COMPARATIVE STUDY OF THE SAND CONTROL METHODS USED IN THE OIL INDUSTRY (CASE STUDY OF THE NIGER DELTA)

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Abstract— Sand production which is the production of formation sand alongside formation fluids (oil, gas and water) due to the unconsolidated nature of the formation is one of the oldest problems plaguing the oil industry because of its safety, economic and/or environmental impact on production. Every reservoir has a threshold pressure which is the pressure at which a well will produce sand free but the threshold pressure is below economic production rate so, the threshold pressure is usually ignored so as to produce at a maximum rate from a sand stone reservoir thus, the occurrence of sand production. There is therefore need for sand control methods. The main sand control methods used in the oil industry in Nigeria are internal gravel packing (IGP) and sand control using chemicals (SCON). In other to properly optimize production and monitor sand controlled wells, it is imperative to evaluate the performance of the well, sand control effectiveness and durability of the sand control methods in other to achieve the main aim of hydrocarbon production. This project work is aimed at comparing the two basic sand control methods with respect to their performance, durability and sand control effectiveness. This aim was achieved by collecting production data from ten wells in the Niger-Delta area where IGP and SCON have been used. The well inflow quality indicator (WIQI) which is the ratio of actual to ideal productivity index and indicates better performance when WIQI is closer to or equal to 1 was used to determine the performance of the sand control methods. Histograms were plotted for volume of sand produced against sand control methods and also for duration (years) against the wells to determine the effectiveness and durability of the sand control methods respectively and the results show that IGP is more effective and more durable than SCON. Based on the result of this project work, IGP is therefore recommended for sand control in the Niger-Delta area of Nigeria.

Keywords: Internal gravel packing, well inflow quality indicator, sand control, Niger-Delta.

1 INTRODUCTION

When oil is produced from relatively weak reservoir rocks, small particles and sand grains which are essentially of no economic value are dislodged and carried along with the flow. This phenomenon is known as sand production. Sand production is one of the oldest problems of oil fields. It is usually associated with shallow formations as compaction tends to increase with depth but in some formations, sand production may be encountered to a depth of 12000ft or more. Sand production greater than 0.1% (volumetric) can be considered as excessive but depending on the circumstances, the practical limit could be much lower or higher.

Sand production is initiated when the formation stress exceeds the strength of the formation. The formation strength is derived mainly from the natural materials that cement the sand grains but the sand grains are also held together by cohesive forces resulting from immovable formation water (residual water). The stress on the formation sand grains is caused by many factors which include; tectonic actions, overburden pressures, pore pressures, stress changes while drilling and drag forces on producing fields. Fluid flow from wells is the consequence of the wellbore pressure being smaller than that in the reservoir. The drag force caused by the flow from large to small pressure is related to the velocity-viscosity product at any point around the well. Hence, when fluids flow toward the wellbore, the tendency is for some of the formation material to flow concurrently with the fluids. Opposing the fluid forces are the restraining forces that hold the formation sand in place. These consist of:

i. Natural cementation (compressive strength)
ii. Friction between sand grains
iii. Fluid pressure in the pores of the rock
iv. Capillary forces

The compressive strength of the rock, the primary restraint, is controlled by inter-granular cementation that is a secondary geologic process. As a general rule, old sediments are more consolidated than are younger sediments. Young formations commonly have little cementing material and are referred to as being poorly con-solidated. Stated another way, they have low compressive strength. Their com-

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pressive strengths are usually less than 1,000 psi and may even be so small that their strengths cannot be measured. The frictional forces are related to the confining or overburden stresses. The stress that causes the rock to fail includes the mechanical stress that results from the overburden and the drag forces associated from viscous flow of fluids through the rock matrix. The overburden stress is partially supported by the pore pressure, so the net stress (the cause of rock failure, the effective stress) is the difference between the overburden stress and the pore pressure.

Capillary forces can also contribute to sand production; there are numerous examples where sand production occurred when water production began. Sand arches form, on occasion, around the perforations. The questions of when and how arches form are related to:

- Flow rate
- Compressive strength of the formation
- Size of the sand and the perforations

However, in some cases the sand production occur late in the life of a well when pressure have declined to the extent that the overburden is being supported mainly by the vertical components of the inter grain stress rather than by the pore pressure. This may cause shearing of the cementing material allowing the sand grains to move and hence be produced into the wellbore or below a certain pore pressure, the point stress between the sand grains exceed there fracture strength and the grains collapse causing instability and onset of sand production.

1.1 Categories of sand production

The general sand production can be classified into three categories namely; transient, continuous and catastrophic. The transient sand production is usually encountered during clean up, after perforation or acidizing. At this stage, sand production would decline with time. The continuous sand production occurs during production from unconsolidated sandstone reservoirs that have no sand control equipment. For this category, sand production is observed throughout the life of the well. The catastrophic sand production refers to a situation where the high rate of sand influx causes the well to die and/or choke. This is the worst case of sand production and it occurs when the reservoir fluids are excessively produced.

1.2 Sand production prediction

There are many sophisticated geomechanics software which can be used to predict sand production over long range of reservoir conditions and time. However, there are some quick indicators like sonic travel time or porosity.

Table 1.1: Indicators for Sand Prediction.

Strength of formation	Sonic travel time	Porosity	Unconfined compressive strength
Strong	<50 sec.	<20%	>1100psi
Moderate	50 to 90 sec	20 to 30%	400 to 1100psi
Weak or unconsolidated	>120 sec	>30%	<400psi

1.3 Effects of sand production

Because of the adverse effects that sand production poses on the oil industry, sand control has become an important aspect of petroleum production. Some of the effects of sand production include;

- Erosion of choke (surface).
- Cuts production of flow line.
- Loads of treating facilities
- Lose of production during work over jobs.
- Lose of valuable man-hour during the period of close-in in terms of wages, which add up to overhead cost.

Some other effects of sand production are summarized in table 1.2

Table 1.2: Effects of Sand Production.

AREA	**PROBLEM**	**EFFECTS**
Reservoir	Wellbore fill	• Restricted access to production interval • Loss of productivity • Loss of reserve

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Subsurface equipment	Sand fouling	• SSSV not operating • Difficult wire line operation
	Erosion	• Equipment replacement • Equipment failure
Surface installation	Sand accumulation	• Malfunctioning of control equipment • Unscheduled shutdown
	Erosion	• Deferred production • Sand separation and disposal

1.4 Sand control methods

Sand production from oil and gas reservoir formations can be minimized using gravel packing or standalone screens. When these screens are plugged due to fine or crushed proppants the productivity of oil producers declines sharply. There are several screenless sand control methods like oriented perforation, selective perforation (Exclude weak zones) screenless fracturing sand consolidation etc. The methods or techniques that are employed to control sand production can be grouped as: mechanical, chemical or combination methods/techniques. The mechanical exclusion of sand is achieved by setting up a physical barrier to the sand movement which still allows for the passage of reservoir fluids. The barrier takes the form of a screen surrounded by fine gravel which is sized so that the formation sand cannot pass through the pore throat of the gravel. Therefore, the mechanical exclusion of the sand is based upon the relationship between the size of the formation sand, the gravel and the screen slot width. This is achieved through Gravel Size Packing (open hole and cased hole), Frac packs, Standalone screens, Wire wrapped screen and Expandable sand screen method. The chemical control method involves the injection of chemicals into the formation usually resins through perforations to cement the sand grains. These chemicals bind the rock particles together creating a stable matrix of permeable, consolidated grains around the casing. Clay concentration can hinder the success of the sand consolidation process so, a clay stabilizer is often used as a pre-flush. The sand consolidation process relies on a process comprising of four distinct stages which are;

- Placement of resin in the formation using a carrier fluid
- Separation of the resin from the carrier fluid
- Accumulation of the resin around the grain contact point
- Curing of the resin.

In addition to the mechanical and chemical sand control methods, several combination of sand control method that use both gravel and plastic have been employed. The aim is to consolidate the gravel pack after it is placed but without the use of a screen or slotted liner. The epoxy and furan techniques involve resin-coated gravel mixed at the surface and pumped into the well. The gravel plastic slurry is then allowed to settle and cure. After curing, the residue is drilled out of the well before it is placed on production. The phenolic resin-gravel processes involve phenolic-coated gravel that is partially polymerized.

1.5 Sand production in the Niger Delta

This project is aimed at evaluating the sand control methods used in the Niger Delta area of Nigeria and the control methods of focus are the internal gravel packing (IGP) and sand control using chemicals otherwise known as sand consolidation (SCON). In Nigeria, hydrocarbon bearing reservoirs are characterized by relatively thin sand with broken shale that breaks and are mostly unconsolidated often due to high permeability and porosity and by the virtue of the considerable porosity of the Niger Delta area, reservoir sand tends to be weakly consolidated or totally unconsolidated and are therefore produced when the reservoir fluid flows. The sand are unconsolidated and are therefore loose and are susceptible to being produced into the wellbore and to the surface unlike the consolidated otherwise known as compacted sands that are carried by fluid drag force. The rate at which a well is produced can lead to sand production in the formation. Every reservoir has a threshold pressure which is the pressure at which the well will produce sand free but this threshold pressure is said to be below economic production rate therefore, the engineer would tend to ignore the threshold pressure so as to produce at a maximum rate from a sand stone reservoir and there would definitely be sand production. When the wellbore pressure is less than the reservoir pressure, there would be an increase in the rate of fluid flow from the reservoir into the wellbore and there is a great probability that the reservoir sand would be produced alongside the high viscosity fluid that flows with high velocity from the reservoir into the wellbore. A reservoir that had previously be certified sand free may begin to produce sand with time because a lot of factors change with time. Some of these factors that could change include: reservoir depletion, water production and increased overburden stress.

1.6 Sand control using chemicals (SCON)

Sand control using chemicals is a means of controlling the undesirable production of sand from unconsolidated sand stone formations. It involves the process of injecting chemical into the semi consolidated or unconsolidated formation. The chemical binder is usually resin, epoxy or some other chemicals. The liquid chemicals are pumped through the perforation into the pore spaces of the formation sand, which goes through an in-situ solidification process with the help of a catalyst or hardener. It coats the sand grains, which is followed by an over flush to improve permeability. It latter hardens, forming permeable synthetic sandstone. Application of the technique can be performed without a rig by bull heading, using a snubbing unit or with a coil tubing unit. Compressive strength of 600 to 700 psi can be attained while retaining 60 to 90 % of the original permeability. In summary, it involves the injection of chemicals into the formation usually resins through perforations to cement the sand grains. These chemicals bind the rock particles together creating a stable matrix of permeable, consolidated grains around the casing. Clay concentration can hinder the success of the sand consolidation process so, a clay stabilizer is often used as a pre-flush. The sand consolidation process relies on a process comprising of four distinct stages which are;

- Placement of resin in the formation using a carrier fluid
- Separation of the resin from the carrier fluid
- Accumulation of the resin around the grain contact point
- Curing of the resin.

Advantages of SCON:

SCON consolidation has several advantages over other methods for sand control. Some of the advantages include:

i. No internal screen is needed with SCON consolidation, thus eliminating the mechanical risks associated with screen placement particularly in through tubing and slim hole applications. Eliminating the screen in these applications also removes one potential production restriction.

ii. No rig is typically required. Once the production tubing is set, the SCON consolidation treatment can be carried out using coiled tubing and electric line for initial completion, plug back recompletion, or repairs. This makes SCON consolidation very attractive particularly in an offshore environment where rig costs are substantial.

iii. Retained permeability after resin is typically greater than 70% with minimal loss of productivity in most of cases.

iv. While the SCON solutions are expensive, the overall treatment process is cost competitive with through tubing gravel packing and frac.-packing techniques.

Disadvantages of SCON:

i. Producing fluids wash away the chemicals used for sand consolidation thereby weakening the chemicals and the sand consolidation technique.

ii. High temperature in the sub surface reduces the consolidation of the sand with time.

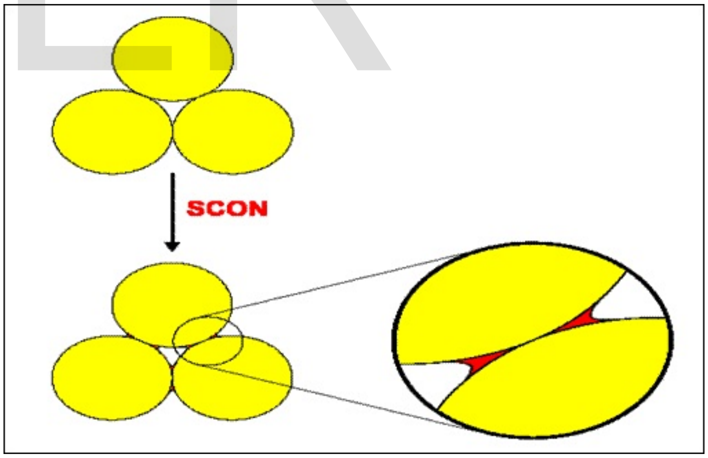

Figure 1.1: Sand Consolidation.

1.7 Internal gravel packing, IGP.

Gravel packing or standalone screen is a means of minimizing the production of sand from oil and gas reservoirs. The exclusion of sand using this method is achieved by setting up a physical barrier to the sand movement which still allows for the passage of reservoir fluids. The barrier takes the form of a screen surrounded by fine gravel which is sized so that the formation sand cannot pass through the pore throat of the gravel. Therefore, the exclusion of the sand is based upon the relationship between the size of the formation sand, the gravel and the screen slot width. It is important to note that if the screen gets plugged, the productivity of oil producers decline sharply.

Procedure for internal gravel packing (IGP)

1. **Cleaning out the well**: Brine is injected into the well to remove junk debris, loose sand and to have enough weight to control the well.
2. **Inserting selected screen:** A gravel pack wire wrapped screen size of about 0.02 inches is then directly place opposite the perforation at the depth of about 6660ft, a centralizer is used to hold the screen at the central position in the well bore**.**
3. RIH slowly the gravel pack assembly which consists of the following: snap latch, seal assembly, welded screen, blank pipe, safety joint, cross-over sub and wash pipe.
4. **Injection of selected gravel:** About 0.02 inches gravels are injected into the well bore using a high viscosity fluid (water pack of viscosity 240cps and pressure of 500psi). The pack of gravel is placed in the annulus between the screen and the perforation and the gravel pack is filled up to the depth interval of the reservoir.
5. The competence of gravel pack is tested and the remaining pressure bleed off.

Factors that can affect internal gravel packing (IGP)

i. ineffective placement technique
ii. wrong gravel size selection
iii. plugging of pore spaces in the gravel pack by debris and loose sand from the formation during production
iv. wrong selection of screen slots to retain the gravel
v. unclean completion fluid which cause contamination

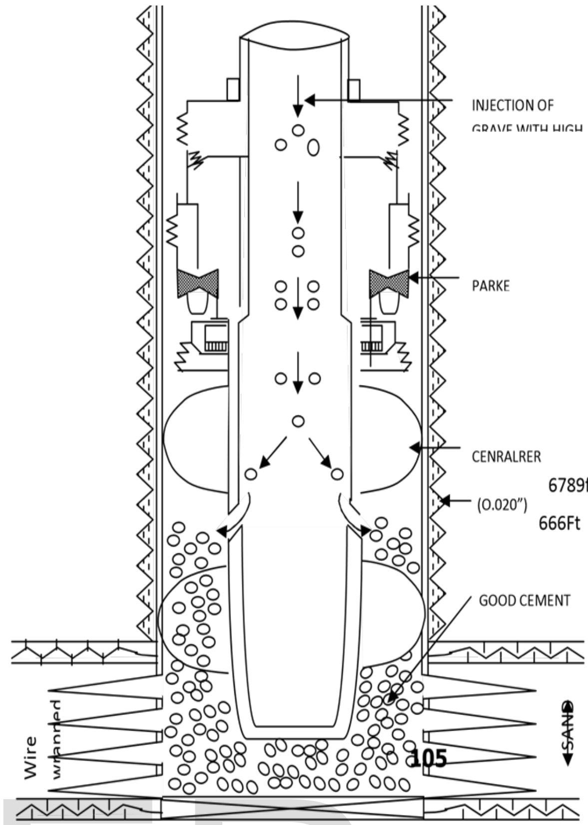

Figure 1.2: Internal Gravel Packing

2.0 Objective

- The objective of this project work is to compare internal gravel packing, IGP for sand control and sand consolidation, SCON (sand control using chemical) in terms of their effectiveness, durability and performance.

3.0 Methodology

The methodology involves evaluating the sand control methods under study (i.e. sand consolidation (SCON) and internal gravel packing {IGP}) based on their performance, effectiveness and durability[1].

3.1 Performance of the sand control methods

To determine the performance of the sand control methods under study, the well inflow quality indicator (WIQI) which is the ratio of the actual productivity index (PI_{actual}) to the ideal productivity index (PI_{ideal}) assuming no formation damage is used. The well inflow quality indicator is given as;

$$WIQI = \frac{PI_{actual}}{PI_{ideal}}$$

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Where $PI_{actual} = \frac{q}{\Delta p} = \frac{q}{P_{r-}P_{wf}}$

And $PI_{ideal} = \frac{7.08E-3 \times k_o \times h}{\mu_{o} \times B_0 \times l_n\left(\frac{r_e}{r_w}\right)}$

$WIQI \leq 1$; which means that when WIQI is closer or equal to 1, the better the performance of the well.

3.2 Sand control effectiveness of the sand control techniques

To determine the effectiveness of the sand control methods, the volume of sand produced (given in lb/1000bbl) from each of the wells is summed and matched against the sand control methods in a histogram.

3.3 Durability of the sand control techniques

To determine the durability of the sand control methods, the difference between the years the treatment types were put in place and the year sand production began is gotten for each well to determine the duration (in years) of the sand control methods for each well. The duration (in years) is then matched against each well in a histogram.

Table 3.1: Data for Wells Treated with IGP and SCON

ber	Treatment type	R_e (ft)	R_w (ft)	K_o (md)	H (ft)	μ_o (cp)	B_o (rb/stb)	P_r(psi)	P_{wf}(psi)	Q (bbl/d)	Year of treatment type installation	Beginning of sand production (years)	Sand produced (lb/1000bbl)
	IGP	1500	0.4	1000	10	2.5	1.5	3000	2803	236.4	1998	2005	7
	IGP	1500	0.7	900	14	1.5	1.3	3200	3100	360	1999	2006	0
	IGP	1500	0.45	1200	11	2.7	1.6	2900	2330	815.1	2001	2005	2
	IGP	1500	0.5	1300	22	1.5	1.1	3500	3299	709.53	1996	2002	12
	IGP	1500	0.5	1200	20	1.7	1.2	3300	3085	670.8	1986	1998	13
	SCON	1500	0.4	1000	15	2	1.5	3000	2810	714.4	2001	2003	16
	SCON	1500	0.5	1100	12	3.5	1.7	2800	2212	1058.4	2000	2002	14
	SCON	1500	0.3	900	8	1.5	1.5	2850	2537	591.57	2001	2005	10
	SCON	1500	0.4	1300	9	1.5	1.8	2800	2646	343.42	2000	2003	13
	SCON	1500	0.4	1350	7	1.7	1.5	3000	2806	599.46	2001	2005	3

4.0 RESULTS AND DISCUSSION

4.1 Performance of the sand control methods

Using well inflow quality indicator (WIQI) which is given as;

$$WIQI = \frac{PI_{actual}}{PI_{ideal}}$$

Where $PI_{actual} = \frac{q}{\Delta p} = \frac{q}{P_{r-}P_{wf}}$

And $PI_{ideal} = \frac{7.08E-3 \times k_o \times h}{\mu_{o} \times B_0 \times l_n\left(\frac{r_e}{r_w}\right)}$

$WIQI \leq 1$; i.e. performance is better if WIQI is closer to or equal to 1.

For well 1,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{236.4}{3000-2803} = \frac{236.4}{197}$ =1.20bbl/day/psi

$PI_{ideal} = \frac{7.08E-3 \times k_o \times h}{\mu_{o} \times B_0 \times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3 \times 1000 \times 10}{2.5 \times 1.5 \times l_n\left(\frac{1500}{0.4}\right)} =$

$\frac{70.8}{30.8607}$ = 2.29bbl/day/psi

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{1.20}{2.29}$ = 0.52

For well 2,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{360}{3200-3100} = \frac{360}{100}$ = 3.60bbl/day/psi

$PI_{ideal} = \frac{7.08E-3 \times k_o \times h}{\mu_{o} \times B_0 \times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3 \times 900 \times 14}{1.5 \times 1.3 \times l_n\left(\frac{1500}{0.7}\right)} =$

$\frac{89.208}{14.9563}$ = 5.96bbl/day/psi

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{3.60}{5.96}$ = 0.60

For well 3,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{815.1}{2900-2330} = \frac{815.1}{570}$ = 1.43bbl/day/psi

$PI_{ideal} = \frac{7.08E-3\times k_o\times h}{\mu_{o}\times B_0\times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3\times 1200\times 11}{2.7\times 1.6\times l_n\left(\frac{1500}{0.45}\right)} = \frac{93.456}{35.0427} = 2.67\text{bbl/day/psi}$

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{1.43}{2.67} = 0.54$

For well 4,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{709.53}{3500-3299} = \frac{709.53}{201} = 3.53\text{bbl/day/psi}$

$PI_{ideal} = \frac{7.08E-3\times k_o\times h}{\mu_{o}\times B_0\times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3\times 1300\times 22}{1.5\times 1.1\times l_n\left(\frac{1500}{0.5}\right)} = \frac{202.488}{13.2105} = 15.33\text{bbl/day/psi}$

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{3.53}{15.33} = 0.23$

For well 5,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{670.8}{3300-3085} = \frac{670.8}{215} = 3.12\text{bbl/day/psi}$

$PI_{ideal} = \frac{7.08E-3\times k_o\times h}{\mu_{o}\times B_0\times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3\times 1200\times 20}{1.7\times 1.2\times l_n\left(\frac{1500}{0.5}\right)} = \frac{169.92}{16.3330} = 10.4\text{bbl/day/psi}$

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{3.12}{10.4} = 0.3$

For well 6,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{714.4}{3000-2810} = \frac{714.4}{190} = 3.76\text{bbl/day/psi}$

$PI_{ideal} = \frac{7.08E-3\times k_o\times h}{\mu_{o}\times B_0\times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3\times 1000\times 15}{2\times 1.5\times l_n\left(\frac{1500}{0.4}\right)} = \frac{106.2}{24.6890} = 4.30\text{bbl/day/psi}$

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{3.76}{4.30} = 0.87$

For well 7,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{1058.4}{2800-2212} = \frac{1058.4}{588} = 1.80\text{bbl/day/psi}$

$PI_{ideal} = \frac{7.08E-3\times k_o\times h}{\mu_{o}\times B_0\times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3\times 1100\times 12}{3.5\times 1.7\times l_n\left(\frac{1500}{0.5}\right)} = \frac{93.456}{47.6379} = 1.96\text{bbl/day/psi}$

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{1.8}{1.96} = 0.92$

For well 8,

$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{591.57}{2850-2537} = \frac{591.57}{313} = 1.89\text{bbl/day/psi}$

$PI_{ideal} = \frac{7.08E-3\times k_o\times h}{\mu_{o}\times B_0\times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3\times 900\times 8}{1.5\times 1.5\times l_n\left(\frac{1500}{0.3}\right)} = \frac{50.976}{19.1637} = 2.66\text{bbl/day/psi}$

$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{1.89}{2.66} = 0.71$

For well 9,

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$$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{343.42}{2800-2646} = \frac{343.42}{154} =$$

2.23bbl/day/psi

$$PI_{ideal} = \frac{7.08E-3 \times k_o \times h}{\mu_o \times B_0 \times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3 \times 1300 \times 9}{1.5 \times 1.8 \times l_n\left(\frac{1500}{0.4}\right)} =$$

$$\frac{82.836}{22.2197} = 3.73\text{bbl/day/psi}$$

$$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{2.23}{3.73} = 0.60$$

For well 10,

$$PI_{actual} = \frac{q}{P_{r-}P_{wf}} = \frac{599.46}{3000-2806} = 3.09\text{bbl/day/psi}$$

$$PI_{ideal} = \frac{7.08E-3 \times k_o \times h}{\mu_o \times B_0 \times l_n\left(\frac{r_e}{r_w}\right)} = \frac{7.08E-3 \times 1350 \times 7}{1.7 \times 1.5 \times l_n\left(\frac{1500}{0.4}\right)} =$$

$$\frac{66.906}{20.9853} = 3.19\text{bbl/day/psi}$$

$$WIQI = \frac{PI_{actual}}{PI_{ideal}} = \frac{3.09}{3.19} = 0.97$$

Table 4.1: Performance of the Sand Control Methods

Well number	Treatment type	WIQI
1	IGP	0.52
2	IGP	0.60
3	IGP	0.54
4	IGP	0.23
5	IGP	0.30
6	SCON	0.87
7	SCON	0.92
8	SCON	0.71
9	SCON	0.60
10	SCON	0.97

From Table 4.1, it can be seen that the wells treated with SCON have WIQI's that are closer to 1 that those that are treated with IGP. The reduction in the performance of IGP may be due to ineffective placement technique, wrong gravel size selection, debris and loose sand from the formation during production which plug the pore spaces in the gravel pack, wrong selection of screen slot to retain the gravel or unclean completion fluid which cause contamination.

The performance of the sand control techniques is further illustrated in the pie chart below

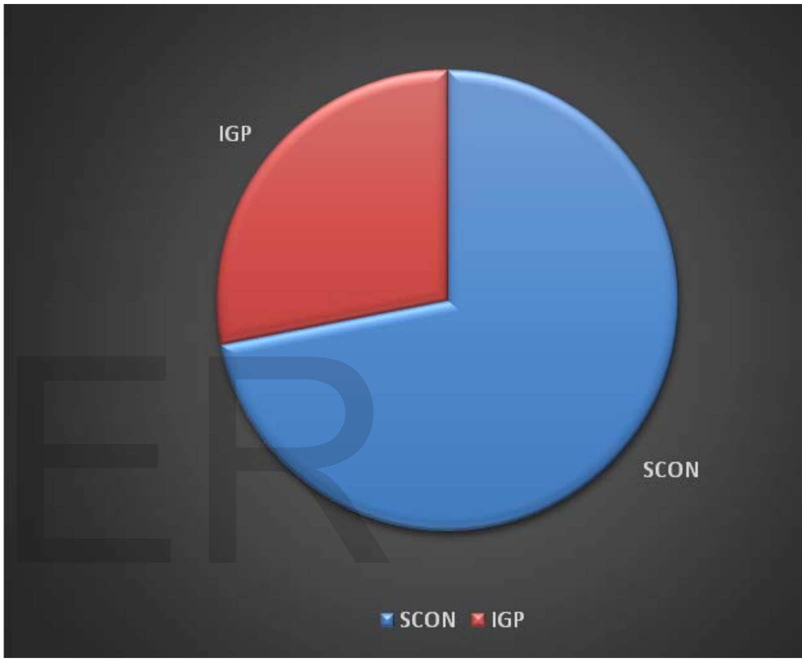

Figure 4.1: Pie chart showing Performance of the Sand Control Methods

4.2 **Effectiveness of the sand control methods**

Table 4.2: Effectiveness of the Sand Control Methods

Well number	Treatment type	Sand produced (lb/1000bbl)
1	IGP	7
2	IGP	0
3	IGP	2

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4	IGP	12
5	IGP	13
6	SCON	16
7	SCON	13
8	SCON	10
9	SCON	13
10	SCON	3

Sum of the volume of sand produced using IGP = 7 + 0 + 2 + 12 +13 = 34lb/1000bbl

Sum of the volume of sand produced using SCON = 16 + 13 + 10 + 13 + 3 = 55lb/1000bbl

4.3 **Durability of the sand control methods**

Table 4.3 Duration of the Sand Control Methods

Well number	Treatment type	Duration (years)
1	IGP	7
2	IGP	7
3	IGP	6
4	IGP	6
5	IGP	12
6	SCON	2
7	SCON	2
8	SCON	4
9	SCON	3
10	SCON	4

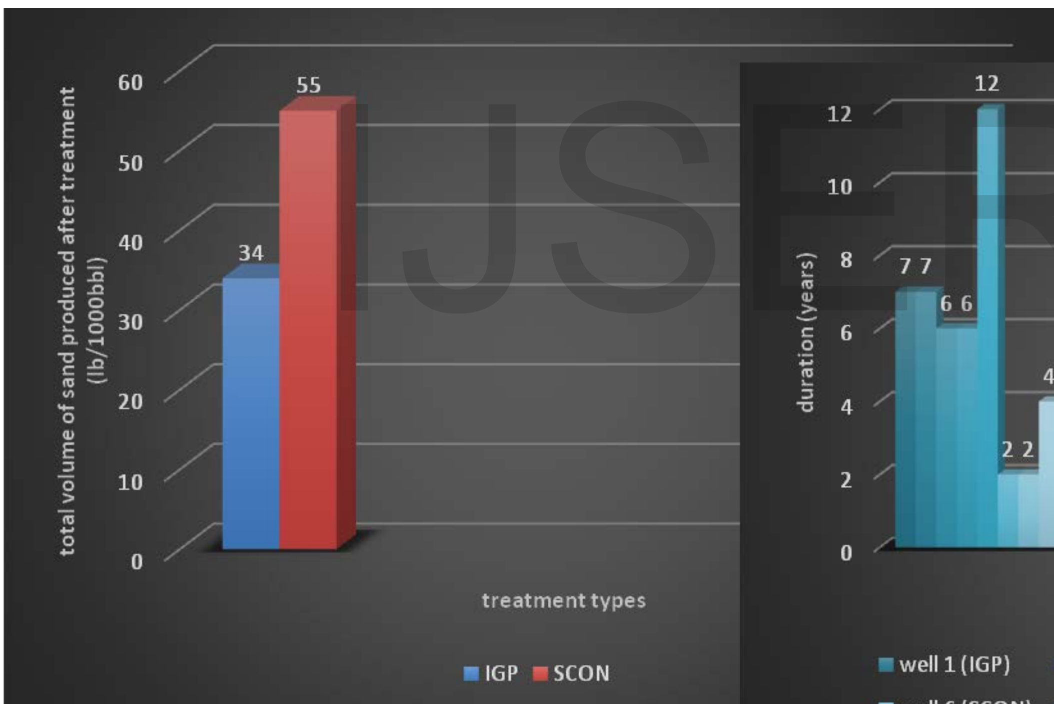

Figure 4.2: Histogram to illustrate the Effectiveness of the Sand Control Methods.

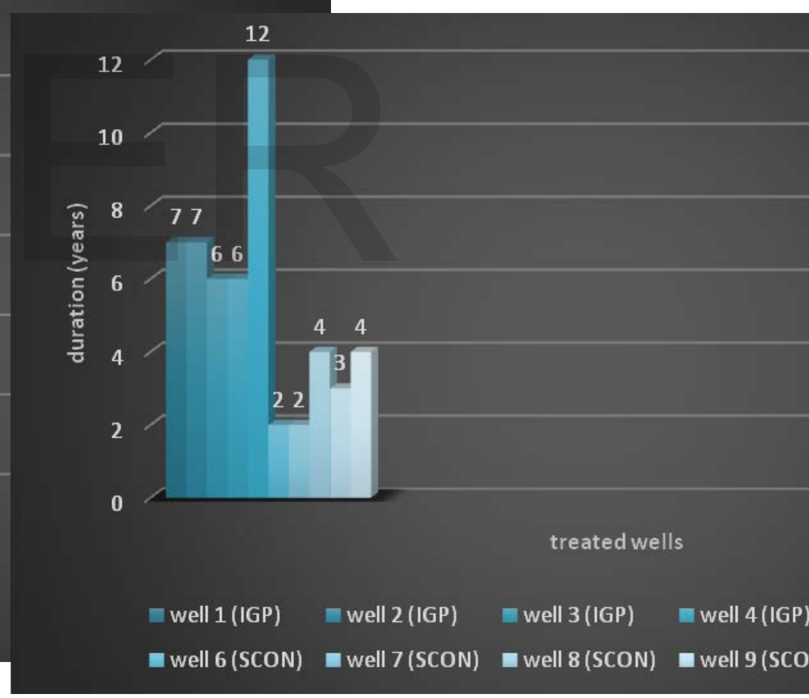

Figure 4.3 Histogram showing Duration of the Sand Control Methods

From Figure 4.2, it can be seen that the wells controlled using sand consolidation (SCON) produced more sand compared to the wells controlled using internal gravel packing (IGP). This is as a result of the fact that the producing fluids tend to wash away the chemicals used for the sand consolidation thereby weakening the chemicals and the sand consolidation, SCON, technique.

From Figure 4.3, it can be seen that the wells treated with internal gravel packing (IGP) last longer than those treat with sand consolidation (SCON). This may be as a result of the fact that high temperature in the subsurface reduces the consolidation of the sand as time goes on thereby reducing the durability of the sand consolidation technique.

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5.1 Conclusion

At the end of this comparative study of sand control using sand consolidation (SCON) and internal gravel packing (IGP) based on their performance, durability and sand control effectiveness, the following conclusions are arrived at;

- That wells installed with sand consolidation (SCON) have better performance than wells installed with internal gravel packing (IGP).
- That wells installed with internal gravel packing (IGP) are more durable than wells installed with sand consolidation (SCON)
- That wells installed with sand consolidation (SCON) produce more sand when the mechanism becomes weak than wells installed with internal gravel packing (IGP). Thus, IGP is more effective in sand control.

5.2 Recommendation

Based on the above conclusions, I therefore recommend that the internal gravel packing (IGP) technique for sand control be preferred to the sand consolidation (SCON) technique for sand control in oil industry for the Niger- Delta area because the internal gravel packed wells are more durable and have better sand control effectiveness when compared to the sand consolidated wells and also because wells installed with SCON have lowered permeability than wells installed with IGP which means that productivity would be better in wells installed with IGP.

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