Characteristics of backwash recovery water from different oilfield filters for water treatment

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Abstract. An investigation on the quality difference of backwash recovery water (BRW) from three filters in NH, TY and TL in an oilfield was carried out, and the influence of recycling BRW on the treatment efficiency of filters was discussed as well. The results show that in spite of different filter media, backwash model and water properties, filters in NH, TY, and TL gives high recycling rates of suspended solids of about 40% and a relatively low treatment efficiency for suspended solids. Filters with external scrubbing backwash process and used to treatment of polymer-containing produced water in TL gives a highest recycling rate of 52% for oil, while other filters give a relatively high and acceptable treatment efficiency for oil.

Keywords: Produced water, filters, backwash recovery water, suspended solids.

1. Introduction
Filter (such as sand filter, cartridge filter, multi-media filter, and membrane filter) is widely used for produced water treatment [1-4]. The design of filter is based on the characteristics of the treated water and the target to be achieved. Filtration is usually the last step of oilfield produced water treatment, which is used to remove residual oil and small suspended solid particles that cannot be separated by gravitational sedimentation or air flotation [3, 5]. Operation of filter relies on the periodic backwashing process for renewal of filter media [6, 7]. In-tank backwashing and external scrubbing are two basic types of backwashing process.

The backwashing water containing impurities is discharged as BRW, which is generally delivered to BRW tank for settling, and then pumped back to inlet water of the water treatment process (IWWTP). The disadvantages of this process have attracted attention in recent years [8]. It is believed that the separation properties by gravitational sedimentation for BRW is worse than that for IWWTP [8]. However, there is no further or deep investigation on the separation properties difference of BRW either from filters loaded with different media or from different backwashing process.

This work presents an investigation on the quality difference of BRWs from three filters for produced water in an oilfield, and the influence of recycling BRW on the treatment efficiency of filters as well, so as to provide fundamental data for design of filter.
2. Experimental

2.1. Water samples preparation

Three water treatment station NH, TY and TL from an oil field were selected for this research, the typical water treatment process (WTP) in these stations is shown in figure 1. The water process is composed of ‘two-stage gravitational sedimentation and filtration’. Properties of water from three stations and the parameters of water process of three stations are shown in table 1 and table 2. Each filter was backwashed twice a day with outlet water of WTP. The backwashing water accounting for 5% of the total treatment water containing impurities is discharged as BRW. BRW were delivered to BRW tank for settling, and then pumped back into IWWTP. The capacity of BRW tank is about 300-400 m³. Drainaging of each filter tank during backwashing lasts for about 1 h, during which water was sampled every 20 minutes, and the three water samples were mixed together and marked as inlet water of backwash recovery water tank (IWBRWT), while the inlet water and the outlet water of one single filter were also taken as comparatives.

![Figure 1. Water treatment process in produced water treatment station](image)

Table 1. Properties of water from three stations

| Station | Processing capacity \((10^4\text{m}^3/\text{d})\) | Water properties |
|---------|---------------------------------|------------------|
|         |                                 | Salinity \(/\text{mg/L}\) | Temperature \(/^\circ\text{C}\) | Polymer content \(/\text{mg/L}\) |
| NH      | 0.7                             | 11837.7           | 50                            | 0                             |
| TY      | 1                               | 10589.7           | 40                            | 15                            |
| TL      | 2                               | 18457.8           | 50                            | 20                            |

Table 2. Parameters of water process of three stations

| Station | Primary settling Tank | Secondary settling tank | Buffer tank | Filter media | Backwash |
|---------|-----------------------|-------------------------|-------------|--------------|----------|
| NH      | 1×2000 m³             | 1×1000 m³               | 2×300 m³    | Quartz sand  | In-tank backwashing |
| TY      | 1×3000 m³             | 1×3000 m³               | 2×1000 m³   | Walnut shell | In-tank backwashing |
| TL      | 2×2000 m³             | 2×2000 m³               | 2×1000 m³   | Walnut shell | External scrubbing  |
2.2. Evaluation of oil content
Evaluation of oil content for waters was conducted with TD-500D oil analyzer.

2.3. Evaluation of suspended solids content (SSC)
SSC was measured according to SY/T 5329 – 2012.

2.4. Stationary-state sedimentation
Waters were kept in 7 measuring cylinders of 250 ml for stationary-state sedimentation at 50°C. 60 ml, 50 ml and 20 ml water was taken from the same position in the middle of measuring cylinder with pipette at 0, 4h, 8h, 12h, 24h, 32h, 48h respectively. The oil content and SSC were analysed for each water sample.

3. Results and discussion

3.1. Water quality of BRW
Table 3 shows the quality of waters from NH, TY and TL. From table 3 it can be seen that through filtration the removal of oil or suspended solids is round 12 mg/L. The oil content and SSC in IWBRWT is much higher than the removed oil content or SSC, which is coincided with that the removed oil and suspended solids retained on the filter media were collected by the backwashing water of 5% total treatment water. Also, the oil content and SSC in IWBRWT is much higher than that in IWWTP. So technically the BRW quality is badly poor.

| Water sample          | NH     | TY     | TL     |
|-----------------------|--------|--------|--------|
|                       | Oil content / (mg/L) | SSC / (mg/L) | Oil content / (mg/L) | SSC / (mg/L) | Oil content / (mg/L) | SSC / (mg/L) |
| Inlet of filter       | 19     | 26     | 20     | 16     | 35                     | 22             |
| Outlet of filter      | 8      | 9      | 12     | 6      | 22                     | 9              |
| The removal from filter| 11    | 12     | 8      | 10     | 13                     | 13             |
| IWBRWT                | 530    | 190    | 317    | 150    | 310                    | 180            |

3.2. Separation properties of BRW under gravitational force
In these three-water treatment process, BRW was delivered to BRW tank for settling, and then pumped back into IWWTP. From the capacity of settling tanks in table 2 and the capacity of BRW tank, the BRW discharged from filters and returned to IWWTP experiences about 20 hours’ dynamic gravitational sedimentation before its re-flows to filter. In order to identify the influence of recovery of BRW on WTP, the residual oil and suspended solids after 48hs’ stationary sedimentation, which is shown in figure 2 and figure 3, were taken as the residual oil and suspended solids in BRW before it
During stationary-state sedimentation the change of residual oil content in IWBRWT from TL, NH and TY.

Take the residual oil in NH as an example. After 48hs’ stationary sedimentation, the residual oil content in BRW of NH is 48 mg/L. When BRW is mixed with IWWTP, the residual oil is diluted 20 times since the backwashing water accounts for 5% of the total treatment water, so the residual oil of 2.4 mg/L is returned back to filter.

3.3. Recycling of impurities during filtration and backwash from different filters

Here a recycling rate is defined as the ratio of the content of impurities recycled to filter to the removal to distinguish the influence of recovery of BRW from different filters, and process of backwash as well. High recycling rate implies low treatment efficiency of filter. For NH the residual oil of 2.4 mg/L is returned back to filter, and the oil removal from filter is 11mg/L. So, the recycling rate of residual oil from BRW of NH is 21%, see table 4. In this case the parameters of recycling rate of oil and suspended solids from BRW of NH, TY and TL are listed in Table 4.

**Table 4. Recycling rate of backwashing water**

| Parameter                        | NH       | TY       | TL       |
|----------------------------------|----------|----------|----------|
|                                  | For oil  | For suspended solids | For oil  | For suspended solids | For oil  | For suspended solids |
| The removal from filter/(mg/L)   | 11       | 12       | 8        | 10       | 13       | 13       |
| Recycled/(mg/L)                  | 2.4      | 5.1      | 0.7      | 4.3      | 6.8      | 4.4      |
| Recycling rate/%                 | 21       | 42       | 9        | 43       | 52       | 34       |
From table 4, the recycling rate of suspended solids from NH, TY, and TL is very close, which is 42%, 43%, and 34% respectively, while the recycling rate of residual oil from NH, TY, and TL is very different, which is 21%, 9%, and 52% respectively, among which the recycling rate of residual oil from TL is the highest. The suspended solid particles, which neither can be removed by gravitational sedimentation nor can pass through the filters will be immigrated to IWBRWT. So, the suspended solids particles in IWBRWT are small particles which are not easy to settle down when they stay in BRW tank or in primary settling tanks or in secondary settling tanks. So, most of the small particles return to filter again, which gives a high level of recycling rate of suspended solids. The recycling rate of residual oil from TL is the highest of 52%, mainly because the filters in TL uses the external scrubbing rather than in-tank backwashing and the water treated in TL is polymer containing produced water. During backwashing process, hydraulic shearing and friction from screen mesh can do work as dispersing forces. Secondly, the polymer content in produced water is about 15 mg/L. The polymer can also lead to emulsification of crude oil during backwashing since polymer used for oil recovery plays a negative role on oil-water separation and a positive role on crude oil emulsification [9, 10]. The above two factors lead to a relatively high emulsified oil content in IWBRWT, which is hard to be removed during dynamic gravitational sedimentation in BRW tank and in two-stage gravitational sedimentation tankers of WTP respectively. Higher is the recycling rate, lower is the treatment efficiency of filter. Filter used for polymer-containing water, loaded with walnut shell, and equipped with external scrubbing gives a low treatment efficiency for oil, while other filters give a relatively high and acceptable treatment efficiency for oil. All the filters engaged give a relatively low treatment efficiency for suspended solids.

4. Conclusions
The removed oil and suspended solids retained on the filter media were collected by the backwashing water. So technically the BRW quality is badly poor. In spite of different filter media, backwash model and water properties, filters in NH, TY, and TL gives high recycling rates of suspended solids of about 40% and a relatively low treatment efficiency for suspended solids. The recycling rate of residual oil from TL is the highest of 52%, because the filters in TL uses the external scrubbing rather than in-tank backwashing and the water treated in TL is polymer containing produced water, while other filters give a relatively high and acceptable treatment efficiency for oil. The differences of recycling rate of residual oil and suspended solids from NH, TY, and TL indicates that design of filter for produced water should take water properties, and backwash mode as well into consideration.

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