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Experimental Research on Water Injection Compatibility in Penglai 25-6 Oilfield

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Abstract

The quality of water injection is a key factor affecting the development effect of water injection in a block of Penglai 25-6 oilfield. According to the characteristics of this block, the reservoir physical properties and water quality were analyzed, and the scaling tendency of water quality was investigated, and the compatibility between the injected water and the reservoir was experimentally studied. According to the characteristics of water quality, corresponding water quality modification measures and chemical screening are taken to provide guidance and on-site implementation basis for the decision-making of oilfield water injection development plans.

Keywords

Injected Water; Reservoir; Compatibility.

1. Introduction

Water injection is the most extensive and effective oilfield development method at present, and it is a secondary oil recovery technology widely used in my country and the world. Water injection has the dual functions of displacing crude oil and supplementing formation energy. Maintaining pressure through water injection is a common method to ensure long-term stable production of oilfields, delay production decline, and improve oilfield development economic benefits, especially in the middle and late stages of oilfield development. At present, the daily water injection volume of the world's oil and gas fields reaches tens of millions of cubic meters. There are 260 oil fields in the former Soviet Union that use water injection for production, and 90% of the oil in the United Kingdom and Canada is produced through water injection.

Due to the unqualified water quality, the injected water and corrosion products of equipment and pipelines cause blockage; the solid phase particles brought by the injected water block the reservoir, resulting in a decrease in injection capacity [1-3]. The reservoir damage caused by the water injection process is completely dependent on the reservoir conditions (lithology, pore structure), the properties of the fluid contained and the injected water quality. The former exists objectively and is a potential factor causing reservoir damage; the latter is an external condition that induces reservoir damage. After the injected water enters the formation, there will be incompatibility with formation fluids and formation minerals. Therefore, efforts to improve the quality of injected water can effectively control reservoir damage, and the quality of injected water is sometimes a key factor in determining the success or failure of water injection. After the injected water enters the formation, it contacts with the formation water to form precipitation (mainly calcareous scale). Under the action of the injected water, it flows to the matching pore throat and becomes blocked, resulting in difficult water injection [4]. According to the SY/T5358-2010 industry standard, it can be seen that the core velocity-sensitive

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damage rate is 72.25%-107.67%, and there is strong velocity-sensitive damage. For oil wells, velocity sensitivity will lead to sand production in oil wells, and for water injection wells, it will lead to deep reservoir blockage [5], and shallow groundwater and production sewage alone will cause less damage to the reservoir. However, the damage of the injected water to the core increases with the increase of the injected water [6]. According to the reservoir characteristics of Penglai 25-6 oilfield, the compatibility of injected water is studied in order to provide guidance for the development and production of the oilfield.

2. Reservoir Overview

Penglai 25-6 oilfield is a medium-sized oilfield, located in the central and southern part of the Bohai Sea, the 11/05 contract area, 120°08'~120°11' east longitude, and 38°17'30"~38°20'30" north latitude. In May 2000, the exploratory well PL25-6-1 was implemented in the north block of the main structure of Penglai 25-6 to the east of the east branch strike-slip fault of Penglai 19-3 oilfield. The well was drilled to a depth of 2357.7m, and was drilled in the Paleogene Kongdian Formation. The oil layer was 171.1m in the Neogene Guantao Formation, and the gas layer was 6.9m in the lower part of the Minghuazhen Formation, and the Penglai 25-6 oilfield was discovered. . The oilfield is adjacent to Penglai 19-3 Oilfield in the west, 8.7km away from Penglai 19-9 Oilfield in the north, 218km away from Tanggu in the northwest, and 78km away from Longkou City, Shandong Province in the southeast. The average water depth in the oil field is 27~33m. The temperature difference between winter and summer is obvious. The average temperature in summer is 22°C, and the average temperature of seawater is 22°C; the average temperature in winter is 0°C, and the average temperature of seawater is 1.4°C. Regionally, the Penglai 25-6 oilfield is located at the northeastern end of the middle section of the Bonan low uplift zone in the eastern part of the Bohai Bay Basin, and developed on the Tanlu fault zone. This fault zone is a fault anticline developed on the background of the uplift of the base of the Bonan low uplift. It is controlled by two groups of strike-slip faults in NE and SN, and the interior is further complicated by NE and near-EW normal faults. into 22 blocks. The Bonan low uplift is adjacent to the Bozhong and Bodong sags in the north, and is surrounded by the mouth of the Yellow River and the Miaoxi sag from the southwest to the southeast. The Penglai 25-6 structure is located on the southeast side of the Penglai 19-3 structure. The structure is about 5.0km long, 4.0km wide from east to west, and has a trap area of about 20.0km2. Strike-slip faults and normal faults are mainly developed in the oilfield. A group of near-SN strike-slip faults and a group of near-NE-trend strike-slip faults are the main control faults in Well Block 3 of Penglai 25-6 Oilfield. Near east to west. 23 faults are mainly involved and explained in the 3 well area. Among them, the structural shape of well block 3 in Penglai 25-6 oilfield is generally flat, with high southwest and low northeast;

3. Compatibility Experimental Protocol and Steps

3.1 Sampling and Preparation of Experimental Water Samples

At present, the injection water of Pengbo Oilfield Group mainly comes from the production sewage and seawater treated by FPSO ships. Combined with the water injection process, the injection water in this study will be the seawater from the deoxygenation tower and the production sewage that has passed through the secondary separator without anti-scaling agent. The three types of water samples injected from the wellhead of the water injection well on the F platform were tested for static compatibility with the produced formation water from the F36 oil well on the F platform. According to the needs of the project and the situation of the oil field, the following water samples are taken and treated accordingly:

(1) Seawater: Sampling at the outlet of the deoxygenation tower of the FPSO treatment vessel in Pengbo Oilfield, anti-scaling agents, deoxidizers and corrosion inhibitors have been added;

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(2) Injection water: sampling from the wellhead of the water injection well on platform F, the injection water is the mixed water of production sewage and seawater, and the dosing conditions are scale inhibitors and corrosion inhibitors;

(3) Formation water: Since all oil wells in the Pengbo Oilfield Group are produced by multi-layer commingled production, the formation water produced by each oil well is basically the mixed water of multi-layer formation water. Therefore, the wellhead fluid production of the typical oil well F36 is used The separated water sample is used as formation water;

(4) Production sewage: the production sewage without anti-scaling agent added to the secondary separator of Pengbo No.

The collected water samples were subjected to natural sedimentation separation. The separated water samples were coarsely filtered through ordinary filter paper to be basically clear, and then finely filtered with a filter membrane with a pore size of 0.45 μm. The filtered water samples are shown in Figure 5-17.

3.2 Compatibility Experimental Scheme

The compatibility test evaluation method is as follows: mix the injected water with the formation water of different oil wells in different proportions, heat the water bath for 8 hours at the reservoir temperature, observe the heated mixed water to see if there is visible suspended matter, and test the heating The content of suspended solids before and after. The filter membrane adsorbed with suspended solids was analyzed by X-diffraction and scanning electron microscope to study its fouling components, particle size, morphology, etc. The experimental scheme is shown in Table 1.

Table 1. Experimental scheme of static compatibility of water injection in Penglai 25-6 oilfield

<table>
<tr><th>Experiment type</th><th>Water type</th><th>Sampling point</th><th>Mixing ratio</th><th>Indoor experiment</th></tr>
<tr><td rowspan="2">Injected water and formation water</td><td>Injected water</td><td>F platform water injection well head water sample</td><td rowspan="8">1:0, 1:3, 1:1, 3:1, 0:1 (1:0, 0:1 take 200ml, 1:3, 1:1, 3:1 are extracted according to the proportion, the total volume is 200ml))</td><td rowspan="8">(1) Microscopic observation of sedimentation scale; (2) Diffraction analysis of suspended matter filter membrane; (3) Electron microscope analysis of suspended scale and sedimentation scale.</td></tr>
<tr><td>formation water</td><td>Formation water produced by oil production well F36 (without drug addition)</td></tr>
<tr><td rowspan="2">Production sewage and seawater</td><td>Production sewage</td><td>Production sewage without anti-scaling agent added to secondary separator</td></tr>
<tr><td>seawater</td><td>Sampling at the outlet of the deoxygenation tower of the FPSO treatment vessel</td></tr>
<tr><td rowspan="2">Production sewage and formation water</td><td>formation water</td><td>Production well F36 produces formation water (without dosing)</td></tr>
<tr><td>Production sewage</td><td>Production sewage without anti-scaling agent added to secondary separator</td></tr>
<tr><td rowspan="2">seawater and formation water</td><td>formation water</td><td>Production well F36 produces formation water (without dosing)</td></tr>
<tr><td>seawater</td><td>Sampling at the outlet of the deoxygenation tower of the FPSO treatment vessel</td></tr>
<tr><td colspan="5">Remarks: The static compatibility test time is 8h, and the test temperature is 60°C. Before the test, all kinds of water are finely filtered through a 0.45μm filter membrane.</td></tr>
</table>

3.3 Compatibility Experimental Steps

In this static compatibility experiment, the traditional measurement method of solid suspensions, the membrane filtration method (SY/T5329), was improved, and the substances extracted from sewage by <0.45μm filter membrane were defined as suspended scale; The material on the surface of the bottle) is defined as sedimentation scale, and the sum of suspended scale content and sedimentation scale content is the total scale.

The specific experimental steps are as follows:

(1) Soak the 0.45μm microporous membrane in distilled water for 30 minutes, wash it repeatedly with distilled water for 3 to 4 times, place it in a weighing bottle, move it into an oven and dry it at 103 to 105 °C for half an hour, Take it out and cool it to room temperature in a desiccator and weigh it. Repeat drying, cooling, and weighing until the weight difference between the two weighings is ≤0.2 mg (after cooling to room temperature, use an electronic balance with an accuracy of 0.1 mg to accurately weigh for use);

(2) Wash the 250 ml conical flask (wash with 10% dilute hydrochloric acid first, then with distilled water), dry it in a drying oven at 100 °C, and put a glass slide in each conical flask to facilitate the end of the experiment Afterwards, the sedimentation scale was observed and analyzed. After the conical flask was cooled to room temperature, it was accurately weighed with an electronic balance for use.

(3) Mix the injected water with the formation water in a volume ratio of 1:0, 3:1, 1:1, 1:3, and 0:1, and take 200 mL of each sample. The water samples were sealed and placed in a constant temperature oven, and kept at a constant temperature of 60 °C for 8 h.

(4) According to the filter method in the industry standard SY/T 5329-2012, the suspended scale in the mixed water after standing and reacting in each conical flask was determined.

(5) After the experiment, dry, cool and weigh each conical flask and the glass slides in it, and calculate the sedimentation scale content.

(6) The components of the suspended scale on the filter membrane were analyzed by X-ray diffractometer, and the microscopic features of the suspended scale were analyzed by scanning electron microscope.

(7) Scanning electron microscope (with energy spectrum) was used to study the type and microscopic morphology of sedimentation scale.

4. Compatibility Test Results Analysis

In order to clarify whether the injected water and formation water of Penglai 25-6 oilfield are compatible, an indoor static compatibility experiment was carried out between the injected water of F platform and the formation water of typical oil well F36. After the injection water and formation water were mixed in different proportions at a constant temperature of 60 °C for 8 hours, (Fig. 1a, b) are the macro photos of the water samples before and after the compatibility test of the injected water and formation water. As the proportion of water increases, the color of the water sample gradually deepens, showing pale yellow. The main reason for the pale yellow color may be that the injected water contains emulsified oil. After the experiment, a small amount of whitish scale can be observed on the inner wall of the experimental vessel, and bubbles emerge when cleaning with 10% HCl, which is presumed to contain carbonate scale. In the early stage of the Pengbo Oilfield Group, the water injection source was seawater. In the later stage, due to the increase of the comprehensive water content of the production wells, the mixed reinjection of production sewage and seawater was adopted. At present, seawater accounts for the vast majority of the injected water in Penglai 25-6 oilfield, but with the development of the oilfield, the proportion of production sewage in the injected water will increase. Therefore, it is necessary to evaluate the compatibility of production sewage mixed with seawater in different proportions. (Fig. 1c, d) are the macro photos of the water samples before and after the compatibility test of production sewage and seawater. After the injection water and formation

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water were mixed in different proportions at 60 °C for 8 hours, the water samples became clear without obvious suspended solids. With the increase of , the color of the water sample gradually deepened, showing pale yellow, the reason may be that the injected water contains emulsified oil and so on. After the experiment, a small amount of whitish scale appeared on the inner wall of the experimental vessel, and bubbles appeared when cleaning with 10% HCl, which was also presumed to contain carbonate scale. The injection water of Penglai 25-6 oilfield is reinjected by mixing production sewage and seawater, but its proportion changes with the oilfield development process and cannot be predicted. In order to further clarify the compatibility of oilfield water injection, indoor static compatibility experiments of production sewage, seawater and formation water were carried out. (Fig. 1e, f) are the macro photos of the water samples before and after the compatibility test of production sewage and formation water. It can be seen from the figure that after mixing production sewage and formation water in different proportions at a constant temperature of 60 °C for 8 hours, the water samples are clear and have no obvious suspended matter. With the increase of the proportion of production sewage, the color of the water sample gradually deepened, showing pale yellow. (Fig. 1g, h) are macro photos of water samples before and after the compatibility test of seawater and formation water. It can be seen from the figure that after mixing seawater and formation water in different proportions at a constant temperature of 60 °C for 8 hours, the water samples are clear and have no obvious suspended matter. The self-scaling ability of seawater is strong. After the reaction, a small amount of whitish scale can be observed on the inner wall of the experimental vessel. When cleaning with 10% HCl, bubbles emerge, which is presumed to contain carbonate scale.

Figure 1. Macro photos of water samples before and after compatibility test

a,b Macro photos of water samples before and after the compatibility test of injected water and formation water; c, d Macro photos of water samples before and after the compatibility test of production sewage and seawater;e, f Macro photos of water samples before and after the compatibility test of production wastewater and formation water; g, h Macro photos of water samples before and after the compatibility test of seawater and formation water

Table 2 shows the experimental results of the static compatibility between injected water and formation water in Penglai 25-6 oilfield. Figure 2a shows the variation trend of post-content with the proportion of mixed water based on the data in the table. After water and formation water are mixed with each other in different proportions, the contents of suspended scale, settled scale and total scale are slightly higher than the calculated values of compatibility. When the ratio of injected water and formation water is 1:1, the scale formation is the largest, and the total scale formation is 43.50 mg/L, indicating that the injection water and formation water have good compatibility. And after mixing the two in different proportions, the total scale content increased by 3.12mg/L~7.75mg/L compared with the calculated value, which was slightly higher than that of the unmixed single formation water. The trend of change is decreasing, and the maximum value appears when the mixing ratio is 1:1. From the contribution of suspended scale and sedimentary scale to the total scale content, it can be seen that the content of sedimentary scale and suspended scale is not much different, and the suspended scale is less than the total scale. The evaluation index is between 0 and 1, and the compatibility is

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good. Table 2 shows the experimental results of static compatibility between Penglai 25-6 oilfield production sewage and seawater. Figure 2b shows the variation trend of the post content with the mixed water ratio based on the data in the table. The data in the chart shows that Penglai 25-6 oilfield production sewage After mixing with seawater in different proportions, the contents of suspended scale, sedimentary scale and total scale are slightly higher than the calculated values of compatibility. When the ratio of production sewage and seawater is 1:1, the scale formation is the largest, the total scale is 63.00 mg/L, and the scale is small, indicating that the production sewage has good compatibility with seawater. After mixing the two in different proportions, the total scale content increased by 4.50mg/L~7.50mg/L compared with the calculated value, which was slightly higher than that of the unmixed single formation water. The total scale content increased gradually with the increase of seawater proportion. When the mixing ratio is 1:1, the maximum increase occurs, and the single seawater itself scales more seriously, reaching 80 mg/L. From the contribution of suspended scale and sedimentary scale to the total scale content, it can be seen that the content of sedimentary scale and suspended scale is not much different, and the suspended scale is less than the total scale. The evaluation index is between 0 and 1, and the compatibility is good. Table 2 shows the experimental results of static compatibility between production sewage and formation water in Penglai 25-6 oilfield. Figure 2c shows the variation trend of the post content with the proportion of mixed water based on the data in the table. After the sewage and formation water were mixed with each other in different proportions, the contents of suspended scale, sedimentary scale and total scale were slightly higher than the calculated values of compatibility. When the ratio of injection water and formation water is 1:0, the scale formation is the largest, and the total scale formation is 68.50 mg/L, which indicates that the production sewage itself has strong fouling ability, and the production sewage has good compatibility with formation water. After mixing the two in different proportions, the total scale content increased by 2.62mg/L~9.38mg/L compared with the calculated value, which was slightly higher than that of the unmixed single formation water. The total scale content gradually decreased with the increase of the formation water ratio. The trend is that the maximum increase in total fouling occurs at a mixing ratio of 1:3. It can also be seen from the contribution value of suspended scale and settled scale to the total scale content that settled scale is the main contribution source of total scale, indicating that the production sewage mixed with formation water is mainly manifested in the adhesion to the rock surface and seepage channels in the near wellbore zone. The surrounding sedimentation scale is mainly, and the suspended scale is less than the total scale. The evaluation index is between 0 and 1, and the compatibility is good. Table 2 shows the experimental results of the static compatibility between seawater and formation water in Penglai 25-6 Oilfield. Figure 2d shows the variation trend of the post content with the proportion of mixed water drawn according to the data in the table. From the data in the table, it can be seen that the seawater in Penglai 25-6 Oilfield and the After the formation water was mixed with each other in different proportions, the contents of suspended scale, settled scale and total scale were slightly higher than the calculated values of compatibility. When the ratio of injected water and formation water is 1:0, the scaling amount is the largest, and the total scaling amount is 111.00 mg/L, indicating that seawater itself has strong scaling ability. Compatibility is good. After mixing the two in different proportions, the total scale content increased by 1.50 mg/L~20.50 mg/L compared with the calculated value, which was slightly higher than that of the unmixed single formation water. The total scale content decreased gradually with the increase of the formation water ratio. trend, with a maximum at a mixing ratio of 1:0. It can also be seen from the contribution value of suspended scale and settled scale to the total scale content that settled scale is the main contribution source of total scale, indicating that the production sewage mixed with formation water is mainly manifested in the adhesion to the rock surface and seepage channels in the near wellbore zone. The surrounding sedimentation scale is mainly, and the suspended scale is less than the total scale. The evaluation index is between 0-1.45, which belongs to mild incompatibility.

Table 2. Compatibility test evaluation results

mixed water sample	Content (mg/L)	1:0	3:1	1:1	1:3	0:1
Injecting water: formation water	Suspended scale	12.5	13.5	18	14	11.5
	sedimentation scale	21.5	24.5	25.5	29.5	26
	total dirt	34	38	43.5	43.5	37.5
	Calculated	34	34.88	35.75	36.63	37.5
	Value Added	0	3.12	7.75	6.87	0
	Evaluation index	\	0.53	0.97	0.91	\
Production sewage: formation water	Suspended scale	17	20.5	23.5	20	15
	sedimentation scale	29	41	47	56	65
	total dirt	46	61.5	70.5	76	80
	Calculated	46	54.5	63	71.5	80
	Value Added	0	7	7.5	4.5	0
	Evaluation index	\	0.9	0.92	0.68	\
Production sewage: formation water	Suspended scale	18.5	16.5	15	10	10
	sedimentation scale	50	48	46	48	32
	total dirt	68.5	64.5	61	58	42
	Calculated	68.5	61.88	55.25	48.63	42
	Value Added	0	2.62	5.75	9.38	0
	Evaluation index	\	0.44	0.8	1.05	\
seawater: formation water	Suspended scale	19.5	17.5	12	5.5	2.5
	sedimentation scale	91.5	75.5	72.5	67.5	30.5
	total dirt	111	93	84.5	73	33
	Calculated	111	91.5	72	52.5	33
	Value Added	0	1.5	12.5	20.5	0
	Evaluation index	\	0.18	1.17	1.45	\

Penglai 25-6 oilfield injected water and formation water were mixed in different proportions, and the scale formation was small. The amount of suspended scale was the largest when the ratio was 1:1, and the amount of settled scale was the largest when the ratio was 1:3. When the production sewage and seawater are mixed in different proportions, the scales are small. The amount of suspended scale is the largest when the ratio is 1:1, and the amount of settled scale is the largest when the ratio is 0:1. When the production sewage and formation water are mixed in different ratios, the scales are small, and the amount of suspended and settled scales is the largest when the ratio is 1:0. When the oilfield seawater and formation water are mixed in different proportions, the scales are small. The amount of suspended scale is the largest when the proportion is 1:0, and the amount of settled scale is the largest when the proportion is 1:0. Electron microscope and energy dispersive electron microscope were used to observe the suspended scale filtered by the water sample after the compatibility test between injected water and formation water to identify its composition and scale particle size. Combined with the energy spectrum analysis results of a single scale sample, it can be seen from Figure 3 and Table 3 that a small amount of calcium carbonate scale is produced after the injection water of Penglai 25-6 oilfield is mixed with formation water, oilfield production sewage and formation water, and oilfield production sewage and seawater. There are various forms, and the particle size is about 2~5μm. According to the judgment criteria in Table 5-11, the compatibility between the injected water and the formation water is good, and a small amount of calcium carbonate scale is produced after mixing, which has little impact on the reservoir, so the reservoir will not be damaged due to scaling after water injection. According to the standard, the compatibility between seawater and formation water is good. With the increase of the proportion of formation water, the compatibility gradually becomes worse, which belongs to mild incompatibility. No reservoir damage will be caused by scaling after water injection.

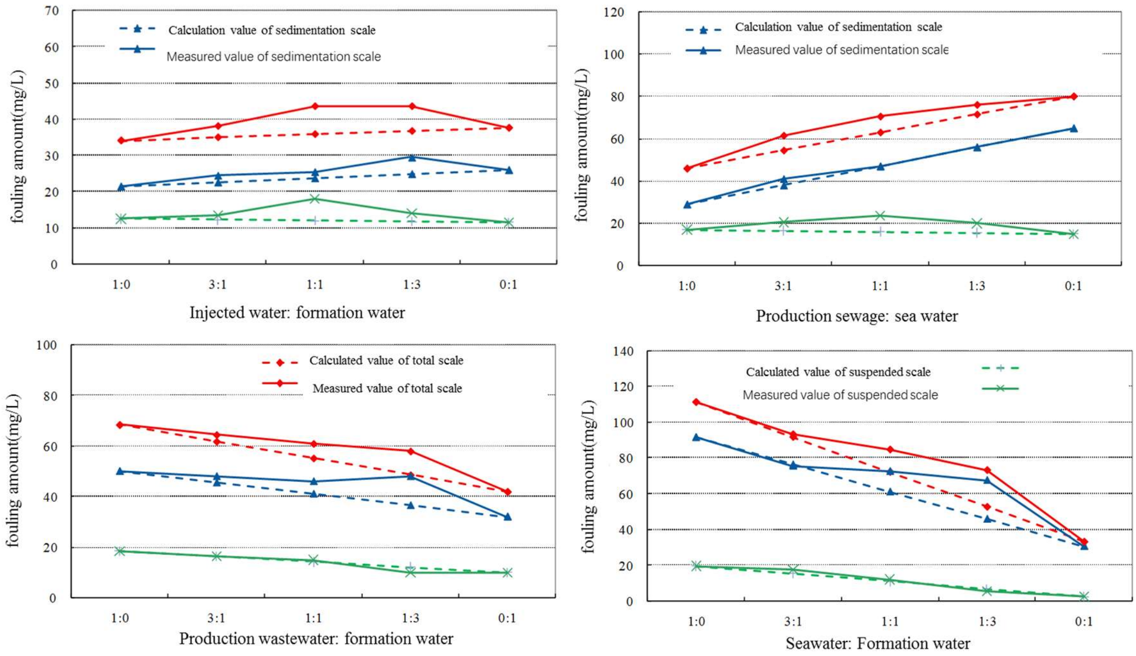

Figure 2. Variation trend of scale content after compatibility test

a Change trend of scale content after the compatibility test of injected water and formation water; b Change trend of scale content after the compatibility test of production sewage and seawater; c Change trend of scale content after compatibility test of production sewage and formation water; d Change trend of scale content after compatibility test of seawater and formation water

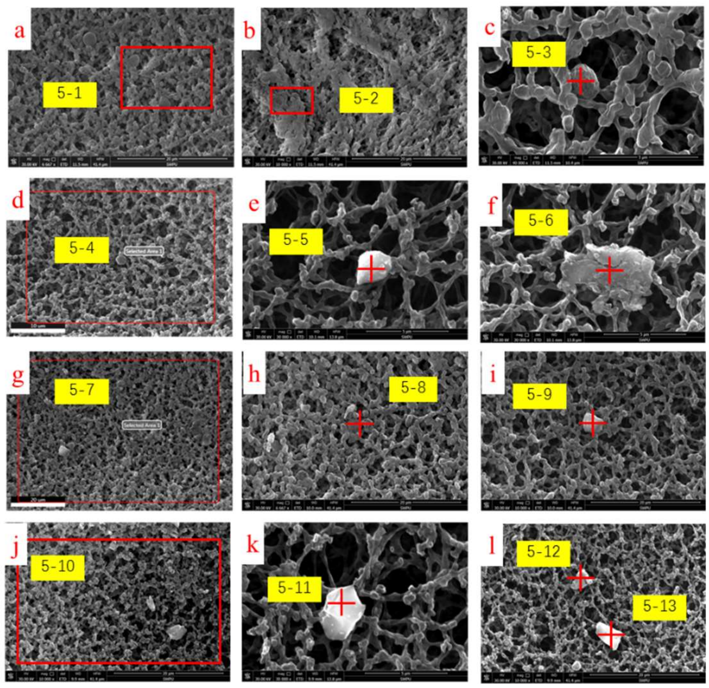

Figure 3. Morphological characteristics of suspended scale under electron microscope

a,b,c Morphological characteristics of suspended scale under electron microscope after 1:1 mixing of injected water and formation water;d,e,f Morphological characteristics of suspended scale under electron microscope after 1:1 mixing of production sewage and seawatersign; g,h,i The morphological characteristics of the suspended scale after the 1:0 mixing of the production sewage and the formation water; j,k,l The morphological characteristics of the suspended scale after the 1:0 mixing of the seawater and the formation water feature

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Table 3. The results of energy spectrum analysis of water-injection compatibility of suspended scale

Spectral Site	Type	Atomic Percent (%)						Spectral Range
		CK	OK	NaK	ClK	SiK	CaK	
5-1	Suspended scale	26.83	28.57	\	\	\	44.6	Global
5-2		25.41	37.64	\	\	\	36.95	Global
5-3		28.46	45.74	\	\	\	25.8	local
5-4		45.09	37.31	0.74	1.52	\	15.34	Global
5-5		19.29	24.68	\	\	\	56.03	local
5-6		27.36	25.02	\	\	\	47.62	local
5-7		40.08	39.41	0.16	0.18	\	20.17	Global
5-8		26.29	42.2	\	\	\	31.51	local
5-9		23.76	34.41	\	\	\	41.82	local
5-10		26.36	38.46	\	\	\	35.18	local
5-11		30.12	37.87	\	\	\	32.01	local
5-12		29.23	37.66	\	\	\	33.11	local
5-13		32.03	38.31	\	\	\	29.67	local

5. Conclusion

The experimental evaluation results of the compatibility between the components of injected water and formation water in Penglai 25-6 oilfield show that:The three water sources of production sewage and seawater have good compatibility with the formation water of Penglai 25-6 oilfield; production sewage and seawater have good compatibility.After mixing different proportions of water, the compatibility is also good, and the total scale increase value is 4.50mg/L~7.50mg/L. Injected water and formation The water has good compatibility, and the total scale increase value is 3.12mg/L~7.75mg/L; The self-scaling ability of production sewage and seawater Strong, the proportion of mixed with formation water is slightly incompatibility, and the total scale increase value of production sewage and formation water is 2.62mg/L~9.38mg/L, the total scale increase value of seawater and formation water is 1.50mg/L~20.50mg/L, slightly incompatible.

The ratio range is 1:1~1:3.

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