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REMOVING



ALE REMOVERS IN
E (CaCO₃) RICH

SCALES

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ABSTRACT

The presence of high concentration metal ions such as Ca^{2+} and Mg^{2+} together with carbonate and sulphate ions in industrial process always gave rise to scaling. The carbonate, and sulfate of calcium, strontium and barium are the most common scales formed. Scales are usually formed when salt water is saturated with the ions and exposed to drastic changes in temperature and pressures. The composition and forms of scales may vary dependent on industry such as the formation of calcium phosphate in sugar refineries while calcium carbonate scaling in boiler tube of steam generating facilities. The objectives of this research are to characterize the nature and component of CaCO_3 based scales, to establish the ability of commercial scale remover formulation in removing CaCO_3 scales and to study the impact of these commercial scale removers on pipe material. Sample of scale were collected at selected plant. The scale samples were analyzed using Fourier-Transform Infrared Spectroscopy (FTIR), X-Ray Diffraction (XRD) technique and Thermal Gravimetric analysis. FTIR analysis confirmed the dominance of carbonate phase in the samples while the XRD analyses confirmed the presence of CaCO_3 as calcite and aragonite. Thermal Gravimetric Analysis enables the determination of amount of carbonate present in the samples. The efficiencies of different commercial scale remover were compared based on their ability to dissolve the scale sample. The effects of scale remover towards carbon steel sample that are commonly used as pipe material were studied. Formulation AM1082 was found to be the most efficient in dissolving the scale sample followed by formulation AM1081, AM1080, sulfamic acid and last the sulfuric acid. Formulation AM1082 has been found to cause minimal leaching of the piped material while sulfuric acid caused the worst effect. Overall AM1082 scale remover proved to be the best formulation and less harmful to the pipe material.

ABSTRAK

Kehadiran kepekatan ion logam Ca^{2+} dan Mg^{2+} pada kepekatan tinggi bersama dengan ion karbonat dan sulfat dalam proses perindustrian sentiasa menyebabkan pembentukan kerak. Karbonat dan sulfat bagi kalsium, strontium dan barium adalah kerak yang paling biasa terbentuk. Kerak biasanya terbentuk apabila air garam tepu dengan ion terdedah kepada perubahan drastik dalam suhu dan tekanan. Komposisi dan bentuk kerak mungkin berbeza-beza bergantung kepada industri seperti pembentukan kalsium fosfat dalam proses penapisan gula manakala pembentukan kerak kalsium karbonat dalam tiub dandang stim. Objektif penyelidikan ini adalah untuk mencirikan sifat dan komponen kerak yang kaya CaCO_3 , untuk mengkaji kemampuan perumusan pembuang kerak komersial, dalam menghilangkan kerak CaCO_3 dan mengkaji kesan formulasi-formulasi perumusan pembuang kerak komersial pada bahan paip. Sampel-sampel kerak telah diambil pada kilang yang terpilih. Sampel-sampel kerak dianalisis menggunakan Spektroskopi Fourier-Transform Infrared (FTIR), teknik Pembelauan X-Ray (XRD) dan analisis Terma Gravimetrik. Analisis FTIR mengesahkan bahawa terdapat dominasi fasa karbonat di dalam sampel manakala analisis XRD mengesahkan bahawa kehadiran CaCO_3 adalah sebagai calcite dan aragonite. Analisis Gravimetri Terma membolehkan penentuan jumlah karbonat yang wujud di dalam sampel. Kecekapan formulasi pembuang kerak komersial yang berbeza dibandingkan berdasarkan kepada keupayaan mereka untuk melarutkan sampel kerak. Kesan pembuang kerak terhadap sampel keluli karbon yang biasanya digunakan sebagai bahan paip juga telah dikaji. Formulasi pembuang kerak AM1082 telah didapati yang paling berkesan dalam melarutkan sampel kerak, diikuti dengan formulasi pembuang kerak AM1081, AM1080, asid sulfamic dan terakhir asid sulfurik. Formulasi pembuang kerak AM1082 telah didapati menyebabkan larut lesap yang minimum terhadap bahan paip manakala asid sulfurik menyebabkan kesan yang paling teruk. Pembuang kerak AM1082 nyata terbukti menjadi perumusan terbaik dan kurang berbahaya kepada bahan paip.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The word “scale” refers to various solid deposits or an incrustation deposit on the inside of a vessel in which water is heated, such as in a steam boiler. Scale has causes so many problems in the oilfield. The three most common types of scales to form in the oil and gas industry are calcium sulfates, barite and calcite. The problem of scale deposits include plugged tubing strings, plugged perforations, stuck valves, stuck down hole pumps, plugged flow lines, fouled fire tubes, damaged boiler tubes and many more.

Scale is divided into four main classes which are gas scale, inorganic, organic and soap. Examples of inorganic scales are Carbonates (Ca, Mg, Fe (II)), sulfates (Ca, Ba, Sr, Ra), Oxides and Hydroxides (Fe (II), Fe (III), Mg), Sulfides (Fe (II) and Zn) and also Silicates (Ca, Mg, Al and Na). The top three inorganic scales deposited in the oil field are Calcium Carbonates (CaCO_3), Calcium Sulfate (CaSO_4) and Barium Sulfate (BaSO_4).

Calcium Carbonate (CaCO_3) scale can be formed by the combination of Calcium ions with Bicarbonate ions. Its solubility is affected by pressure drops in the system, temperature, total dissolved solids and pH. The tendency for Calcium Carbonate scale to form increases as pressure drops, temperature increases, and water with high salts content is diluted and pH increases. It is usually removed by treating it with either organic acids or hydrochloric acid.

Scale deposition is one of the most serious oil field problems that inflict water injection systems. If we ignore it, it could lead to other problems or make it even worse which is disrupting the plant production. Plants rely on its production to keep the business going. Interrupted production, means fewer products being produced. However, scale deposition is not the only problem that may disrupt plants production. Disrupted pipeline due to corrosion may cause the situation to be even worse. Thus, this research is mainly to establish the ability of commercial scale removal formulations in removing scale and also to investigate the impact of these formulations on selected pipe material. Then we will know if the formulations give benefits to plants production or the way round.

The waters produced in the oilfield are complex. Some wells produce almost pure water while others produce brine. The dissolves solid are present as ions in the water. Some of the ions combined and become compounds with very little solubility in water. Since water has a limited capacity for maintaining these compounds in solution, the compounds will precipitate from solution into solids once it reached its limit. Thus, the precipitated solids form scale. The precipitation of solid can either form on a surface such as pipe wall or can stay in suspension of water. Figure 1.1 briefly show the formation of scale.

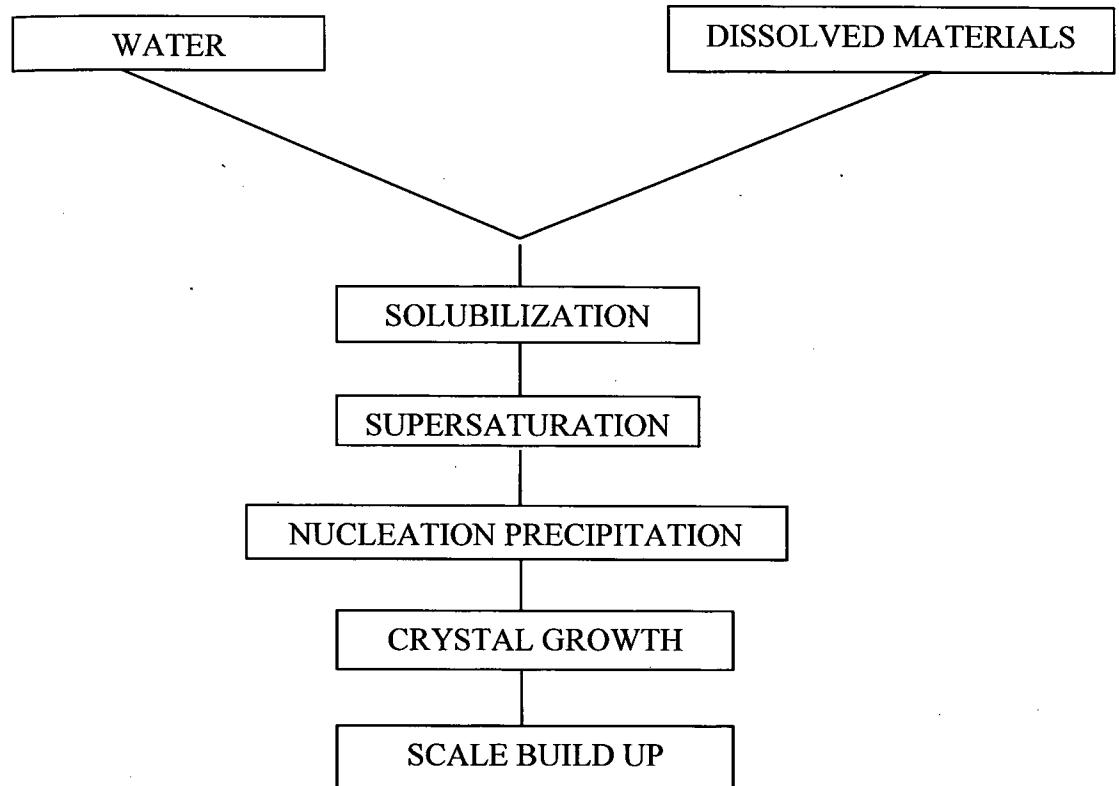


Figure 1.1 - Scale Formation

Scale deposition is commonly caused by the pressure, temperature, pH and total dissolved solids changes and also commingling of produced water and/or surface water. Scale control consists of prevention and removal. Inhibitors chemical have a tendency to bind to the scale surface or nucleating scale crystallite at the growth sites and thus, disturb its growth.

Removal of scale should be done if scale is already deposited. There are many ways in removing scales which are by using chemical, mechanical or both. Removal process using chemical consist of dissolving the scale while mechanical is by drill out the deposited scale. The removal of scale accumulation will be successful if the scale composition is being determined. In selection of scale removal, the formulation types of scale that might form in water under certain condition need to be identified first. Hydrochloric Acid is an

example of a good chemical remover in scaling problem and is the cheapest and easiest way to treat most of scale problems.

To overcome scaling problems, we can avoid mixing incompatible waters. However, it seems impossible to avoid, thus to reduce scaling problem it can be start with prevention. Early prevention is much better as the saying goes, prevention is better than cure. Scale inhibitors available in the market are in form of organic and inorganic compound. The most widely used scale control chemical in the oilfield industry today is organic scale inhibitors.

The water condensing on the inner surface of pipe is usually soaked with corrosion products. This causes the pH in water to increase thus cause the formation of more or less protective corrosion product films covering the steel surface. The films act as reducing the corrosion rate. There are however alternatives to help reducing the corrosion rate of carbon steel for transporting hydrocarbons which was stated by A. Dugstad *et al.* (1994) that the method consist of applying corrosion inhibitors, applying hydrate preventers, reducing water wetting, increasing the pH, reducing the CO₂ partial pressure, selecting optimized materials and avoiding flow disturbances.

1.2 PROBLEM STATEMENT

Descaling is not a simple process. In most cases, scale is not in pure form. A Calcium Carbonate (CaCO₃) scale might be mixed with Gypsum (CaSO₄) or hydrocarbons. Hydrocarbons or Gypsum (CaSO₄) are non-acid soluble. Thus it will block the acid from reaching the scale.

This study shows the effectiveness of scale remover and the impacts on production's pipe material. Scale remover might work in removing scale in the industry. It also gives side effects mainly on the pipe material. It can cause corrosion to the pipe thus shorten the lifetime of a pipeline.

1.3 OBJECTIVES OF STUDY

So, the objectives of this research are

1. To characterize the nature and component of CaCO_3 based scales
2. To establish the ability of commercial scale remover formulations in removing CaCO_3 rich scales
3. To study the impact of these formulations and another two acids on the pipe material

Thus, the performance of the brands will be elucidated and hopefully will lower the cost of scale remediation.

CHAPTER 2

LITERATURE REVIEW

2.1 SCALING

Scale is generally known as a hard mineral coating that forms on the inside surface of boilers, kettles and other containers in which water are repeatedly heated. Same goes in the industries; in which scaling usually took place in plate heat exchanger and other equipments involving cooling or heating of water. Scaling or fouling is a process of scale formation under certain circumstances or as stated (Andritsos *et al.*, 2003) it is the accumulation of undesirable deposits on industrial equipment surfaces and is a complex phenomenon with severe economic consequences, affecting a wide range of industrial processes.

Mineral scales precipitation may causes many problems in the oil and gas production operations as being mentioned by Amer Badr Mohammed (2007), it may causes formation damage, production losses, increased workloads in producers and injectors, poor injection water quality and equipment failures due to under-deposit corrosion. The formation of mineral scale in conjunction with the production of hydrocarbons has been an issue especially in the oilfield operation industry. As quoted by Khatib (1994), Krueger (1986), Lindlof and Stoffer (1983) and Moghadasi *et al.* (2003), it depends on the nature of scale and on the fluid composition, the scale deposition can occur inside the reservoir which causes formation damage or in the production facilities where blockage can cause severe operational problems.

According to the University of Michigan Dept. of Engg. Research Bulletin No. 15 (1930), scale formation was due to impingement of solid particles on the heat transfer surfaces. The term “scaling” often refers to the formation of deposits of inverse-solubility salts (CaCO_3 , CaSO_4 , $\text{Ca}_3(\text{PO}_4)_2$ etc.), although it generally denotes the hard and adherent deposits due to inorganic constituents of water. Scaling and corrosion can cause serious damage and economic problems in the course of production, both to wells and the utilization systems (Pátzay *et al.*, 1998).

Supersaturation is the main driving force for scale formation and this can be considerably augmented by the superimposed effect of concentration polarization (T.Y. Soror, 2009). Supersaturation is the state where the solutions that contain higher concentrations of dissolved solute than their equilibrium concentration. According to Shaheen *et al.* (1973), the solid particle that is impingement is then adhered to the surfaces and builds it up gradually in order to form a continuous coating and if a solution is supersaturated, it will have a tendency to form crystals.

There are also other factors influencing the precipitation at the metal surface, such as temperature, pH, pressure or feed water composition deviations. The solubility can be affected by its temperature. Transition from cold to hot water will cause scale to form. As temperature was increased, the scaling tendency of the carbonate scaling brine increased, whereas that of the high sulphate scaling brine system was found to decrease according to Dyer *et al.* (2002). CO_2 is evaporated when temperature is increased which then allow scale to precipitate. Besides that, heating of water also causes evaporation and leaving minerals behind.

Furthermore, the pH also changes on solubility. The solubility of Calcium Carbonate (CaCO_3) decreases with the increase in pH. pH is a measure in acidity of a liquid, thus, the lower the pH level, the higher the acid content and resulting in more of dissolved Calcium Carbonate (CaCO_3).

The change in pressure will also give effect on solubility. As stated by Dyer *et al.*, 2002, as pressure was increased, the scaling tendency of the Carbonate and Sulphate scaling brines tested was found to decrease, as was predicted by scale prediction software. Thus, the transition of water pressure from high to low can cause scale formation. The causes of pressure drop might be either due to the internal friction between the water, external friction between the water and the walls of the piping system or rough area in the channel through which the water flows. This change occurred because Carbon Dioxide (CO₂) will evaporate at a lower pressure state, thus pH will increase.

2.2 SCALES IN OILFIELD

In oilfield scale formation, water is primarily important, since scale will occur only if water is produced. All natural waters contain dissolved components acquired through contact with mineral phases in the natural environment. Scale formation at oil producing well screens eventually results in lower oil yields and well failure (Bamidele *et al.*, 2009). Oilfield scales are inorganic crystalline deposits that form as a result of the precipitation of solids from brines present in the reservoir and production flow system (Baraka-Lokmane *et al.*, 2010). There are many type of scales formed in the oilfield. There are Sulfates, Carbonates, Sulfides and silicates. However, according to Dyer *et al.* (2002), the common oilfield scales are the insoluble Barium/Strontium/Calcium Sulphates and Calcium or Magnesium Carbonates. In addition, there are some scale deposits in oilfield environments that are called pseudo scale; that is, the deposit of a reaction product between two or more anthropogenic-introduced chemicals (Bamidele *et al.*, 2009). However, this problem is not limited to these minerals only. It has been reported recently that unusual type of scales such as Zinc and Lead Sulfides is also formed (Collins and Jordan, 2003).

Sulfates formed commonly by incompatible mixing of formation water and seawater. To a lesser extent, pressure reductions can also cause precipitation. Anhydrite is formed at temperatures above 110 °C and in high salinity brines whereas gypsum forms below 110 °C. Sulfate scales are very hard to be removed and it need the most stringent mechanical means. The most common sulfate scalants encountered are CaSO₄, BaSO₄ and

SrSO_4 (T.Y. Soror, 2009). Carbonates are formed from both incompatible mixing, also changes in temperature, pressure and gas chemistry. Iron Carbonate can be a corrosion product. Sulfides are formed from sour wells and hydroxides from spent acids. Oxides and Oxyhydroxides from corrosion often occur after acid treatment. Forms of silica, silicates and rare earth sulfides can form in high temperature and low pressure geothermal wells.

As stated by T.Y. Soror (2009), precipitation of inorganic species is initiated by nucleation. Homogeneous nucleation requires a relatively high degree of saturation whereas heterogeneous nucleation requires much lower levels of supersaturation to initiate.

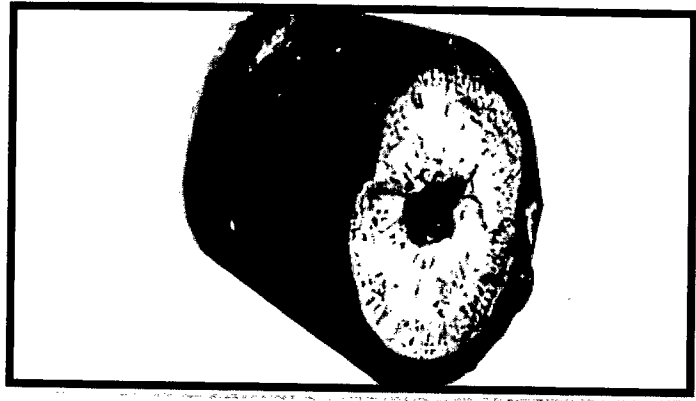


Figure 2.1 – Scales formed in tubes

There are three factors influencing the scale occurrence which are incompatible mixing, self-scaling and also production of wet gas. Mixing of incompatible waters means the mixture of injected waters versus the formation water, commonly Barium Sulphate or Calcium Carbonate. Self scaling is the changes in physical conditions of production or injection water, commonly Carbonates or Sodium Chloride. Production of wet gas is the least common causes which involve the evaporation of water into an expanding gas as a gas bubble travels to surface, then leads to precipitation of salts from the solution.

2.3 DIFFERENCE OF COMPONENTS BETWEEN SCALES

Scales can be categorized into three broad groups based on their solubility in water, reaction with Hydrochloric Acid (HCl) or their removability with HCl, which consist of water-soluble, acid soluble and acid insoluble. These classifications are simplified since pure calcium carbonate or pure calcium sulfate is rarely deposited. However, scale deposit is usually a mixture of one or more major inorganic components plus corrosion products, congealed oil, formation fines, paraffin and other impurities.

According to (Yongming Tang, 2008), calcite is the dominant crystal form in the absence of inhibitors. However, in the presence of Polyacrylic Acid (PAA), vaterite is the main crystal form and calcite is the least crystal form. In the presence of Aminotrimethylenephosphonic Acid (ATMP), the main crystal form of CaCO_3 is calcite, yet the ratio of vaterite is as high as 20.24 %. In the presence of Polyamino Polyether Methylene phosphonate (PAPEMP), the dominant crystal form is calcite and the ratios of aragonite and vaterite are very low.

It is known that calcite is stable thermodynamically while vaterite is the least stable in either three of the polymorphic forms of CaCO_3 . Calcite is usually formed from the transformation of aragonite. Vaterite can be formed while in the absence of inhibitors and it is the initial phase that usually forms in most supersaturated solution of CaCO_3 and then gradually it changes to calcite.

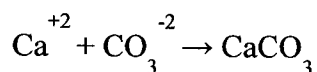
Calcite and aragonite are the two types of Calcium Carbonate that usually formed. Calcite can be usually found around the warm tropic environments because of its chemistry and properties. It is easier to precipitate in warmer conditions than it does in colder environments since warmer environments do not help the dissolution of Carbon Dioxide (CO_2). The lower the temperature and ion concentration, the longer the induction period and the higher the percentage of calcite precipitated (Xiaokai *et al.*, 2005).

2.4 CALCIUM CARBONATE SCALE (CaCO₃)

Calcium Carbonate is the predominant component of scales deposited from natural water (Yongming Tang, 2007). Calcium Carbonate is by far the most common scale compound, forming tenacious layers in several industrial systems, including cooling water circuits, potable water supply lines, desalination units, and petroleum and gas production systems (Andritsos *et al.*, 2003). Calcium Carbonate scale can be formed by altering the solubility of Calcium Bicarbonate or the combination of calcium ions with bicarbonate ions as also stated by Amer Badr (2007). Its solubility is affected by pressure drops in the system, temperature, total dissolved solids (TDS) and pH. Carbonate scales are predicted to form during the life of the fields as the reservoir pressures gradually decrease and dissolved Carbon Dioxide evolves (Dyer *et al.*, 2002). It is normally removed by treatment with either hydrochloric acid or organic scale remover. An inhibition is given best by Phosphonates with polymers being of second choice.

In several recent patents, by Salutsky and Herbert and his co-workers, it is claimed that polymeric compounds “having two carboxylic groups adjacent to one another and spaced along the polymeric chain” are useful for preventing the precipitation of Calcium Carbonate and also Calcium Sulfate scales in steam boilers and in evaporation of sea water (Shaheen *et al.*, 1973).

Based on the research made by Xiaokai *et al.* (2005), it was found that Calcium Carbonate deposition is mainly controlled by the diffusion of Ca²⁺ and HCO³⁻ ions. According to Amer Badr (2007), Calcium Carbonate crystals are large, but when the scale is found together with impurities in the form of finely divided crystals, then the scale appears uniform. The deposition of CaCO₃ scale is the results of the precipitation of Calcium Carbonate. The equation is as the following:



According to Clemmit *et al.* (1985), Calcium Carbonate scale is formed by a different mechanism. The scaling potential of CaCO_3 arises from the decomposition of Calcium Bicarbonate as few waters contain the actual carbonate ion. The decomposition occurred due to the pressure reductions which then releasing Carbon Dioxide. Precipitation is then occurring when the quantity of Calcium Carbonate produced exceeds its solubility in the water. The most effective way to dissolve Calcium Carbonate is by using Hydrochloric Acid under most conditions. Concentrations of 5 – 15 % HCl are normally used (Connell, 1983). However, a corrosion inhibitor need to be added to the acid in order to stop it from attacking the pipe work while a surfactant usually added to make the surfaces water wet.

2.5 CONDITION OF SCALE

During CaCO_3 crystal growth, the inhibitor molecules or ions containing phosphonic groups, such as ATMP and PAPEMP, can absorb onto the active growth sites of the crystal surface, and disturb the regular outgrowth of CaCO_3 crystal (Yongming Tang, 2008). Research made by Xiaokai *et al.* (2005) stated that under most conditions, fouling is more severe during boiling heat transfer because of the mechanisms of bubble formation and detachment during boiling.

In a study of Tzotzi *et al.* (2007), they examined the pattern and characteristics of CaCO_3 scale formation on the thin film composite polyamide membranes with time by undergo several runs of different duration under almost identical experimental conditions for instance at the same feed pH, temperature and cross-flow velocity. The scale and scaling patterns could be easily detected judging by the change of the “reflectivity” of the membrane surface. The presence of deposits is observed by the “blurring” on the membrane surface for example the reduction of membrane surface reflectivity. Scanning Electron Microscopy (SEM) is used to determine the correlation between “blurring” and scale deposits.

According to C. Wang *et al.* (2006), they examined the samples using Fourier Transform Infrared Spectroscopy (FT-IR) with the absence and presence of Polyacryamide.

Cubic-like calcite crystals were formed in the absence of Polyacrylamide. The peak of the Calcium Carbonate (CaCO_3) in the absence of Polyacrylamide showed at 875 cm^{-1} and those of aragonite are at 857 cm^{-1} and 1082 cm^{-1} . Other studies of FTIR analysis on limestone sample (F. Bosch Reig *et al.*, 2002) show that the limestone sample GSR-6 is mainly composed of calcite ($1420, 875, 712\text{ cm}^{-1}$) and other species are also identified such as quartz, dolomite (double Calcium Carbonate and Magnesium) ($1446, 881, 730\text{ cm}^{-1}$) and clays ($3689, 3627, 1033, 1010, 912\text{ cm}^{-1}$). In their research also studied the Silica and Calcium Carbonate in mixtures of both components to quantify each analyte. As they stated, the band appear at 798 and 779 cm^{-1} is silica while the band appear at 875 and 712 cm^{-1} represent Calcium Carbonate.

While in another study by C. Wang *et al.* (2010) they characterized the crystalline phase by doing the X-Ray Diffraction (XRD) analysis. Their XRD result revealed that the Calcium Carbonate (CaCO_3) crystal that they obtained is calcite. The important factors those are responsible for oriented nucleation are ion binding, lattice matching and stereochemical recognition.

2.6 SCALE REMOVAL AND PREVENTION

The best scale removal technique depends on knowing the type and quantity of scale and also its physical composition. Ethylenediaminetetraacetic Acid (EDTA) was an early candidate to answer the need for improved chemical removal and is still used today in many forms (Crabtree *et al.*, 1999). EDTA treatments are expensive and slower than Hydrochloric Acid but it work well on deposits that need a chemical approach.

Removing scale or descaling is an important step because the production of a plant can be adversely effected by a scale layer. Besides that, corrosion is accelerated under a scale layer and bacteria will grow again since the biocides do not penetrate the scale and thus do not kill the bacteria. Scale formation accelerates when “seeded” by existing scale or in other words, scale will form quicker in a dirty system than a clean system.

In order for scale to be removed, we first need to identify which types of scale might form for water under certain condition. Precipitation age has been identified as an important criterion for consideration since older precipitates which have undergone the process of ripening have proven harder to clean (T.Y. Soror, 2009). Different type of scales requires different kind of removal. If a scale is a mixture of different types which usually occurred in the industry, it might need several steps to remove it. If a scale is predominately one type, it is only necessary to clean up the major component. For example, let say a scale contain 90 % of Calcium Carbonate, 5 % of Iron Sulfide, 5 % of sand; only the Calcium Carbonate need to be remove. The Iron Sulfide and sand will wash out without any treatment.

As discussed, scale is divided into three sections which are acid soluble scale, acid insoluble scale and hydrocarbons. An acid is used to remove an acid soluble scale. There are two acid types, mineral acids or inorganic and organic acids.

The best approach is prevention through the lowering of the operation temperature, reducing the concentration factor to keep brine concentration below scaling threshold or by softening of the sea water (T.Y. Soror, 2009). While according to (Stáhl *et al.*, 2000), the first step in prevention is to study the scaling and corrosion processes and simulate them by simple computer and experimental models. However, the great way to prevent scale from forming during the oil production is to actually prevent the creation of supersaturation of the brine. This might be possible to do by altering the operating conditions of the reservoir. However, economics usually dictate that the use of inhibitors is preferred (Amer Badr, 2007). Besides that, scale can be prevented by avoiding mixing of incompatible waters and controlling the pH. By lowering the pH, the solubility of carbonate scales will thus increase which however can cause other problems such as corrosion. However, this way is not widely used in the oilfield because it needs an accurate pH control but it is useful for cooling waters.

Polyelectrolytes and Organophosphorous compounds are two types of inhibitor extensively used. These inhibitors could inhibit scale forming by distortion of crystal lattice

to prevent crystal nuclear growth and/or dispersing the tiny grains in water (Tang *et al.*, 2008). There is a new inhibitor being developed for scale control in water desalination which is Polyamino Polyether Methylenephosphonate or PAPEMP. It work not just on Calcium in water but also has the ability to control both Calcium Carbonate and Calcium Sulfate when both are at extremely high supersaturations.

Descaling test conducted by Malik *et al.* (1995) regarding the descaling performance of Hydrochloric Acid, Sulfamic Acid and Sulfuric Acid showed that the amount of Mg (OH)₂ dissolved is lower than CaCO₃ for Hydrochloric Acid and Sulfamic Acid. It is observed that Hydrochloric Acid is the best descalant for CaCO₃ followed by Sulfamic Acid and Sulfuric Acid. As for Mg (OH)₂ scales, Sulfuric Acid appear to be the best descalant, followed by Hydrochloric Acid and Sulfamic Acid.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, show the experimental research work done in order to fulfill the objectives of this study. Materials used, experimental set up and proposed experimental procedures are described in the following sections.

3.2 MATERIALS USED

The materials used in this study are listed as in the following section:

3.2.1 Commercial Scale Removers

i. AM1080

It is a blend of non-hazardous, non-corrosive, biodegradable descaler which is specially designed to remove Carbonate (CO_3) based deposits. These types of dissolve Carbonate deposits can be found in all types of water operated equipment such as boilers, cooling towers, closed loops, heat exchangers and aluminum molds. Besides that, it also has the ability to dissolve and also remove deposits cause by corrosion byproducts for instance Iron Oxides, Iron Carbonate or Zinc Carbonates.