Cu content in both treatments was found in the Manitoba copper content range, but it was below the worldwide average.

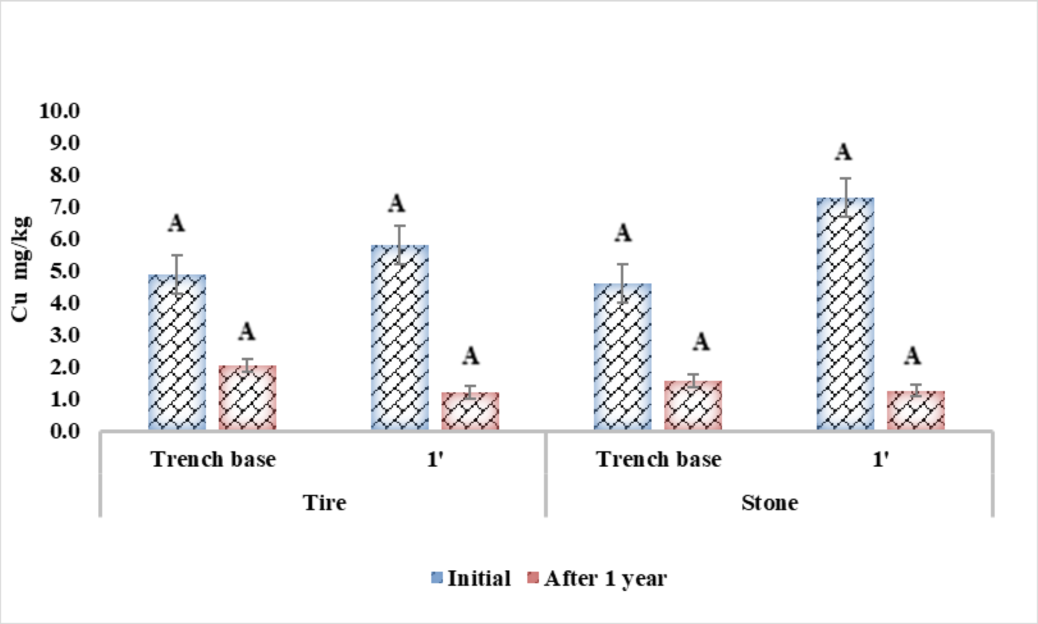

Figure 3.8.3 Mn content in the soil

Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

The initial average Cr content under the TDA trenches at the base of the trench and one foot was 1.3 ± 0.2 mg/Kg and 1.18 ± 0.2 mg/Kg, respectively. After one year, the Cr content for the same treatment site and the same depth 1.5 ± 0.2 mg/Kg and 1.3± 0.2 mg/Kg, respectively. The initial average Cr content under the natural aggregate trenches at the base of the trench and one foot was 1.5 ± 0.2 mg/Kg and 1.5 ± 0.2 mg/Kg, respectively. After one year, the copper content for the same treatment site and the same depth was 1.5 ± 0.2 mg/Kg and 1.7 ± 0.2 mg/Kg, respectively. Overall, there were no statistical differences (p<0.05) between different depths in the TDA and natural aggregate field treatments, as shown in figure 3.8.4.

According to (Haluschak, Eilers, Mills, & Grift, 1998), in Manitoba soils, the Cr content median value is 46 ppm and is below the worldwide average of 54 ppm. The initial and after one-year Cr content in both treatments was not statistically different, and it was well below the Manitoba median value and the worldwide average value.

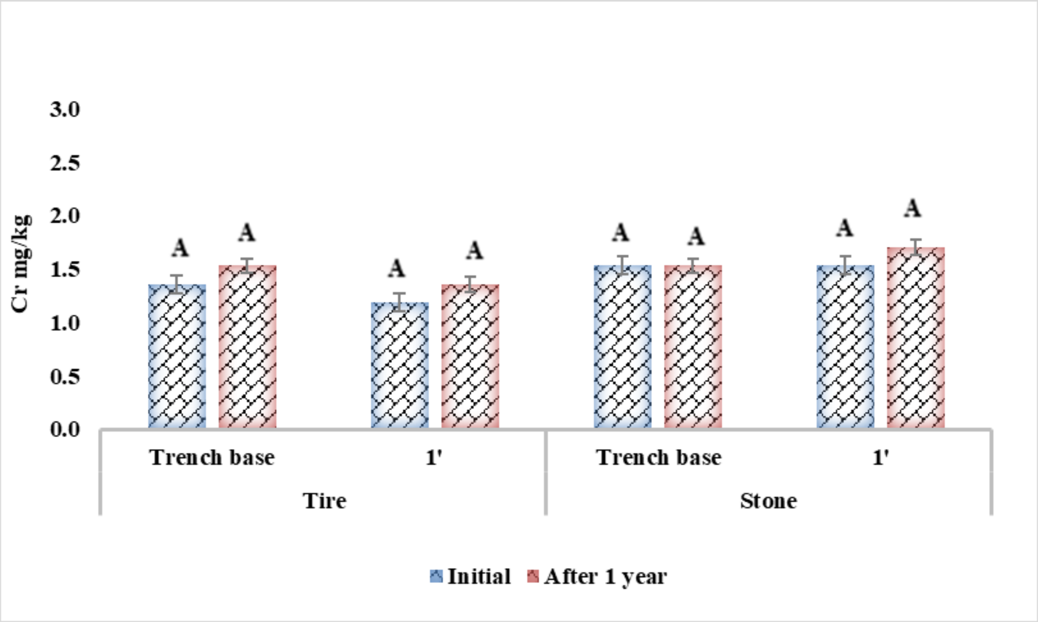

Figure 3.8.4 Cr content in the soil
Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

The initial average Fe content under the TDA trenches at the base of the trench and one foot was 263.2 ± 39.4 mg/Kg and 198.56 ± 39.4 mg/Kg, respectively. After one year, the Fe content for the same treatment site and the same depth was 168.2 ± 39.4 mg/Kg and 176.2± 39.4 mg/Kg, respectively. The initial average Fe content under the natural aggregate trenches at the base of the trench and one foot was 173.68 ± 39.4 mg/Kg and 200.4± 39.4 mg/Kg, respectively. After one year, the Fe content for the same treatment site and the same depth was 163.8 ± 39.4 mg/Kg and 204.3 ± 39.4 mg/Kg, respectively. Overall, there were no statistical differences

($p<0.05$) between different depths in the TDA and natural aggregate field treatments, as shown in figure 3.8.5. According to (Haluschak, Eilers, Mills, & Grift, 1998), in Manitoba soils, the iron content ranges from 0.17 to 5 percent. The initial and after one-year iron content in both treatments was not statistically different.

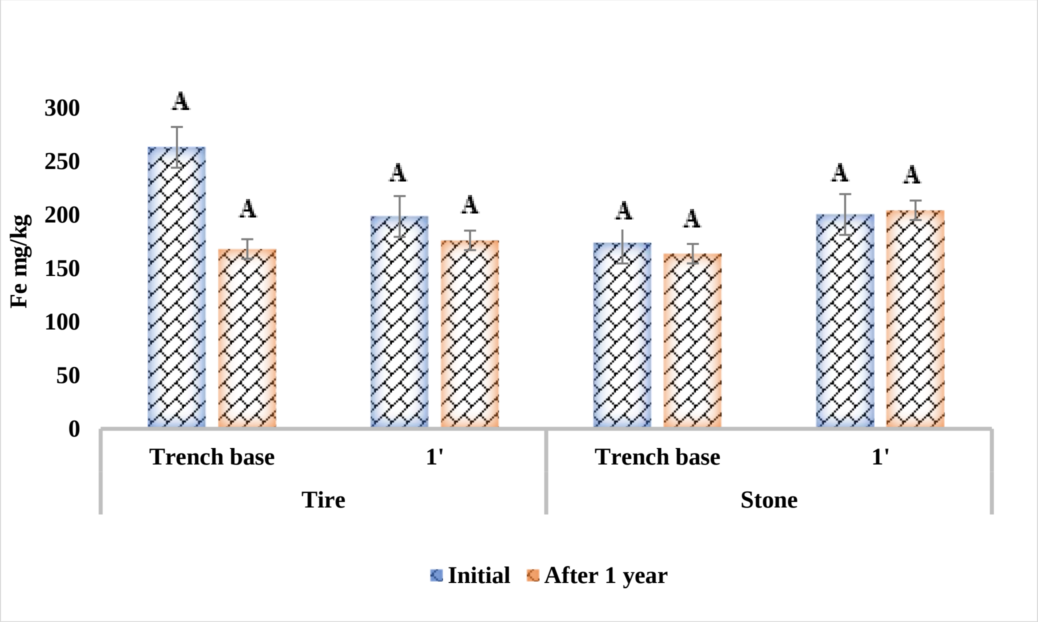

Figure 3.8.5 Fe content in the soil

Note: *Sharing the same letter between treatments represent no statistical difference. The error bar represents the standard error.*

Nickel (Ni) was also measured in the soil samples on both treatment sides; however, the results were under the detection limit.

3.9 Total Coliform and E-coli

Total Coliform and E-coli were collected once on April 23, 2019, due to the reduced amount of water in the lysimeters. The water samples were collected from 1 foot and 3 feet below on both sides of the treatment. For example, four water samples were collected at 1-foot depth in the natural aggregate side, and the samples were combined in order to have 500 ml of composite sample for each depth. The total number of samples collected was 16; however, the ASL laboratory received 4 composite samples of 500 ml, one for 1-foot depth in the TDA treatment, the second one for 1-foot depth in the natural aggregate treatment, the third one for 3-feet deep in the TDA side and the last one for 3-feet depth in the natural aggregate treatment. Total coliform and E-coli results were under the detection limit at 1foot and 3-feet soil depth for natural aggregate and TDA treatments. According to (Bouma, et al., 1972), under the typical operating characteristic of the septic tank was observed that pathogenic bacterial indicators die off within 3 feet of the vadose. Other studies have also reported a better removal efficiency of fecal coliform. For instance, the sample collected between 12-13 feet below the ground surface showed that the primary removal process of fecal coliform was filtration and inactivation, and the removal rate was 99 percentage (US EPA, 1999).

Conclusions

In this research, the performance of two different aggregates was monitored for a period of 18 months. The goals are to determine the differences between septic fields with tire-derived aggregate and natural aggregate. The following are the conclusions:

- The pH of 8.55 in the natural aggregate field at 3 feet below the trench base shows that TDA and natural aggregate follow similar patterns, and increases in pH are related to the presence of lime in the soil.
- Reductions in COD, phosphorous and ammonia concentrations occurred in both septic fields without any differences between the treatments.
- Nitrite concentration in both treatments was under the detection limit.
- Concentrations of Ag, Al, Cu, Fe, and Zn collected from the lysimeters were below the NSDWRs (or secondary standards).
- Mn was the only metal that exceeded the NSDWRs (or secondary standards) in both treatments at one foot below the trench base. High Mn above the NSDWRs may cause cosmetic effects (such as skin or tooth discoloration) and aesthetic effects (such as taste, odour, or colour) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply with the standard.
- Zn, Mn, Cu, Fe and Cr in soil samples in both treatments at the trench base and one foot below the trench were below or within ranges of uncontaminated soils in Manitoba or worldwide.
- Overall, tire-derived aggregate, type A nominal, is a suitable alternative substitute for natural aggregate in the septic field in regard to wastewater treatment.

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Appendix 1 –Site assessment report

REPORT ON SOIL CONDITIONS ON FARMSTEAD LOCATED IN THE SOUTHEAST ¼ OF 27-26-08 WPM

Prepared by

Gordon F. Mills, BSA, MSc

August 27, 2015

Aneda Soil at Site 2

Soil Pit at Site 2

REPORT ON SOIL CONDITIONS ON FARMSTEAD LOCATED IN THE SOUTHEAST ¼ OF 27-26-08 WPM

INTRODUCTION

On August 13, 2015, a field inspection was carried out on a farmstead situated in the SE ¼ of 27-26-08 WPM in the RM of Siglunes in the Interlake area of Manitoba. The purpose of this investigation is to document soil and landscape conditions on the farmstead located in the north-west corner of the SE ¼ of section 27. The information collected on soil and site characteristics at the farmstead is required to support a research proposal to examine alternate construction methodology for installation and management of a septic field for safe and sustainable on-site handling of domestic sewage effluent.

METHODOLOGY

The examination of two soil pits in a small wooded area immediately to the west of the farmhouse was facilitated by backhoe excavations to a depth of 1.3 m (Figure 1). Each soil was described by standard soil survey terminology utilized as a basis for identifying and classifying the soils (The Canadian System of Soil Classification, Second Edition 1987 and Manual for Describing Soils in the Field, Revised 2007). The location of the study area is shown on the reconnaissance soil map in Figures 1 and 2 and on the Landsat Imagery in Figure 3. The soil at Site 1 was described in detail but not sampled. The closely similar soil at Site 2 was described in detail, and the soil parent material at this site was sampled for particle size analysis at five depth increments between 45 and 140 cm.

GENERAL AREA DESCRIPTION

Soil information for the study area is available at a reconnaissance scale (1:125 000) in Soil Report No. 16, Soils of the Grahamdale Area, 1971 (Figure 1). The study area is located in the Interlake-Westlake Till Plain. The soils are mapped as a complex association of Fairford, Inwood and Meleb soils developed on extremely calcareous, medium to moderately fine textured glacial till derived from the underlying Paleozoic limestone bedrock. The surface of the till plain is characterized by a distinctive low ridge and swale topography with a general northeast to the southwest pattern.

The two soils described in this study are closely similar in morphological and physical characteristics and are both classified in the Aneda series. Both sites occur under unproductive woodland cover of native vegetation consisting mainly of aspen with occasional bur oak. The two soils described in the following section occur on a gently sloping till ridge trending in a northwesterly to southeasterly direction. The surface horizons of both soils (upper 25 to 30 cm) are characterized by a concentration of roots resulting from the forest cover and in part related to the calcareous nature of the soil parent material. The extremely calcareous nature of the parent material of the Aneda soil effectively restricts the potential of the forest to explore a greater soil depth for nutrients. Each soil described in this study was examined by means of a backhoe pit excavated to a depth of 130 cm.

SOIL and SITE DESCRIPTIONS

SITE 1

The Aneda soil at Site 1 is developed on moderately well drained medium to moderately fine textured, very stony, extremely calcareous glacial till. The Aneda soils are classified as Orthic

Dark Gray Chernozem soils in which the surface texture ranges from loam to clay loam. The topography is irregular, very gently to gently sloping. Surface runoff is moderate, and permeability is medium to moderately slow.

The Aneda soils are characterized by a thin neutral to slightly acid partially decomposed leaf mat and a dark gray mineral Ahe horizon, 3 to 10 cm thick underlain by a weakly developed, dark yellowish-brown Btj horizon, 6 to 12 cm thick. The majority of roots under the forest cover are concentrated in the surface 25 to 30 cm. A transitional moderately calcareous BC horizon separates the B horizon from the underlying extremely calcareous parent material. The extremely calcareous ($CaCO_3 > 50\%$) C horizon is very stony and consists of very pale brown silt loam to silty clay loam, which may be somewhat platy. The Aneda soil described below was exposed on the crest to upper slope position of a subdued northwest to southeast trending till ridge.

L-H - 2 - 0 cm, black (10YR 2/1 moist) leaf and sod mat, slightly acid, abrupt smooth boundary.

Ahe - 0 -8 cm, very dark grayish brown (10YR 3/2 moist), clay loam, moderate medium granular, firm when moist and hard when dry, slightly acid; clear wavy boundary.

Btj - 8 – 30 cm, dark gray to dark grayish brown (10YR 4/1 and 4/2 moist) clay loam, strong medium subangular blocky, very firm moist and hard dry; abrupt smooth boundary.

BC - 30 – 50 cm, grayish brown to pale brown (10YR 5/3 to 6/3 moist) silty clay loam; medium fine granular, friable when moist and slightly hard when dry; clear gradual boundary.

Ck1 - 50 – 74 cm, brown and pale brown (10 YR 5/3 and 6/3 moist), silty clay loam; weak fine granular, very firm when hard, clear gradual boundary.

Ck2 - 74 – 120 cm, pale brown (10YR 6/3 moist) silt loam; weak fine granular to weak fine platy, firm moist and hard when dry.

SITE 2

The soil at Site 2 was examined by means of a second backhoe pit excavated some 20 meters southwest and slightly downslope from Site 1. This soil occurs along the side slope of the subdued ridge on which the farmhouse is located. The land surface between the two sites is very gently sloping (1.5 to 2.0 % slope).

The soil at Site 2 is classified as an Orthic Dark Gray Chernozem member of the Aneda series and is very similar to that observed at Site 1 differing primarily in slightly more moist subsoil conditions below about 1.2 m. A thin Ahe horizon (8 to 10 cm in thickness) consists of very dark brown to black clay loam and occurs below a thin partially decomposed leaf and sod surface horizon. The A horizon has a moderate fine to medium granular structure with a slightly hard to firm consistency. The weakly developed B horizon is clay textured, resulting from leaching from the soil surface. This soil is characterized by a concentration of roots in the surface horizons (in the upper 20 to 30 cms of soil, similar to the soil at Site 1). ABC horizon, some 20 cm thick forms a transition between the thin solum at the soil surface and the underlying extremely calcareous, stony parent material. The Ck horizon is very stony and consists of very pale brown silty clay loam material with a somewhat platy, fissile structure. At about 130 cm, the subsoil is a massive clay material with weak mottling indicative of slightly impeded moisture conditions. Soil samples for particle size analysis were obtained from the central portion of each of the parent material layers (Ck1, Ck2, Ck3, Ck4 and Ck5). The analytical data is presented in Table 1, and a description of the Aneda soil at Site 2 follows:

L-H – 4 - 0 cm, black (10YR 2/1 moist) leaf and sod mat, slightly acid, abrupt smooth boundary.

Ahe - 0 – 8 cm, very dark brown (10YR 2/2 moist) clay loam, moderate medium granular, firm when moist and hard when dry, slightly acid; clear wavy boundary.

Btj - 8 – 25 cm, dark gray to dark grayish brown (10YR 4/1 and 4/2 moist) clay loam, strong medium subangular blocky, very firm moist and hard dry; abrupt smooth boundary.

BC - 25 – 45 cm, grayish brown to pale brown (10YR 5/3 to 6/3 moist) silty clay loam; medium fine granular, friable when moist and slightly hard when dry; clear gradual boundary.

Ck1 - 45 - 90 cm, pale brown (10YR 6/3 moist), very pale brown (10YR 8/2 dry) silty clay loam, weak fine to medium platy breaking to weak fine to medium granular, moist friable, dry hard, clear gradual boundary.

Ck2 - 90 – 120 cm, brown (10YR 5/3 moist), light gray (10YR 7/2 dry), silty clay loam, massive braking to weak fine to medium granular, moist friable, dry very hard, abrupt smooth boundary.

Ck3 - 120 -130 cm. yellowish brown (10YR 5/4 moist) and light brownish gray (10YR 6/2 dry) silty clay loam, massive breaking to weak fine subangular blocky, moist firm, dry hard, clear smooth boundary.

Ck4 – 130 - 140 cm, brown (10YR 5/3 moist) and light brownish gray (10YR 6/2 dry) silty clay, massive braking to weak fine to medium angular blocky, moist firm, dry slightly hard, abrupt smooth boundary.

Ck5 – 140 +cm, dark brown (10YR 4/3 moist and light brownish gray (10YR 6/2 dry) clay, massive breaking to moderate medium angular blocky, moist, very firm, dry hard.

Table 1. Physical Properties of the Aneda Soil Parent Material at Site 2

Hor.	Depth cm	Particle Size Analysis %* Sand	Silt	Clay	Soil Textural Class **	Consistence
Ck1	45 - 90	24.7	34.4	40.9	Clay	Moist, friable; Dry hard
Ck2	90 - 120	26.7	42.4	30.9	Clay loam	Moist Friable; Dry very hard
Ck3	120 – 130	13.4	48.8	37.8	Silty clay loam	Moist firm; Dry hard
Ck4	130 - 140	13.4	48.8	37.8	Silty clay loam	Moist firm; Dry slightly hard

Ck5	140 +	25.4	32.8	41.8	Clay	Moist very firm; Dry hard

*Particle Size Analysis data and ** Soil Textural Classification from A & L Canada Laboratories Inc.   2136 Jetstream Rd. London, Ontario, N5V 3P5

SUMMARY OF THE SOIL CHARACTERISTICS AT THE PROPOSED RESEARCH STUDY

The soil characteristics at Site 1 and Site 2 are closely similar, which is to be expected considering their close proximity in the landscape. The two soils are classified in the Aneda series and are typical of well to moderately well drained soil developed on extremely calcareous glacial till parent material in the southern portion of the Interlake area. This portion of the southern Interlake occupies a transitional area between Chernozemic soils developed under grassland and grassland transition vegetation to the south and Brunisolic and Luvisolic soils of the Boreal forest to the north.

The interpretation of soil resource information contained in soil survey reports for site-specific uses such as suitability for septic tank absorption fields is of a general nature due to limitations imposed by ground truth and map scale. For this reason, the guidelines utilized in making the interpretation are included in the soil report to aid the user of the information. The guidelines utilized for assessing soil suitability for septic tank absorption fields are shown in Table 2.

In consideration of the objective for the project proposal, the Aneda soils mapped in this portion of the Interlake are rated FAIR for use as a septic tank absorption field due to a limitation of moderate permeability (Podolsky, 1982). Soils rated as FAIR in their present state have one or more moderate limitations that would affect the proposed use. These moderate limitations would be overcome with special construction, design, planning or maintenance. (See Definition of Soil Suitability Classes for Selected Engineering Uses, Page 28 in Podolsky, 1982).

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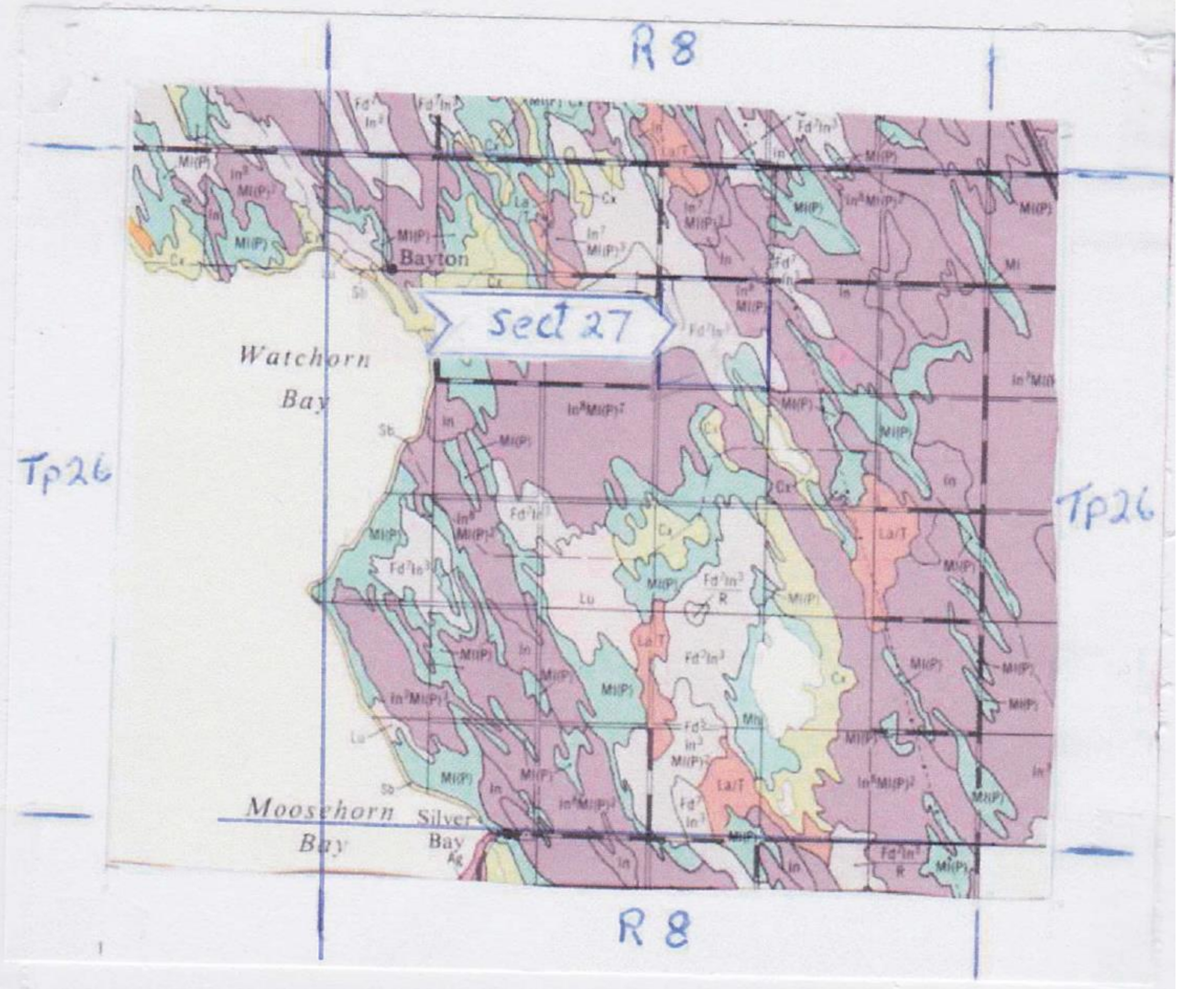

Figure 1. Portion of Grahamdale Reconnaissance Scale Soil Map for Study Area

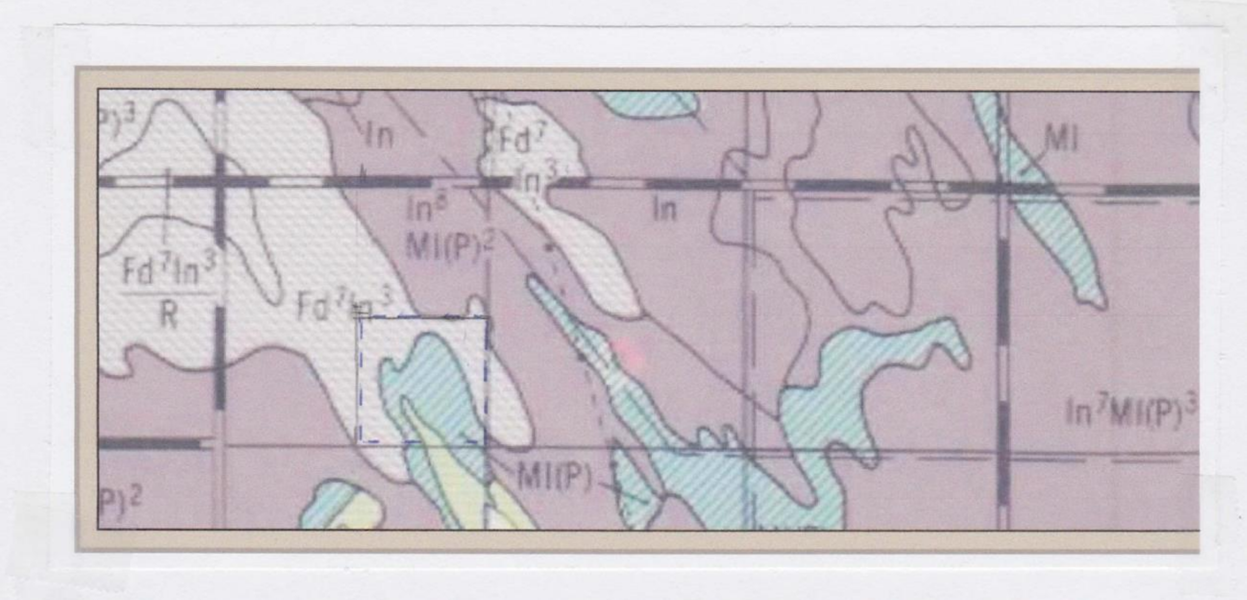

Figure 2. Section 27-26-8 WPM and location of study area and farmstead in the Southeast

Figure 3. Landsat images showing subdued ridge and swale topography in study area and

Table 2 Guide for assessing soil suitability for septic tank absorption fields.

This guide applies to soils to be used as an absorption and filtering medium for effluent from septic tank systems. A subsurface tile system laid in such a way that effluent from the septic tank is distributed reasonably uniformly into the natural soil is assumed when applying this guide. A rating of poor need not mean that a septic system should not be installed in the given soil, but rather, may suggest the difficulty, in terms of installation and maintenance, which can be expected.

Symbol[1]	Items Affecting Use	Degree of Soil Suitability			
		Good - G	Fair - F	Poor - P	Very Poor - V
k	Permeability[2]	Rapid to moderately rapid	Moderate	Slow	Very slow
	Percolation Rate[3] (Auger hole method)	About 8-18 min/cm[3]	18-24 min/cm	Slower than 24 min/cm	
h	Depth to Seasonal Water Table[4]	>150 cm[5]	100-150 cm	50-100 cm	<50 cm
i	Flooding	Not subject to flooding	Not subject to flooding	Subject to occasional flooding (once in 5 years)	Floods every year
t	Slope	0-9%	9-15%	15-30%	>30%
d	Depth to Hard Rock, bedrock or other impervious materials	>150 cm	100-150 cm[6]	50-100 cm	<50 cm

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[1] The symbols are used to indicate the nature of the limitation.

[2] The suitability ratings should be related to the permeability of soil layers at and below depth of the tile line.

[3] Soils having a percolation rate less than about 8 min/cm are likely to present a pollution hazard to adjacent waters. This hazard must be noted, but the degree of hazard must, in each case, be assessed by examining the proximity of the proposed installation to water bodies, water table, and related features. The symbol g is used to indicate this condition. Refer to U.S. Dept. of Health, Education and Welfare (1969) for details of this procedure.

[4] Seasonal means for more than one month. It may, with caution, be possible to make some adjustment for the severity of a water table limitation in those cases where seasonal use of the facility does not coincide with the period of high water table.

[5] A seasonal water table should be at least 100 cm below the bottom of the trench at all times for soils rated Good (U.S. Dept. of Health, Education and Welfare, 1969). The depths used to water table are based on an assumed tile depth of 50 cm. Where relief permits, the effective depth above a water table or rock can be increased by adding appropriate amounts of fill.

[6] Where the slope is greater than 9%, a depth to bedrock of 100-150 cm is assessed as poor.