STUDY ON EFFECTS OF SOIL PROPERTIES TOWARDS CORROSION OF CARBON STEEL PIPELINE

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ABSTRACT

Corrosion is one of the most terrifying incidents that engineers does not want on the pipeline, especially when involving billion of dollars losses. Many industries depended on the pipeline for transporting their raw material or products from the places of source to the place of treatment and finally to the consumers. Among the industries that widely used the function of pipeline were oil and gas industries, water treatment and also crude oil industries. Therefore, as the most important part in transportation role, pipeline need to be ensured always in great condition and anything that could cause damages to these railways must be control immediately before unwanted accident happens. Currently, there were report that said pipeline damages was very dangerous to the environment whether to the human being or to the nature. There were some human fatality and body damages of the environment that caused billion of dollars losses. Due to all consequences that would occur in the future as the punishment for the lack of information on the conservation of pipelines, the research based on this problem will be done to find out the cause of buried pipelines damages due to the soil. The research will focus on the soil properties and its effects towards the corrosion of carbon steel pipeline. The parameters that will be the variables in this research are clay content, moisture content, pH value and also particles size of soil. Relationship between these parameters with the corrosion rate will be investigated properly. The pipelines samples will be taken from actual segment and will be buried in different condition of soil based on previous parameters. About 180 samples plates will be buried for at least 5 months to get the real corrosion rate for different type of soil condition. Once a month the retrieval procedure will be done to check the rate of corrosion and also to ensure the soil properties remain stables as been set up. After all the samples had been retrieve from its medium of different soil conditions, the data will be interpreted in form of tables and graph to shows different parameters will get different results. The result from linear regression analysis and also using excel analysis had shown that the pH parameter were could accept the hypothesis of pH condition were the major influence in corrosion rate phenomenon while others had rejected the hypothesis to become the major influence. The ANOVA analysis also shown the correlation coefficient of all the parameters were high but only the pH condition were satisfy the significance value with lower than 0.05. The pH condition, moisture and clay parameter could be study further while the particles size particles does not suitable for further study.

ABSTRAK

Kakisan adalah salah satu kejadian yang paling menakutkan bagi jurutera tidak mahu pada saluran paip, terutama apabila melibatkan kerugian berbilion dolar. Banyak industri bergantung kepada saluran paip untuk mengangkut bahan mentah atau produk mereka dari tempat-tempat sumber ke tempat rawatan dan akhirnya kepada pengguna. Antara industri yang digunakan secara meluas fungsi saluran paip adalah industri minyak dan gas, rawatan air dan juga industri minyak mentah. Oleh itu, sebagai bahagian yang paling penting dalam sistem pengangkutan, talian paip perlu dipastikan sentiasa dalam keadaan yang baik dan apa-apa yang boleh menyebabkan kerosakan kepada kereta api ini mesti dikawal sebelum kemalangan yang tidak diingini berlaku. Oleh kerana semua akibat yang akan berlaku pada masa akan datang disebabkan kekurangan maklumat mengenai pemuliharaan saluran paip, penyelidikan berkenaan masalah ini akan dilakukan untuk mengetahui punca kerosakan paip yang ditanam disebabkan oleh tanah. Kajian ini akan memberi tumpuan kepada sifat-sifat tanah dan kesannya terhadap kakisan karbon paip keluli. Parameter yang akan menjadi pembolehubah dalam kajian ini ialah kandungan tanah liat, kandungan kelembapan, nilai pH dan juga zarah saiz tanah. Hubungan antara parameter ini dengan kadar kakisan akan disiasat dengan betul. Sampel saluran paip akan diambil dari segmen sebenar dan akan dikebumikan dalam keadaan yang berbeza daripada tanah berdasarkan parameter sebelumnya. Kira-kira 180 sampel akan ditanam sekurang-kurangnya 5 bulan untuk mendapatkan kadar kakisan sebenar untuk berlainan jenis keadaan tanah. Sebulan sekali prosedur pengambilan akan dilakukan untuk memeriksa kadar kakisan dan juga untuk memastikan tanah ini stabil seperti yang telah ditetapkan. Selepas semua sampel telah diambil dari keadaan tanah yang berbeza, data yang akan diterjemahkan dalam bentuk jadual dan graf untuk menunjukkan parameter yang berlainan akan mendapat keputusan yang berbeza. Hasil daripada analisis regresi linear dan juga menggunakan analisis excel menunjukkan bahawa parameter pH dapat menerima hipotesis sebagaimana keadaan pH adalah pengaruh yang utama dalam fenomena kadar kakisan manakala yang lain telah menolak hipotesis untuk menjadi pengaruh yang utama. Analisis ANOVA juga menunjukkan pekali korelasi bagi semua parameter yang tinggi tetapi hanya keadaan pH telah memenuhi nilai signifikan dengan lebih rendah daripada 0.05. Keadaan pH, kelembapan dan tanah liat parameter boleh dibuat kajian lanjutan manakala saiz zarah tidak sesuai untuk kajian lanjut.

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LIST OF ABBREVIATIONS

CR	*corrosion rate*
K	*constant*
T	*time exposure*
A	*area in cm2*
W	*mass loss in g*
D	*density in g/cm3*

Subscripts

b	*bubble*
g	*gas*
l	*liquid*
eff	*effective*
s	*solid*
eqn	*equation*

LIST OF ABBREVIATIONS

RSPA/OPS	*Research and Special Programs Administration, Office of Pipeline Safety*
ASTM	*American Society for Testing and Material*
BS	*British Standard*
AGA	*America Galvanizers Association*
TOD	*Transmission Operating Division*
PGU	*Peninsular Gas Utilization*
SCC	*Stress Corrosion Cracking*
MIC	*Microbiologically-Influenced Corrosion*
PHMSA	*Pipeline and Hazardous Materials Safety Administration Office of Pipeline Safety*

1.0 INTRODUCTION

1.1 Overview

Pipeline is the major medium in transportation of liquid, gas, water and other substances between regions or countries. According to the Field-Listing of the World Factbook statistical calculation until 2010, over 1 million kilometers of pipeline transporting oil, gas, crude oil, water and other substances across the world. This number expected will be increasing through another years. These pipelines had been through all type of condition in the world whether from sea water or buried under the ground. Pipelines was the most useful transportation to supply substances from one place to another for a large amount and safely. Pipelines was used in various kind of industries such as water treatment, oil and gas, hazardous chemical or even some of the electrical industries used pipeline to secure their cable under the ground. But the biggest used was to transport oil, gas and also water. In this research, we will discuss more on the usage of pipelines in oil and gas industries.

Malaysia has been one of the most extensive natural gas pipeline networks in Asia since the Peninsular Gas Utilization (PGU) project had been completed in 1998. PGU systems can transport the capacity of 2 billion cubic feet per day (Bcf/d) of natural gas (Energy Information Administration, 2011). Currently, Malaysia has over 2,554 km of high pressure gas pipeline across the country. This pipeline was monitoring by one of the PETRONAS Gas Berhad (PGB) operating division that is Transmission Operating Division (TOD) for over 24 years and had shown the great achievement in pipeline safety (Mohd Nazmi, 2008). These pipelines were buried underground across the country which means that the pipeline had been buried in several types of soil environments to reach the refinery or process factory. The TOD need to ensure that the gas reached the certain place safely as this substance is one of the major energy source in Malaysia. The condition of the pipeline and its railways must always been inspect to ensure the pipeline does not have any leaking or damages.

1.2 Damages of pipelines

The U. S. Department of Transportation's Research and Special Programs Administration, Office of Pipeline Safety (RSPA/OPS) had compiles data on pipeline accidents and their causes. Damages to the pipeline could occur by many types of aspect whether comes from inside force or outside force. The inside force such as the type of substances that been transport, the pressure inside the pipeline and other thing that could causes any damage from the inside of the pipelines. Outside force damage can include the effects of earth movement, lightning, heavy rains and flood, temperature, high winds, excavation by the operator, excavation by a third party, fire or explosion external to the pipeline, being struck by vehicles not related to excavation, rupture of previously damaged pipe, and vandalism. The data show that for hazardous liquid pipelines and gas transmission pipelines, the largest portion of outside force damage results from excavation damage. This may occur when excavation activity occurring near the pipeline causes an accidental hit on the line. The range of excavation damage runs from damage to the external coating of the pipe, which can lead to accelerated corrosion and the potential for future failure, to cutting directly into the line and causing leaks or, in some cases, catastrophic failure.

The statistical calculation from U.S Department of Transportation shows that more than 900 pipeline failure incidents in the continental United States in the years 1997-2000, around a third were due to third-party damage incidents. The numbers of human's fatalities and body injuries also high due to this problem. A major study of pipeline leakages, undertaken in 1998 by Concawe confirmed this figure. The National Transportation Safety Board had been release new latest report on their website about the accident happen on the pipeline. On Sunday, July 25, 2010, at 5:58 p.m., eastern daylight time, a segment of a 30-inch-diameter pipeline (Line 6B), owned and operated by Enbridge Incorporated ruptured in a wetland in Marshall, Michigan. The rupture occurred during the last stages of a planned shutdown and was not discovered or addressed for over 17 hours. During the time lapse, Enbridge twice pumped additional oil (81 percent of the total release) into Line 6B during two start-ups, the total release was estimated to be 843,444 gallons of crude oil. The oil saturated the surrounding wetlands and flowed into the Talmadge Creek and the Kalamazoo River. Local residents self-evacuated from their houses, and the environment was negatively

affected. Cleanup efforts continue as of the adoption date of this report, with continuing costs exceeding $767 million. About 320 people reported symptoms consistent with crude oil exposure. No fatalities were reported (National Board of Safety, 2012).

1.3 Pipelines Corrosion

Even though the damages of pipeline could cause from many aspects, but in this research, we will discuss more on the corrosion part. Corrosion had been defined as the degradation of a material or its properties due to a reaction with the environment. According to NASA-KSC, there were several type of corrosion such as uniform corrosion, galvanic corrosion, concentration cell corrosion, pitting corrosion, crevice corrosion, filiform corrosion, intergranular corrosion, Stress Corrosion Cracking (SCC), corrosion fatigue, fretting corrosion, erosion corrosion, dealloying, hydrogen damage, corrosion in concrete microbial corrosion. Uniform corrosion or also known as general corrosion is the surface effect produced by most direct chemical attacks is a uniform etching of the metal. Galvanic corrosion is an electrochemical action of two dissimilar metals in the presence of an electrolyte and an electron conductive path. It occurs when dissimilar metals are in contact. Concentration cell corrosion occurs when two or more areas of a metal surface are in contact with different concentrations of the same solution. Pitting corrosion is localized corrosion that occurs at microscopic defects on a metal surface. The pits are often found underneath surface deposits caused by corrosion product accumulation. Crevice or contact corrosion is the corrosion produced at the region of contact of metals with metals or metals with nonmetals. It may occur at washers, under barnacles, at sand grains, under applied protective films, and at pockets formed by threaded joints.

Meanwhile, Filiform corrosion occurs on painted or plated surfaces when moisture permeates the coating. Long branching filaments of corrosion product extend out from the original corrosion pit and cause degradation of the protective coating. Intergranular corrosion is an attack on or adjacent to the grain boundaries of a metal or alloy. Stress corrosion cracking (SCC) is caused by the simultaneous effects of tensile stress and a specific corrosive environment. Stresses may be due to applied loads, residual stresses from the manufacturing process, or a combination of both. Corrosion fatigue is a special case of stress corrosion caused by the combined effects of cyclic

stress and corrosion. No metal is immune from some reduction of its resistance to cyclic stressing if the metal is in a corrosive environment. Fretting corrosion is rapid corrosion that occurs at the interface between contacting, highly loaded metal surfaces when subjected to slight vibratory motions is known as fretting corrosion. Erosion corrosion is the result of a combination of an aggressive chemical environment and high fluid-surface velocities. Dealloying is a rare form of corrosion found in copper alloys, gray cast iron, and some other alloys. Dealloying occurs when the alloy loses the active component of the metal and retains the more corrosion resistant component in a porous "sponge" on the metal surface. Hydrogen embrittlement is a problem with high-strength steels, titanium, and some other metals. Control is by eliminating hydrogen from the environment or by the use of resistant alloys. Microbial corrosion is also called Microbiologically-Influenced Corrosion (MIC) is corrosion that is caused by the presence and activities of microbes. This corrosion can take many forms and can be controlled by biocides or by conventional corrosion control methods.

Naturally the corrosion happen on all types of material but it was had been most commonly associated with metals. Metals corrode because we use them in environments where they are chemically unstable. Only copper and the precious metals (gold, silver, platinum, etc.) are found in nature in their metallic state. All other metals, to include iron-the metal most commonly used-are processed from minerals or ores into metals which are inherently unstable in their environments. Metallic corrosion is a process in where the surface of a metallic structure is oxidized or reduced to a corrosion product such as rust by chemical or electrochemical reaction with the environment. The metal structures will undergo the migration of ions away from the surface, resulting in material loss over time. In other words there is enough time to the material loss can result in significant reduction of area, which in turn leads to a reduction in the structural capacity of a given metallic element. When this eventually happened, the corrosion destroys a sufficient amount of the structure’s strength and finally a failure will occur (Hubbell, 2006).

Since the pipelines commonly made by the metals, there are very highly risk on corrosion attack could happen on them. Corrosion on the pipelines can cost a large amount of lost the government as it was used in many industries such as water treatment, oil and gas and also for installing electrical cable. Most of the pipeline was

used in oil and gas industries which means there were very huge lost if the pipelines undergoes corrosion without inspection. For example such happened at the US industries when they are already lost an estimated $170 million per year to maintain the pipelines safe in use. The US oil and gas industries had done some research to reduced the amount of maintenances by exploring the potential solution to avoid more corrosion to the pipelines occur and cost a large amount of money (Denis et. al, 1987). The maintenances of these underground pipelines in Malaysia had been regularly done by the TOD but there is still serious risk from the corrosion attack that need to concern on. The research on the soil properties towards corrosion of the pipeline is hardly available due to the assumption that there is minor effect of this parameter on corrosion dynamic which eventually lead the pipeline into major damage and can be neglected (Noor et al., 2011). Therefore it is very convenient to conduct some research to prevent more losses from happening by knowing the soil properties and its effects.

1.4 Problem statement

The high risk of corrosion attacks on pipeline was become more serious nowadays as the pipelines were used for decade to transporting the chemical, liquid or gas. Pipelines that was buried underground transport whether crude oil, gas or water will across various environment such seawater (offshore) and soil (onshore) that may lead into the corrosion attack and finally leaking situation. The corrosion of pipelines will cost huge amount of money to repair it and will brought the huge lost to the government. The study of soil as the corrosive environment towards steel pipelines corrosion is necessary to avoid more losses and hazardous condition to economical and environmental due to large number of pipelines had been buried these days (Ferreira et al., 2007). Corrosion of pipeline will lead into leaking and also rapture of it that very unsafe to the environment especially human being as these pipelines may across their neighbourhood. This hazardous situation can inflict human fatality and also badly damage the environment, assets, and even human as the substances that had been transport using the pipelines was highly in pressure (Hopkins, 1995; National Energy Board, 1996; Yahaya et al., 2009). Therefore, this study was conducted to expose more on the danger of corrosion to the pipelines and also the effect of soil properties towards pipelines corrosion.

1.5 Scope and objective

The corrosion can occur from the outside and also from the inside of the pipelines. However, we are more interesting on discussing about the outside factor which is the soil properties towards the corrosion of the pipelines. Soil corrosion is very complex phenomenon because of involving many factors or variables. It's had been defined as the deterioration of metal or other material brought by the chemical, mechanical and biological action by soil environment (Chaker and Palmer, 1989). There were many factors that could caused corrosion from the soil properties such as alkaline, pH and hardness. Alkalinity, hardness, and pH interact to determine whether the water will produce scale or corrosion or will be stable. In general, corrosion is the result of water with a low pH. Acidic waters have lots of H+ ions in the water to react with the electrons at the cathode, so corrosion is enhanced. In contrast, water with a higher pH (basic water) lowers the solubility of calcium carbonate so that the calcium carbonate is more likely to precipitate out as scale. Scaling tends to be the result of water with a high hardness. Hard water typically contains a lot of calcium compounds which can precipitate out as calcium carbonate. However, if the hardness in the water is primarily non-carbonate, the chlorate and sulphate ions will tend to keep the calcium in solution and will prevent scale formation.

Alkalinity is a measure of how easily the pH of the water can be changed, so it can be considered to be a mitigating influence with regards to pH. Water with a high alkalinity is more likely to be scale-forming even at a relatively low pH. In contrast, low alkalinity waters lack the buffering capacity to deal with acids, so they can easily become acidic and corrosive. The other factors was bacteria, Bacteria can both cause and accelerate the rate of corrosion. In general, bacterial colonies on pipe walls accelerate corrosion below them due to oxygen cell concentration, causing increased pitting and tuberculation. Like humans, some bacteria produce carbon dioxide, which can combine with water to become carbonic acid and accelerate corrosion. The bacterial colonies also block the deposition of calcium carbonate scale on the pipe walls (Faisal et al, 2012). Besides that, the moisture content, clay content and also the size of soil particles also have a huge influence in controlling the corrosion rate of the pipeline. Even though there is a lot of soil properties that could influenced the corrosion rate of the pipelines, but in this research we will focusing more on the effects of the soil

particles size, pH value, clay content and also moisture content towards corrosion of the underground pipeline.

The scope of this study will be limited in the lab. It is because there are enough equipment in the lab rather than outside the lab. Furthermore, to do the experiment outside the lab will cost higher amount of money and transportation needed. Moreover, to buried the samples at the actual site, there must been some approval from Petronas authorities and its will take much more time than just doing in lab. For the samples that will be used, only carbon steel will be take part in this study to ensure the corrosion rate on one type of material, and study just for the soil properties such as the pH value, moisture content, clay content, and also the particles size of the soil. Other properties of soil will not be study in this experiment. As for the data analysis, the method that will be used only weight loss measurement. This is because this method much more practical due to its cost and also the equipment needed. Weight loss method much easier to used, and its results is quite good as other methods such as electrochemical test method and salt spray test.

2.0 LITERATURE REVIEW

2.1 Introduction

The huge production of materials either in solid, liquid or gas form could have their own side effects. The excess of unwanted or rejected of these materials became waste products and dangerous to the environment (Frank Ackerman, 1997). Even the usage materials also will became one of the waste products when new products were produced. This situation could harm our environment and damage our lovely earth. The waste materials that could not be recycles had buried in the soil and polluted the soil composition with their chemicals and solids wastes.

The hazardous waste materials could affects the soil composition and became unsafe for plant and animals that depend on the flora and fauna as their habitat and place to growth. But this topic will not be discuss further here since the real agenda was to discuss on the development of the world technologies and industries now days. Even though there were competition between each industries, but they also somehow need each others to sustained their production and kept their industries moving forwards. Each industries need their own suppliers and buyers to balance the source came in with the product came out. The real target for the industries companies was to gain as much profit as possible before their competitor does. Therefore they need the regular suppliers and regular customers to ensure their production keep growth from time to time while of course continued to find new customers for more profit.

Each industries may be different from each other in terms of production values, amount of production or amount of source, but the transportation of the source always the same with each other (Yung-yu Tseng et. al, 2005). For example, if the industries were need the solids raw materials they could used land transportation such as lorries, train or other kind of transport that could send their need using railways. Sometimes the industries used the water transportation such as ship to send the raw materials with a huge of amounts and sometimes they also used plane. Neither less, all the mentions transportations were very costing and need a lot of money. In order to reduce their cost, many industries in the world prefer to used the pipeline transportation rather than

mention before. But this kind of transportation only valid for liquid and gas material since it could be flow and can be compressed.

Pipeline had been proved by many research as the safest transportation for gas and liquid materials (D. F.Roth et. al, 2013). Pipeline had been used for many industries worldwide especially in oil and gas industries. Pipeline was the major transportation in supply or sending the gas or liquid material from one place to another. For example, the industries in United States had been used pipeline as their major transportation for century and had proven to be much efficient and easier to handle. Pipelines have been used as the major transportation of American natural gas or oil to be send worldwide such as from Canada to the United States, for three quarters of a century. Almost thousands miles of interstate pipeline were crisscross United States, carrying petroleum products, crude oil and natural gas. This phenomenon also could be seen in Malaysia when all the crude oil from the offshore were sent using pipeline and been supply to the refinery plant for further process. This extensive and complex operational infrastructure network was heavily regulated and gazette by the Ministry of Transportation, which always monitoring the very important issues which always caused controversy that are safety and reliability.

2.2 Pipeline Usage

The question of whether pipeline transport of oil and gas is safe were possible to answer based on the past centuries experience. It was moreover, possible to do the comparison between the record of oil and gas transport using pipelines with the one that transported via rail and road. The pipeline capacity had become manifest if the fuel shipment were become one of the comparison between these kind of transportation since the transportation by rail and road need to used very high consumption of fuel for the transport and also need have personnel that willing to do the job. Neither less, the rail and road transportation had become increasing as limitations on. U.S. Department of Transportation had provided the review of safety and accident statistics for the extensive network of existing U.S. pipelines which also included many linked all over the country such as to Canada. The statistics clearly show that the pipeline does not only

a substantial cost advantage, but it also had prove that only fewer spillage or leakage incidents and personal injuries compared with the transportation using road and rail.

As mentioned before, pipelines were used as the primary mode of transportation for petroleum products, crude oil and natural gas. The Association of Oil Pipeline had stated that approximately 70 percent of petroleum products and crude oil were transported using pipeline on a ton-mile basis. Meanwhile, the tankers and barge traffic accounts for 23 percent of oil shipments and the trucking accounts for 4 percent of shipments. The rail transportation were recorded for the remaining 3 percent. Essentially all dry natural gas is shipped by pipeline to end users. Data on pipeline safety were gained from the United States Department of Transportation Pipeline and Hazardous Materials Safety Administration Office of Pipeline Safety (PHMSA) stated that the majority of incidents of natural gas transportation occur on road and rail compared with the one transported using the pipeline. The data gained by the report of operators to PHMSA in case any incident occur for the pipeline that crosses a certain safety threshold. These reports enable the public to compare the safety of pipelines to that of road and rail.

Even though the pipeline were proven as the safest transportation for the liquid and gas, but it still facing its own problems that need to be handle and need to be taken care of. The most common problems due to the pipeline systems was the leakage. Leakage of the pipeline could sound simple and just a small thing, but this small thing could caused huge problem depending what kind of material it carrying. Pipeline that carried water from the refinery to the household residential area maybe not dangerous enough. The only loss were to the company which need to repair their pipeline and caused their money loss. But if the pipeline were carrying the natural gas, crude oil, petroleum products or other kind of flammable products, this small leakage problems could caused no only losses to the company but could also caused human injuries or fatalities as well as the properties damages.

Leakage of the pipeline could caused from many factors. It could be from the external or internal factors. For internal factors such as the composition of the materials carried could damages the pipeline from inside of it. From Report 2013-B of pipeline performance in Alberta, the internal corrosion remains the leading cause of pipeline

failure, representing 54.8 per cent of all releases. This comes as little surprise as most Alberta pipelines transport raw oil and gas before the corrosive components of the produced products are removed. Meanwhile, the external factors such as external corrosion, explosion, site construction or other kind of incidence happen outside the pipeline were also became the major factors of pipeline leakage. for example, the external corrosion is the second leading cause of pipeline failures based on the Report 2013-B which stated that the statistical data were 12.7 per cent, and is primarily due to external pipeline coatings failing from either age or excessive production temperatures.
In this study, the factors that had been concentrate more were in corrosion part which occur from outside of the pipeline which also means the external corrosion for simple understanding. Corrosion is the gradual destruction of materials which were usually metals by chemical reaction with its environment. The corrosion also could be defined as the electrochemical oxidation of metals in reaction with an oxidant such as oxygen. The environment that want to study here were the soil. This was due to the pipeline were always been buried under the soil to protect it from any larger problems. But the soil itself have many composition which need to be study to ensure the soil could always protect the pipeline from any damages. The soil criteria need to be study first before any pipeline could be installed in it since not all kind of soil type or properties were suitable with all kind of pipeline conditions. This means, different soil properties need to be installed different kind of pipeline materials or the pipeline need to be protected first with coating or other kind of protective materials based on the soil conditions.

2.3 Soil Behaviour

Soil is one of the natural element that had been provided to complete the earth balance, consisting of several layers that different from one another. Soil's major composition was minerals such as sand, clay, silt and etc that mixed with some organic compound which have different properties from major materials such as in terms of color, chemical and biological characteristics, structures, textures and etc. Commonly, soil had been viewed as the loose covering of mineral particles that thinly overlie the surface of earth (Peter.W, 1999). In the Principles of Geology book, the author had defined the soil as the end product of the climate influence, relief such as slope of

terrain and etc, organisms activities and minerals reaction over periods of time (Waters et al, 1975). Soil is the indestructible materials since its continually undergoes development either physically, biologically or through chemical process. Known as the 'skin of earth', soil have the interface between atmosphere, hydrosphere, lithosphere and biosphere (Ward, 2008).

Soil is a major component of the Earth's system of self-regulation that has created the environmental conditions necessary for life on this planet. Soil is the largest surficial global Carbon reservoir, and it is likely one of the most reactive to human disturbance and climate change. As earth warms, soils add additional carbon due to increased biological activity. Thus, soil carbon losses likely have a huge positive feedback response to global warming. Soil acts as an engineering medium, a habitat for soil organisms, a recycling system for nutrients and organic wastes, a regulator of water quality by removal of impurities, killing of disease agents, and degradation of contaminants. It's also a modifier of atmospheric composition by absorbing oxygen and methane, and releases carbon dioxide and nitrous oxide. Not only that, the soil also is a medium for plant growth by providing physical support, air, water, temperature moderation, protection from toxins, and nutrients. Since soil has a tremendous range of available niches and habitats, it contains most of the earth's genetic diversity. Soils can convert dead organic matter into various nutrient forms, such as humus, that allow for the nutrients to be readily available for and useable by plants and animals. The process of respiration can then be carried out by heterotrophic organisms, which allows for the return of the carbon content of dead organic matter back into the atmosphere.

Soil, as the corrosive environment is probably of greater complexity than other environment. The corrosion process of buried metal structures is extremely variable and can range from rapid to negligible. In fact pipe in soil can be perforated within one year, presenting very localized or uniform corrosion attack. With background knowledge of the principle soil specifics and their influence on metal corrosion, the most serious corrosion problem can be prevented. Soil properties had been found to be one of the parameter in influencing the corrosion of underground pipeline. The engineering properties of the soil clearly need to be concern by the pipeline company to avoid their products corrode and last longer in different type of soil and their condition, many industries had put their trust on transporting reactants and products using underground

pipeline and could loss a huge amount of money if anything happen on their railways. To overcome these concerns, this study will be conduct to investigate more on the effects of soil engineering properties to the corrosion of pipelines and will focusing on several type of soil characteristics. The moisture content, clay content, soil's pH and also size of soil particles will be the main aspect in this study.

Previous research had found that the moisture content in soil have the most profound effect when considering corrosion potential than any other factors. There are three types of sources which provide the soil moisture such as free ground water, gravitational water and capillary water (Norhazilan et al, 2012). Certainly, they have significant influence on the determination of corrosion growth. From the Agricultural Information Bank 2011, the classification and definition of soil water was explained with their detailed. Groundwater is water that comes from the ground. Groundwater comes from rain, snow, sleet, and hail that soak into the ground. The water moves down into the ground because of gravity, passing between particles of soil, sand, gravel, or rock until it reaches a depth where the ground is filled, or saturated, with water. The free ground water is present in the soil below the surface and usually only river crossing pipelines are surrounded by ground water. In such condition, corrosion is regarded to occur in an aqueous environment. Gravitational water occupies the larger soil pores (macro pores) and moves down readily under the force of gravity. Water in excess of the field capacity is termed gravitational water. Gravitational water is of no use to plants because it occupies the larger pores. It reduces aeration in the soil. Thus, its removal from soil is a requisite for optimum plant growth. Soil moisture tension at gravitational state is zero or less than 1/3 atmosphere. The main sources of gravitational water are snow, rainfall, irrigation and flood. This water enters and flows through the soil, governed by soil physical properties, including pore and capillary spaces at various zone in the soil profile. Capillary water is held in the capillary pores (micro pores). Capillary water is retained on the soil particles by surface forces. It is held so strongly that gravity cannot remove it from the soil particles. The molecules of capillary water are free and mobile and are present in a liquid state. Due to this reason, it evaporates easily at ordinary temperature though it is held firmly by the soil particle; plant roots are able to absorb it. Capillary water is, therefore, known as available water. The capillary water is held between 1/3 and 31 atmosphere pressure. The capillary water represents an important reservoir of water in soil.

Generally, corrosion rate increases with the increasing of moisture content. In previous research, they had used the poly bag as the container to keeps the soil and buried their samples, but the poly bags contain holes at their side and could not hold the water in the soil accurately. This means that the moisture in the containers will not have constant moisture and the result may not quite appropriate to state as the effects of moisture. To avoid that situation, this research will use the plastic containers with the lit to get the accurate corrosion rate of carbon steel cause by moisture content.

Soil are commonly named and classified according to size range of their particulate matter. Particle size plays a very large role in determining the longevity of pipeline in a particular soil. Particle size will dictate the amount of aeration as well as the time of wetness for contacting pipelines. Soil particle sizes are generally divided into three categories: sand (0.07 – 2 mm), silt (0.005 – 0.07 mm), and clay (< 0.005 mm) (America Galvanizers Association AGA, 2011). In real world, the classification of the soil particles size was more than stated by AGA, the details of soil classification had been stated as cobble (> 60mm), gravel (2mm-60mm), sand (2mm-0.063mm), silt (0.063m-0.002mm) and clay (<0.002mm) (Y.Nordin et al, 2012). Variation of proportion of soil size groups determines many properties of the soil. In sandy soils, the larger particle size allows for air to enter between the particles and promote aeration of the soil. At the same time, aerated soils allow moisture that remains in the soil from rainfall or other sources to evaporate at a much faster rate than non-aerated soils of smaller particle size. This resulting aeration and shorter time of wetness correlates to a lower corrosion rate of pipelines. Another scholar that give the opinion and done some research on the correlation between particles size and the corrosion of metal was Rich Davis. He had written on the Helier Pier World that the smaller the particles size of soil, the higher the corrosion potential of the soil. Since particle size and resistivity are positively correlated, these two factors could be considered redundant, although there are case histories that belie this correlation.

Besides that, clay contents also considerably among the biggest factors involving the corrosion of the pipeline. Term commonly used for clay classification such as sandy clay, clay loam, silty clay loam and etc. Clay soil is the smallest soil in soil particles size classification and basically contain in everywhere, the previous research had investigate the relationship of the clay content in particular soil towards the

corrosion rate. According to Yahaya, the high clay content soils present in particular soils will give more packed particles and have less pore capacity for moisture (water) and gases (oxygen) diffusion than an open-type-soil such as sand/gravel. Therefore, soils with high clay content are less corrosive (N. Yahaya et al, 2011). Another scholar had wrote about the clay content was Lucien Veleva, 2005. In her articles, she had said that the clay was very plastic mixtures with highly moisture content and were considered as the most important inorganic constituents of the soil. For the common used, the clays often were grouped depending on the weathering conditions for example montmorillonite, illite and also kaolinite.soil with fine texture due to high clay content present more packed particles and less pores capacity for moisture and gases such as oxygen to allow the diffusion process to occur compared to other open-type soil such as sand. In her articles also said that the clay mineralogy and properties are closed related to corrosion aggressiveness of soil, and this fact needs to be taken as very high concern and more attention needs to be given. The clay content in the soil will be measure first before the samples been buried.

Corrosion rate also occur differently according to the pH value of the soil. The higher pH in the soil means the alkaline condition while the lower pH of the soil means the soil in acidic condition. Some previous research had been done in this characteristic, Powell 1995 had indicate that the reduction rate or corrosion rate increases with decreasing of pH value. The acidic environment with pH lower than 6 are more corrosive compared to pH from 6–8 or alkaline pH higher than 8 (Bradford, 1993). According to Benmoussat and Hadjel, the acidity of the medium may have resulted from humic acid (HA) formed from organic matter. It has also been observed that soils can become acidic due to leaching of basic cations (Ca^{2+}, Mg^{2+} Na^{+} and K^{+}). Robert Baboian had said in his book that the pH of soil considered one of the major effects in metal corrosion.

`Soil moisture or electrolyte can be describe as acidic (pH < 7), neutral (pH=7) and also alkaline (pH > 7), based on the relative ratio of hydrogen ions to hydroxyl ions. When hydrogen ions predominate over hydroxyl ions, the soil is acidic and vice versa. The corrosion effects of soil moisture acidity or alkalinity depends very much on the specific metal of interest. Acidity soil could occur upon the results of natural process of weathering under humid conditions, such as mineral leaching, decompositions of acidic

plants, industrial wastes, acid rain, and certain forms of microbiological activity. Based on Robert book, the most of the soil is on the range of 4.5 to 8 in pH classification. More acid in soil means that pH lower than 4.5 can cause rapid metal corrosion and serious risk to common construction materials, including some stainless steel grade.

As the summary, the soil properties such as clay content, moisture contents, pH value and also particles size had been prove that they also play an important part to contribute in the corrosion process of the buried pipelines. The previous research had successfully revealed the influences of these parameters to the corrosion rate but not much of them reveal the corrosion rate of these parameters in their different of condition such as the corrosion rate in more clay content soil compare to the less one. Here, we will conduct a study to reveal these different conditions of soil could effects the corrosion of underground pipelines.