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Oil Field Scale in Petroleum Industry

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ABSTRACT: One of the most important issues in the oil industry is scale formation, which causes a decline in output or financial loss. Scale deposits may range in severity from minor to severe. If the scale deposit is allowed to persist, it reduces formation pores, lowers production, and finally blocks the wellbore, resulting in unplanned downtime. Increased deposition results in lower operating efficiency, posing a serious problem for the sector. To address the problem, a more effective management plan is required. Rather of allowing the scale to grow up and then taking corrective action, the scale prevention approach should be applied from the beginning. Descaling is also a costly technique from a financial standpoint. Methods that can limit or eliminate the scale deposition technique in the early phases should be applied so that it does not adhere to the production should indeed be implemented. The notion of scale creation must be investigated in order to prevent making poor corrective decisions that might jeopardize output. The study considers the establishment of scales and their implications for the oil sector.

KEYWORDS: Inorganic, Oil Field, Petroleum, Scale Formation, Scale Deposition.

I. INTRODUCTION

Inorganic, Organic, or crystal water make up the majority of scales. Among the most difficult problems in petroleum production but even water injections are scale deposit. It is caused by the combination of two incompatible fluids in most cases. When the two fluids interact chemically, these mineral precipitates, resulting in scale development. Scale deposition begins in the systems when the percentage of salts that are generally soluble in natural fluids utilized in the treatment during manufacturing and processing surpasses the saturation levels during the treatments. It's a system in which the aqueous system is supersaturated with scaling ions and elevated to levels that surpass the solubility of a certain salt under ideal circumstances. Scale development is visible and troublesome in systems such as oil well water, slag cooling water, boiler water, industrial cooling water, etc. Temperature, salinity, pressure, pH, and the kinds of scaling ions are all important elements in the scale generation process [1], [2]. These characteristics impact the scaling potential directly or indirectly, therefore changes in these components affect scale solubility and result in kinetic and thermodynamic changes in scales formation. Corrosion or dissolved gases are two more processes that contribute to the creation of scale. Sulfides, as well as other scales such as carbonates and hydroxides, are affected by H_2S and CO_2. Scale production is further aided by nucleating places in the brine systems where scale crystals already are present on the equipment's surface. Figure 1 depicts the creation of scale in a pipe [3], [4].

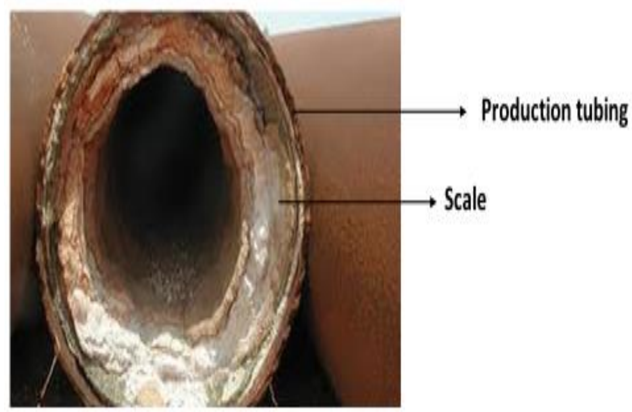

Figure 1: Illustrate the Scale formation in the Layers of the Pipe

A. *Scale Formation or Scales Deposition*

Aggregation, Crystal Growth, and Agglomeration are the four stages of the scale creation process. Whenever the brine solution becomes supersaturated with scaling ions, the aggregation process begins. In solution, these ions clash to create ion pairs, which then form micro-aggregates. Inside the nucleation stages, the micro-aggregates act as nucleation sites for crystallization, resulting in the development of micro-crystals. These microcrystals grow into bigger microcrystals, which then fuse together to produce adherent microcrystals. The agglomeration stage is characterized by the formation of macro-crystals into a scale layer on a surface, which eventually results in a scale deposit. The full technique of scale deposition is shown in Figure 2.

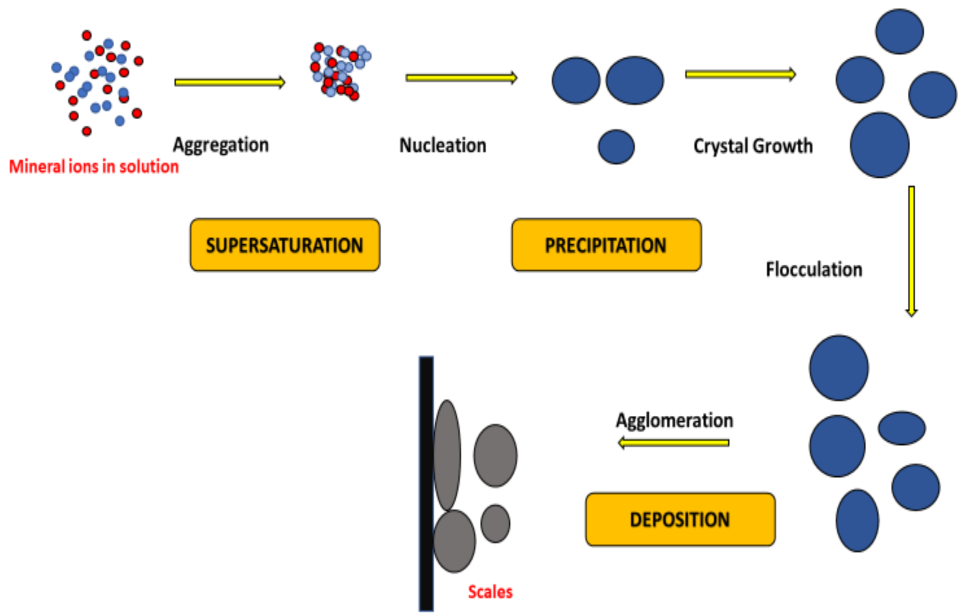

Figure 1: Representing the Scale Deposition Mechanism

B. Types of Scales

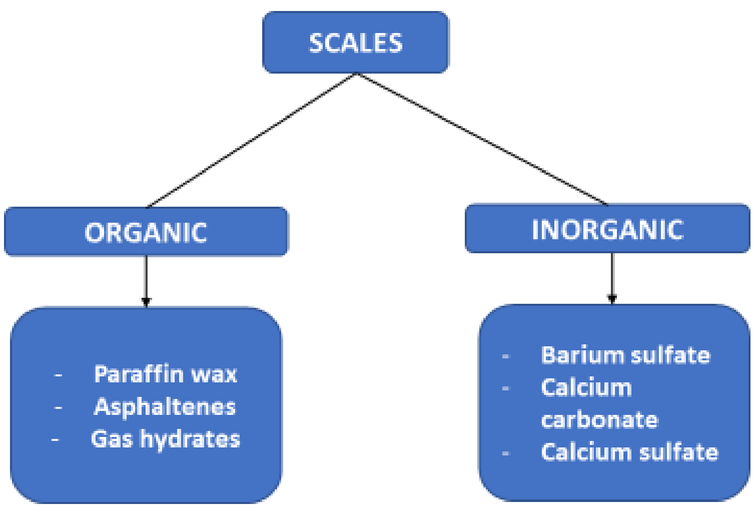

Figure 3: Illustrating the Oilfield deposits can be classified in two major categories

These two forms are mutually inclusive, and they tend to exist in the same system at the same time, which is referred to as mixed scale. Mixed scales need more severe treatment because of their very complicated structure, which makes them difficult to cure and expensive to remediate. Supersaturation of any one kind of scale-forming water owing to physical circumstances under which the water occurs is the principal cause of oilfield scale deposition as shown in Figure 3. It may also happen when two incompatible waters are mixed together during the manufacture of well fluids. If water may be combined without forming insoluble precipitate compounds, it is said to be compatible. It's referred to as incompatible water when it forms precipitates. The precipitates are unappealing because they reduce the permeability of producing rocks and input wells. They may also play a role in the production and deposition of scale in pumps and lines [5]–[7]. When formation water mixes with other brines, such as injection water, mineral deposits termed inorganic scales occur. As a consequence of the mixing changes, which create interactions between incompatible ions, the thermodynamic and equilibrium states of the reservoir fluids are changed. As a consequence, inorganic salts become supersaturated and precipitate. The most frequent inorganic scales found in the oil business are carbonates and sulfates; sulfides and chlorites are also widespread [8]–[10].

Oilfield fluids contain the ions Ca^{+2}, Ba^{+2}, Sr^{+2}, and Fe^{+2}, which produce precipitate in unsuitable waters. Incompatible waters include sea water, which has a high percentage of the SO_4^{-2} but a lower content of Ca^{+2}/Ba^{+2}/ Sr^{+2} and formation water, or it has a very lower content of SO_4^{-2} but just a higher proportion of Ca^{+2}/ Sr^{+2}/ Ba^{+2}. Whenever these two liquids are combined, $CaSO_4$, $SrSO_4$, and $BaSO_4$ precipitate. It's also conceivable that liquid waste is harmful to the environment. If waste water is coupled with saltwater for re-injection, there seems to be a risk of scale formation [10]–[12]. Scale buildup not only slows down production, but it also leads to failure and inefficiency. Excessive scale development could result in equipment failure. Scale deposition is a key concern when water injection is used. Deposition can occur in casings flow outlines, tubing, heaters treater, downhole pumps, tank, or even others processing apparatus, especially surface facilities. The scales have clogged up production processes, machinery, including fluid stream. Processing equipment failure, alternative downtime, increased maintenance costs, and a drop in total production effectiveness will be the consequences. If machines and equipment including instruments fail, workers' safety might well be jeopardised. Biochemical mismatch among possible injecting fluids and reservoir brine causes scale development in water flooding techniques. The most common oilfield scales are shown in Table 1 [13]–[15].

Table 1: Illustrate the Oilfield scales and its Chemical Formula

Name	Chemical Formula
Calcium Carbonate	$CaCO_3$
Calcium Sulfate Gypsum Hemihydrates Anhydrite	$CaSO_4.2H_2O$ $CaSO_4.1/2H_2O$ $CaSO_4$
Barium Sulfate	$BaSO_4$
Strontium Sulfate	$SrSO_4$
Ferrous Carbonate Ferrous Sulfide Ferrous Hydroxide Ferrous Hydroxide	$FeCO_3$ FeS $Fe(OH)_2$ $Fe(OH)_3$

C. Factors responsible for scale formation

Pressure increases between the fluids existing in the reservoir as well as the dissolved salts during well drilling and production in a hydrocarbon reservoir. After the well is completed, the fluid loses its balance, and salts begin to precipitate. When the soluble limit possible for a single or more components is exceeded, the scale begins to develop. Scale development is influenced by the following factors:

Pressure changes

- Temperature shifts
- Amount of agitation
- Crystal size and number
- Phosphorus shift
- Supersaturation level

D. Chemistry of the scale's formation

Scale precipitation happens as a result of the mixing of incompatible brine fluids, as well as deviations in external parameters such as temperature, pressure, or pH. The precipitation of solids form brines present in producing flow systems or reservoirs causes the formation of mineral crystallographic deposits known as oilfield scales. Minerals scale precipitation is driven by changes in brine content and products, and also pressure, temperature, or PH. The approaches used to classify the factors of variation are as follows:

- A drop in pressure or temperature causes the salt's ionic solubility to decrease.
- The mixing of two incompatible brines.
- As the salt content in the brine grows over the saturation point, salty precipitation occurs.

Scale development by any mechanism accumulates over time and eventually causes a blockage in the pipeline as well as production tube. It should be noted that following water injection, scales deposition happens not only in the production tubing but also with the well head or reservoirs. The production of scales in the injection pipeline is caused by dissolved minerals in the water transported by the tubing, and the deposition of mineral scales is accelerated by temperature changes. The major cause for scale development in production tubing is temperature fluctuation, although a shift in pressure resulting in fluid or gas phase compositional changes is another explanation. Because CO_2 is liberated from the water as a consequence of a pressure shift, the pH of the water changes. The creation of scale at the bottom hole is caused by the mixing of two incompatible waters and is unlikely to be altered by temperature changes [16]–[18].

E. Types of mineral scale

- There are two types of oilfield scale deposits: pH independent or pH sensitive scales.

Scale that isn't affected by pH: Barium, Strontium, or calcium sulphate are the compounds in question. The sulphate ions in seawater interact with the naturally occurring Ba^{+2}, Sr^{+2}, or Ca^{+2} ions in water. These compounds are likewise just slightly soluble in water, thus they precipitate out or form solid solutions [19].

$$Ba^{+2}+SO_4^{-2} \longrightarrow BaSO_4 \downarrow$$
$$Sr^{+2}+SO_4^{-2} \longrightarrow SrSO_4 \downarrow$$
$$Ca^{+2}+SO_4^{-2} \longrightarrow CaSO_4 \downarrow$$

- pH-dependent scales: Acids soluble carbonates (dolomite, calcite, or siderite) or sulfide scales. Their structures are shown in the equations below.

$$Ca^{+2} + CO_3^{-2} \longrightarrow CaCO_3 \downarrow$$
$$Fe^{+2} + S^{-2} \longrightarrow FeS \downarrow$$
$$Zn^{+2} + S^{-2} \longrightarrow ZnS \downarrow$$
$$Pb^{+2} + S^{-2} \longrightarrow PbS \downarrow$$

F. Mechanism of the scale's deposition

Due to the abundance of limestone areas, calcium carbonate, also known as calcite scale, is commonly discovered in oilfield operations. Calcite is the most frequent oil field scale found at production sites since it is the most stable in terms of strength. The reaction that lead to the solids calcium carbonates production are follows:

Carbon dioxide first combines with water to form carbonic acids.

- $CO_2(g) + H_2O\ (l) \leftrightarrow H_2CO_3(aq)$

This carbon dioxide will continuing to dissociate hydrogen, resulting in the formation of additional deprotonated carbonic acids species.

- $H_2CO_3(aq) + H_2O\ (l) \leftrightarrow H_3O^+(aq) + HCO_3^-(aq)$
- $H_2CO_3(aq) + H_2O\ (l) \leftrightarrow H_3O^+(aq) + CO_3^{-2}(aq)$

There will be a combination of species H_2CO_3, HCO_3^-, but also CO_3^{-2} in the water mixture.

Carbonate will precipitate in the form of calcium or carbonic acids.

- $CO_3^{-2}(aq) + Ca^{+2}(aq) \leftrightarrow CaCO_3(s)$

Since, produced water usually contains a carbonic acid and calcium ions, a recombination of these reactions

- $Ca(HCO_3)_2(aq) \leftrightarrow CO_2(g) + H_2O\ (l) + CaCO_3(s)$

Water, solid calcium carbonate, and CO_2 gas will be in balance with calcium or carbonic acids in liquid form. Calcium sulphate scaling are crystalline but mostly include calcium and sulphate ions, while they may also contain residues of a variety of other ions. They may produce solid solutions when co-precipitated with strontium sulphates. If precipitated from oil fluids, it may include trace amounts of silt or wax. Scale deposits are generated when two incompatible fluids, such as injected saltwater into a reservoir during effective rehabilitation procedures or formation water, combine down the well. Scale components become oversaturated in the generated water. This occurs because saltwater has a lot of SO_4^{-2} whereas formation waters include a lot of ions like Ca^{+2} or Ba^{+2}. Sulphate scales including such $CaSO_4$ or $BaSO_4$ occur when these two precipitates are mixed.

- $Ca^{+2}(aq) + SO_4^{-2}(aq) + 2H_2O\ (l) \leftrightarrow CaSO_4.2H_2O\ (s)$

One of the most harmful scales is barium sulphate. They cause issues in oilfields such as clogged valves, clogged flow lines, and a decline in oil output owing to constraints developed in the production tubing, resulting in millions of dollars in lost production.

The combination of seawater for use as injection water or formation water results in the production of barium scale. Seawater is often high in SO_4^{-2} anions, but deep subterranean waters are high in ions like Ba^{+2} or Sr^{+2}. When the condition of any natural fluid is disrupted until the solubility limit for one or more of the elements is surpassed, barium sulphate scales begin to precipitate.

- $Ba^{+2}(aq)$ (formation water) + $SO_4^{-2}(aq)$ (seawater) $\leftrightarrow BaSO_4\ (s)$

Strontium sulphate scales occurred in oil fields inside the existence of Barium sulphate scale till recently. $SrSO_4$ scales act similarly to $BaSO_4$ scales, however they are lower soluble in water than $BaSO_4$ scales. As a consequence of combining incompatible water or thermodynamic conditions, scales development is linked to water injection processes. So acid resistant scale is broken up using powerful chelating chemicals that tie up the metallic ions of the scale inside their closed ring structure. Figure 4 depicts possible scale creation locations.

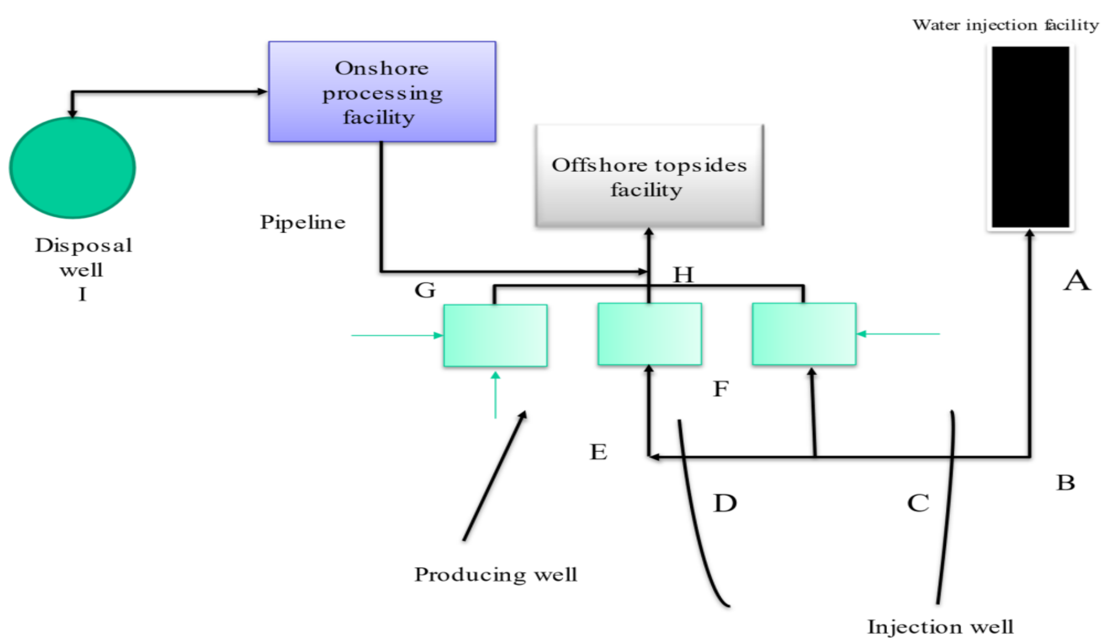

Figure 4: Illustrate the Probable Scale Formation Sites.

- Where incompatible water is blended before injection at a surface water injection sit
- Injection wells in which the injected water mixes with reservoir formation water.
- The injected water disperses formation water downhole in the reservoir.
- Downhole in the reservoir, near the producing well, where the injected water and formation water are going to meet.
- Tubing used in the manufacturing process.
- A branching zone at the junction generated diverse water.
- In a multi-block zone, when water is generated from several blocks within the same zone
- Produced fluids are combined at topside facilities to extract oil and gas from produced waters, or the pipeline transporting fluids to onshore processing facilities.

G. Problems caused due to Scale Formation

The formation of scales may occur in the reservoir, surface facilities or deposits may cause

- Formation damage
- Blocking pore throats
- Corrosion under the scale deposits
- Instrumental failure
- Flow meter failure
- Pump wearing
- Safety valves failure
- Completion failure by plugging perforations and gravel pack
- Flow restriction by choking the flow tubing's
- Reduce oil – water separation efficiency

II. DISCUSSION

Scale is a word used in the oil industry to describe large stores that build up over time or impede liquid flow via pipelines, syphons, valves, or other equipment, causing crucial production losses as well as hardware damage. Oilfield scale restraints are a method of preventing scale from impeding or constraining liquid entry through pipelines, valves, or syphons used in the oil production and transportation process. Scale inhibitors are a kind of specialty chemical that is used to delay or prevent scaling in waterways. A store or coating produced on the external layer of a metal, rock, or other object. Scale may be defined as precipitation induced by a synthetic reaction to the surface, precipitation caused by material responses, a change in strain and temperature, or even a change in the organization of a response. The term is also used to denote a thing that is deteriorating. Calcium carbonate, iron sulfide, barium sulfate, calcium sulfate, iron oxides, strontium sulfate, iron carbonate, various silicates, including phosphates but also oxides, or any of a number of insoluble or slightly soluble in water combinations are now all common scales. Scale, also known as stores, may build up in wellbore tubulars and other downhole components, presenting a major danger to the well's continuous operation. With the increased use of oil and gas and the necessity for transportation to satisfy that demand, all petroleum and pipeline engineers need exact consumption or scaling data. The Fundamentals of Corrosion and Scaling for Petroleum or Environmental Engineers will provide draughtsman with the quick data they need to work on the consistency of usage and scale control improvements, as well as manage scale storage, prevent shortfalls, and ensure equipment honesty.

III. CONCLUSION

A scales statement happens when the arrangements harmony of both the water is disrupted by strain or temperature variations, broken down gases, or a disparity between blending water. Scale stores are a common and aggravating problem in the oil business, and they may develop in both creation as well as infusion wells. Scale deposition is one of the most serious issues in the oil or gas industry. It not only has a negative impact on production, but it also has a negative impact on formation. The incompatibility of the waters causes the creation of scale, which causes problems at the facilities and ultimately leads to production failure. Large stores that increase over time, obstructing or degrading liquid circulation through pipelines, valves, siphons, and other similar systems, resulting in substantial declines in flow rates as well as hardware damage, are referred to as scale in the oil business. Rather of allowing the scale to get out of control before intervening, the scale prevention technique should be used from the start. Descaling is also an expensive procedure in terms of money. Methods that can restrict or remove the scale deposition approach in the early stages should be employed to ensure that it does not adhere to the production. In order to avoid making bad corrective judgments that risk production, the concept of scale creation must be examined.

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